Sustainability in SNS JU Projects

Targets, Methodologies, Trade-offs and Implementation Considerations Towards 6G Systems

SNS JU TB Sustainability Task Force

Presenter: Ali Rezaki, TB Sustainability Task Force Leader

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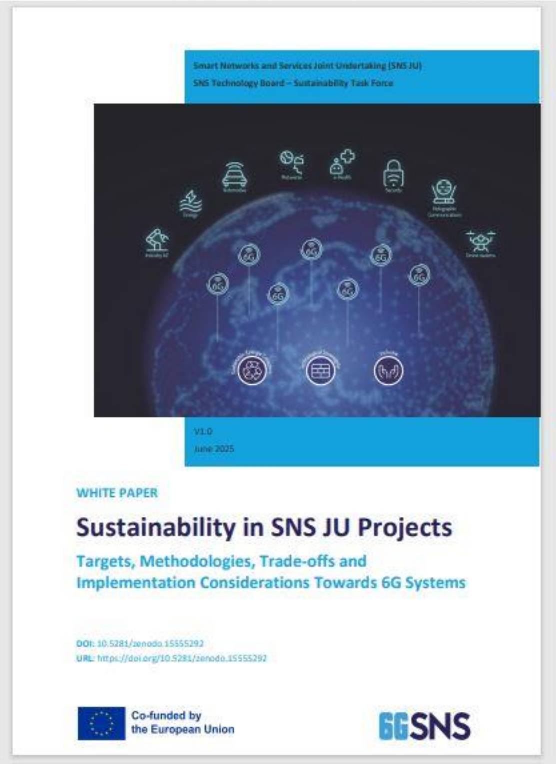
Smart Networks and Services Joint Undertaking (SNS JU)
SNS Technology Board – Sustainability Task Force

V1.0
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WHITE PAPER

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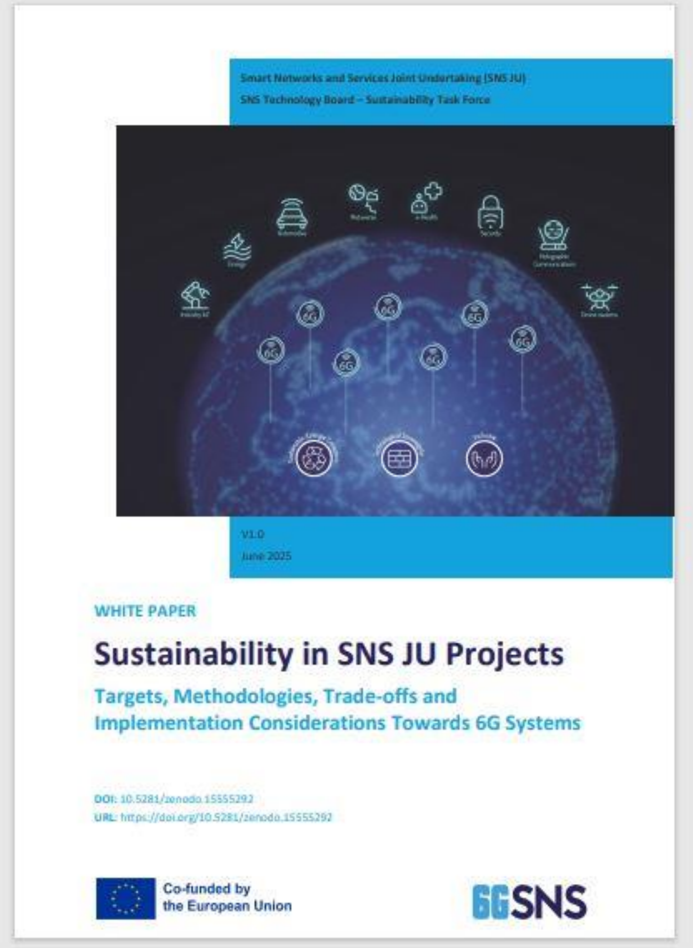
6G4Society	BeGREEN	SEASON
6G-DISAC	CENTRIC	SNS CO-OP
6G-EXCEL	Eco-eNet	SUNRISE-6G
6G-GOALS	ETHER	SUPERIOT
6G-NTN	FIDAL	TeraGreen
6G-Reference	Hexa-X-II	TERRAMETA
6G-SENSES	HORSE	TrialsNet
6G-SHINE	iTrust6G	VERGE
6G-XR	NANCY	

Agenda

- Sustainability TF Questionnaire and Analysis
- Observations and key insights on:
  - Targets
  - Methodologies
  - Trade-offs
  - Implementation Considerations
- Lessons Learned
- Research Gaps
- Recommendations for Stakeholders
- Way Forward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Sustainability TF Questionnaire and Analysis Process

- The questionnaire was developed with know-how from the research activities of a few SNS JU projects advanced in their sustainability coverage and updated by the task force.
- The questionnaire contained 60 questions in 4 groups: Sustainability Targets, Sustainability Methodologies, Sustainability Trade-offs and Implementation Considerations.
- 16 Call 1 & 11 Call 2 projects responded to the questionnaire. Review interviews of 1.5/2 hours each were held by the task force leader over a period of 7 months with the projects.
- All the project responses were analysed by a team of Sustainability TF volunteers. For each question, a numerical and graphical analysis was made, as well as the generation of key observations, insights and conclusions. An internal report was created accordingly.
- Subsequently the task force team worked on developing the external white paper with the assignment of editor, contributor and reviewer volunteers, exchanging roles along the way.
- The white paper focused on making the TF findings available to a wide audience.

Observations - Sustainability Targets

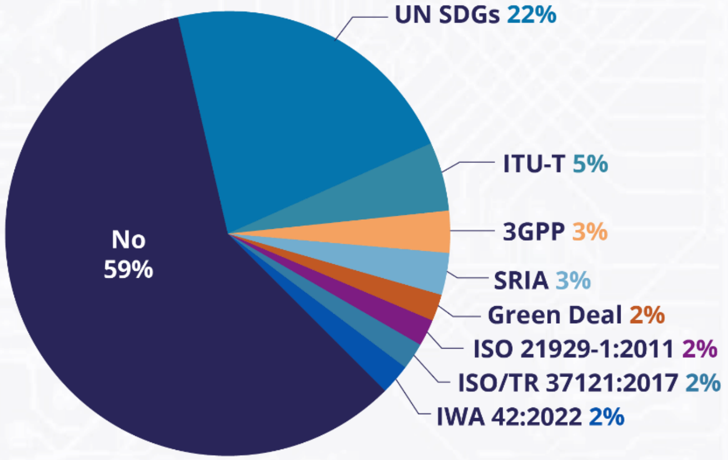
- Average TRL level of projects is around 4. Projects target diverse use cases and technologies. Energy Efficiency & AI are widely addressed, use of RIS, ISAC, O-RAN, NTN are common.
- SNS projects share a rather uniform perspective on environmental goals, centered around energy efficiency, while other aspects such as GHG emissions, circularity and LCA are much less covered.
- Societal sustainability is mostly interpreted as helping with social and digital inclusion or safety, through coverage and through applications in vertical sectors such as health, education, transport and energy.
- In terms of societal aspects, the underlying assumption is that connection is positive (focus is on overcoming digital exclusion and divides), and there is limited mention of negative rebounds.
- Projects currently see cost savings or new market opportunities for growth as key business/economic priorities with varying definitions and terminology.
- The relationship between economic sustainability and the other two sustainability pillars is explored by a small number of projects.
- Biodiversity is not explicitly addressed by the projects.
- Only one project is engaged in policy and regulatory aspects of sustainability!

Key insights - Sustainability Targets

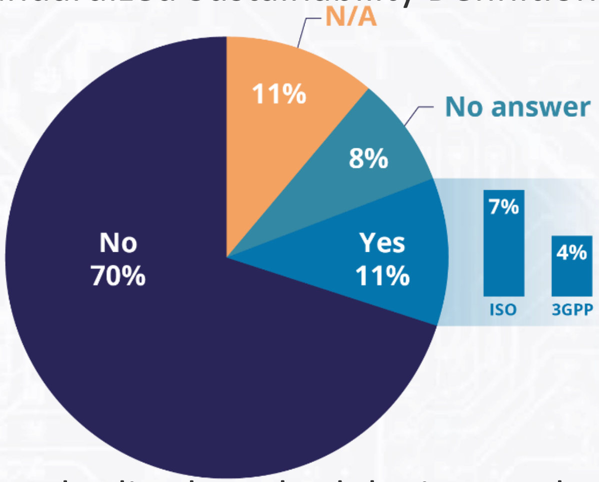
- Most of the projects interviewed operate at low TRL, focusing on technology enabler feasibility in conceptual or lab environments. This limits the ability of projects to engage directly with sustainability goals or to assess real impact, emphasizing the need to build capacity to address sustainability in the early stages of technology development.
- While energy efficiency and savings are broadly targeted, other aspects of environmental sustainability, such as circularity and life cycle assessment as well as social and economic sustainability pillars get much less coverage, emphasizing the need for a holistic, system level target setting, recognizing the interconnectedness of the three sustainability domains.
- A holistic approach to sustainability requires diverse competences. Addressing broader aspects of sustainability and circularity typically requires the inclusion of experts from diverse fields such as economics and ecology. However, unless these competencies are explicitly requested in the call documentation, project teams may be reluctant to expand their composition accordingly. As a result, more comprehensive consideration of sustainability across all three pillars is likely to depend on clear prioritization and explicit guidance within future calls.

Observations - Sustainability Methodologies

- Around ~40% of Call 1 projects (6 out of 16) considered high level standardized sustainability definitions, such as UN SDGs. This number was ~50% for Call 2 projects. ~60% of Stream A and ~40% of Stream B projects responded positively. No Stream C or D project considered standardized sustainability definitions.
- Low adoption of standardized methodologies for sustainability impact assessment, probably due to barriers including lack of awareness, resources, and comp
- Two projects included lifecycle assessment considerations.
- Coverage of full supply chain sustainability is not prevalent.
- Among sustainability metrics and indicators, the most used ones are on energy efficiency.
- KVIs are targeted by many projects, challenges in uniform definitions, baselines and targets and assessments.
- Three projects use some circularity and eco-design principles
- Proactive sustainability-by-design approaches largely focus on energy aspects with limited assessment aspects
- Majority of projects use some form of resource sharing.



Standardized Sustainability Definitions across projects



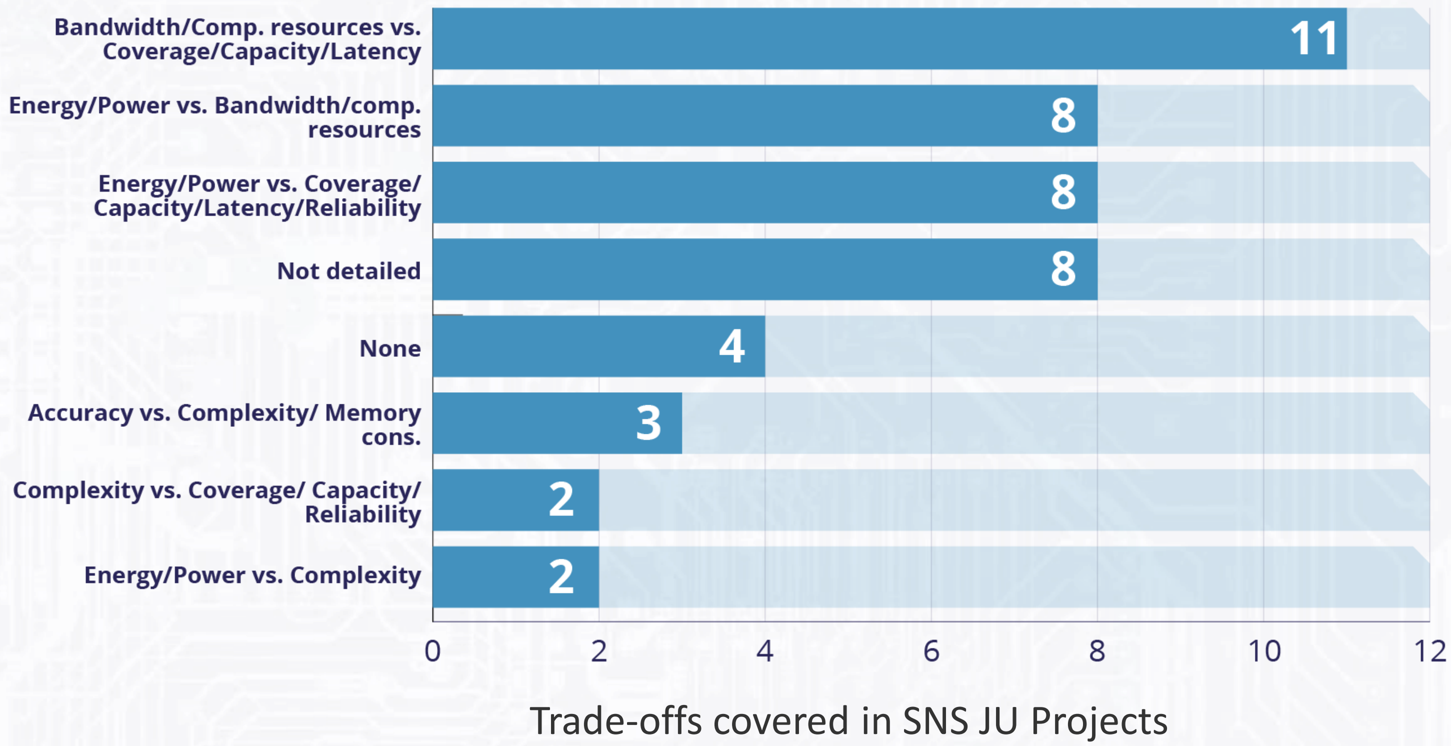
Standardized Methodologies Used across Projects

Key insights - Sustainability Methodologies

- There is a broad recognition of sustainability as a relevant concern across projects.
- Among the various dimensions of sustainability, EE is the most systematically addressed.
- KVIs are used with varying degrees of formality and structure.
- Life cycle and supply chain considerations tend to be underrepresented.

Observations - Sustainability Trade-offs

- Performance versus resource use is the most common trade-off handled in projects.
- Trade-offs (towards co-optimization) with sustainability parameters is rare, other than energy considerations.
- Around half of the projects are addressing resilience one way or another through redundancy.



Key insights - Sustainability Trade-offs

- EE emerges as the main common sustainability consideration of SNS JU projects, as part of different trade-offs and co-optimizations.
- Technology improvements and architectural considerations will significantly affect EE and power consumption
- Early design decisions & EE trade-off analysis may significantly impact performance
- Focus on Sustainability by design will embed co-optimization of sustainability parameters with other performance and functionality parameters and requirements.

Observations - Sustainability Implementation Considerations

- One third of projects indicated investments in statistics, explainability and transparency mostly for AI use.
- Scalability is a priority for most SNS Projects – 59% of respondents acknowledge the importance of scalable implementations, avoiding solutions requiring full-node upgrades across a domain.
- Most projects do not focus on serviceability and upgradeability
- There is a mixed tendency with a significant portion (45%) not prioritizing min. system requirements while a considerable amount (29%) works towards reducing hardware dependencies, driven by cost-saving strategies
- Only three projects target increasing the level of recycled, refurbished, repurposed components.
- 78% of the projects indicated that they are working on developing measurable sustainability indicators, demonstrating a strong commitment to sustainability assessment, mostly in the energy domain.
- End-of-life treatment of solutions is not considered by projects.
- Linking social and economic outcomes to technology enablers and creating causality between them is covered by KVI use, however, there is no uniform application or assessment.

Key insights - Sustainability Implementation Considerations

- At the end-user side, EE has emerged as a key concern.
- Coverage of challenges at the application layer appear less common.
- At the system and infrastructure levels, projects generally avoid introducing unnecessary complexity.
- Forward-looking approaches to sustainability are beginning to gain traction.
- While scalability and modularity are familiar, maintainability is less of a focus.
- Circular design receives limited attention overall.
- KVI use is on the rise.
- Trustworthiness emerging as a key concern, but still not globally adopted.
- Sufficiency or digital sobriety received limited attention.

Lessons Learned

- Energy efficiency dominates the agenda
- Low TRLs limit systemic impact evaluation
- Sustainability-by-Design is gaining traction
- KVIs are a useful but under-structured tool
- Sustainability requires interdisciplinary expertise

Research Gaps

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- While EE and the reduction of energy consumption are at the forefront of sustainability efforts, the use of ***renewable energy*** is infrequently targeted.
- ***Policy and regulatory*** considerations are under-represented components of SNS JU research.
- There is a general limitation regarding the identification and assessment of ***second-order effects*** in sustainability evaluation.
- A minority of projects currently integrate ***Life Cycle Assessments*** (LCA) or ***circular economy*** principles. End-of-life impacts, modular upgrades, and recyclability are largely unexplored.
- There is a valuable opportunity to enhance engagement with ***societal and ethical dimensions*** in the development of 6G networks.

Recommendations for Stakeholders – Telecom Equipment Vendors:

- Adopt sustainability-by-design frameworks, prioritizing modular, energy-efficient, carbon-aware, adaptable and recyclable hardware, targeting socio-ecological impact as well as economic growth.
- Co-develop metrics and methodologies for circularity, including standardized material impact indicators.
- Collaborate with academia to pilot eco-design approaches and validate through real-world demonstrators.

Recommendations for Stakeholders – Telecom Operators:

- Push for architectures enabling energy-aware orchestration and dynamic scaling, balancing user QoE with sustainability.
- Partner with projects to test and benchmark renewable energy integration strategies.
- Invest in transparent energy monitoring systems for end-to-end tracking of emissions and energy savings.

Recommendations for Stakeholders – Academia:

- Integrate environmental and systems science, ethics, and economics into 6G research programs to broaden sustainability perspectives.
- Lead in developing and refining KVIs and SNVC-aligned methodologies.
- Expand focus on societal sustainability impacts (e.g., equity, inclusion, health) and develop corresponding metrics, through interdisciplinary collaboration.

Recommendations for Stakeholders –

SMEs and Startups:

- Serve as agile innovators piloting modular, interoperable solutions focused on circularity and renewable integration.
- Collaborate with verticals to tailor use cases addressing specific sectoral sustainability challenges.
- Embrace open-source sustainability frameworks to accelerate adoption and interoperability.

Recommendations for Stakeholders – Policymakers and the European Commission :

- Require all future calls to explicitly define expectations for all three sustainability pillars (environmental, social, economic).
- Fund interdisciplinary support teams for SNS projects to embed lifecycle, regulatory, and ethical expertise.
- Incentivize testbeds and field pilots to evaluate second-order effects in verticals, using real-world KPIs and KVIs.
- Facilitate the determination of social, economic and ecological requirements, use cases and value indicators for the technology research projects to target and to develop technology enablers for.

Way Forward – Key Research Directions

- ***Lifecycle Sustainability Assessment*** (LCSA) and circular design should be systematically embedded into 6G R&D, covering supply chain to disposal, considering not only environmental but also social and economic sustainability aspects.
- ***Social Impact Modelling*** techniques, including anticipatory methods grounded in SSH (Social Sciences and Humanities) methods and insights, should be pursued.
- ***Rebound Effect Analysis*** should be included in R&I projects in order to study unintended consequences of efficiency gains.
- ***Sufficiency*** strategy development in support of relevant policy and regulatory frameworks needs to be investigated to ensure long-term sustainability outcomes.
- In ***Implementation and Network Design*** the following aspects need to be promoted: *Design for Modularity and Reusability, Resilience without Redundancy, Carbon-Aware Networking and Orchestration, Security-Sustainability Synergy.*
- ***Support mechanisms*** for sustainability research could be established, such as,
  - a pan-European *Sustainability Observatory for 6G* to collect, benchmark, and share sustainability-related KPIs, KVIs, methodologies, and use case outcomes
  - a *6G Circular Economy Lab* could be launched to validate, among others, recyclable hardware, modular software, and energy harvesting devices in real-world testbeds
  - certification and labelling schemes could be developed for sustainable 6G technologies, in collaboration with ETSI, ITU, and ISO.

Reference

Please access the SNS JU Sustainability Task Force White Paper at:

- *https://smart-networks.europa.eu/wp-content/uploads/2025/05/sns_ju_sustainabilitytf_whp_june2025_v1.0-1.pdf* .
- DOI: 10.5281/zenodo.15555292
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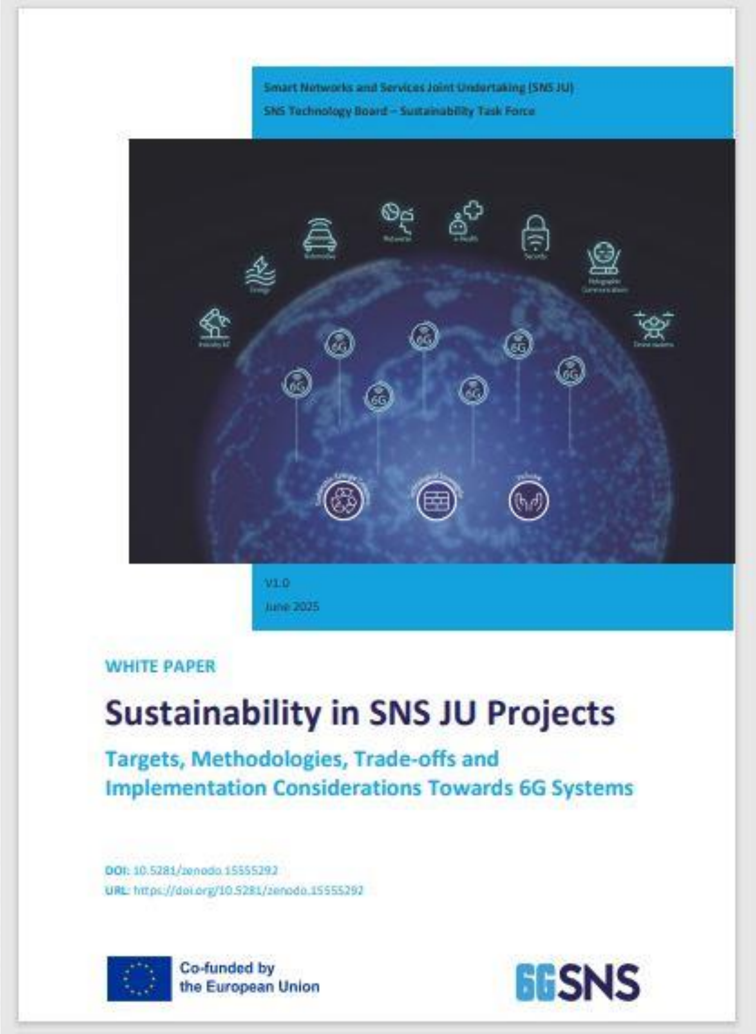
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