How 6G Will Change Innovation and What Policy Should Do

Innovations and Telecommunications Policy
Shaping Tech, Markets and Policy

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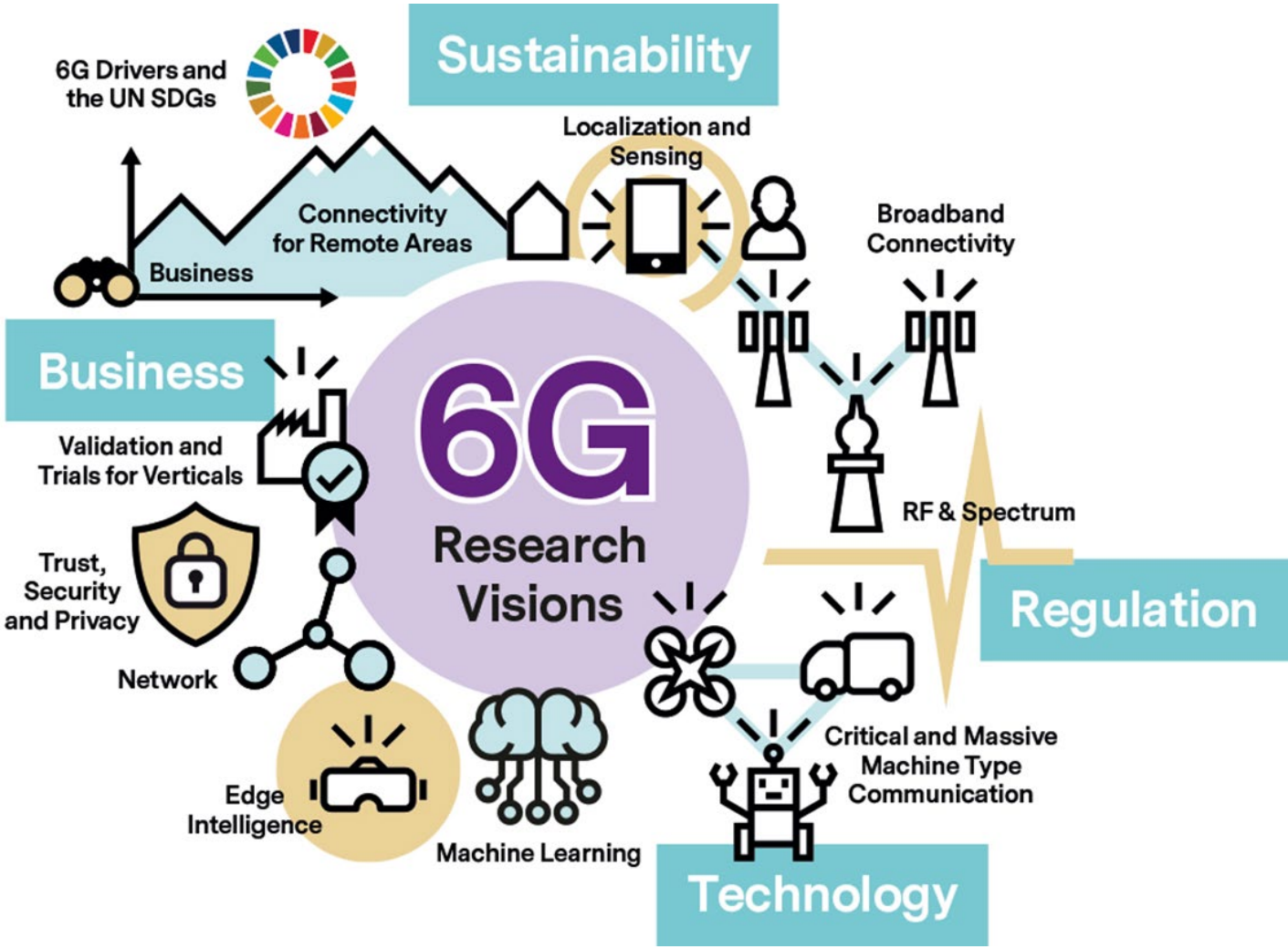
Finnish 6G Flagship's multi-disciplinary agenda (2018-2026)

- Finnish 6G Flagship's multi-disciplinary research roadmap includes **technology, business, regulation and sustainability** perspectives.
- Multi-stakeholder collaboration emphasises academia, industry, and public sector interplay.



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Values driven ICT development

- European Commission funded 6G research projects in *Smart Networks and Services Joint Undertaking (SNS JU)* are driven by values, which calls for multi-disciplinary research.
- A lot of effort is spent on identifying so called “key value indicators” to complement traditional performance driven mobile communication technology development following values-driven research**.

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Key value indicators: A framework for values-driven next-generation ICT solutions

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ABSTRACT

Technology design, development and evaluation has long been driven by functional performance optimization and estimated market opportunitie
Today, societal challenges and sustainable development goals are calling for a paradigm shift towards aligning technology development with
values-based consideration and re-prioritization of different ecological, social and economic outcomes. Values have been identified as key drivers
Information and Communication Technology (ICT) research. They are taken into account in the development of 6G networks, e.g. in the context
EU research funding frameworks, but a clear conceptual framework for values-driven development is still missing. This paper deals with the conce
of Key Value Indicators (KVIs) as a method for analyzing the values-related outcomes stemming from ICT developments. Leveraging establish
definitions, frameworks and value identification methods, the paper proposes a structured KVI framework tailored to the ICT research a
development (R&D) sector. The proposed framework comprises five steps, starting from the use case-related identification of values to t
assessment of value outcomes. ICT-enabled smart cities are analyzed as an example use case to illustrate how this framework can be applied. T
KVI framework is aimed to be a useful tool for the ICT research sector (to be used - primarily but not exclusively - by ICT research projects a
programs) to address social challenges in technology design and development phases and to identify and estimate value outcomes from technolo
use. In addition, the proposed framework aims to assist policy makers to establish value-related targets and set requirements and conditions for I
developments.

*Smart Networks and Services Joint Undertaking (SNS JU). https://smart-networks.europa.eu/

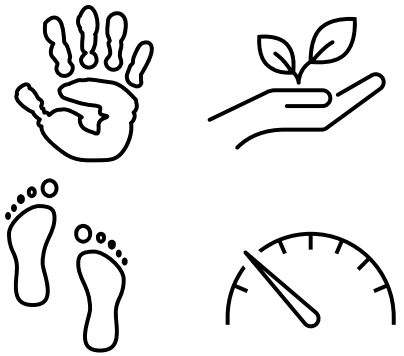
**G. Wikström, N. Bledow, M. Matinmikko-Blue, H. Breuer, C. Costa, G. Darzanos, A. Gavras, T. Hossfeld, I. Mesogiti, K. Petersen, P. Porambage, R.-A. Stoica, S. Wunderer. (2024). Key value indicators: A framework for values-driven next-generation ICT solutions. Telecommunications Policy, Vol. 48, No. 6. https://doi.org/10.1016/j.telpol.2024.102778

Sustainability and sustainable development

Sustainable development[1] is the "**development that meets the needs of the present without compromising the ability of future generations to meet their own needs**".

Sustainability[2] is the "**principle of ensuring that our actions today do not limit the range of economic, social, and environmental options open to future generations**".

- **ICT sector's enabling role** to help different sectors of society towards environmentally and socially sustainable operations via ICT solutions and services in an economically feasible manner.
- **ICT** solutions and services' **own sustainability burden** keeps increasing and rapid changes must be done to stop this development (e.g., total energy consumption).



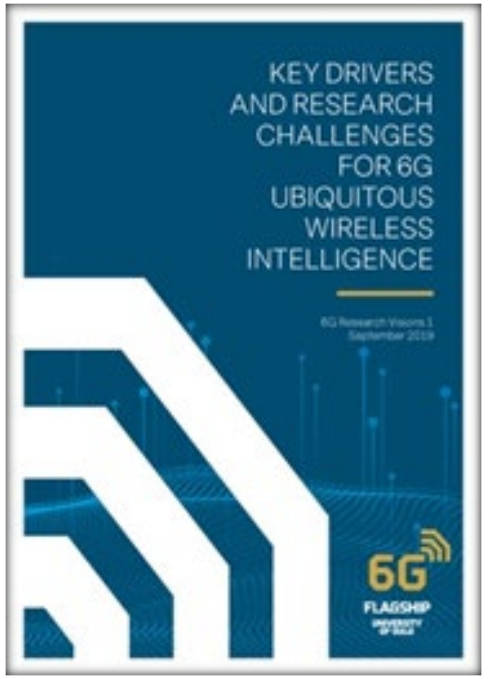
SUSTAINABILITY WILL CHANGE THE GAME.
Total consumed mobile data will no longer determine, which countries are the leaders.

[1]World Commission on Environment and Development's Brundtland report ´Our Common Future`. 1987.
[2]J. Elkington. Cannibals with forks: The triple bottom line of 21st-century business. Capstone Publishing Ltd. 1997.

Sustainability was agreed to drive 6G R&D globally in 2019

- The world's first 6G White Paper[1] from Finnish 6G Flagship concluded in 2019 that 6G R&D is driven by sustainability and United Nations' Sustainable Development Goals (UN SDGs).
- Follow-up work[2] in 2020 connected 6G with UN SDGs and envisaged a three-fold role of 6G as:
  1) a provider of services to help support activities towards reaching the UN SDGs,
  2) a measuring tool for reporting of indicators;
  3) a reinforcer of developing 6G in line with the UN SDG.

WE ARE FAR AWAY FROM SUSTAINABILITY BEING THE REAL DRIVER FOR 6G.



[1] **M. Latva-aho & K. Leppänen (eds.) (2019). Key drivers and research challenges for 6G ubiquitous wireless intelligence. (6G Research Visions, No. 1). University of Oulu, Finland. http://urn.fi/urn:isbn:9789526223544**

[2] **M. Matinmikko-Blue, et al. (eds.). (2020). White Paper on 6G Drivers and the UN SDGs. (6G Research Visions, No. 2). University of Oulu. http://urn.fi/urn:isbn:9789526226699**

Environmental, social and economic sustainability considerations in ICTs

Environmental sustainability

- Climate (scope 1/2/3 GHG emissions)
- Energy (energy consumption, energy efficiency, renewable energy)
- Resource usage (water, land, raw materials usage)
- Other environmental (e-waste, recyclability, repairability, toxicity, product life-time, life-cycle assessment, circularity)

Social sustainability

- Availability of resources for good living (food, health, education, income, work, equality, human rights, trust, security, affordability, fairness)
- Digital inclusion bridging the digital divide and providing meaningful, safe and affordable access to life-enhancing digital services (including technologies, infrastructure, equipment, services, skills, security, trust, privacy)

Economic sustainability

- Sustainable economic growth at corporate, ecosystem, and national levels without negatively impacting environmental and social aspects of communities
- Sustainable business models, new business opportunities, circular economy

Global 6G policy discussions

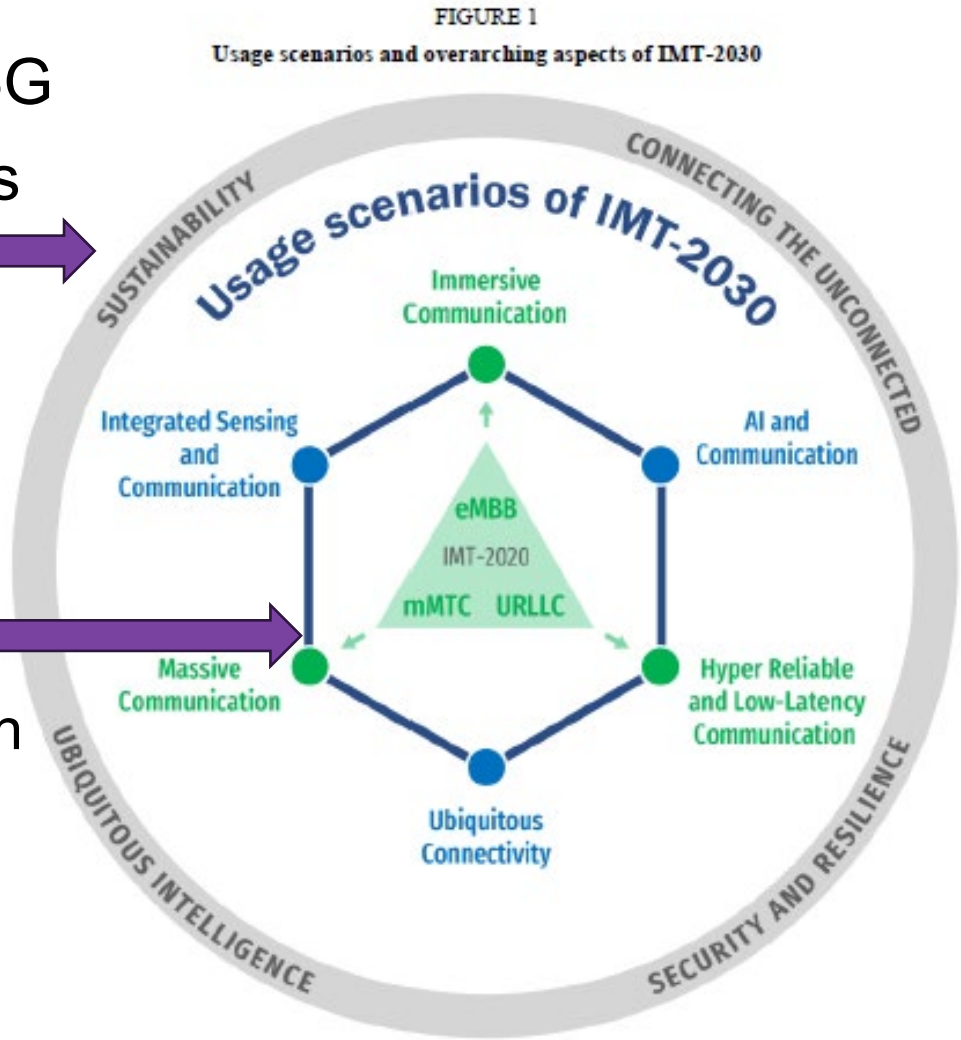
Sustainability in Joint Statement of EU-US TTC in 2023

- EU - US Trade and Technology Council's (TTC) Joint Statement EU-US TTC in Sweden (europa.eu)'s 6G Outlook Annex introduces sustainability in 6G as follows:

6G technologies must also be an **enabler for sustainability, considering environmental, social, and economic perspectives**. A **reduced carbon footprint** and **energy efficiency** will be important design goals for 6G networks. More broadly, 6G should allow for **reduced energy consumption across all sectors** of the economy and society. Ideally, 6G technologies will **generate less pollution** and **reduce other environmental** impacts to better contribute to **long-term social sustainability** while **maintaining economic feasibility**.

Global 6G Framework recommendation

- UN based ITU-R published global framework for 6G
- New elements – four overarching design principles
  - **Sustainability**
  - **Security and resilience**
  - **Connecting the unconnected**
  - **Ubiquitous intelligence**
- Six usage scenarios (expanding three 5G usage scenarios and three new)
  - Immersive communication, massive communication and hyper reliable and low-latency communication
  - Integrated sensing and communication, AI and communication and ubiquitous connectivity



Getting sustainability into global IMT-2030 framework was extremely difficult. Many companies and administrations objected to it and wanted to delete it time after time.

Recommendation ITU-R M.2160-0 (11/2023) - Framework and overall objectives of the future development of IMT for 2030 and beyond

Backgroud on changing market structues – Emergence of a large number of local 5G and 6G networks

Success story from collaboration between academia, industry and regulatory bodies: Local 5G networks with local operator models and spectrum licensing in 2016-2018.

- Different stakeholders can deploy their own local 5G/6G networks[1], which could be public or private, depending on end user groups and national conditions.
- Local spectrum availability[2] is a key pre-requisite. Currently, divergence between countries is high[3], leading to market fragmentation and competitive disadvantages.

[1]M. Matinmikko, et al. (2017) **Micro operators to boost local service delivery in 5G**. Wireless Personal Communications, 95(1), 69-82.
[2]M. Matinmikko, et al. (2018) **On regulations for 5G: Micro licensing for locally operated networks**. Telecommunications Policy, 42(8), 622-635.
[3]M. Matinmikko-Blue, et al. (2019). **Analysis of Spectrum Valuation Elements for Local 5G Networks: Case Study of 3.5-GHz Band**. IEEE Transactions on Cognitive Communications and Networking, 5(3), 741-753.

Key Drivers and Research Challenges for 6G Ubiquitous Wireless Intelligence - 6G Flagship

6G spectrum challenges

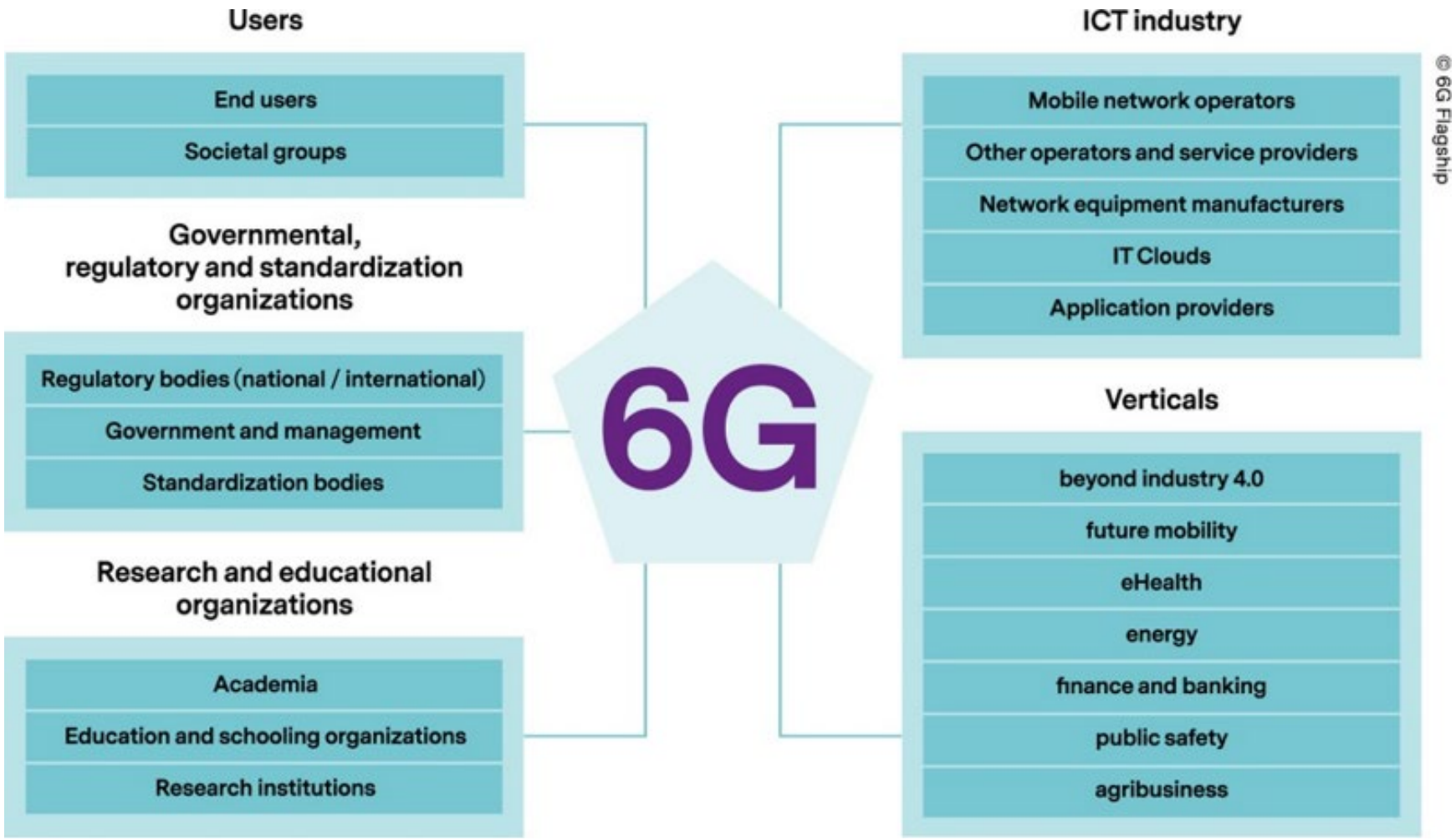
- **Market structures** change – local 5G networks that were strongly opposed are a reality. Local 6G networks can be public or private, and deployed by different stakeholders using different spectrum access options, whose availability will vary between countries.
- **Networks for vertical applications** may or may not be local. There is not enough spectrum for everybody to build separate vertical specific systems for all verticals, which calls for sharing in multiple fronts including spectrum sharing virtual networks via network slicing.
- **Competition** over the scarce spectrum resource continues to be fierce between the different wireless services. There are no “clean” spectrum bands for 6G. Spectrum sharing is a necessity in the 6G era.
- **Traditional spectrum requirement estimations** have provided high-level total amounts of spectrum needed for mobile communications to justify new spectrum allocations. They do not accurately characterize the expected spectrum needs of future stakeholders.
- **Complexity and range of spectrum bands and spectrum access models** has increased with 5G. The same will continue in 6G.
- **Serving the unconnected** is still a challenge. Making spectrum available where and when it is not used by existing holders of spectrum usage rights is still not a reality widely.

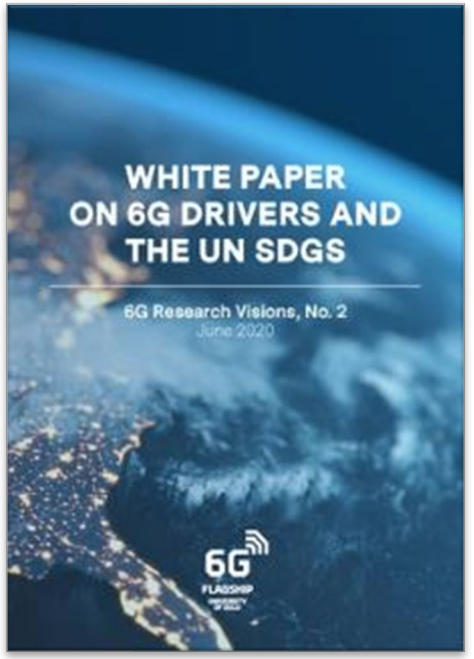
Sustainable spectrum management

- **Sustainability is a cross-cutting priority** that needs to enter different thematic topics, including spectrum management, considering that we should not limit the range of environmental, social and economic options open to future generations.
  - Environmental sustainability examples:
    - The capabilities of devices increase, impacting spectrum use. Processing of data locally in end user device or network edge changes how data flows occur in the future. With sustainability thinking, the goal is to minimize transmitted data and only transfer what is needed. Total amount of consumed data is not sustainable.
    - High energy efficiency per bit can be achieved only when data rates are extremely high requiring wide bandwidths. Only use cases that will need it and can utilize it should be promoted.
    - Selection of communication solutions which cause the lowest environmental impact once this info is available.
  - Social sustainability: Digital inclusion – affordable access to digital services and local community driven networks.
  - Economic sustainability: reasonable auction prices that allow investment in the networks.
- **Question: How do long-term exclusive spectrum licenses without obligations to share unused spectrum fit in the new sustainable spectrum management framework?**

M. Matinmikko-Blue, S. Yrjölä, P. Ahokangas, Multi-perspective approach for developing sustainable 6G mobile communications, Telecommunications Policy, Vol. 48, No. 2, 2024, https://doi.org/10.1016/j.telpol.2023.102640.

Collaborations between academia, industry, and governments





M. Matinmikko-Blue, et al. (eds.). (2020). White Paper on 6G Drivers and the UN SDGs. (6G Research Visions, No. 2). University of Oulu. http://urn.fi/urn:isbn:9789526226699

https://www.6gflagship.com/white-paper-on-6g-drivers-and-the-un-sdgs/

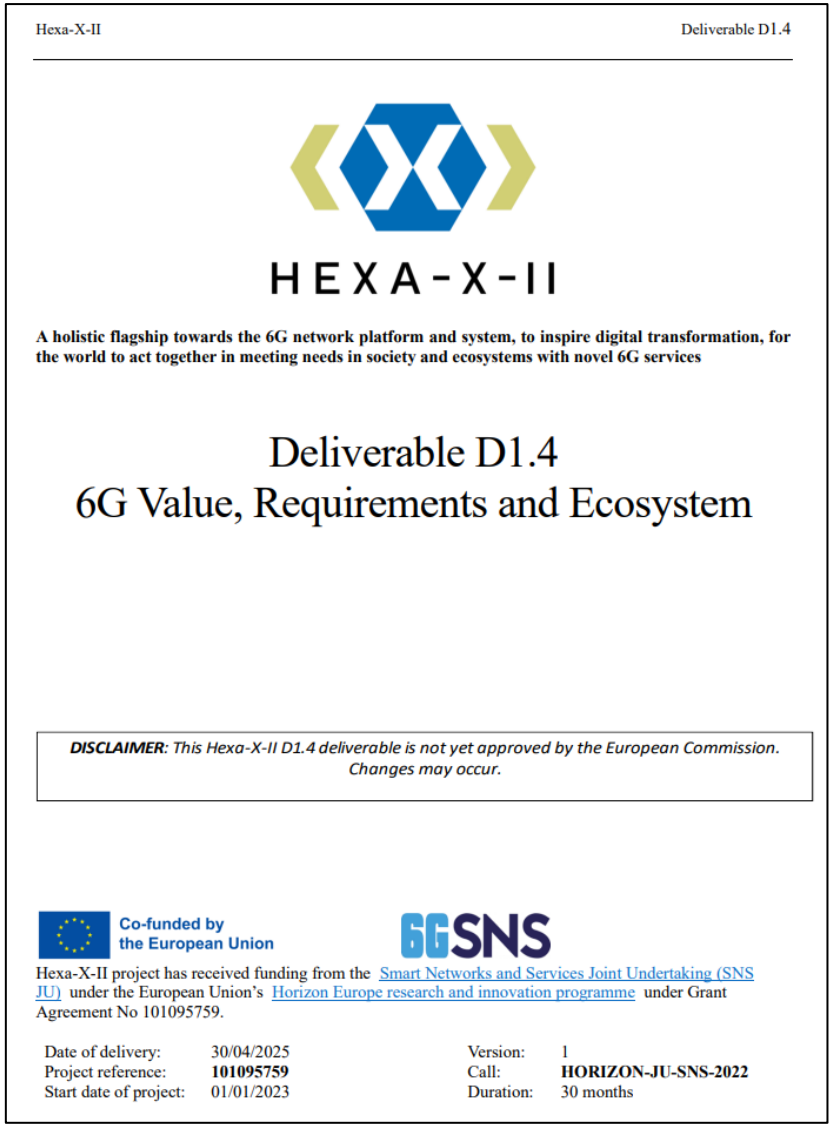
Recent European 6G research activities

- Hexa-X-II project's final sustainability deliverable is out

https://hexa-x-ii.eu/wp-content/uploads/2025/05/D1.4-final.pdf

- SUSTAIN-6G project has started

https://sustain-6g.eu/



Conclusions

- **Values driven ICT development** is in focus in European 6G research. Especially, **sustainability is a key driver for 6G R&D** (in Europe), including minimizing negative and maximizing positive impacts on environment, people and economy, considering environmental, social and economic sustainability pillars.
  - End users (consumers and verticals) in Europe want to know the sustainability impact for informed decision making that puts sustainability in the center. Yet, ICT business is still about selling more and encouragement to consume more. The whole thinking needs to change.
- Spectrum decisions are long-term compromises between conflicting stakeholder claims, calling for **proper stakeholder management**.
  - How to make sure that there is room for innovation? Who looks after the interests of end users and those without dominant position?
- **Spectrum sharing needs to be incorporated into 6G spectrum discussions from the beginning** of the technology development phase and not a restriction posed afterwards.
  - Impact of new technological developments (AI, local processing, increased device capabilities) and deployment models (local 5G/6G, flying objects) on interference management within existing regulatory framework needs to be understood and taken into consideration when developing regulations.
- Close collaboration between academia, industry and governments benefits everybody. This calls for multi-disciplinary multi-stakeholder mindset and actions. **Strengthening the role of research community** in providing evidence-based results to decision making benefits everybody.

Thank you!

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