# Multi-disciplinary approach to sustainable 6G development

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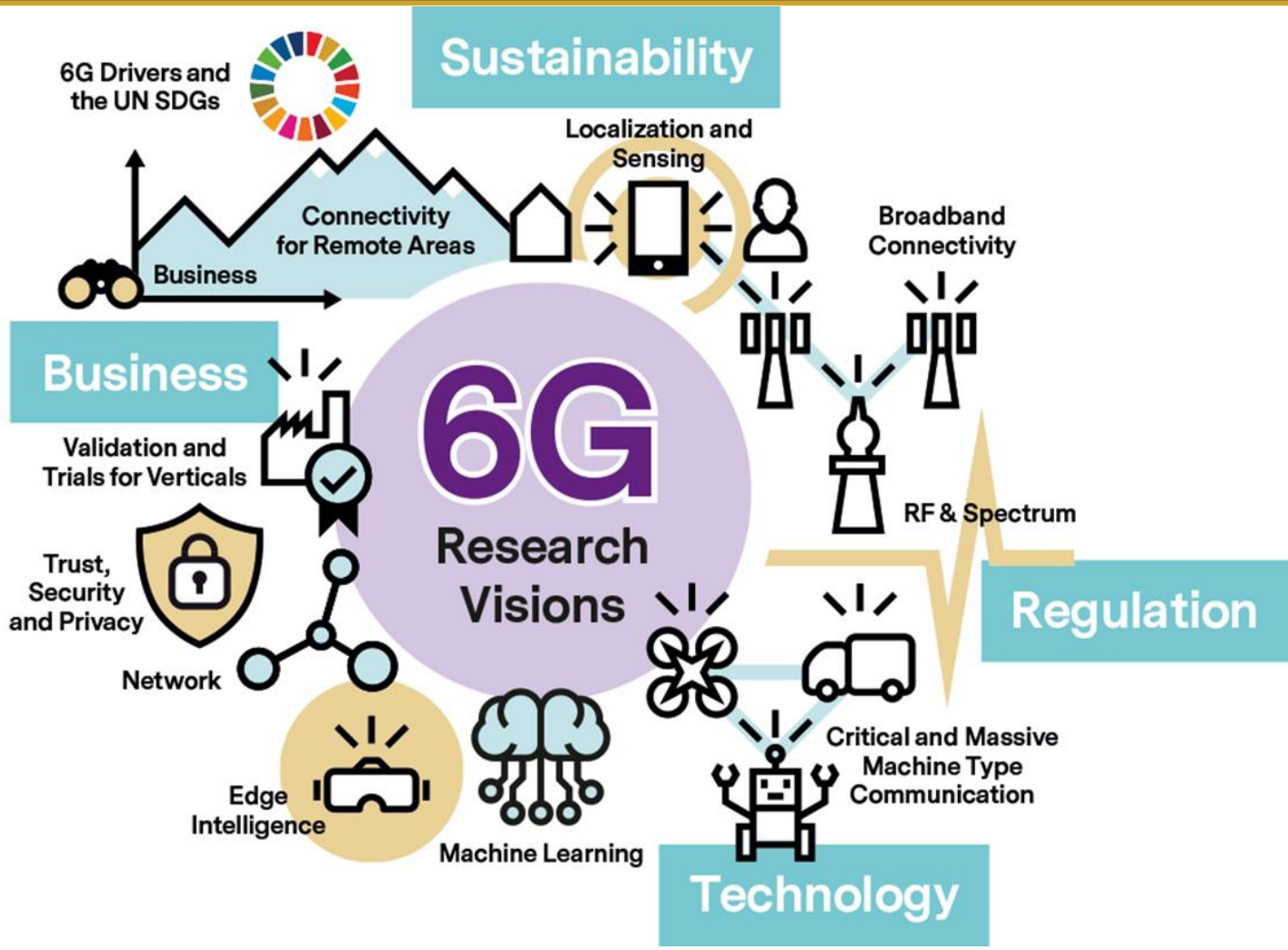
# Finnish 6G Flagship's multi-disciplinary agenda (2018-2026)

- 6G Flagship's multi-disciplinary research roadmap includes technology, business, sustainability, and regulation perspectives.
- Multi-stakeholder collaboration emphasises academia, industry, and public sector interplay.
- Sustainability and UN SDGs identified as global drivers for 6G R&D.
- Contributions to ITU-R process on IMT-2030.



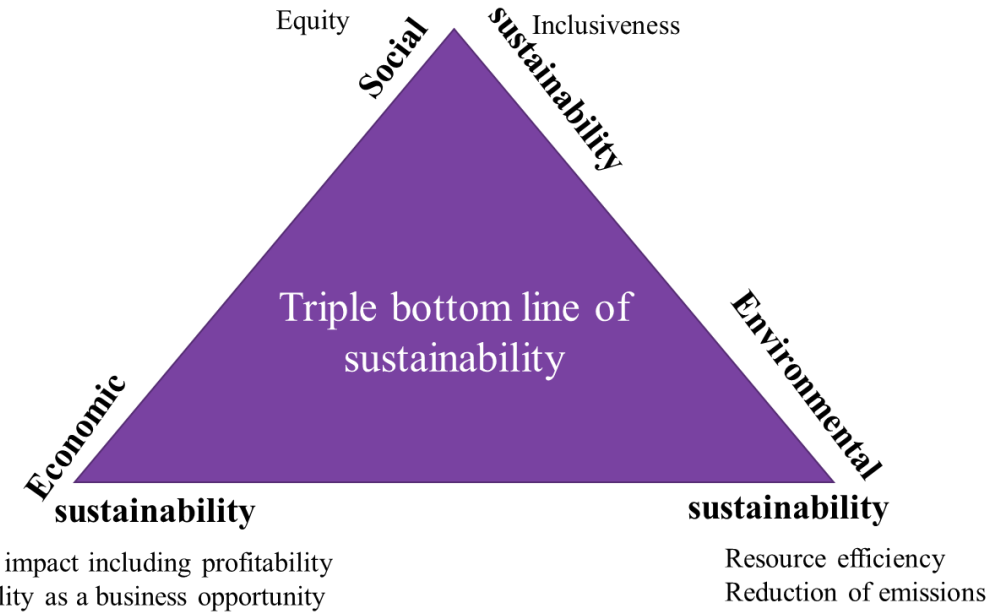

Success story: **Local 5G operator concept with local spectrum licensing introduced in EuCNC 2017.**

# SUSTAINABILITY CONSIDERATIONS

# 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 <u>economic, social, and environmental</u> options open to future generations**".




**SUSTAINABILITY WILL CHANGE THE GAME IN MOBILE COMMUNICATIONS. 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.

# Connecting UN SDGs to ICTs


| SDG: | Target: | Indicator: |
|---|---|---|
| 4 QUALITY EDUCATION | **4.4** By 2030, substantially increase the number of youth and adults who have relevant skills, including technical and vocational skills, for employment, decent jobs and entrepreneurship | **4.4: Proportion of youth/adults with ICT skills, by type of skills** |
| 5 GENDER EQUALITY | **5.b** Enhance the use of enabling technology, in particular information and communications technology, to promote the empowerment of women | **5b: Proportion of individuals who own a mobile telephone, by sex** |
| 9 INDUSTRY, INNOVATION AND INFRASTRUCTURE | **9.c** Significantly increase access to information and communications technology and strive to provide universal and affordable access to the Internet in least developed countries by 2020 | **9.c: Percentage of the population covered by a mobile network, broken down by technology** |
| 17 PARTNERSHIPS FOR THE GOALS | **17.6** Enhance North South, South South and triangular regional and international cooperation on and access to science, technology and innovation and enhance knowledge sharing on mutually agreed terms, including through improved coordination among existing mechanisms, in particular at the United Nations level, and through a global technology facilitation mechanism | **17.6: Fixed Internet broadband subscriptions, broken down by speed** |
| 17 PARTNERSHIPS FOR THE GOALS | **17.8** Fully operationalize the technology bank and science, technology and innovation capacity building mechanism for least developed countries by 2017 and enhance the use of enabling technology, in particular information and communications technology | **17.8: Proportion of individuals using the Internet** |

**There are only 5 ICT indicators (previously 7) in the UN SDG framework of 169 targets and 231 indicators. In reality, the linkage to ICT is stronger.**

THE 17 GOALS | Sustainable Development (un.org)

# ICT sector’s dual role

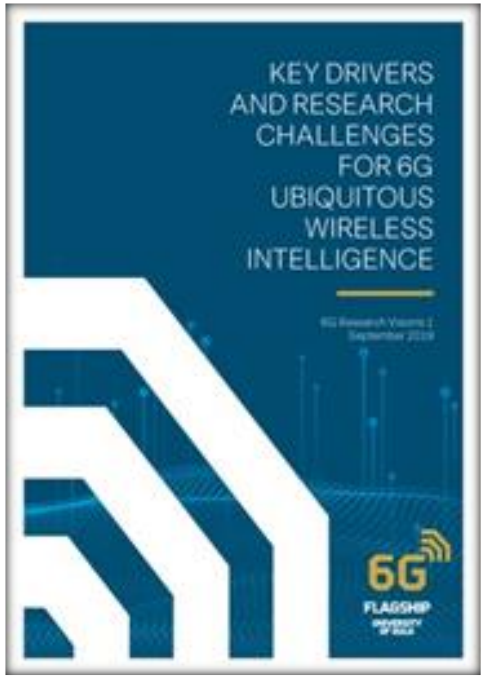
- **Enabling role** to help different sectors of society towards environmentally and socially sustainable operations via ICT solutions and services in an economically feasible manner (so called handprint).
- **ICT** solutions and services’ **own environmental sustainability burden** (so called footprint) keeps increasing and rapid changes must be done to stop this development.

- The role of 6G for **emitting and consuming less** is equally important, as is support for **absorbing and enabling more** in other sectors.
- Urgent need for **new indicators, measurement methods and requirements** for future sustainable 6G solutions and services and their use to solve major sustainability challenges.

# Sustainability was agreed to drive 6G R&D globally

- 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**

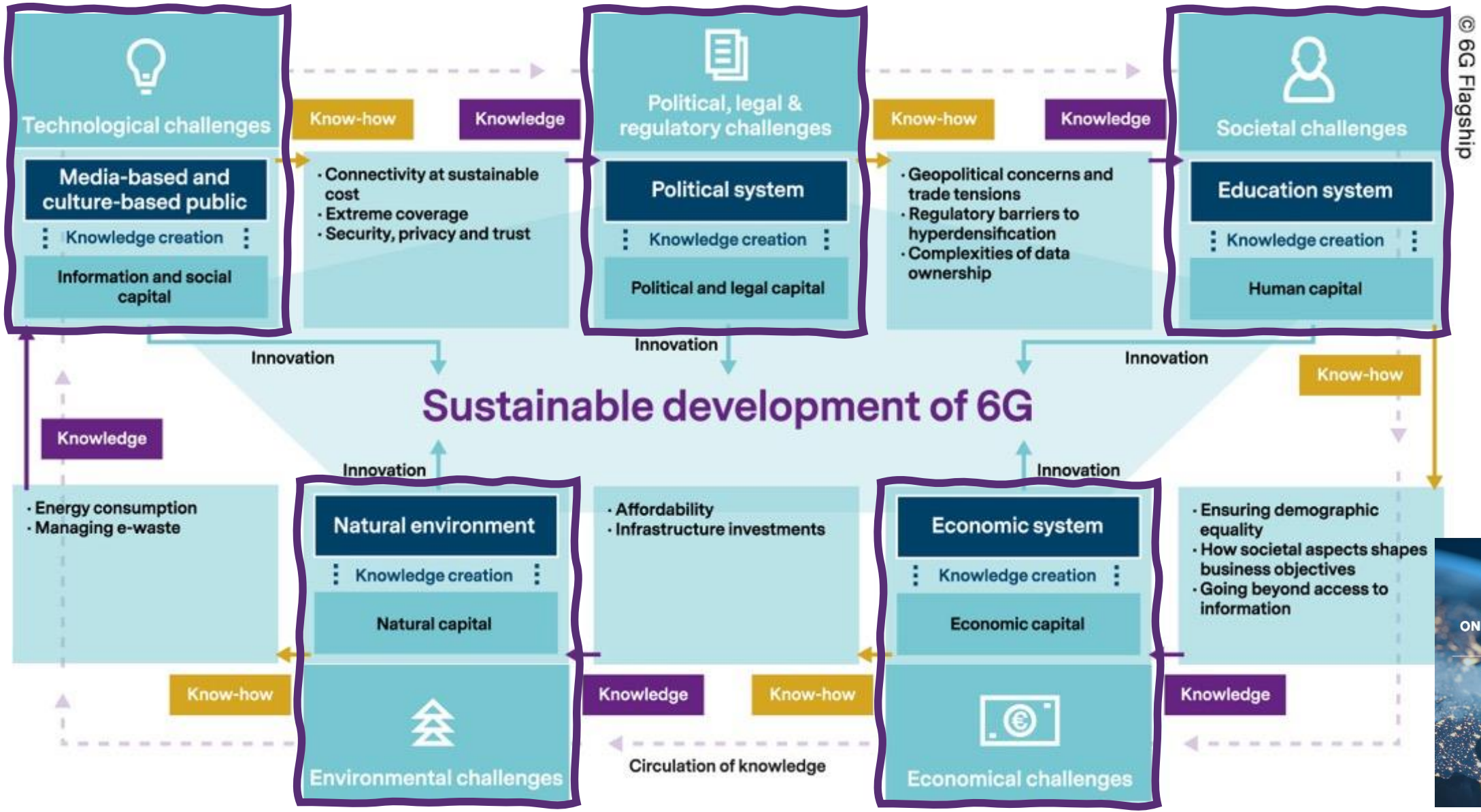
# Linking 6G and UN SDGs via existing indicators

4 QUALITY EDUCATION

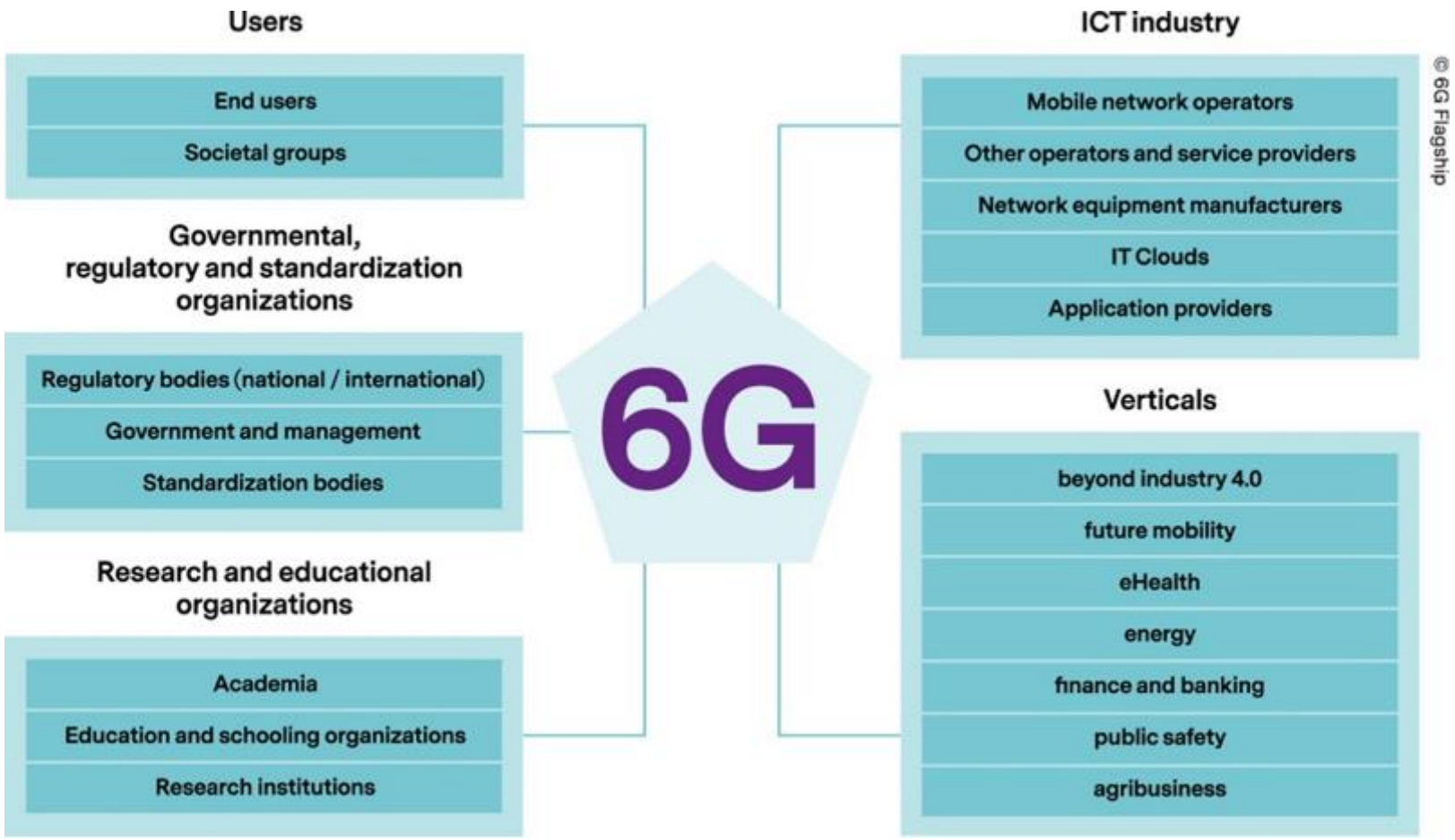

| UN Targets | UN Indicators | 6G can |
|---|---|---|
| **4.2** By 2030, ensure that all girls and boys have access to quality early childhood development, care and pre-primary education so that they are ready for primary education | **4.2.1** Proportion of children under 5 years of age who are developmentally on track in health, learning and psycho-social well-being, by sex<br><br>**4.2.2** Participation rate in organized learning (one year before the official primary entry age), by sex | **Increase access to remote learning and developmental activities** to children under 5 years.<br><br>**Enable improved socialization** through virtual interactions.<br><br>**Improve remote access to pediatrics** in locations with poor connectivity.<br><br>**Facilitate remote and virtual training** of local pediatricians.<br><br>**Help improve and develop the knowledge and skills** of local medical community.<br><br>**Deliver prosthetic technologies** to support handicapped children.<br><br>**Permit family and experts to monitor** the cognitive development of children with Brain-Computer Interfaces.<br><br>**Help coordinate virtual meetings** for preschoolers. |

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

# Identified key challenges of 6G-driven sustainable development using Quintuple Helix model




# Key stakeholders in sustainable development of ICTs





[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

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

# Environmental sustainability impact of the use of ICTs

- ICTs have environmental impacts at each stage of their lifecycles (**first order effects**).
- ICTs can enable efficiencies in lifestyle and in all sectors of the economy through the provision of solutions that can improve energy efficiency, inventory management and business efficiency by reducing travel and transportation (**positive second order effects**).
- ICT can be used to maintain or even increase fossil-based economy, resulting in higher GHG emissions. (**negative second order effects**)
- Effects enabled by the use of ICTs can be modified due to rebound, i.e., the tendency that increased efficiency is offset by increases in emissions due to e.g., consumption. (**higher order effects** that can be positive or negative.)
- ICTs have structural effects at the societal level by reshaping how people lead their lives. (**higher order effects** that can be positive or negative.)
- **Expanding this to social and economic sustainability and applying the sustainability impact thinking to minimize negative impacts and maximize positive impacts should be a priority.**

Recommendation ITU-T L.1480 (12/2022). Enabling the Net Zero transition: Assessing how the use of information and communication technology solutions impact greenhouse gas emissions of other sectors.

# GLOBAL WORK

# 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) 6G Outlook annex includes sustainability as follows:

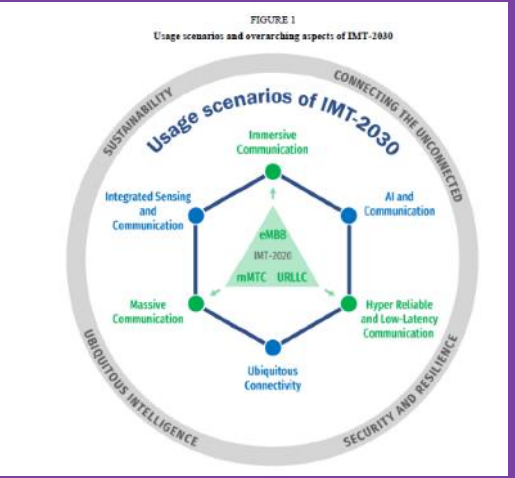
6G technologies must also be an **enabler for sustainability, considering environmental, social, and economic perspectives**. A **reduced carbon footprint** and **energy efficiency** will be important design goals for 6G networks. More broadly, 6G should allow for **reduced energy consumption across 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**.

# Sustainability in Global IMT-2030 Framework at ITU-R

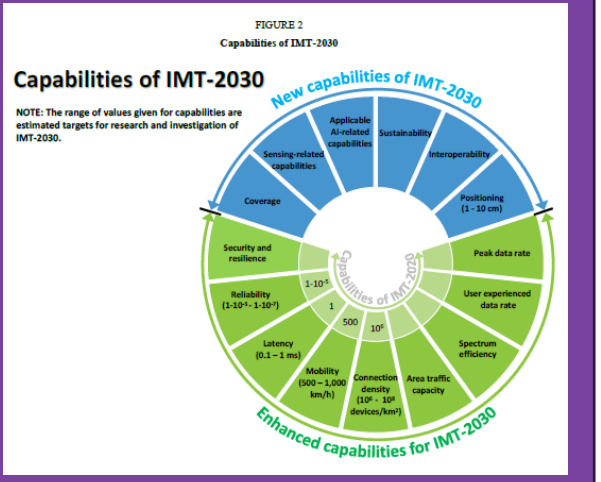
## Trends and drivers

- Motivation and societal considerations
- User and application trends
- Technology trends
- Spectrum implications

## Usage scenarios




## Capabilities




Sustainability is a cross-cutting priority included in all parts of the global IMT-2030 framework. However, it was not easy.

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

# 2.1 Motivation and societal considerations / IMT-2030

**Sustainability** refers to the **principle of ensuring that today's actions do not limit the range of economic, social and environmental options to future generations**. IMT-2030 is envisaged to be built on energy efficiency, low power consumption technologies, reducing greenhouse gas emissions and appropriate use of resources under the applicable model of circular economy, in order to address climate change and contribute towards the achievement of current and future sustainable development goals.

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

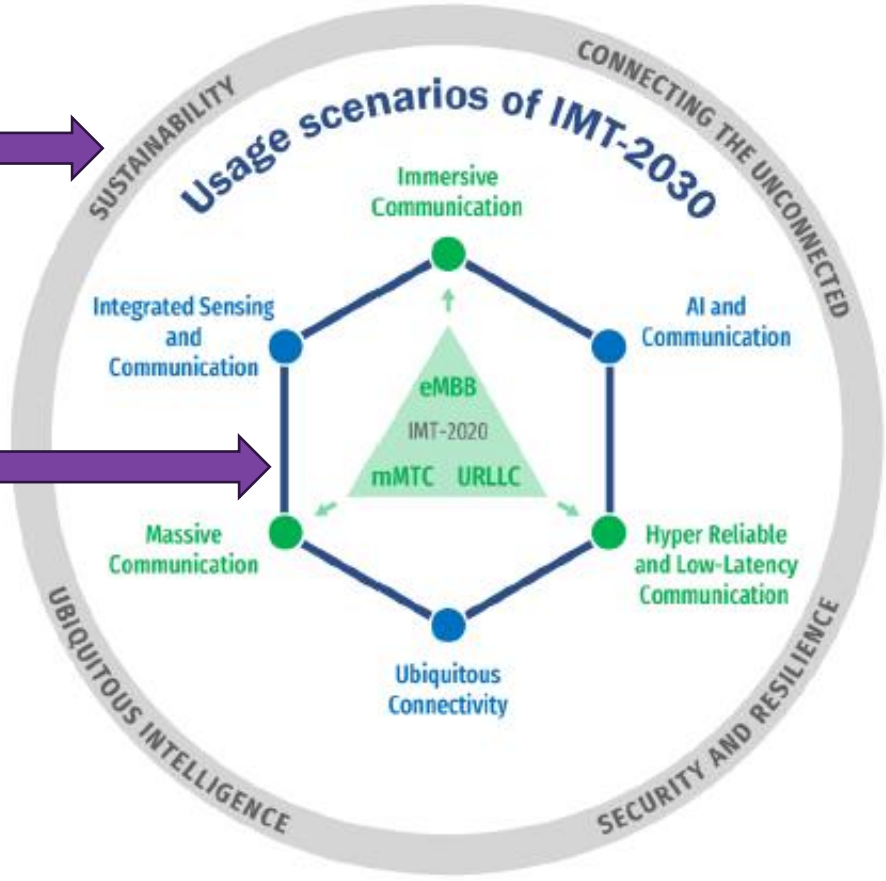
# Usage scenarios for IMT-2030

- New elements – four overarching design principles
  - **Sustainability**
  - Security and resilience
  - **Connecting the unconneted**
  - 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 countries objected to it and wanted to delete it time after time.

FIGURE 1

**Usage scenarios and overarching aspects of IMT-2030**




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

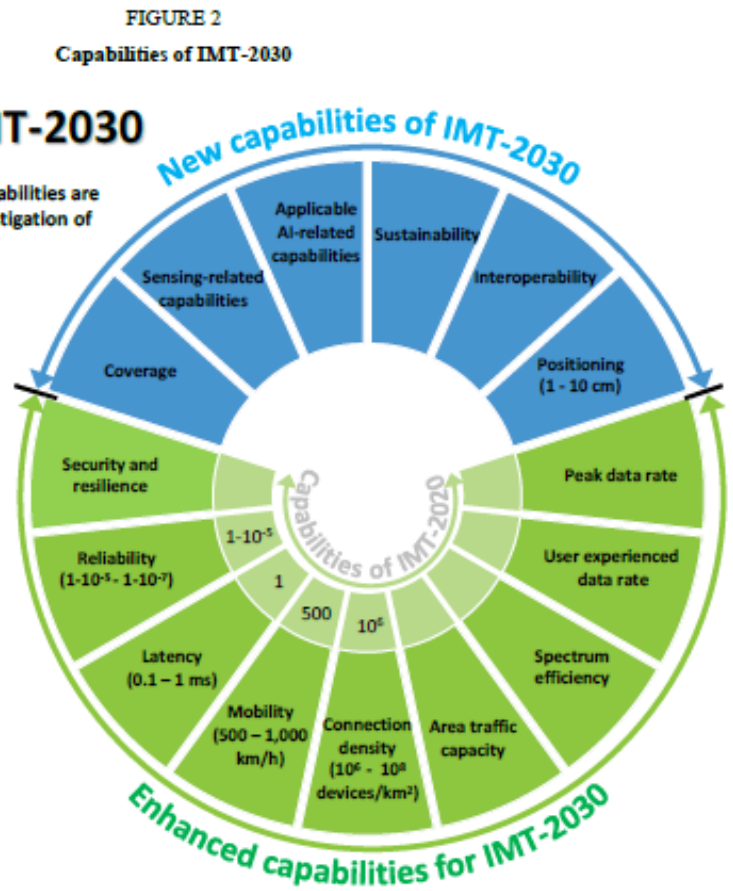
# Capabilities – performance indicators

ENHANCED:

- Peak data rate
- User experienced data rate
- Spectrum efficiency
- Area traffic capacity
- Connection Density
- Mobility
- Latency
- Reliability
- Security and resilience

NEW:

- Coverage
- Positioning
- Sensing-related capabilities
- Applicable AI-related capabilities
- **Sustainability**
- Interoperability




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

➢ **Requirements for IMT-2030 radio interface will be defined in 2024-2025 in ITU-R WP5D. It is difficult to include non-technical requirements into the work**

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

# MULTI-DISCIPLINARY APPROACH

# Sustainability considerations for 6G

- 6G combines communication with other services, like imaging, sensoring, and locationing, providing a **measurement tool** with hyper-local granularity.
- New mechanisms are needed to reduce the carbon footprint through **sharing and optimizing the use of all potential resources**.
- **Optimization of the collection, processing, storage and transfer of data** between different network locations is critical.
- Technologies for significant improvement of **energy efficiency** and **reduction of total energy consumption** for 6G are needed including new end to end measures, measurement methodologies and techniques.
- **Sharing of data and methods** on the impact of the wireless communications sector **between sectors and stakeholders** is needed to develop sustainable solutions.
- The challenge of **connecting the unconnected** needs to be solved with affordable solutions to support social sustainability.

# Example: Environmental sustainability throug ”6R”

## Reduce

- **End-to-end energy consumption** needs to be reduced and **energy efficiency** needs to be improved.
- End-to-end visibility and transparency on **supply chains' resource use** for circular economy.
- Measurement and **reduction of CO2 and other emissions** over the product/service lifecycle.
- Assessment, evaluation and monitoring of **human exposure to EMF.**

## Reuse

- The **reuse of resources** (incl. infrastructure, spectrum) needs to increase.
- **Open source** paradigm expands to increasing the reuse of SW and data.
- Introduction of new generation mobile communication technology needs to reuse existing infrastructure.
- **Modular structure** of devices would allow reuse of components.

M. Matinmikko-Blue, S. Yrjölä, P. Ahokangas, K. Ojutkangas & E. Rossi. (2021). 6G and the UN SDGs - Where is the connection? Wireless Personal Communications. https://doi.org/10.1007/s11277-021-09058-y

## Recycle

- Higher level of **recycling of materials/devices/components** is needed.
- Redefining waste.

## Recover

- Parallel use of different generations of **component technologies** to optimize resource use and minimize sustainability burden.

## Redesign

- **User experience** needs to be at the center and rethought including different types of users.
- De-centralized (zones/communities) could emerge.
- New network architecture needs to accommodate variety of different needs for communications, computing and other services.
- The different roles of users and non-users needs to be addressed.

## Remanufacture

- Increasing use of “as a service (aaS)” business models.
- Considering remanufacturing as a convenient business opportunity for developing countries.

# Example: Sustainable spectrum management

**Principle I:** Exclusive spectrum licenses should come with obligations on social sustainability (e.g. coverage)

**Principle II:** Rapid access to spectrum to solve major sustainability challenges needs to be ensured with new sharing-based spectrum access models

**Principle III:** The most environmentally sustainable transmission solution must always be selected

**Principle IV:** Proper metrics and measurement methods need to be defined and developed for sustainable spectrum access

**Principle V:** Proper mix of spectrum management models is needed to allow a variety of stakeholders to deploy wireless systems

**Principle VI:** The role of spectrum sharing as the enabler needs to be acknowledged and developed

**Principle VII:** Proper stakeholder management needs to be incorporated into spectrum decision making

M. Matinmikko-Blue. (2022). Sustainable Spectrum Management for 6G. Invited paper at 25th International Symposium on Wireless Personal Multimedia Communications (WPMC). Herning, Denmark, 30 October-2 November 2022.

# Multi-perspective approach to sustainable 6G development (1/3)

| | Business | Regulation | Technology |
|---|---|---|---|
| **Environmental sustainability** | Growth of existing business and creation of new businesses.<br>New business opportunity to solve environmental sustainability problems. | Requirements on ICT sector's negative impact on environment (footprint).<br>Incentives for reducing other sectors' negative impact on environment (handprint). | Methods to measure footprint and handprint.<br>Innovations to reduce footprint and increase handprint. |
| **Social sustainability** | Social enterprises, frugal community innovations.<br>Spillovers, social returns. | Ensuring and monitoring the achievement of the targets of UN SDGs. | Development of trustworthy network technologies. |
| **Economic sustainability** | Feasibility and continuity of operations. | Healthy and functioning competitive market.<br>Public-private-people partnersips. | Affordable digital infrastructure available for all. |

Marja Matinmikko-Blue, Seppo Yrjölä, Petri Ahokangas, Multi-perspective approach for developing sustainable 6G mobile communications, Telecommunications Policy, Volume 48, Issue 2, 2024.

# Multi-perspective approach to sustainable 6G development (2/3)

| | Researchers | Companies | Regulators |
|---|---|---|---|
| **Environmental sustainability** | Metrics and methods to evaluate energy and electricity consumption and GHG emissions and materials consumption across value chains. | Developing standards for measuring environmental footprint and hanprint. Reporting of scope 1, 2 and 3 emissions. | Defining limitations for ICT's negative impacts on environment (footprint). Defining incentives to reduce negative impacts on environment of other sectors through ICTs. |
| **Social sustainability** | Metrics and methods to address social sustainability challenges including digital divide. Development of solutions to social sustainability challenges. | Social responsibility reporting. Frugal innovation associated with low-cost new products, methods and designs for the unserved lower end of the mass-market. | Setting requirements on sustainability in sector specific regulations. Promoting open innovation. |
| **Economic sustainability** | Open architecture to enable ecosystemic value processes and complementary innovations. New sustainable and resilient business opportunities and business models. | Scalable and replicable solutions. Responsible business. Developing new standards for sustainability at large. | Globally harmonised approaches to avoid fragmented markets. Public-private partnerships. |

Marja Matinmikko-Blue, Seppo Yrjölä, Petri Ahokangas, Multi-perspective approach for developing sustainable 6G mobile communications, Telecommunications Policy, Volume 48, Issue 2, 2024.

# Multi-perspective approach to sustainable 6G development (3/3)

| | Researchers | Companies | Regulators |
|---|---|---|---|
| **Business** | Conduct research on business including new business opportunities and business models from sustainable development. | Business decisions driving operations. | Balancing conflicting stakeholder claims with different business interests.<br>Ensuring functional and competitive markets. |
| **Regulation** | Conduct research on regulations and standardization.<br>Provide unbiased research findings to support decisions making.<br>Research on outcomes and impact of regulation. | Dominance of existing strong market players.<br>New players with no power/resources/procedures to influence. | Setting rules and conditions and enforcement. |
| **Technology** | New sustainable technology R&D. | New innovations and technology development.<br>IPR creation. | Keeping up with technology development.<br>Impact of new technology on society and possible changes regulations. |

Marja Matinmikko-Blue, Seppo Yrjölä, Petri Ahokangas, Multi-perspective approach for developing sustainable 6G mobile communications, Telecommunications Policy, Volume 48, Issue 2, 2024.

# Example: Sustainable spectrum management (1/3)

| | Business | Regulation | Technology |
|---|---|---|---|
| **Environmental sustainability** | Rapid access to spectrum for new wireless solutions for solving environmental sustainability challenges as a new business opportunity. | Criteria for assessing spectrum usage footprint.<br>Selection of most sustainable technology and spectrum combination. | Comparison of environmental footprint of spectrum access techniques. |
| **Social sustainability** | Frugal innovations from communities enabled by local access to spectrum. | Setting requirements for connecting the unconnected.<br>Introducing social sustainability related obligations in all spectrum decisions. | Affordable techniques to operate in challenge areas under different spectrum access models. |
| **Economic sustainability** | Opportunities for local business via local network availability.<br>Functioning spectrum markets. | Reasonable licensing fees.<br>Predictability and certainty of spectrum availability. | Timely introduction of global affordable solutions. |

Marja Matinmikko-Blue, Seppo Yrjölä, Petri Ahokangas, Multi-perspective approach for developing sustainable 6G mobile communications, Telecommunications Policy, Volume 48, Issue 2, 2024.

# Example: Sustainable spectrum management (1/3)

| | Researchers | Companies | Regulators |
|---|---|---|---|
| **Environmental sustainability** | Methods and metrics to evaluate environmental sustainability of spectrum access options. | Development of energy and resource efficient technologies and methods. | Rapid access to spectrum for solutions solving challenges. |
| **Social sustainability** | Sharing based spectrum access solutions for challenge areas to bridge the digital divide. | Development of affordable solutions to bridge the digital divide. | Social sustainability obligations in new exclusive licensing (coverage obligations, use it or share it). |
| **Economic sustainability** | Identification of business opportunities and alternative business models for old and new stakeholders in local and global contexts. | Timely access to the quality spectrum driven by business/service requirements. | Making spectrum available at reasonable terms. Licensing fees. Reduce transaction costs and friction in spectrum leasing. |

Marja Matinmikko-Blue, Seppo Yrjölä, Petri Ahokangas, Multi-perspective approach for developing sustainable 6G mobile communications, Telecommunications Policy, Volume 48, Issue 2, 2024.

# Example: Sustainable spectrum management (1/3)

| | Researchers | Companies | Regulators |
|---|---|---|---|
| **Business** | Innovative spectrum access models for new business opportunity. Development of new business opportunities, models and ecosystems around local spectrum availability. | New business opportunities via innovative spectrum access models for old and new stakeholders. | Local licensing models to open market for new entry. Functional spectrum market for trading rights of use. Incentives for using sustainable connectivity solutions. |
| **Regulation** | Understanding spectrum regulations. Contributing sharing techniques, studies and models to regulation. | Promotion of company's agenda in regulatory fora regarding spectrum sharing, spectrum authorization, spectrum bands. Promoting or hindering developments. | Balanced mix of spectrum access models. Acknowledge the role of spectrum sharing. Introduction of proper stakeholder involvement. |
| **Technology** | Development of sharing techniques based on factual assumptions. Development of digital twin of spectrum usage. | Development and promotion of technology according to company's interest. | Refining regulations based on new technology development. |

Marja Matinmikko-Blue, Seppo Yrjölä, Petri Ahokangas, Multi-perspective approach for developing sustainable 6G mobile communications, Telecommunications Policy, Volume 48, Issue 2, 2024.

# Conclusions

- **Sustainability** is a key driver 6G R&D and needs to be taken seriously in the wider community. Sustainability **needs to translate into visible design criteria and solutions,** ensuring that our actions today do not limit the range of **economic, social, and environmental** options open to future generations.
- **End users** (consumers and verticals) **want to know the sustainability impact** already today for informed decision making that puts sustainability in the center..
- A lot of work on sustainability is on-going with different terminology and bold claims. **Avoiding green washing and overpromising** is important.
- **Companies play a crucial role – making sure that organisations' sustainability and responsibility reports' statements are actually reflected in people's work should be a priority.**
- **ICT business is still about selling more and encouragement to consuming more – it is not sustainable.** The whole thinking needs to change.

# Thank you!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# On-going research activities

6G Flagship – More than wireless

Finnish 6G Flagship at University of Oulu


GreenI ICT Visiiri – Vihreän siirtymän kansallinen ICT-ekosysteemi | TIEKE

VISIIRI – Vihreän siirtymän kansallinen ICT-ekosysteemi projekti

Hexa-X-II - European level 6G Flagship project

European level 6G Flagship project