Kansallisen Green ICT-ekosysteemin 4. tapaaminen 14.2.2025

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Oulun yliopisto

OULUN YLIOPISTO

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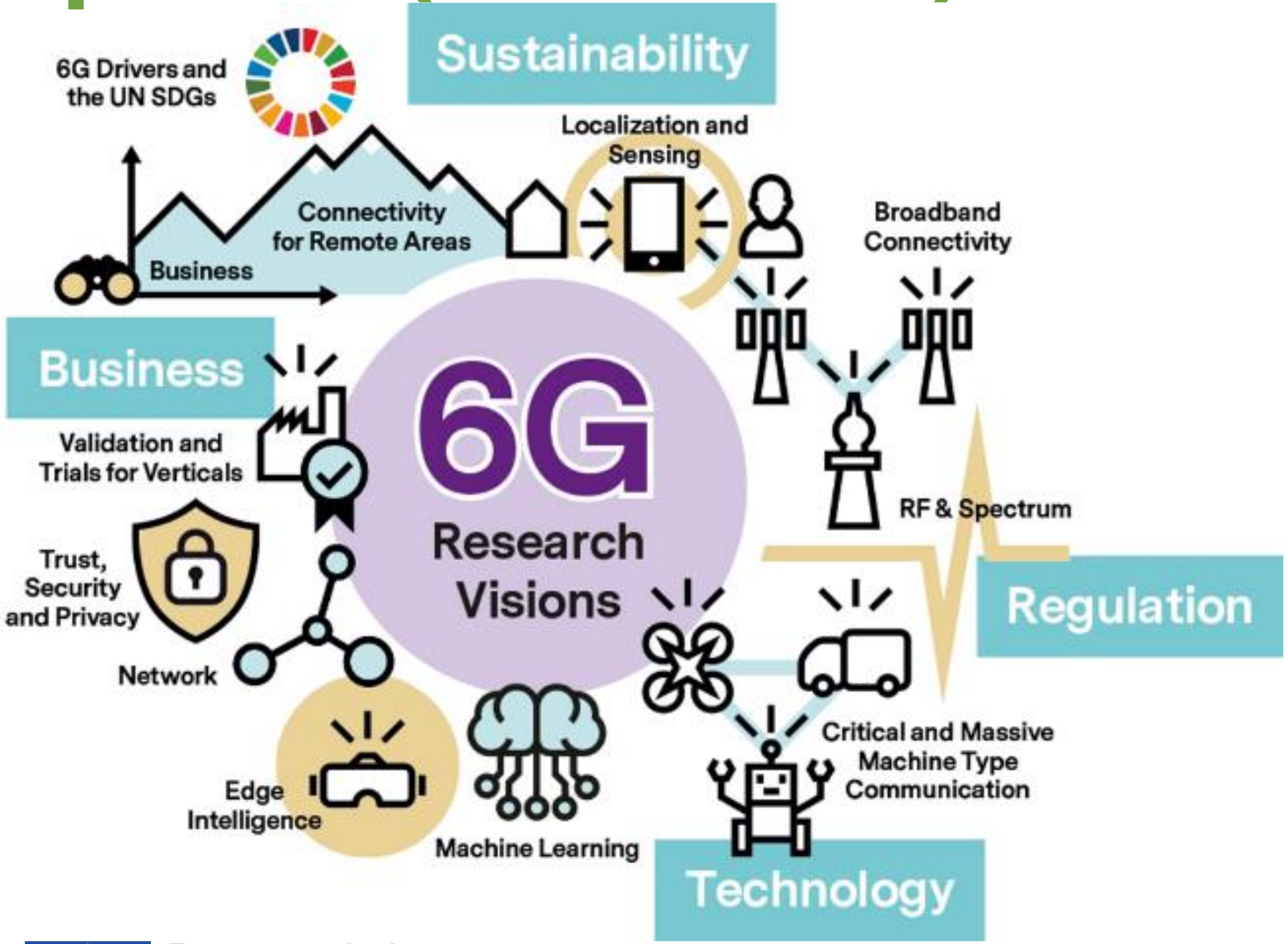
Elinkeino-, liikenne- ja ympäristökeskus

Finnish 6G Flagship and sustainable 6G development (2018-2026)



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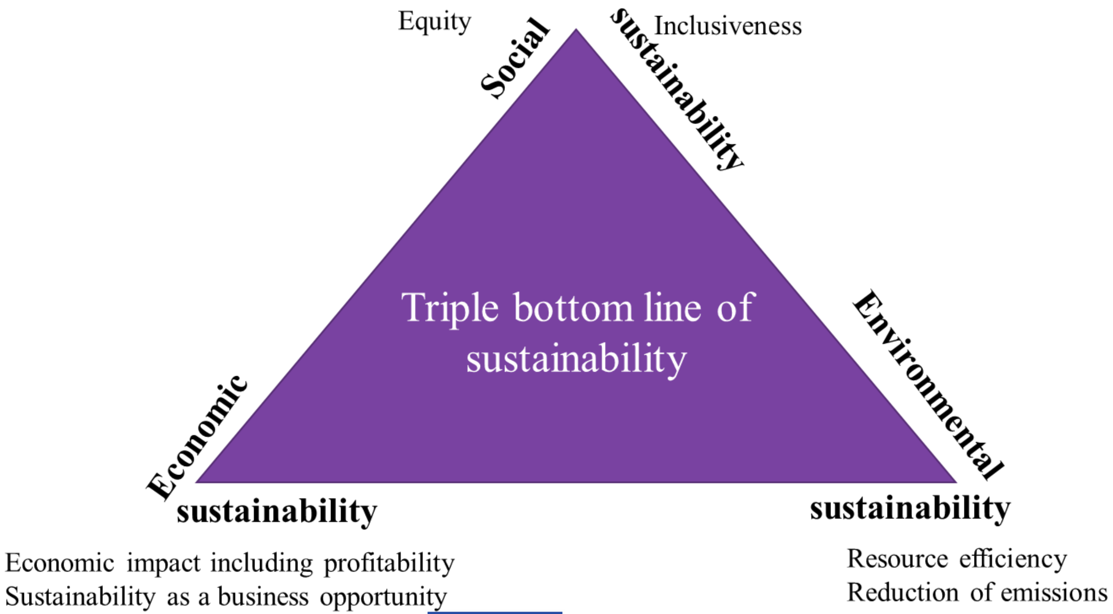
https://www.6gflagship.com/

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**".



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

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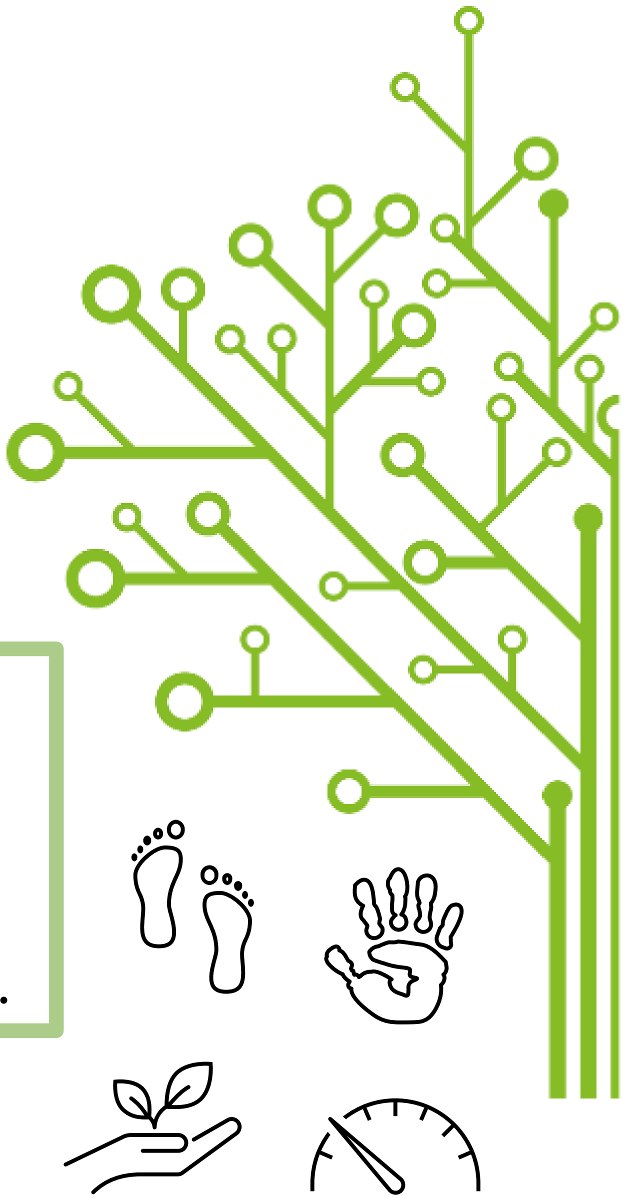
[1]World Commission on Environment and Development's Brundtland report ´Our Common Future`. 1987.
[2]J. Elkington. Cannibals with forks: The triple bottom line of 21st-century business. Capstone Publishing Ltd. 1997.

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 goal is to **simultaneously minimize the negative impacts while maximizing the positive impacts.**
> - Urgent need to define **indicators, measurement methods and requirements** for future sustainable ICT solutions and services and their use to solve major sustainability challenges.



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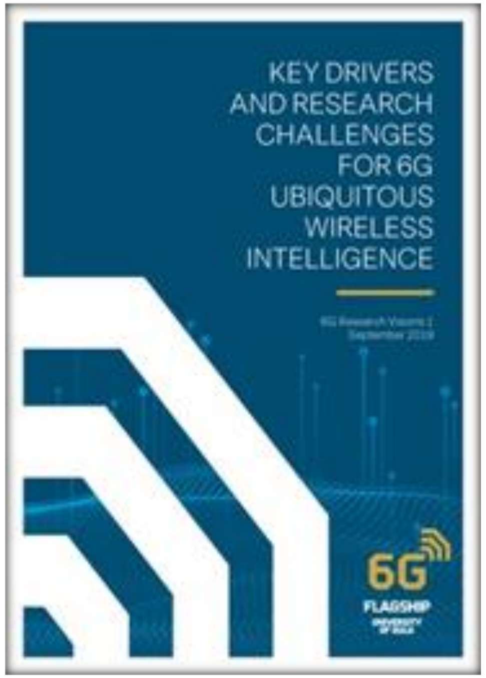
White Papers on 6G and sustainability

6G White Paper 2019



M. Latva-aho & K. Leppänen (eds.) (2019). Key drivers and research challenges for 6G ubiquitous wireless intelligence. University of Oulu. http://urn.fi/urn:isbn:9789526223544

6G White Paper 2020

M. Matinmikko-Blue, et al. (eds.). (2020). White Paper on 6G Drivers and the UN SDGs. University of Oulu. http://urn.fi/urn:isbn:9789526226699

6G White Paper 2020

S. Yrjölä, P. Ahokangas & M. Matinmikko-Blue (eds). (2020). White Paper on business of 6G. University of Oulu. https://urn.fi/URN:ISBN:9789526226767

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https://www.6gflagship.com/white-papers/

Example from European 6G Research: Hexa-X-II

ENVIRONMENTAL SUSTAINABILITY

- Ecological footprint, land use, water use
- Carbon footprint, greenhouse gas emissions, carbon neutrality, decarbonization, net zero
- Use of natural resources, resource efficiency, energy efficiency, energy consumption, use of renewable energy
- Materials, waste management, circularity, recycling, durability
- Assessment of environmental impacts (carbon footprint, resource and water, land, waste, biodiversity footprints)

SOCIAL SUSTAINABILITY

- Availability of resources for good living (food, health, education, income, work, equality, human rights, trust, security, affordability, fairness)
- Digital inclusion – affordable access to digital services for all (including technologies, infrastructure, equipment, services, skills)
- Trustworthiness, security, privacy.

ECONOMIC SUSTAINABILITY

- Corporate level, ecosystem level, societal level for ICT and other sectors
- Sustainable growth, endeavour to net zero
- Sustainable business models, new business opportunities from footprint reduction and handprint effect, circular economy

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Hexa-X-II project Deliverable D1.1.
Hexa-X-II_D1.1_final-website.pdf

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.**

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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.

Examples of environmental sustainability indicators for ICTs

- Energy related indicators
  - Energy consumption
  - Energy efficiency
  - Use of renewable energy
- Climate related indicators
  - Carbon emissions (direct from energy, GHG scope 1)
  - Carbon emissions (indirect from energy, GHG scope 2)
  - Carbon emissions (other indicrect, GHG scope 3)

- Environment related indicators
  - E-waste production
  - Distribution/utilisation of recycled/refurished/reused products
  - Recycled/refurbished/reused components used in products
  - Recyclability
  - Reparability
  - Expected lifetime
  - Raw materials depletion
  - Water usage consumption
  - Waste heat recovery
  - Land use
  - Eco toxicity
  - Human toxicity
  - Eutrophication

European Commission, Joint Research Centre, Baldini, G., Cerutti, I. and Chountala, C., Identifying common indicators for measuring the environmental footprint of electronic communications networks (ECNs) for the provision of electronic communications services (ECSs), Publications Office of the European Union, Luxembourg, 2024, https://data.europa.eu/doi/10.2760/093662, JRC136475.

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Example: France

Electronic communications operators:

- GHG emissions (scope 1 and 2),
- energy consumption of networks (by technology)
- mobile phones volumes (sold, collected, recycled and repackaged).

Device manufacturers:

- GHG emissions
- Use of rare earths and precious metals
- Devices volumes:
- sold by the screen size and by the screen technology or by network compatibility (mobile phone)
- sold repackaged (only for mobile phones)
- collected in order to recycle or repackage them.
- in use by year of sale
- Devices duration of use by year of commercialisation
- Electric consumption of TV and computer screen in operating and idle mode

Data Centres operators:

- GHG emissions
- Number and location of data centres
- Floor area (total, reserved to host IT equipment)
- data centres energy consumption
- IT equipment energy consumption
- maximum permissible electrical power of IT equipment
- Water consumption by types of water
- Cooling systems used
- water discharge areas and conditions

BEREC Report on Sustainability Indicators for Electronic Communications Networks and Services. (2023).

Example: Other countries

Belgium

Electronic communications operators:

- Electricity consumption of different parts of the network (datacentres, network, offices, retail, modems/set top boxes)
- Production and use of renewable energy
- Total energy consumption,
- Energy efficiency (consumption in function of data/clients/revenue)
- CO2-emission (Scope 1 and 2, if available Scope 3)
- Carbon neutrality
- Water consumption, reuse of water, waste,
- Efforts on recycling and refurbishment,
- Number of items recycled/refurbished

Spain

Electronic communications operators:

- Electricity consumption per data unit (kWh/GB)
- Global CO2 emissions
- Consumption per user (Wh/user)
- PUE (Power Usage Effectiveness) for data centres

Finland

Network operators:

- Energy consumption of networks
- Use of renewable energy

BEREC Report on Sustainability Indicators for Electronic Communications Networks and Services. (2023).

Example: ICT sector's GHG emissions

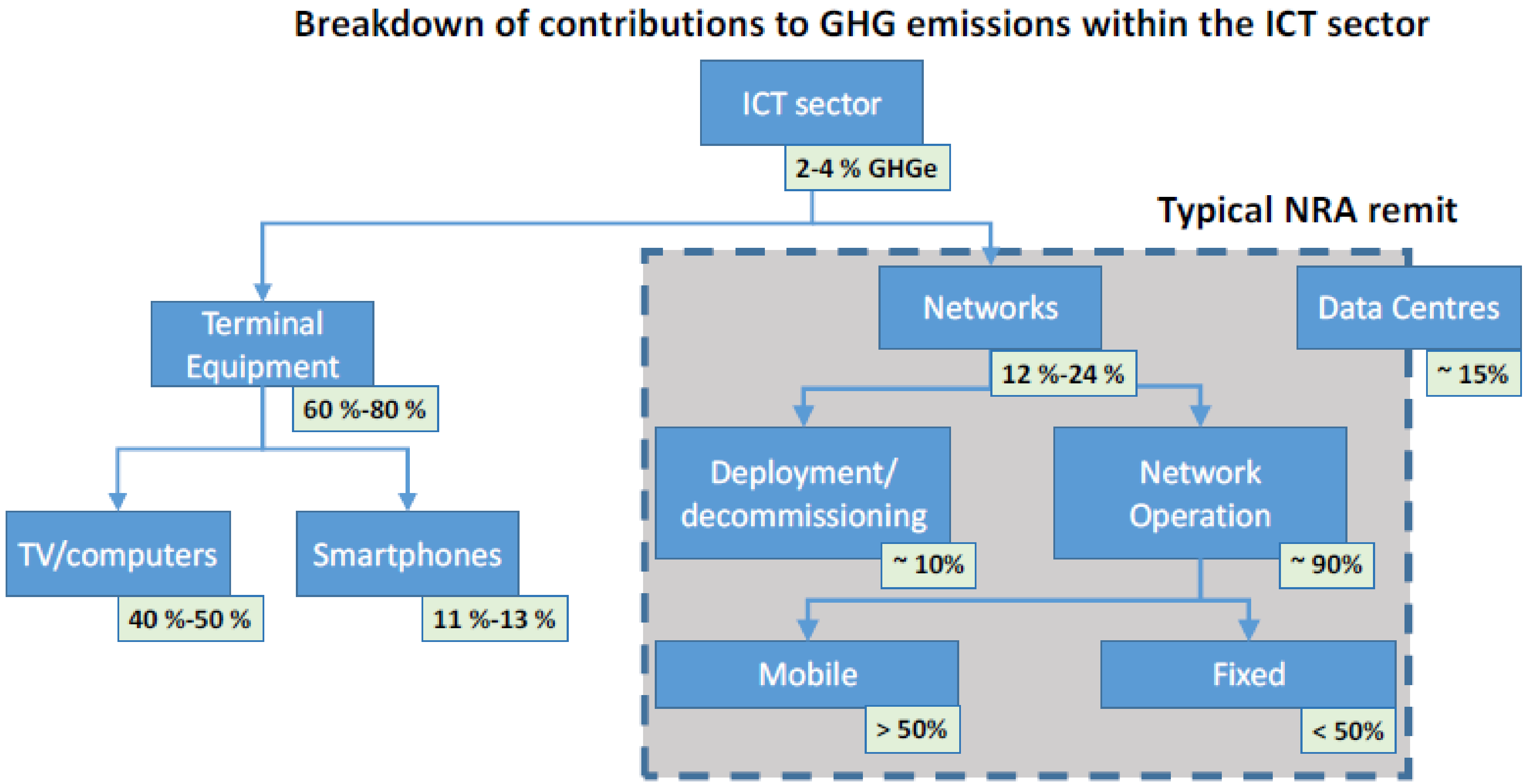

Figure 4 Breakdown of contributions to GHG emissions within the ICT sector. Image drafted by the JRC with data source from (WIK-Consult 2021)).

Source: European Commission, Joint Research Centre, Baldini, G., Cerutti, I. and Chountala, C., Identifying common indicators for measuring the environmental footprint of electronic communications networks (ECNs) for the provision of electronic communications services (ECSs), Publications Office of the European Union, Luxembourg, 2024, https://data.europa.eu/doi/10.2760/093662, JRC136475.

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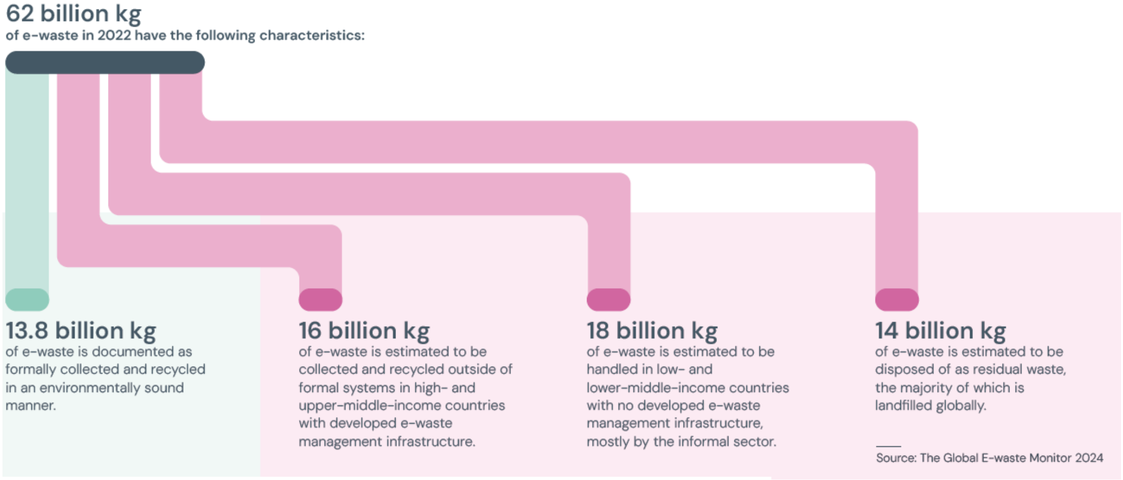
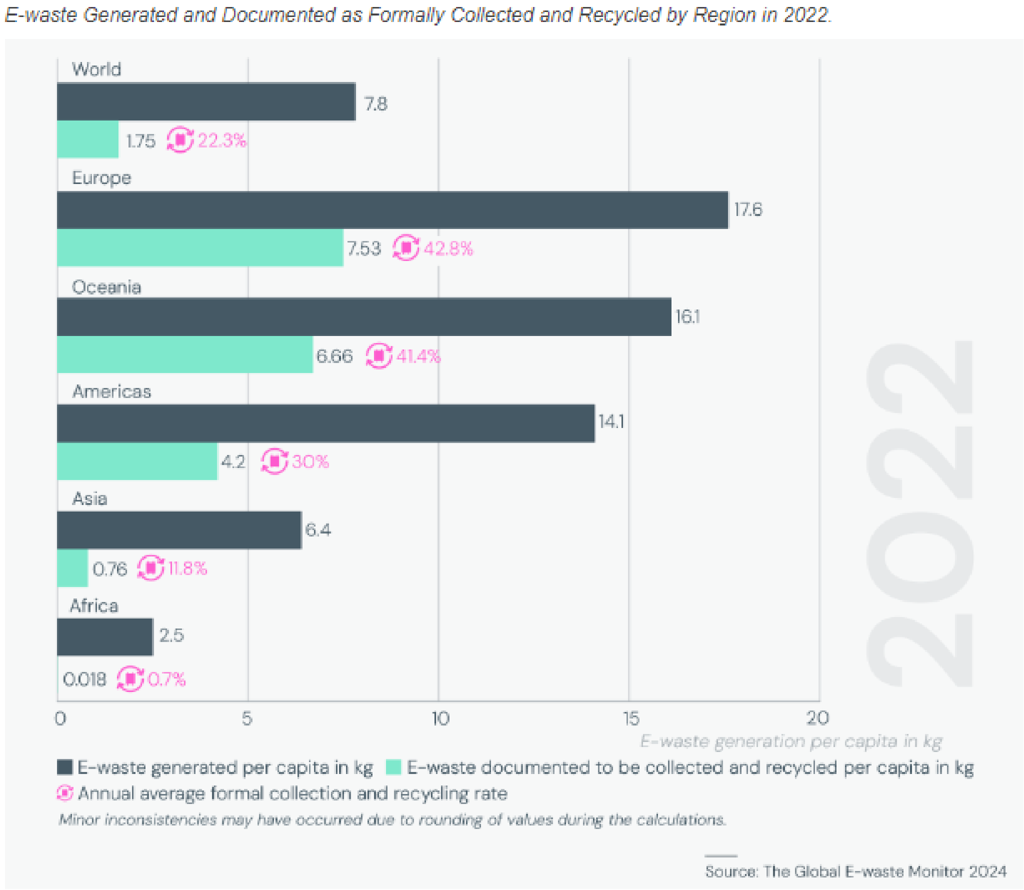
Example: E-waste

- In 2022 the world generated 62 billion kg of e-waste, or an average of 7.8 kg per capita.
- Only 22.3 per cent (13.8 billion kg) of the e-waste generated was documented as properly collected and recycled.





https://www.itu.int/en/ITU-D/Environment/Pages/Publications/The-Global-E-waste-Monitor-2024.aspx

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THE GLOBAL EWASTE MONITOR 2024. Cornelis P. Baldé, Ruediger Kuehr, Tales Yamamoto, Rosie McDonald, Elena D'Angelo, Shahana Althaf, Garam Bel, Otmar Deubzer, Elena Fernandez-Cubillo, Vanessa Forti, Vanessa Gray, Sunil Herat, Shunichi Honda, Giulia Iattoni, Deepali S. Khetriwal, Vittoria Luda di Cortemiglia, Yuliya Lobuntsova, Innocent Nnorom, Noémie Pralat, Michelle Wagner

Example: Mobile network energy consumption

- 73% of the energy of the participating operators is consumed in the radio access network (RAN). The network core (13%), owned data centres (9%) and other operations (5%) account for the rest.
- RAN energy consumption. This includes BTS, Node B, eNodeB and gNodeB energy usage and all associated infrastructure energy usage such as from air-conditioning, inverters and rectifiers. It includes energy usage from repeaters and all energy consumption associated with backhaul transport. It excludes picocell, femtocell and core network energy usage, as well as mobile radio services.
- Core energy consumption. Energy consumed by the core network related to the mobile network. This includes the RNC, BSCs, MSC (or MSC-S and MGW), SGSN, GGSN, HLR (including AuC), SMS-C, MMS-C, MME, Serving Gateway and all associated infrastructure energy usage such as from air-conditioning, inverters and rectifiers. It includes energy usage from NOCs and value-added service platforms, and all energy consumption associated with backhaul transport. It excludes energy usage from BSS and OSS, fixed network equipment, call centres and offices.
- Data centre energy consumption – energy consumed by data centres, which are the physical sites that host operators' IT, including OSS and BSS and intranet infrastructure. Our analysis only includes energy consumption for data centres owned by an operator; it does not include that related to leased or outsourced capacity from webscale providers such as AWS, Microsoft and Google.
- Other operations – energy consumed by the mobile operator for its own operations. This includes offices, shops, retail activity and logistics.

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Source: GSMA Intelligence. Going Green. 2021.

Sustainability and 6G

- EU - US Trade and Technology Council’s (TTC) Joint Statement EU-US TTC in Sweden (europa.eu) 6G Outlook annex from 2023 introduces sustainability in mobile communications 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 definition work

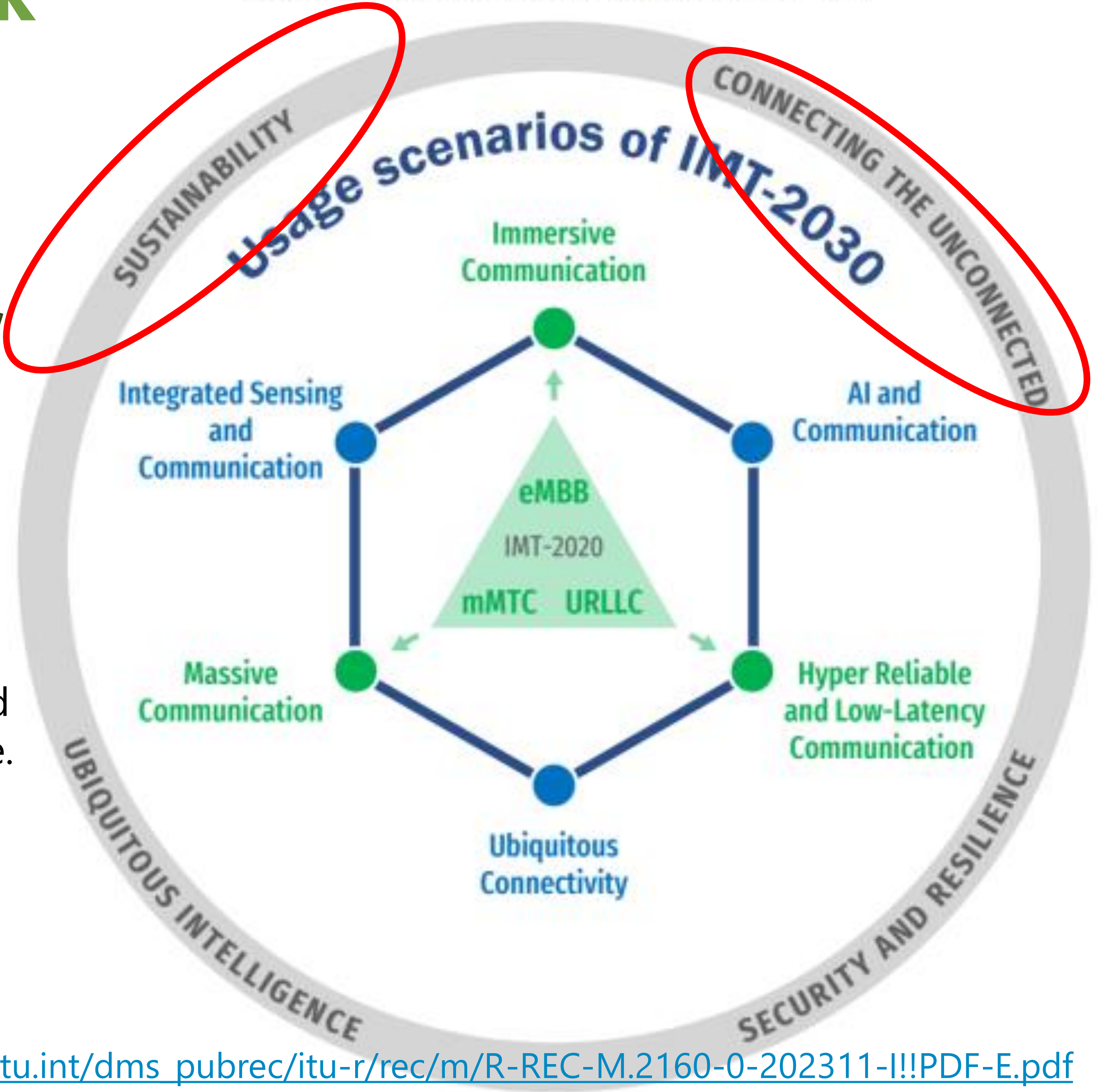
Recommendation ITU-R M.2160-0 (11/2023). Framework and overall objectives of the future development of IMT for 2030 and beyond.

- 6 usage scenarios
- 4 overarching design principles

Sustainability, or more specifically **environmental sustainability,** refers to the ability of both the network and devices to minimize greenhouse gas emissions and other environmental impacts throughout their life cycle. Important factors include improving energy efficiency, minimizing energy consumption and the use of resources, for example by optimizing for equipment longevity, repair, reuse and recycling.

FIGURE 1

Usage scenarios and overarching aspects of IMT-2030



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https://www.itu.int/dms_pubrec/itu-r/rec/m/R-REC-M.2160-0-202311-I!!PDF-E.pdf

Global 6G definition work: Capabilities / performance indicators

ENHANCED FROM 5G:

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

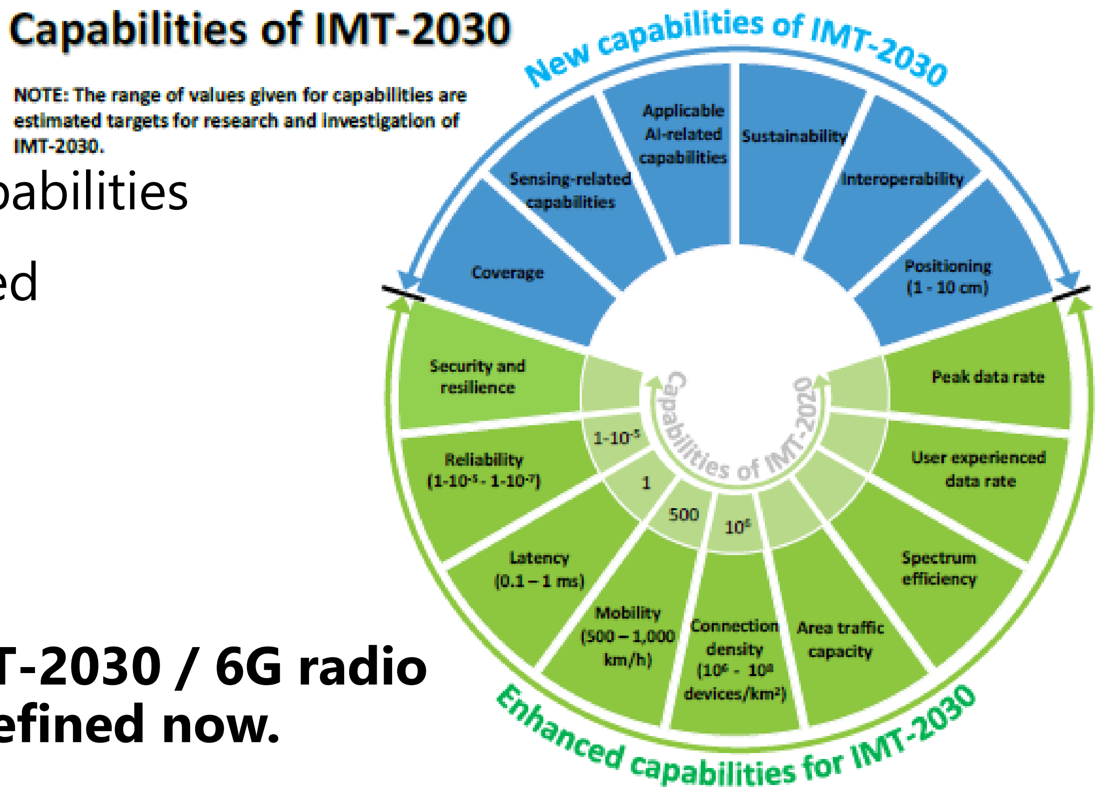
NEW:

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

➢ **Requirements for IMT-2030 / 6G radio interface are being defined now.**

FIGURE 2

Capabilities of IMT-2030



> Getting sustainability into global 6G framework was extremely difficult. Many companies and Asian countries objected to sustainability 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]

Conclusions

- **Environmental sustainability is closely related to economic and social sustainability perspectives. Maximising the positive impacts while minimizing the negative impacts is the shared goal.**
- **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.
- **People and organizations play a crucial role – making sure that sustainability and responsibility reports' statements are actually reflected in people's work should be a priority. Today that rarely is the case.**
- **ICT business is still about selling more and encouragement to consuming more – it is not sustainable.** The whole mindset of the business needs to change.

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