Hexa-X-II D1.4 Deliverable

6G Value, Requirements and Ecosystem











Hexa-X-II

hexa-x-ii.eu

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Sustainability Analysis and Hexa-X-II Use case Methodology

Sensitivity: Internal

Introduction



This deliverable provides the final set of 6G Use Cases, with analysis based on the sustainability pillars and technical understanding. The sustainability values of each use case and how 6G supports them are highlighted through the Key Values and Key Value Indicators.



The value of 6G in use cases is addressed through business modelling and stakeholder analysis. In addition, different outcomes of the exchanges and interactions with the ecosystem members are presented.



It also provides a summary of key concepts and learnings that have been compiled during the work made by all the tasks involved. It also provides an analysis of the evolution of the services focusing on the value that is generated in all the different areas.

Sensitivity: Internal

High-level Human and Planetary Goals (1/2)

The sustainability evaluation for a use case includes the formulation of the High-Level Human and Planetary Goals (HPGs) for the ICT context and its connection to the United Nations' Sustainable Development Goals (UN SDGs).

High-level Human and Planetary Goals (HPGs)		Description	Hexa-X-II Sustainability Pillar(s)	United Nations' Sustainable Development Goals (SDGs)
1	Foster Resilience	Resilience is the capacity of a system, be it an individual, a forest, a city or an economy, to deal with change and continue to develop.	Environmental Social Economic	All SDGs
2	Protect Biodiversity: land, water and air	Biodiversity is the diversity within species, between species and ecosystems, and describes the variety of plants, animals and ecosystems.	Environmental Social Economic	14. Life below water 15. Life on land
3	Curb Climate Change	Climate change is affected by human activities, especially the increased emissions of greenhouse gases (GHG) causing a global temperature increase.	Environmental	13. Climate action
4	Preserve Natural Resources	Natural resources are raw materials found on and below the Earth's surface. They are formed without any human intervention and cannot be created (e.g.., gold).	Environmental	6. Clean water and sanitation 12. Responsible consumption and production
5	Minimize Waste	Closely connected to Preserve natural resources, there is a need to minimize waste. One example is electronic waste used in ICT and elsewhere which s important to handle properly.	Environmental	12. Responsible consumption and production 14. Life below water 15. Life on land
6	Minimize Emissions and Disposals to Water, Air and Soil	Minimizing all types of emissions and disposals focuses on the processes in the complete life cycle of ICT products and services and their relationship with the atmosphere, biosphere and the geosphere.	Environmental	13. Climate action 14. Life below water 15. Life on land
7	Protect Human Rights	Human rights are inherent to all of us, regardless of nationality, sex, national or ethnic origin, colour, religion, language, or any other status. Human rights include the right to life and liberty, freedom from slavery and torture, freedom of opinion and expression, the right to work and education, and many more. Everyone is entitled to these rights, without discrimination.	Social	2. Zero hunger 3. Good health and well-being 4. Quality education 5. Gender equality 8. Decent work and economic growth 11. Sustainable cities and communities 16. Peace, justice and strong institutions

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High-level Human and Planetary Goals (2/2)

High-level Human and Planetary Goals (HPGs)		Description	Hexa-X-II Sustainability Pillar(s)	United Nations' Sustainable Development Goals (SDGs)
8	Increase Digital Inclusion	Digital inclusion refers to ensure all individuals have access and the ability to successfully use ICT related services.	Social	4. Quality education 5. Gender equality 8. Decent work and economic growth 9. Industry, innovation and infrastructure 10. Reduced inequalities
9	Ensure ICT Trustworthiness	Trustworthiness covers security and privacy, since trust revolves around confidence that people, data and devices will function or behave in expected ways.	Social Economic	9. Industry, innovation and infrastructure 16. Peace, justice and strong institutions
10	Enhance Health & Well-being	Health is a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity.	Social Environmental	2. Zero hunger 3. Good health and well-being 6. Clean water and sanitation
11	Foster Decent Employment	Decent employment means opportunities for everyone to get work that is productive and delivers a fair income, security in the workplace and social protection for families.	Social	8. Decent work and economic growth
12	Supporting Quality Education	Education is a fundamental requirement for people to improving their lives, contributing to communities, societies and economies.	Social	4. Quality education
13	Build Long-term Sustainable Economic Growth	Economic growth is only sustainable if it does not harm social equity and the environment both in the short and the long term.	Economic	8. Decent work and economic growth 9. Industry, innovation and infrastructure 10. Reduced inequalities 12. Responsible consumption and production
14	Ensure Transparency	Transparency refers to a process by which information about existing conditions, decisions and actions is made accessible, visible and understandable. It is a fundamental requirement for both governance of companies and public sector, and in technological solutions to promote stability, reliability, mutual trust and public support.	Social Economic	8. Decent work and economic growth 9. Industry, innovation and infrastructure 10. Reduced inequalities 11. Sustainable cities and communities 12. Responsible consumption and production 16. Peace, justice and strong institutions
15	Ensure Ethical Conduct	ICT ethics seeks to understand the application of ethics to the development and (mis)use of systems which include digital and electronic components.	Social Economic	12. Responsible consumption and production 16. Peace, justice and strong institutions

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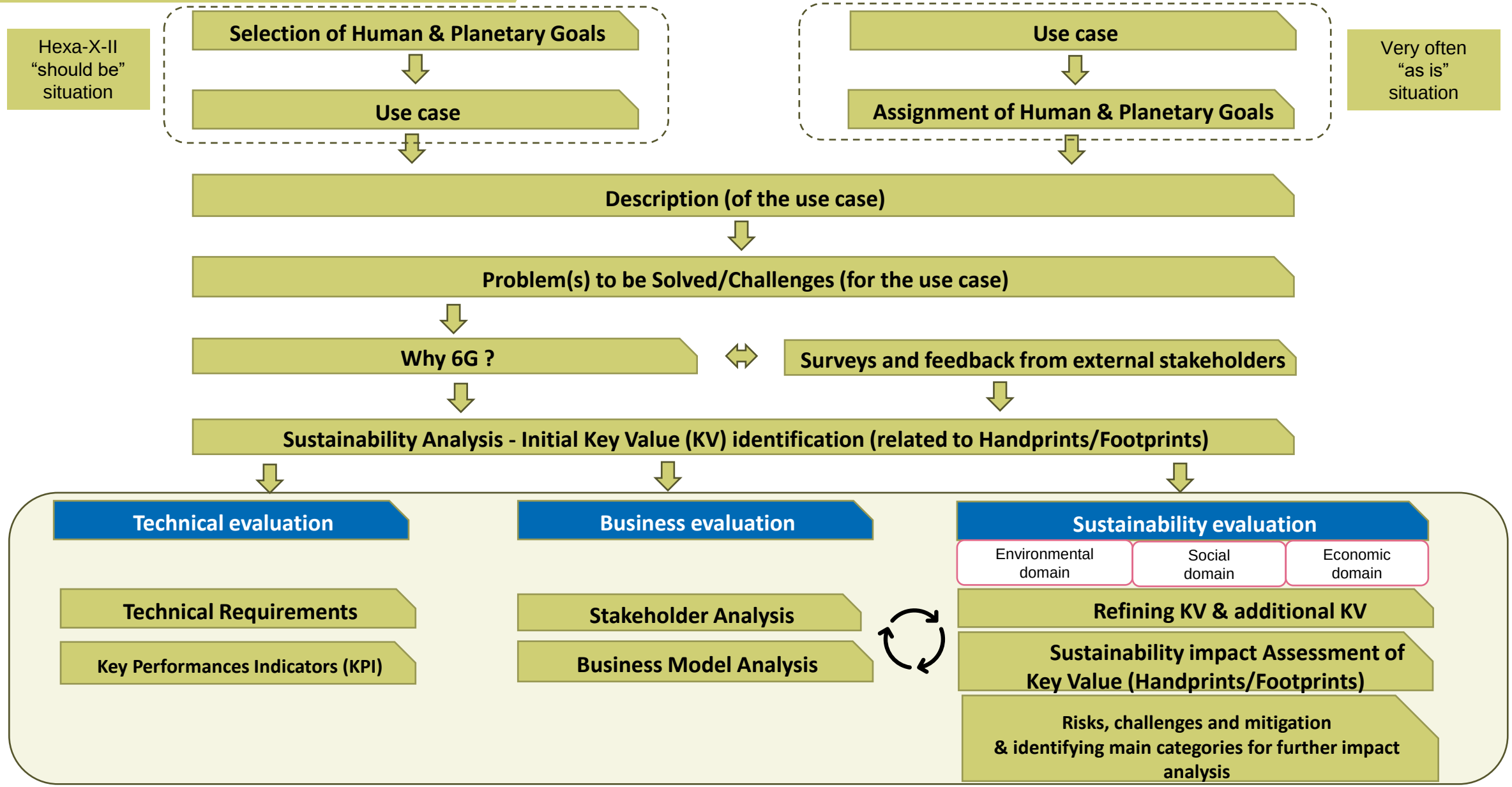
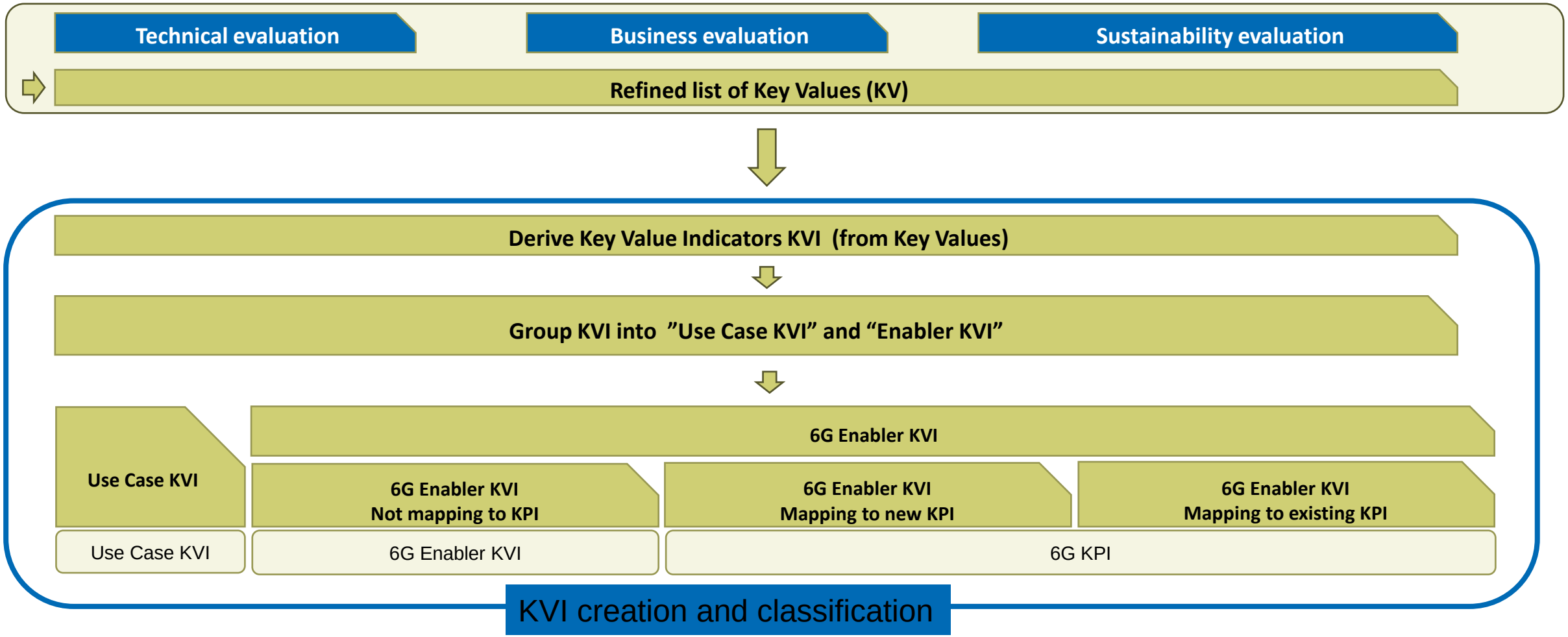
Sustainability analysis and Hexa-X-II Use-case methodology (1/3)



Sustainability analysis and Hexa-X-II Use-case methodology (2/3)



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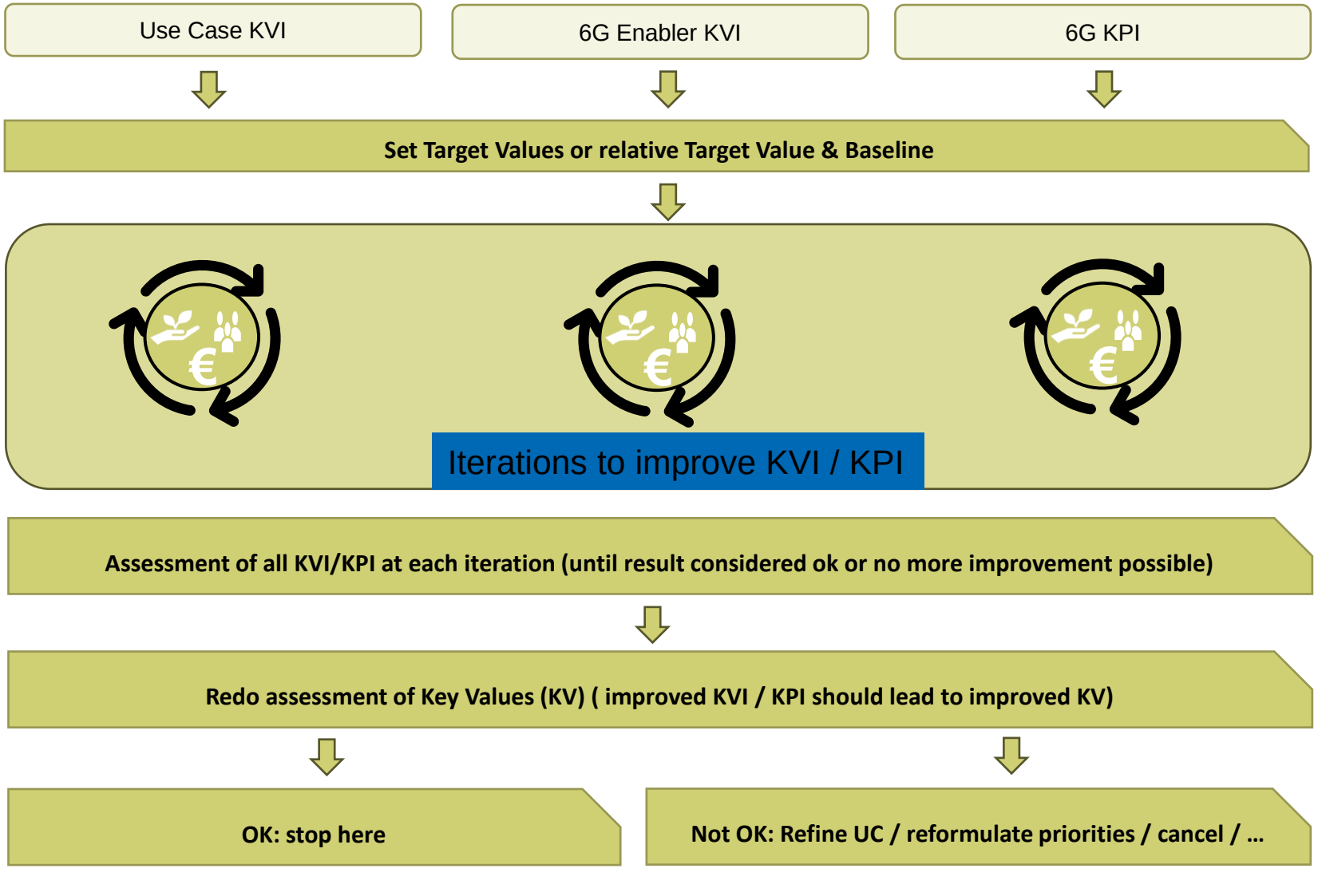
Sustainability analysis and Hexa-X-II Use-case methodology (3/3)



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6G Ecosystem and Exchanges with Stakeholders

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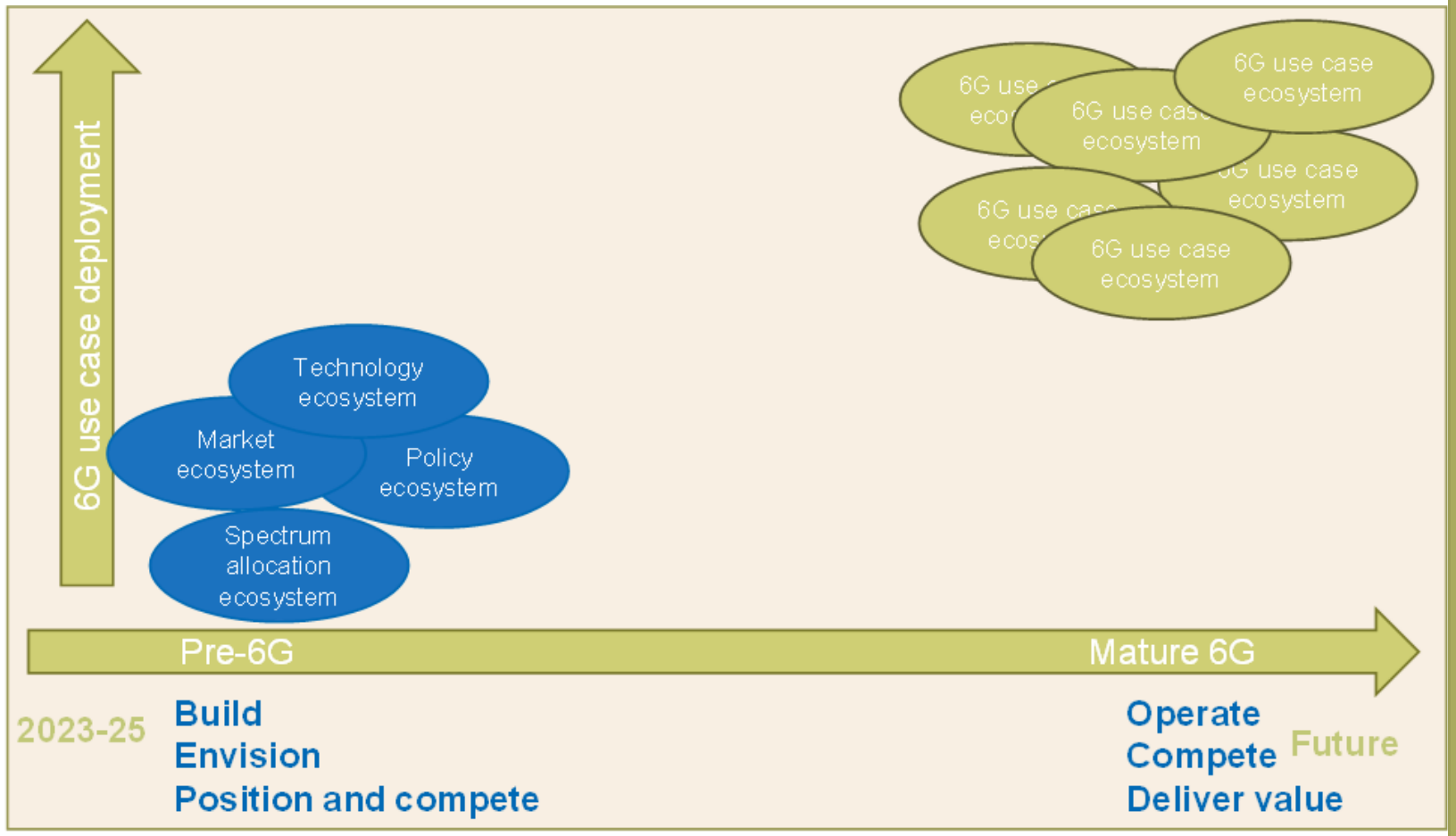

6G ecosystems

- **Future 6G use case business ecosystems:** business stakeholders creating and capturing value jointly in future markets
- **General ecosystems:** current stakeholders for markets, technologies, policy and spectrum who control, desire, suggest, finance, know, develop, and are affect by key 6G resources and components important for future 6G use case business ecosystems

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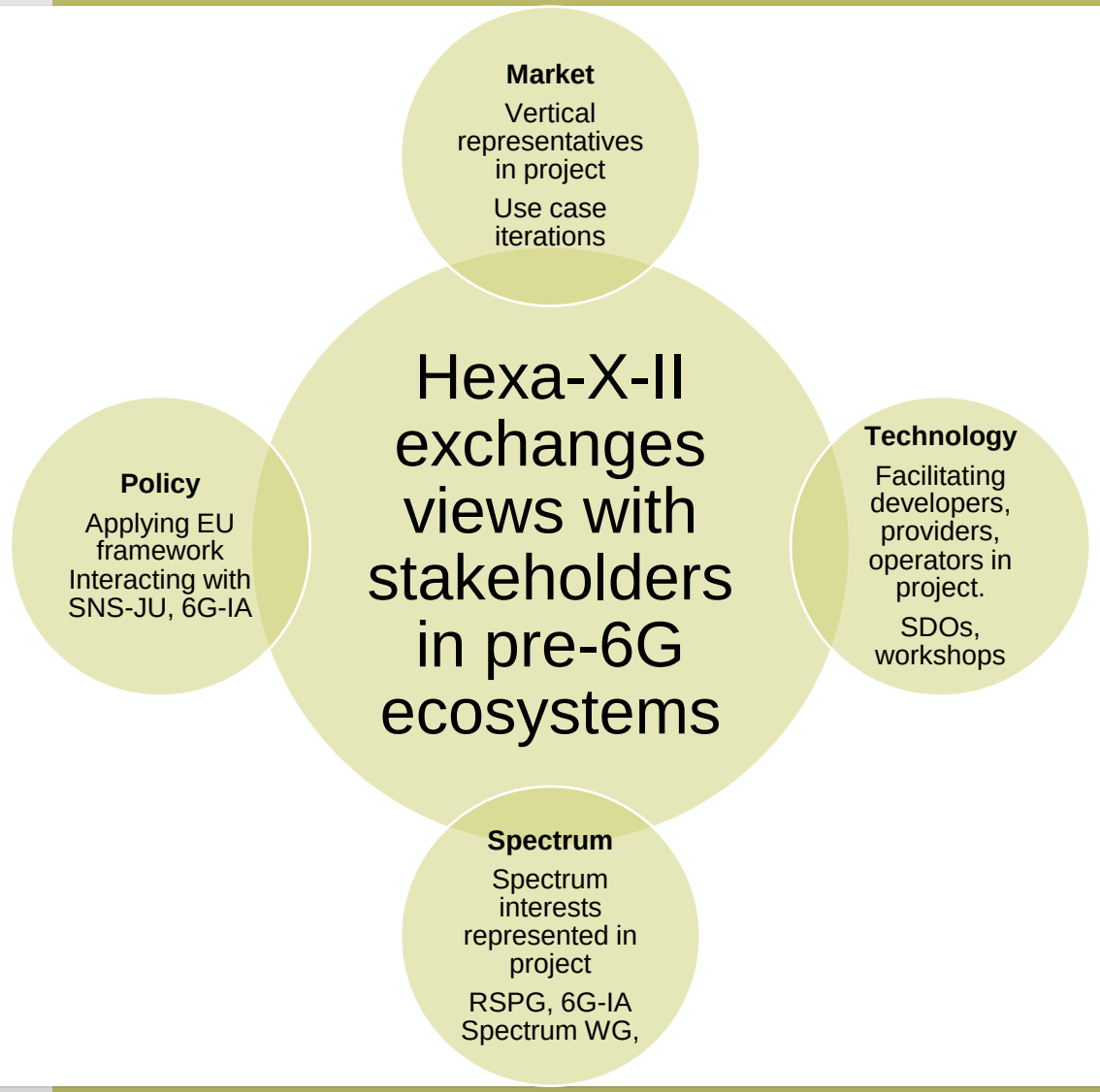

Hexa-X-II exchange views with 6G stakeholders

- Stakeholders in pre-6G markets form and develop insight, beliefs, and preferences
- Stakeholders shape 6G evolution via their responsibilities and decisions, representing competing motivations and strategic interests
- Hexa-X-II ensure project insight is shared and made accessible to stakeholders

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Insights from Stakeholders

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Insights from network provider surveys

Recent Ericsson surveys explore user expectations and connectivity challenges, focusing on network reliability, inclusivity, and enterprise needs for 6G. The studies examine network performance in high-density scenarios, demand for personalized connectivity, and the role of scalable networks in digital transformation.

Understanding Connectivity Demands in High-Density Scenarios

- Attendees at large events face **network congestion, slow speeds, and unreliable connections**, affecting access to digital services.
- To improve performance, **URLLC, edge computing, and better resource allocation** are being explored to enhance capacity and stability.

The Need for Tailored Connectivity for Enhanced User Experiences

- Users seek **personalized network services**, with gamers prioritizing low latency and streaming users demanding high bandwidth.
- While premium connectivity offers value, concerns about **digital inequality and data privacy** highlight the need for balanced implementation.

Enabling Value Creation of Connectivity Among Enterprises

- Enterprises require **reliable, scalable networks** for IoT, remote collaboration, and AI-driven operations.
- **Telecom API integration, cloud solutions, and stronger data security** are seen as key for digital transformation.

Sensitivity: Internal

Expert Group Activities



Expert Group Formation



Diverse Participation



Key Discussion Themes



Strategic Focus



Recommendations

- An **Expert Group** was set up in Hexa-X-II to embed **social values** in 6G through stakeholder dialogue.
- It included **external experts** from **Gustave Eiffel University, Resilient Regions Association, Digital Norway, PSCE**, and **Free University of Berlin**.
- **Internal members** from the Hexa-X-II consortium- **Nokia, Ericsson, Orange, University of Oulu**, and **TNO** ensured a multidisciplinary team.
- Discussions focused on **sustainability, inclusivity**, and **ethical considerations** tied to public concerns. Key issues like **data privacy, digital inclusion**, and tech advancement pace were addressed.
- Strategies were explored to **minimize 6G's environmental footprint**, build **public trust**, and promote **inclusive community engagement**.
- **Key recommendations** included ensuring **transparency, bridging digital divide**, and enhancing **public-private collaboration** for societal alignment.

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Engagements with civil society and business in France (1/2)

Results (Approx. 500 persons interviewed). More details in Annex 1.



Societal

Highlighting the impact of technology on human relationships and mental well-being, emphasizing the need for solutions that promote social inclusion and balance between real and virtual life



Environmental

Ensuring that new digital innovations are assessed for their negative externalities and overall value, positioning digital technologies as enablers of ecological transition



Security

Emphasizing the necessity for robust security measures to mitigate digital risks (e.g., data breaches) while advocating for digital sovereignty to ensure that companies and governments retain control over their digital environments

"The ultimate goal is to ensure that digital advances serve humanity, by putting **the general interest first**, advocating governance **by cooperative organizations and encouraging citizen participation** in technological choices."

Sensitivity: Internal

Engagements with civil society and business in France (2/2)

Condition for implementations

Access to a minimum service for all populations

- **Universal connectivity**: The necessity for equipment in underserved areas, including rural and remote regions.
- **Significance of Robust Infrastructure**: Emphasizing the importance of both physical equipment and technological frameworks, along with a thorough understanding of local contexts.

"Connectivity everywhere with high-speed internet is a dream (…). However, it is technically challenging. A compromised solution can be to focus on providing basic connectivity everywhere."

The pooling of infrastructures, or even the concentration of certain actors

- **Resource and Knowledge Sharing**: Collaborating to optimize infrastructure usage, enhance reliability, and foster innovation.
- **Concept of Technology "Commons"**: Considering the establishment of a European public service that integrates both infrastructure and services.

"It is a commons, but it has not been defined. We should define the commons of technologies in Europe before inventing other things."

The involvement of all actors and strong governance to impose regulatory principles

- **Democratic Governance and Collective Ownership**: Essential for addressing societal needs and promoting environmental sustainability.
- **People-Centric Value Models**: Developing new models that prioritize individuals, ensuring technology benefits all members of society.

"Cyber is a real war (...) public authorities must be able to protect their citizens on the internet and in the street. You must have the right to walk safely in the street."

Engagements with municipalities in Portugal

Portugal has already established a wide coverage of 5G,with constraints in remote locations with lack of accessibility

Aspects needing improvements:

- Lack of regulations
- Security and privacy of data
- Access regulation
- Increase in digital literacy

Benefits:

- Fast and remote access to information
- Enabling decision-making
- A sense of constant connectivity

The four municipalities were quite adamant about the need to create better conditions for 5G and beyond deployment, improving infrastructures and creating adjusted regulations following the examples of water and energy fields.

the municipalities have been preparing to disseminate the advantages of these technologies to their citizens, in order to engage them and facilitate an easier adoption of 6G

A strategic plan has been created to increase the wider acceptance of these technologies:

- digital literacy sessions
- community Q&A sessions
- live demos
- storytelling campaigns

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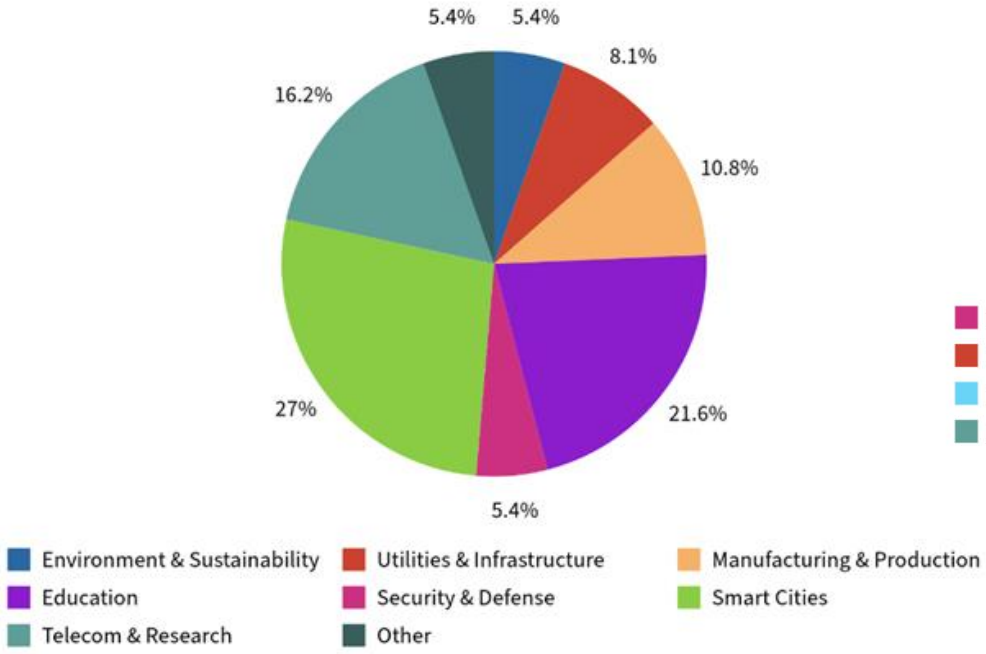
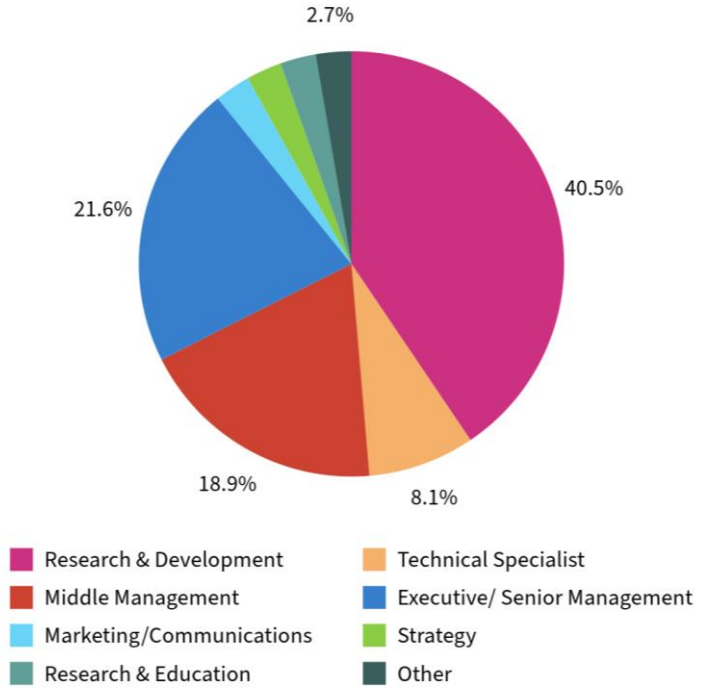
Stakeholder Feedback Overview: Anchoring 6G in Society

Professional role results



Work sector results



Anchoring 6G in Society: Survey Results

- **Survey Scope:** Explore user perspectives on technological, environmental, social, and economic aspects of future mobile networks
- **Participants & Key Demographics:** 37 respondents (predominantly 35-44 age group at 37.8%, 70.3% male, 70.3% urban residents)
- **Survey Structure:** 12 key sections covering demographics, technological needs, network benefits, environmental/social/economic aspects, and emerging tech (XR/AR, Cobots)
- **Key objective:** Balance innovation with social well-being for responsible technological evolution

Sensitivity: Internal

Key Technological Needs and Expectations

Current Challenges & Future Requirements

- **Current Connectivity:** Majority expressed satisfaction, but significant improvement areas identified
- **Top Technological Needs & improvement areas:**
  - Reliable remote work connectivity (highest priority)
  - High-speed data transfer and processing capabilities
  - Seamless cloud integration for productivity
  - Enhanced collaboration and communication tools
- **Network priorities:**
  - High-speed internet and wide coverage remain most pressing concerns
  - Low latency critical for specific applications
  - Security and machine-to-machine communication important for enterprise users
  - Targeted improvements needed in areas with connectivity gaps

Sustainability & Social Responsibility

- **Environmental Priorities:**
  - Energy consumption (highest priority)
  - Electronic waste reduction
  - CO2 reduction & natural resource conservation
  - Function integration efficiency
- **Social Imperatives:**
  - Privacy protection
  - Digital inclusion essential for bridging technological divides
  - Health and wellbeing considerations for safe network development
  - Equal access to mobile networks for inclusive digital environment
  - Skills adaptation support

Sensitivity: Internal

Social, Economic and Emerging Tech Insights

Economic Impact & Future Technologies

- **Economic Considerations:**
  - Cost efficiency & affordability without compromising quality
  - Cybersecurity resilience (most pressing economic concern)
  - Business innovation to drive competitive advantage
  - Economic growth & innovation support
- **XR/AR Technologies:**
  - Healthcare & education transformation
  - Strong support for collaborative robots in repetitive tasks
  - Data privacy and user consent: key trust factors
  - Accessibility improvements for inclusive design
  - Critical XR needs: low latency, battery efficiency, seamless connectivity
- **Collaborative Robots (Cobots):**
  - Highest acceptance for repetitive/physical tasks
  - Strong support for XR-based training and safety features
  - Need for enhanced trust in autonomous features
  - Ethical imperative that technology should improve human quality of life

Sensitivity: Internal



Final Set of Use Cases and Value

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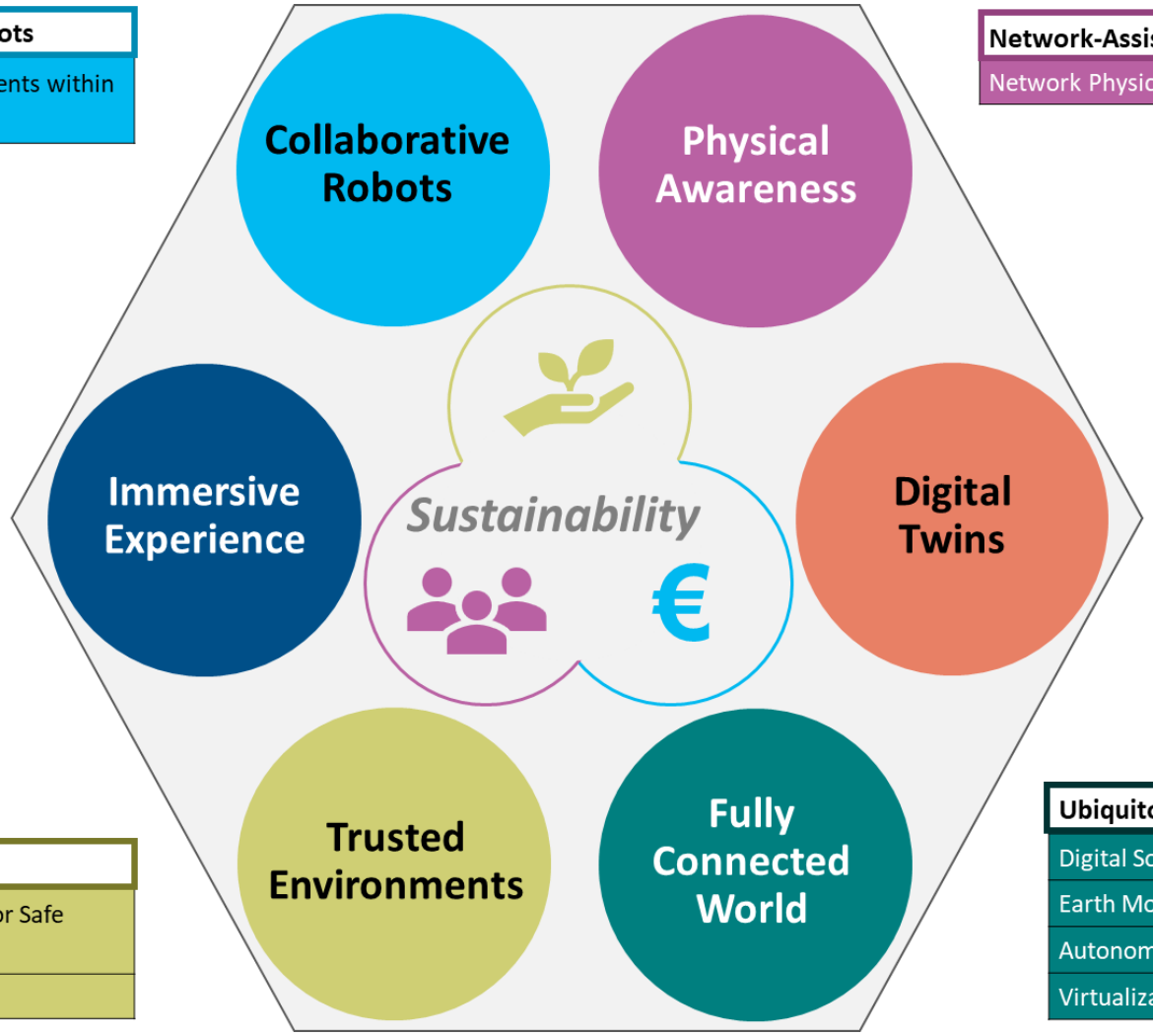
Hexa-X-II Use Case Families

Cooperating Mobile Robots
- Autonomous Embodied Agents within Flexible Manufacturing

Network-Assisted Mobility
- Network Physical Data Exposure



Seamless Immersive Reality
- Immersive Education
- Immersive Gaming
- Live and Interactive Immersive Content Creation

Real-time Digital Twins
- Cloud Continuum
- Smart Maintenance
- Digital Twins for Construction

Human-Centric Services
- Industrial Sensors Network for Safe Production & Manufacturing
- Wireless In-Vehicle Network

Ubiquitous and Resilient Network
- Digital Sobriety and Enhanced Awareness
- Earth Monitor / Sustainable Food Production
- Autonomous Supply Chain
- Virtualization of Device Functionalities

Please note, as the IMT-2030 capability-related KPI values indicated in the following slides are formulated at an early point in time and derived from theoretical analysis and simulations, real deployments may not always fulfil these requirements. In the end, use cases will be realized if they can be delivered with acceptable cost and sustainability footprint. The feasibility of such use cases in an environmentally, socially, and economically sustainable way still needs to be evaluated beyond this project

Sensitivity: Internal

IMMERSIVE EXPERIENCE

Immersive Experience use cases are based on an evolving XR technology.

Immersive Experience is all about "experiencing" a now digitally extended or virtual environment to understand and to act.



AI-generated image (Dall-E)

Use Cases

Seamless Immersive Reality | Immersive Education | Immersive Gaming | Live and Interactive Immersive Content Creation

*Extract: For full details, see D1.4

Seamless Immersive Reality*

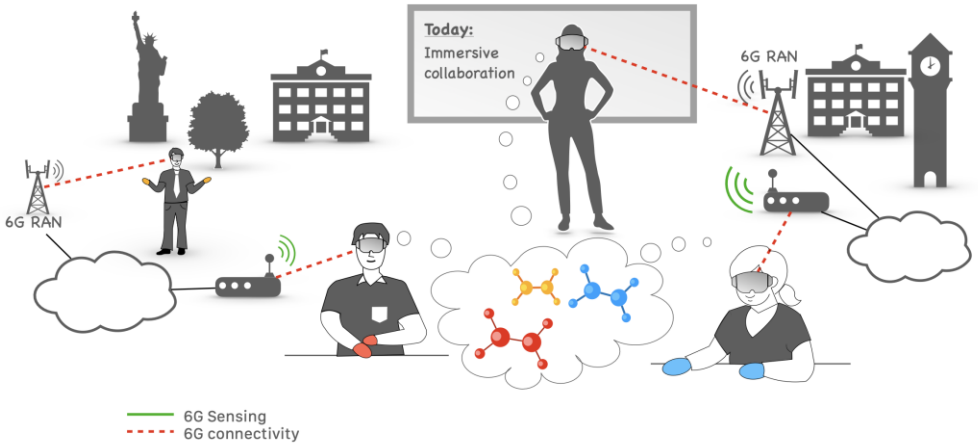
Immersive Experience

Today's technology and devices are precedents to the use case SIR which is expected to leverage existing and evolving XR technologies such as AR, VR, and MR.

Immersive reality combines immersive telepresence and immersive collaboration. Immersive telepresence will allow remote participants to appear as physically present in the very same environment as co-located participants and perceive it as realistic thanks to the stimulation of their visual, hearing and haptic senses. Immersive collaboration will provide a fundamentally new way of interacting with people and on objects or topics independently of their location, their physical nature, or their abstract character.

Finally, seamless immersive reality targets at low E2E latency and service continuity between different modes like for instance between AR and VR or between MR and actual reality. SIR will achieve a quantum leap in Quality Of Experience facilitating interaction, collaboration, co-presence, and co-experience in many if not all aspects of life including work, be it in the office or on a construction site, in education, or healthcare, as well as in many aspects of our cultural, social, and personal lives.

Two scenarios were described: Immersive collaboration meeting, immersive classroom (S1), and Immersive experience "on-the-go"(S2).



Problem(s) to be Solved/Challenges

- Enabling significantly improved quality of experience
- Living and working from anywhere
- Achieve seamless service continuity
- Ensure privacy protection

Requirements

•**AI/ML and compute** capabilities are needed for rendering immersive video and audio, and for tasks like object detection and speech recognition.
•**Sensing**: an immersive experience requires the human sensory system to receive realistic stimuli from a mixed or virtual reality. Some scenarios may use ISAC or may apply sensor fusion of network and sensor data of connected sensors..
•**Positioning**: Accurate positioning is essential for seamless immersive reality.
•**Privacy protection**: Crucial aspect due to the nature of the data used for immersive experiences.
•**Service continuity**: Consistent service quality is needed across various network types for satisfactory user experience.
•**On-body and in-body sub-networking**: Support for haptic actors and sensors, including in-body monitoring applications.
•**Synchronization**: Low latency synchronization of participants and data streams is crucial.
•**Digital immersive mapping**: Provided as a service by the network to assist seamless immersive reality.

	KPI	Scenario	Target Range	Comments / Justification
Communication	User-experienced data rate DL [Gb/s]	S1	0.25 1 >10	Streaming Collaboration Gaming
		S2	0.02	Telepresence
			0.25	Streaming, e.g., in city park or in car passenger seat
	Area traffic capacity [Gb/s/m²]	S1	0.25	
		S2	0.02	
	Latency [ms]	All	< 150	S1: E2E latency (interactive collaboration) S2: E2E latency (conversational services)
		All	< 10	S1: DL + UL latency budget for wireless only (split rendering) S2: One-way RAN latency
	Reliability [%]	All	99.9– 99.999	Depends on service and data stream
	Mobility [km/h]	S2	up to 200	E.g., German highway
Positioning & New Capabilities	Positioning accuracy [m]	S1	< 0.1	Some services may use network-assisted positioning; high positioning accuracy typically requires device-based sensors and sensor fusion.
		S2	< 1	
	Sensing-related capabilities [Y/N]	All	Yes	Some service scenarios may include ISAC or may apply sensor fusion of network data and sensor data of connected devices
	AI/ML-related capabilities [Y/N]	All	Yes	Device-embedded and/or provided by network

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PHYSICAL AWARENESS

Physical Awareness use cases build on beyond-communication capabilities in networks: sensing, positioning, compute, and AI. By gathering 3D data about physical scenarios and situations, efficiency and safety can be improved.



AI-generated image (Dall-E)

Use Cases

Network-Assisted Mobility | Network Physical Data Exposure

*Extract: For full details, see D1.4

Network-Assisted Mobility*

Physical Awareness

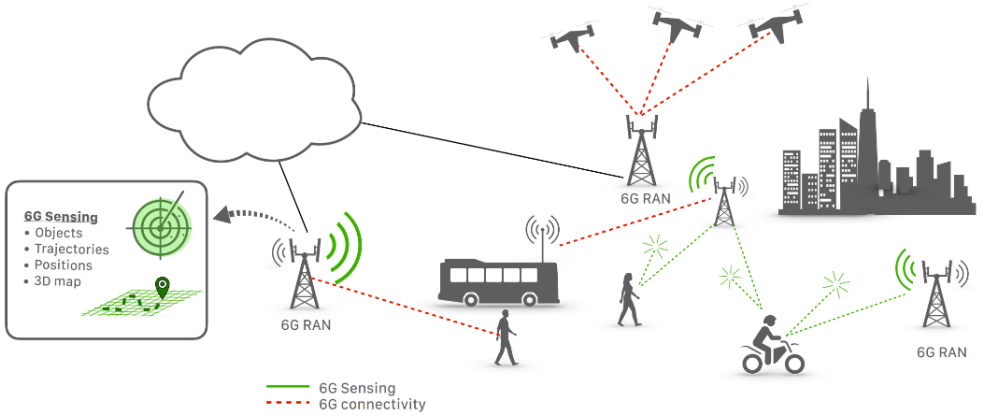
In this use case, vehicles (cars, AGVs, UAVs/drones, etc.) rely on the network nodes and devices for localization of connected and unconnected objects and for determination of their properties such as size and velocity, contextual info, trajectories etc. Connected vehicles have a reliable link to the network through onboard UEs, with services available in a well-defined service area. Networks measure the physical environment in various scenarios and analyse to detect objects, and aggregate with data of device positions and from this large data set extract information to relay to UEs in connected vehicles. Position data shared with vehicles can include vulnerable road users (VRUs), such as pedestrians and cyclists.

This can be done on several levels; networks can provide raw or processed environment and position data, or navigational support ranging from collecting and sharing of data, over navigation assistance, to full operation, leveraging on beyond-communication capabilities. The network can thereby support vehicles with different levels of autonomy and different modes of operation and enable smart transport in urban areas.

Furthermore, there is a possibility to use the physical environment understanding around nodes and devices to improve communication with vehicles by tailoring beams, avoiding blockers, etc.

Some examples of the services provided by networks are network assistance info, network assistance map, network navigation, full vehicle operation, and context-aware communication.

Three scenarios were described: Autonomous drone transport, Smart intersections, and Assisted vehicles.



Problem(s) to be Solved/Challenges

- Risk of accidents with intense and automated transport scenarios
- Energy consumption and generated emissions from transport
- Cost of transportation of goods and people
- Access to reliable transport
- Privacy in public spaces

Requirements

- **Privacy**: Personal identities in public spaces must be handled in such a way that privacy is not jeopardized.
- **Localization**: Use of network-capabilities (ISAC, positioning) to detect unconnected objects, and combine these with inputs from multiple sources (i.e., sensor fusion).
- **Connectivity**: Reliable communication is critical for safety reasons. Additionally, the network should have the capability to predict and notify the connected vehicles in case of predicted unavailability of the communication link, or find adjacent links to ensure connectivity.
- **Compute**: Networks should have the capability of reliable compute and AI/ML-related functionality that can be accessed at all times from any point in the network.

	KPI	Target Range	Comments / Justification
Communication	User-Experienced Data Rate [Mb/s]	1-10 (<100)	Depends on the service type: lower for warnings and assistance, higher for digital maps. (For sensor fusion exchange of data may be higher.)
	End-to-end latency [ms]	20	Similar to V2X services
	Reliability [%]	99.99	Fraction of packets within latency bound E2E
	Coverage [%]	Within service space: 99.9	Fraction of defined service space (in 3D) within latency bound.
	Service availability [%]	Withing service space: 99.99	Probability to get communication service (as defined with E2E latency) within service space when requested. (Can replace coverage and reliability)
	Connection density [devices/km^2]	Urban: 10^4 Rural: 10^2	Not expected to be a challenge
	Mobility [km/h]	Up to 300, seamless handover	Speed of vehicles (cars, drones, trains) in urban areas. Handover within latency bound
Positioning & New Capabilities	Position accuracy [m]	Within service space: 1m 3D precision with 90% probability Sensor fusion: 0.1	Reliable positioning with high availability is important for the use case, but likely multiple sources (e.g. from onboard sensors) can be combined to achieve more precise positioning.
	Sensing-related capabilities [Y/N]	Yes	Performance within service space: Object detection probability, Object location accuracy/resolution, Object velocity accuracy/resolution, Object size accuracy/resolution.
	AI/ML-related capabilities [Y/N]	Yes	Probability of a response time of compute/AI capabilities within a latency limit.

DIGITAL TWINS

Digital Twins is a set of use cases where digital equivalents of the real world are created and displayed for interaction, control, maintenance, as well as process and component management.



AI-generated image (Dall-E)

Use Cases

Real-time Digital Twins | Cloud Continuum | Smart Maintenance | Digital Twins for Construction

*Extract: For full details, see D1.4

Real-time Digital Twins*

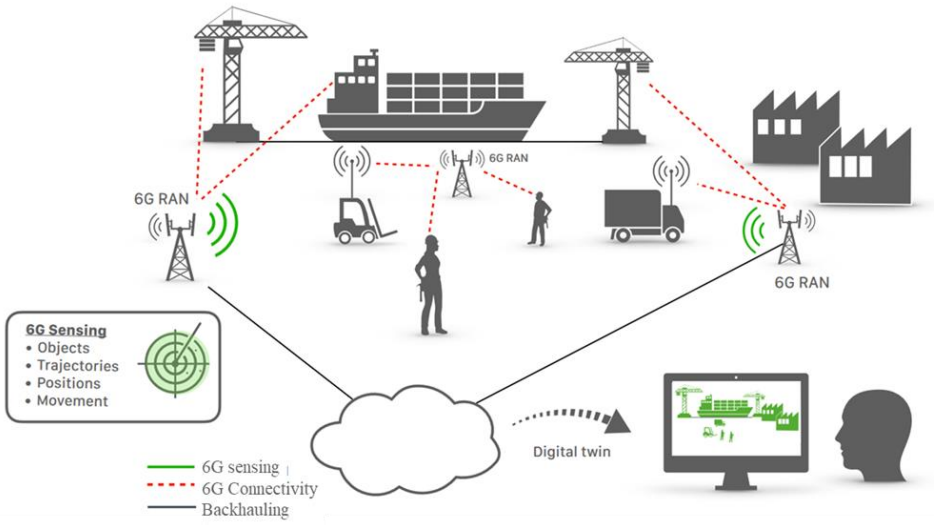
Digital Twins

A Digital Twin (DT), being a contextual digital equivalent of the real world, offers unified access to users and/or agents for interaction, control, prediction, testing, maintenance, and management of processes and components.

The Real-Time Digital Twin (RT DT) use case needs network connectivity to ingest data from multiple sources, e.g., databases, sensors, tags, network data, data models, and optionally, to steer/control the respective systems via continuous and seamless feedback loops. A digital twin is aggregated, generated, visualized, and can offer control by running dedicated software, including specialized AI/ML algorithms. The real-time aspect, enabled by the low latency capability of the 6G network, allows to extend today's digital twin use case towards direct control of the actual physical processes. This is supported by the sensing capabilities of the 6G network providing environmental data towards the digital twin.

In conclusion, the RT DT use case enables moving intelligence away from the machines itself towards a higher software layer (the digital twin) and it allows the 6G network sensing to be extended with sensing fusion on the network.

Scenarios documented: Production plant (S1, figure) + Overarching smart city digital twin (S2).



Problem(s) to be Solved/Challenges

- Increase production quality and efficiency
- Prevent situations where humans are put at risk
- Guaranty the privacy & trustworthiness
- Accessibility of DT models

Requirements

- **Real-time aspect:** Accurate synchronization of physical and virtual requires low latency & high availability control loops
- **Full coverage**: Complete network coverage with appropriate QoS levels is needed for seamless handover in all areas.
- **Network Sensing**: Real-time data from the network eliminates the external sensors need, simplifying the DT ecosystem.
- **Sensors**: Connected sensors are necessary for data beyond network sensing, requiring advanced technology for accuracy.
- **Improved human-machine interaction**: For the seamless immersive interaction with DT.
- **Compute** resources to handle complex DT models and databases with advanced AI skills to simulate, steer, and predict.
- **Privacy/trustworthiness:** Secure networks are essential to guarantee data privacy, especially in smart cities
- **Hierarchy of Digital Twins**: Large systems of overarching DT incorporating multiple lower-level DT (massive twinning)
- **M&O capabilities** Flexible resource allocation and orchestrated sensing/sensor data collection are required.
- **Interoperability**: Open interfaces enhance flexibility and manageability of DTs, incl. proprietary and legacy systems.
- **Strong system integrators:** complex RT DTs require integration of multiple technologies and low compatibility systems.

	KPI	Scenario	Target Range	Comments / Justifications
Communication	User experienced data rate [Mb/s]	S1	<10	Low. Mainly data from sensors/to attenuators
		S2	< 50	Medium. Video will be most demanding (up to 150 Mb/s)
	End-to-end latency [ms]	S1	≤ 5	Critical: Very low latency for the real-time aspect
		S2	10	High
	Reliability [%]	S1	99.99999	Critical: the control of real-time industrial processes requires very high service reliability.
		S2	99.999	Medium for non-real-time DT
	Mobility [km/h]	All	< 100	Low: Seamless handover required. Mobility includes both mobility of users and of objects (sensors, etc)
	Connection density [devices/m^2]	All	1-10	High: to cope with the large volume of sensors (with very dispersed data rate needs)
	Coverage [%]	All	99.99	High: Service coverage for both outdoor & indoor
Positioning & New Capabilities	Position accuracy [m]	All	≤ 0.1	High: Accurate positioning to enrich the DT model
	Object detection probability [%]	All	>99%	High: Collision avoidance
	Sensing capabilities	All	Yes	Network-sensing: accuracy, resolution, and range to enrich the digital twin model
	AI/ML-related capabilities [Y/N]	All	Yes	AI services can be provided by the service itself (embedded AI) or exposed by the 6G network (AI/ML provided by the network) but no AI-Native is required (6G network AI).

Sensitivity: Internal

FULLY CONNECTED WORLD

*Ensuring connectivity **everywhere**, expanding beyond purely traditional terrestrial networks to deliver the benefits of communications to everybody.*

Besides expanding coverage cost-effectively, it also enables network function availability for crisis management, earth monitoring, digital health services, virtualisation of device functionalities, or support of autonomous supply chains.



AI-generated image (Dall-E)

Use Cases

Ubiquitous and Resilient Network | Digital Sobriety and Enhanced Awareness | Earth Monitor / Sustainable Food Production | Autonomous Supply Chain | Virtualization of Device Functionalities

*Extract: For full details, see D1.4

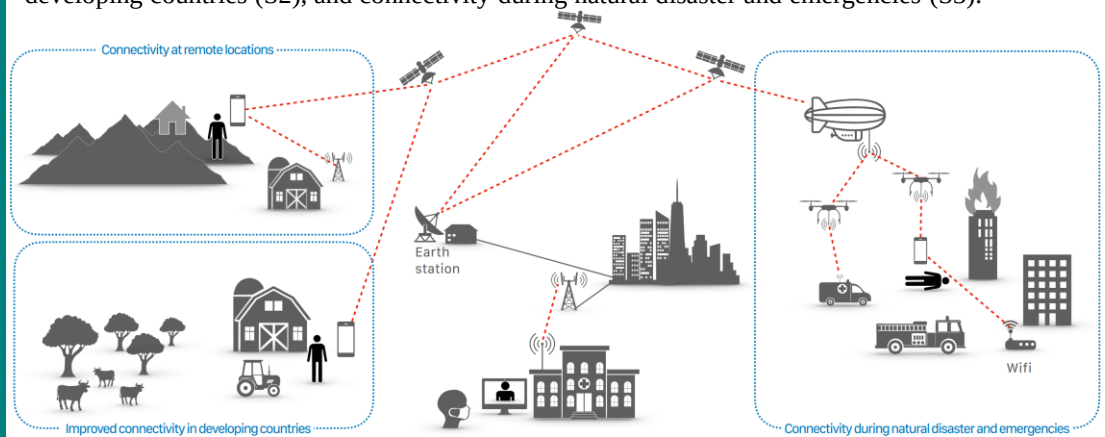
Ubiquitous and Resilient Network*

Fully Connected World

The Ubiquitous Network use case focuses on delivering Mobile Broadband connectivity to every human on Earth, leaving no "white zones". It therefore involves providing network access everywhere, encompassing remote areas, zones with harsh geographical conditions (e.g., mountains, forests), the airspace for aerial operation (e.g., drone operation), as well as the open ocean.

This ubiquitous network will be enabled through seamless access to both TN and NTN – including satellites, HAPS, air-to-ground networks, and unmanned aerial vehicles/drones – in a transparent way for the end user, meeting the requirements to ensure that every-day needs are covered, with the desired quality of service. Although most users in these areas will not be able to enjoy the services with the maximal performance (e.g., no URLLC), they will be able to benefit from a wide set of services with reliable connectivity, including high-quality voice or video streaming services. Moreover, other 6G-related use cases could be enabled, such as compute offloading if the technical/physical limitations allow it. Ubiquitous Network will allow everyone on Earth to access the Internet and its most common uses, but it will also enable the delivery of new services, such as digital health services. Remote consultations with doctors will be possible in areas lacking medical infrastructure. Some institutions, such as schools, could also benefit from more advanced applications for remote virtual education. Finally, integrating TN with NTN, allows the network to deliver guaranteed connectivity whatever the conditions, maintaining a minimum set of services even in the event of a crisis. This network resilience will be crucial for emergency services, in difficult climatic conditions such as storms (in which network elements may be damaged), or in natural disasters, such as floodings, earthquakes, tsunamis, human-induced catastrophes (e.g., conflicts) or other events that nowadays cause network downtime.

Three scenarios were described: Connectivity at remote locations (S1), Improved connectivity in developing countries (S2), and connectivity during natural disaster and emergencies (S3).



Problem(s) to be Solved/Challenges

- Digital inclusion
- Reduce educational and health-services gaps
- Enabler for earth monitoring
- Delivers increased network resilience, crucial in the event of disasters

Requirements

- **Connectivity**: The 6G system will need to provide ubiquitous access even in the most remote or hard-to-reach areas with extreme coverage needs.
- **Resilience**: The 6G system should be able to ensure resilient, seamless operation even in environments with intermittent or limited network connectivity.
- **Flexibility**: The 6G system must be able to deploy flexible network topologies to overcome obstacles such as limited infrastructure or signal attenuation/interference.
- **Service Continuity**: Tight integration between different topologies and network elements is needed, including the integration between TNs and NTNs.
- **Privacy and Security**: Consistent privacy and security must be guaranteed across all access networks and during handovers.
- **Affordability**: It is crucial to provide a cost-efficient E2E ecosystem to ensure widespread adoption.
- **6G-NTN convergence**: All necessary services should work properly, irrespective of the network on which the service is running.

	KPI	Scenario	Target Range	Comments / Justification
Communication	End-to-end latency [ms]	All	10-500	'Real-time' interactions are not considered as part of this requirement (e.g., no remote surgeries).
	Availability [%]	S1, S2	98.5	Reaching new areas can promote new use cases/businesses/ services. As there is no viable alternative, those services will fully rely on this connectivity.
		S3	99.999	The ecosystem needs to be designed in a fully reliable and resilient way in case of emergencies.
	Reliability [%]	S3	99.9 –99.999	Reliability KPI is important for the emergency scenario, in which erroneous transmission can delay or mislead the rescue operation
	User experienced data rate [Mb/s]	All	Downlink: 0.1 –25 Uplink: 2	Good quality video streaming should be delivered.
	Connection density [devices/km^2]	S1, S2	1-100	Connection density is not a stringent requirement, as it does not target massively connected deployments. Also, connection density for rural areas is low.
		S3	10^5	Required in urban settings in case of a crisis scenario
	Coverage [%]	All	99.9%	The definition of environment should cover inhabited areas, but with human activity, such as highways or cruise ships.
	Mobility [km/h]	All	up to 120	Related to seamless handover between TN and NTN. It should support terrestrial vehicle speeds.
Positioning & New Capabilities	Position accuracy [m]	All	Low (≈ 10)	The global coverage option is not prone to high accuracy requirements.
	Sensing [Y/N]	All	No	Sensing is usually not needed, except for some specific cases
	Positioning availability	All	99%	High positioning reliability is required to support emergency services
	Positioning latency	All	1s	The global coverage option is not prone to low latency positioning requirements; however, some applications may require lower latency
	AI/ML-related capabilities [Y/N]	All	No	AI services can be provided offline, utilizing big data analytics.

TRUSTED ENVIRONMENTS



AI-generated image (DALL-E)

Comprehends use cases in local environments (streets, hospitals, schools, retirement homes) delivering human-centric services and promoting health, well-being, safety, inclusion, and autonomy in daily life.

These are based on sensing technologies as well as AI/ML and compute support to create spatial and situation awareness and enable context-driven interventions.

Use Cases

Human-Centric Services | Industrial Sensors Network for Safe Production & Manufacturing | Wireless In-Vehicle Network

Human-Centric Networks*

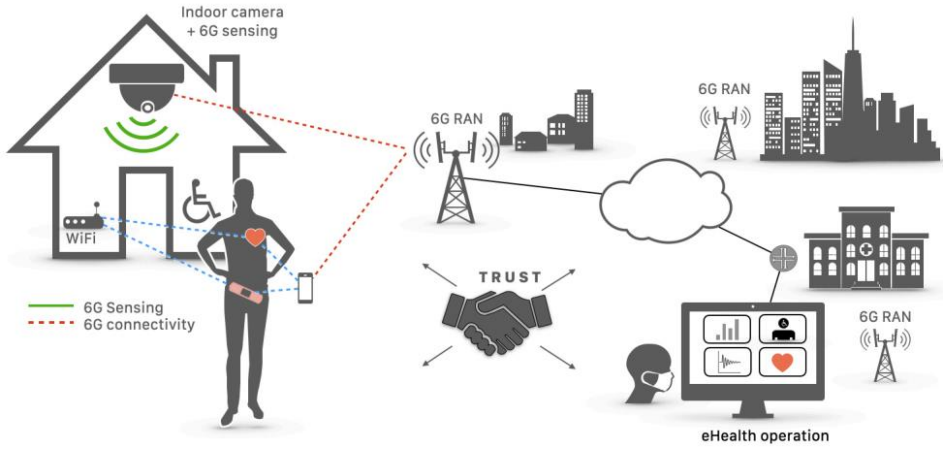
Trusted Environments

This use case focuses on the human at the centre of a wide range of 6G services. Human-centric services demand the use of trusted environments where privacy and reliability are key characteristics to make the services trustable by the public. Some examples of these services are:

Precision healthcare, where health monitoring, diagnosis, and therapy will enable personalized diagnosis and treatment. A 6G tele-medical paradigm can be enabled by both in-body and off-body sensing and AI/ML-based analytics in conjunction with wide-area connectivity.

Creating **safe environments** in places such as schools, workplaces, or hospitals is essential for the well-being, safety, inclusion, and autonomy of children, the elderly, and people with disabilities. To achieve the latter, sensing and AI/ML mechanisms will enhance activities like accurate localization, target identification, behavioural analysis and spatial-temporal situation awareness, providing alerts to help prevent physically risky situations and accidents, as well as for socially critical situations and potential incidents.

Public safety services during big events: at big public events such as football matches, big concerts, or parades, public safety services may use human-centric information, e.g., location, personalized data, and emergency contacts, which need to be anonymized and privacy-protected.



Problem(s) to be Solved/Challenges

- Extended access to high-end health monitoring and diagnosis
- Deliver safe environments for increased well-being, mental health, safety, inclusion, and autonomy
- Safety, health, and peace of mind for hard-hat workers, as well as visitors of big public events
- Deal, fuse, and interpret huge amounts of data from multiple sources in real-time; together with ensuring the reliability and accuracy of the interpretation of a given situation.
- Achieve the right trade-off between privacy and security aspects, and the desired outcomes of the HCS.
- Human-centric privacy models.

Requirements

•**High privacy protection**: Privacy is essential for this use case. It must be ensured through techniques like anonymization, pseudonymization, and advanced coding.
•**High service reliability**: Reliable services are crucial for user trust and timely alerts in human-centric applications.
•**Guaranteed QoS**: Network capabilities must guarantee QoS in health and well-being scenarios.
•**Localization**: Accurate detection and localization of passive objects are needed for behavioural analysis.
•**Accurate target identification and activity recognition**: High-accuracy identification and activity recognition are required based on backscattered waveforms.

	KPI	Target Range	Comments / Justification
Communication	End-to-end latency [ms]	< 250	Critical for scenarios of coalition avoidance regarding AGVs and care robots, e.g. in homes for the elderly and in hospitals.
	Reliability [%]	99.9 – 99.999	High service availability is key for this use case.
	Connection density [devices/m^2]	Indoor: 1 to 10 Outdoor: < 0.001	For safe environment scenarios, indoor refers to connection density per floor in scenarios.
	Mobility [km/h]	< 20	Pedestrian, slow vehicular
Positioning & New Capabilities	Location accuracy [m]	< 5	Location accuracy
	Positioning accuracy [m]	Pos. Accuracy: < 0.3 to < 1 Rel. Positioning accuracy: < 0.1	Relative positioning accuracy, e.g. critical in scenarios of collision avoidance
	Positioning availability [%]	99.9	High positioning reliability is required for most human-centric applications
	Positioning latency [ms]	10	Low-latency positioning is required for most human-centric applications
	Sensing-related capabilities [Y/N]	Yes	Relevant for most of the scenarios
	AI/ML-related capabilities [Y/N]	Yes	Relevant for most of the scenarios

Internal

COLLABORATIVE ROBOTS



The network's main users are machines.

Emphasis lies on task-specific local connectivity. Depending on the task or needs, the network topology may undergo frequent changes. The level of machine autonomy determines the communication requirements.

Use Cases

Cooperating Mobile Robots | Autonomous Embodied Agents with Flexible Manufacturing

AI-generated image (Dall-E)

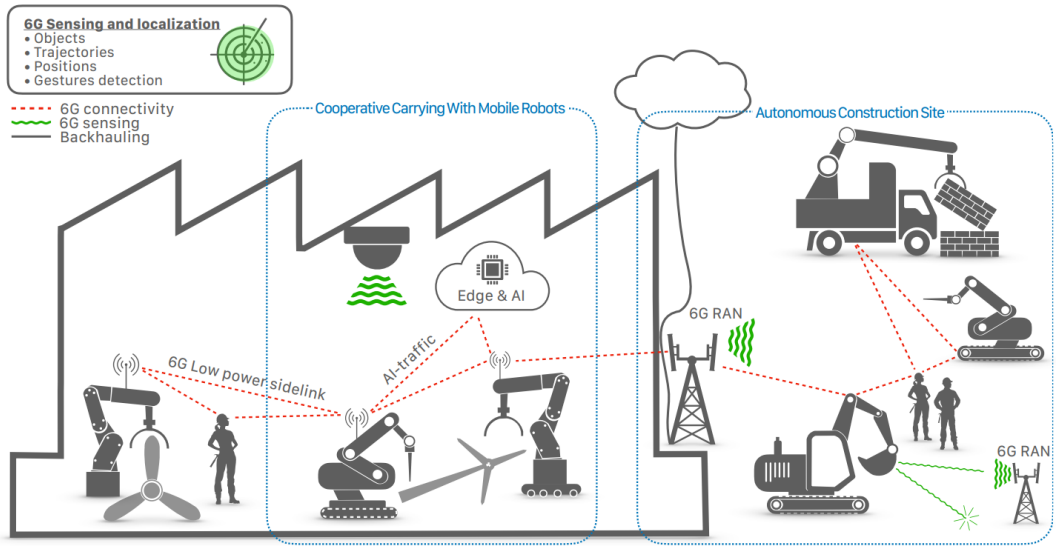
Cooperating Mobile Robots*

Collaborative Robots

At the centre of this use case are autonomous robots with the ability to move, sense their environment, and perform a productive task collaboratively. These robots can communicate with each other, with other machines, and with nearby humans to perform individual tasks that contribute to a common cooperative objective. The purpose of the communication is safety and cooperation, to enable a group of robots to perform tasks beyond their individual capabilities, but potentially also helping people to perform tasks irrespective of their current capabilities.
This use case focuses primarily on local ad hoc connectivity between cooperating robots embedded in private networks. In this context, the network of the future is envisioned to enable local cooperation among robots, to support autonomous task-solving by the robots, to enhance the safety of human-machine interaction, and to ensure that only authorized machines and humans can participate in task solving. Multiple robots form a communication cluster for the following purposes:

- Coordinating and controlling their actions for successful task execution.
- Exchanging raw or processed sensor data.
- Sharing AI/ML models, weights, and federated learning.
- Ensuring safety for humans nearby in the event of an emergency.

The scenarios described are Cooperative carrying with mobile robots, Lot-size-1 production, Automated industrial task, Autonomous farming, Autonomous construction site and Smart workshop.



Problem(s) to be Solved/Challenges

- Understanding and addressing the communication requirements of machines in the future
- Using limited resources efficiently
- Adapting to dynamic requirements of the market
- End-user access to custom manufacturing
- Safe and trustworthy interactions with tools that can make decisions

Requirements

•**Local ad hoc connectivity**: Task-specific, temporary subnetworks within campus networks to meet stringent latency and reliability targets.
•**Support of Private Networks**: Private networks tailored to the specific requirements of a scenario.
•**Extremely reliable and low latency communications**: Crucial for industrial and safety-critical applications.
•**Mobility**: Movement of machines induces frequent handovers, which must be seamless.
•**Sensing, positioning, and AI/ML**: Integrated sensing and AI/ML enhance robot coordination and perception of its environment.
•**Energy efficiency**: Find appropriate trade-offs between energy efficiency and production KPIs to ensure production quality.

	KPI	Target Range	Comments / Justification
Communication	Application data rate		
	Industrial Communication/ control traffic [Mb/s]	≤ 2.5 DL and UL	Symmetric DL/UL data rates: UL=DL
	Between robots and network [Mb/s]	< 10 < 250	Critical: timely transfer of (raw) data. The data rate might be significantly higher depending on the type of data exchanged with the campus network (e.g. video stream)
	Connection density [devices/m²]	≤ 0.5	Local concentration of mobile robots depends on the scenario
	Mobility [km/h]	< 20	Slow vehicular
	D2D latency [ms] | (one way)	≤ 5 ≥ 0.8	Critical: exchange of coordination messages and control messages up to 600 times per second. Note, this results in a transfer interval of ca. 1.66 [ms]. E2E latency limit is set to at most half that interval. This provides enough margin for ARQ.
	Between robots and network [ms] | (one way)	1 - 10	Critical, if timely response expected (e.g. digital twin data) Not critical, if no real-time response is expected (e.g. AI/ML model exchange)
	Max/min transfer interval [ms]	≤ 10 ≥ 1.66	Critical: deterministic periodic communication with very low latencies in collaborative robotic use cases
	Message error rate	< 10^{-5}-10^{-7}	Critical. Application-side safety net mechanisms like “survival time” or “grace period” are employed to compensate for occasional packet losses and delays at the link level. Selected applications may have an even more strict packet reliability requirement of up to 99.999 999% [3G22.104-24] (= message error rate of 10^{-8}).
	Message size [Byte]	250-500	Applications are putting more and more information into the control data, 500 Bytes with localization information
	Coverage [%]	100 (localized)	The localized nature of a joint task makes local ad hoc connectivity favourable.
Positioning & New Capabilities	Positioning accuracy [m]	< 0.1 < 1	Collaborative tasks such as handing over material and objects or robot navigation in close distance to other objects require more accurate positioning. Tasks like robot localization can work with less accurate positioning.
	Human presence detection [m]	0.4	Identifying human presence is very important: 40 cm resolution within 1 m of the machine, velocity.
	Sensing-related capabilities [Y/N]	Yes	Robots and cobots depend on capturing the environmental context. Network-integrated sensing may complement or replace dedicated onboard sensors. Efficient transport of data/information from connected external sensors is likely needed.
	AI/ML-related capabilities [Y/N]	Yes	Robots and cobots depend on advanced ML. Execution may be embedded in the device and/or offloaded at a local edge and/or provided by the network as an over-the-top service.

Visibility: Internal

Cooperating Mobile Robots | KV/KVI analysis [Extract]

Collaborative Robots

SP	H/F	KV	KVIs (EKVI & UCKVI)	HPG	SDG
Environmental	Sustainability Handprint	Resource efficiency: Functionalities may be provided by machines with less materials, energy, and waste generated	1. Overall GHG footprint of the materials involved [tCO_2e] 2. Virgin materials (in) [tons]/Material used in products (out) [tons] 3. % of produced products remaining in stock/not possible to sell/scrapped **4. Energy consumption per process/overall [MWh]**	4, 5	6, 12, 14, 15
		Function integration eliminates the need for multiple dedicated machines with individual functions	1. # of different dedicated machines in a production plant 2. downtime of robot while switching functionality 3. # of functions a robot can undertake	4	6, 12
	Sustainability Footprint	Energy is consumed and materials are used to manufacture, deploy, and operate robots and associated services	1. Energy usage related to cobots through their life cycle [MWh] 1a. Energy used in manufacturing components [MWh] 1b. Energy used in transportation processes [MWh] **1c. Energy used in operation phase [MWh]** **1d. Energy used in data transfer (optimising packets and volume of data) [MWh]** 1e. Energy used in end-of-life phase [MWh] 2. Emissions related to energy usage in all previous KVIs [tCO_2e] 3. Environmental footprint related to materials usage, across the life-cycle 4. Material usage of cobots, across their life-cycle [tons, total footprint] **5. 'Data efficiency' on storage [Terabytes]**	3, 4	6, 12, 13
		The manufacturing, including material extraction and industrial processes, and transportation of robots generate GHG emissions	**1. Total life-cycle emissions [tCO_2e]** **2. Share of recycled or reused materials used [%]** **3. Materials used after/Materials used before [%]**	3	13
		The disposal of machines and devices results in increased electronic waste	**1. Life expectancy of robots [unit of time]** 2. % of recyclability of robots **3. # of virtualized functionalities** 4. Weight of e-waste [tons] 5. Weight of e-waste properly recovered/reused/ recycled [tons]	5	12, 14, 15
Social	SF&SH	…	…	…	…
Economic	SF&SH	…	…	…	…

- The table on the **left**, shows an extract for only the environmental aspects on the KVs identified for the Cooperating Mobile Robots' (CMR) use case, and their related KVIs.
- Those KVIs which have the potential to be influenced through technical design, are highlighted as **Enabler KVIs (EKVI)**.
- These were then grouped into categories and value requirements and linked to technical requirements for subsequent evaluation by WP2, as shown in the table **below**.

- D1.4 contains the complete table, displaying also the social and economic impacts.
- It must be noted that the process of establishment of Key Values and Key Values Indicators remains a subjective process and requires the involvement of all stakeholders

Categories	Value Requirements	Example EKVIs	Technical Requirements
Energy	Minimise the energy usage for the correct operation of robots, both on communication links and in the data processing, data storage, and data collection aspects.	• Energy consumption per process/overall [MWh] • Energy used in operation phase [MWh] • Energy used in data transfer (optimising packets and volume of data) [MWh] • 'Data efficiency' on storage [TB]	• Energy-efficient Network operation • Energy neutral devices • Energy-efficient AI/ML training and inference
Materials/ Waste	Reduce material dependency, foster longer-lasting materials/products, use materials where it is really necessary, choose materials with lower environmental impact, etc. The latter spans from infrastructure-related materials to operational aspects, where 6G-related services can have an impact.	• Total life-cycle emissions [tCO_2e] • Share of recycled or reused materials used [%] • Materials used after/Materials used before [%] • Life expectancy of robots [unit of time] • # of virtualised functionalities	• Modularization • Virtualization • Softwarization • Compute offloading • Resilience • Predictable Low-latency
Safety	…	…	…
Trustworthiness/ Privacy/Security	…	…	…
Costs	…	…	…
Productivity / Efficiency	…	…	…

Sensitivity: Internal

Cooperating Mobile Robots | Business evaluation

Step 1
Ecosystem Business Model Canvas

- **Ecosystem Value Proposition:** Improved efficiency, quality, safety, security, flexibility and reliability from collaborative mobile robots conducting complex tasks in a coordinated manner within pre-defined geographical spaces.
- **Ecosystem Co-Value Creation Process:** Co-creating and enabling a total solution for robots, machines and humans to conduct complex tasks jointly.
- **Ecosystem Outcomes:** Environmental, social and economic benefits from, e.g.: higher resource efficiency and productivity of processes, etc.

Step 2
Stakeholder Analysis

- **Identification of Stakeholders:** Mobile Network Operator, Network Infrastructure Provider, Provider of Cobots, Modem Chipset Manufacturer, Provider of SW for Robots, System Integrator, Manufacturer, Co-workers.
- **Stakeholders' Value Descriptions:** Value Proposition to customer, Value co-creation towards others, Benefits, Costs, Revenues/pricing, Activities, Resources.

Step 3
Ecosystem Pie

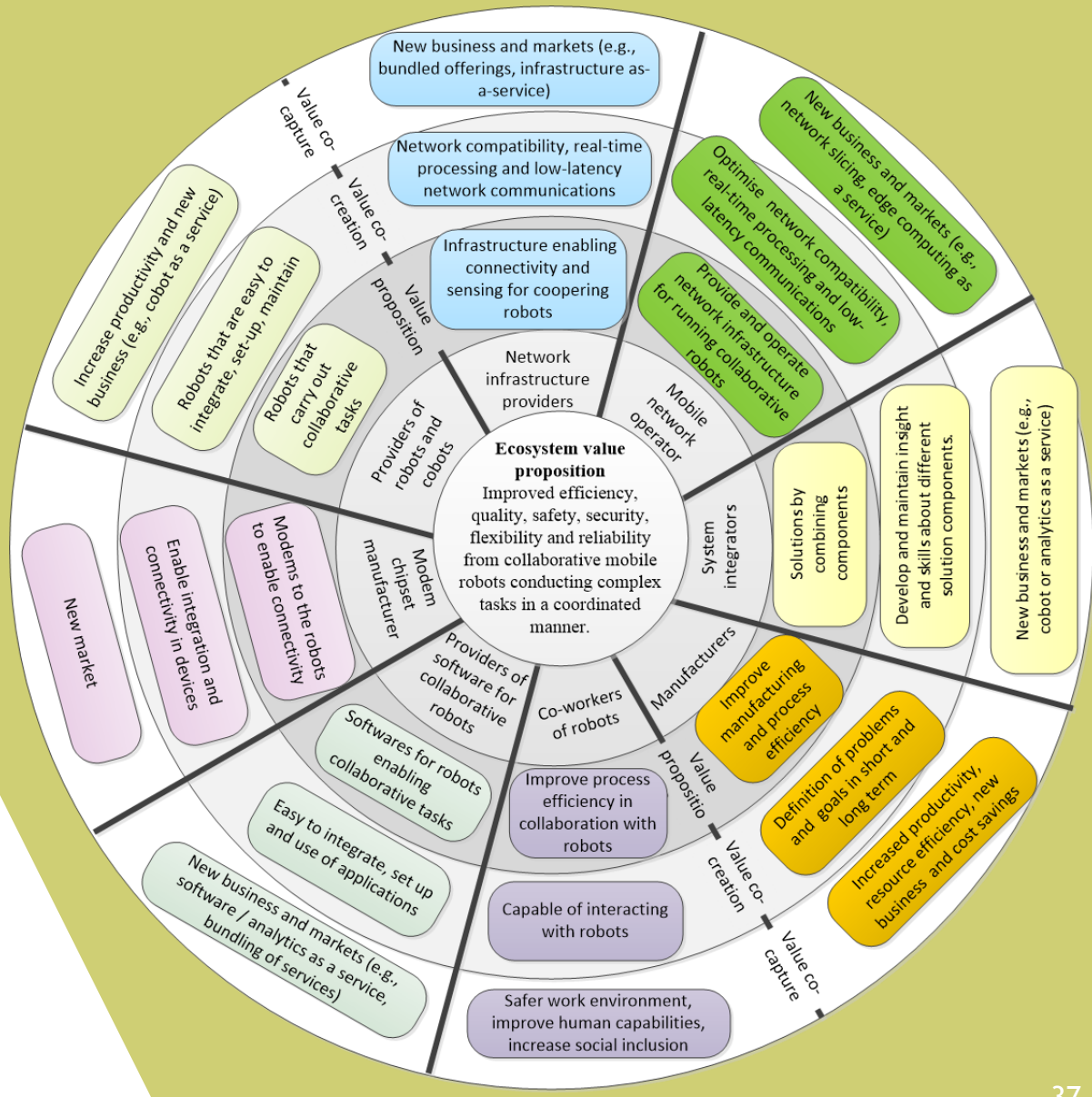
- **Graphical Visualization of Business Model:** Ecosystem value proposition and stakeholders' value propositions, value co-creations and value co-captures

Sensitivity: Internal

Cooperating Mobile Robots | Business evaluation

Stakeholders

- Mobile network operator
- Network infrastructure provider
- Provider of robots and cobots
- Modem chipset manufacturer
- Provider of software for collaborative robots
- System integrator
- Manufacturer
- Co-workers of robots

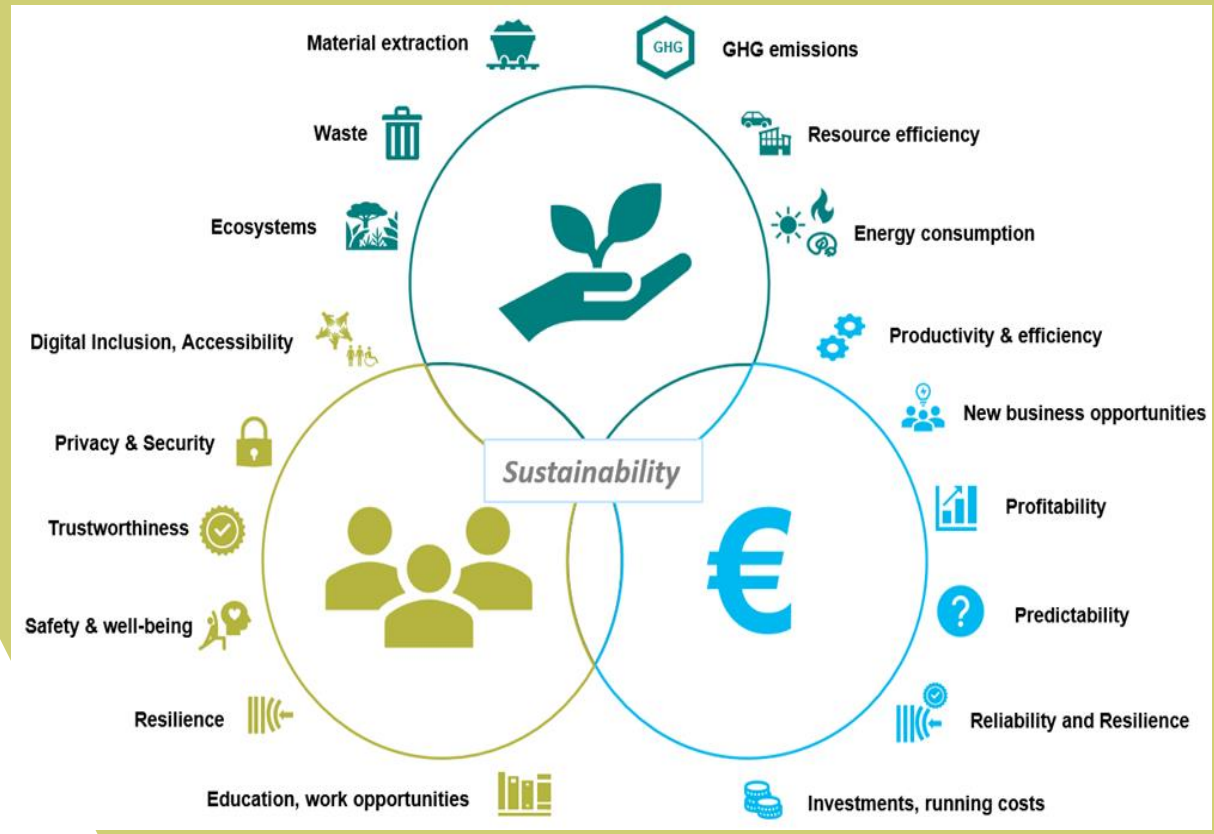


Ecosystem Pie

Sensitivity: Internal

Summary of use cases value

- Looking at the KVs for the selected use cases and concluding some of the potential effects of 6G for planet, people and society overall, there are many commonalities between the use cases.
- For environmental, social and economic sustainability, it is relevant to separate the KVs of use cases into **‘Sustainable 6G’ vs. ‘6G for sustainability’.**
- The purpose is to clarify what would be the direct effects of the design and use of the network vs. what induced effects the network could have on sustainability.
- For the latter, the opportunities of value creation are larger, but the possibilities to control the outcome are lower, compared to the design of the network itself, since there are many other affecting factors.



Sustainability aspects of the three pillars

Sensitivity: Internal



Conclusions

Sensitivity: Internal

Conclusions

The results of this deliverable have been keeping the principle of value-oriented design on 6G.

A challenge of this magnitude will not be solved only with technology.

We need to manage our footprint in the best possible way to contribute to a sustainable and resilient society and planet.

Requires continued engagement with ecosystem stakeholders to enforce values and principles.

Stakeholder analysis in the context of 6G development has been essential to understand the diverse expectations, concerns, and priorities.

The analyses of 6G use case, revealed stakeholders affected and those that could mitigate issues.

The findings from surveys, expert discussions, and municipal engagements provide a strong foundation for guiding responsible innovation.

Hexa-X-II has used business modelling as the method for business evaluation and integrated stakeholder and sustainability thinking into ecosystem level business modelling.

Sensitivity: Internal

Conclusions



With respect to use cases, these have shown the potential of the 6th generation of mobile communication to offer a solution to a wide variety of problems together with bringing new opportunities to our future using innovative and transformative technologies.

- It has also been clear how there can be multiple approaches for a given problem.
- It is important to aim not only for the solution with the highest performance but rather for the one which maximizes the value while still meeting the requirements.
- Stressing the need for taking the value approach into account and considering what is the solution meeting the requirements and creating additional value for the ecosystem and the society.
- Real-life use cases require many other technologies besides 6G (like robotics and vertical industries) as well as social and economic factors to achieve their outcome and deployment
- Metrics and measurements for KVI are challenging as they might not be quantitative and objective all the time, since they may have a qualitative and/or subjective nature as well.

Sensitivity: Internal

Conclusions



The research work should continue to address fully all the aspects that 6G requires and may realize over time.

A transparent collaboration among social and economic domain experts and technologists to co-design a 6G technology that complies with the required value outcomes is required.

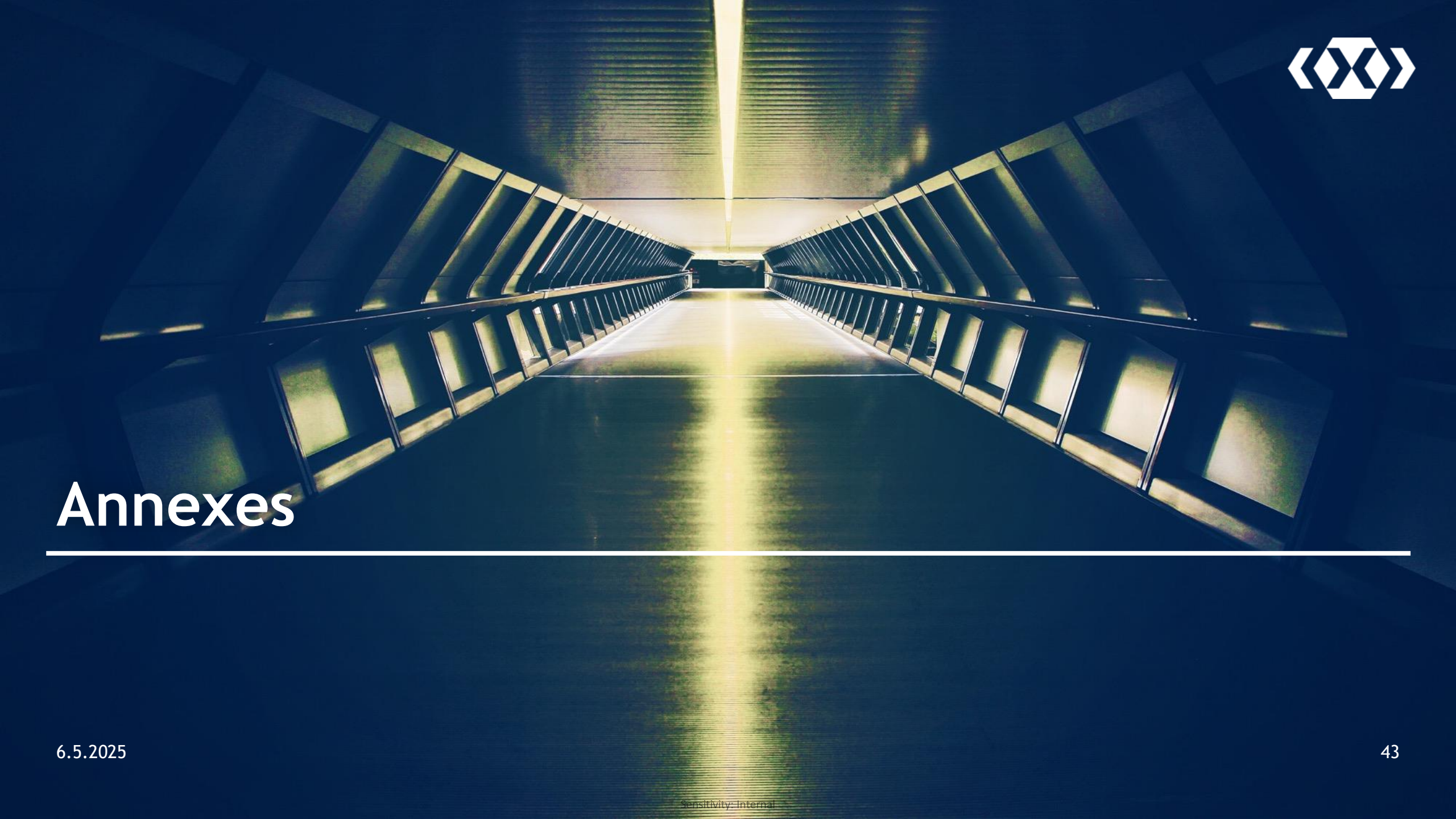


The deliverable suggests methods and approaches for use case development, stakeholder analysis and ecosystem business modelling that enables the possible evaluation of a value driven design.



The work on how to refine and improve further the use cases and their business modelling must still go through further iterations to build insight and build and implement 6G technologies in a successful way for the ecosystems and society at large.

Sensitivity: Internal

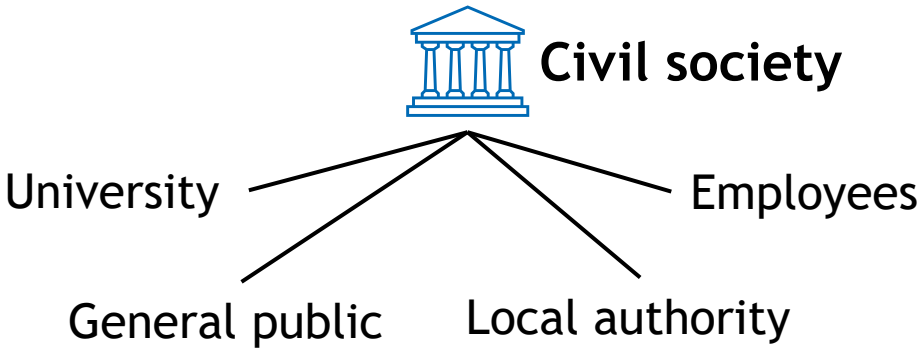


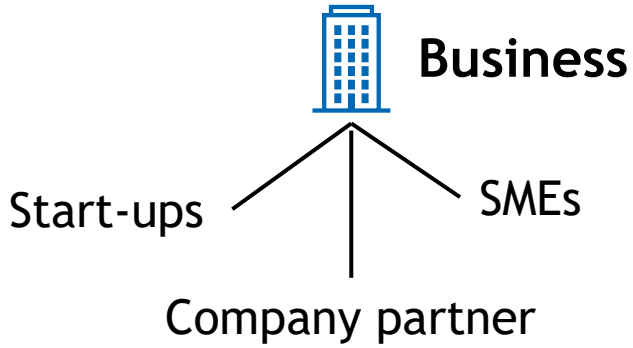
Annexes

Sensitivity: Internal

Annex 1 : Engagements with civil society and business in France

Societal dialogue methodology





Qualitative

Hackathons

Workshops

Qualitative & quantitative

Exhibition & Questionnaire

Online surveys

Qualitative & quantitative

Workshops

Online surveys

Pop vox

Sensitivity: Internal



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6GSNS

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