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SEamless integratioN of efficient 6G WirelesS tEchnologies for Communication and Sensing

D6.4 - Business Plans, Exploitation Strategies and Project Impact Assessment

July 2026

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Executive Summary

This deliverable presents the comprehensive outcomes of the 6G-SENSES activities related to business planning, exploitation strategies, and project impact assessment, as developed under Task 6.3 “Impact Assessment, Technology Roadmap and Exploitation Activities.” It consolidates and finalizes the work initiated in earlier stages of the project, providing a complete view of how 6G-SENSES results can be translated into tangible market opportunities and broader socio-economic value.

Building upon the preliminary analyses and methodologies previously defined, this deliverable outlines the refined and validated business models and business plans aligned with emerging 6G network capabilities and service paradigms. It considers evolving market conditions, stakeholder roles, and the specific characteristics of the 6G ecosystem, offering a structured approach for positioning 6G-SENSES outcomes within realistic commercial contexts.

Furthermore, **D6.4** presents the exploitation strategies developed by individual partners and at consortium level for the Key Exploitable Results (KERs) and assets of the project. These strategies address pathways to market, potential commercialisation routes, Intellectual Property (IP) considerations, and collaboration opportunities. A particular emphasis is placed on identifying synergies across technologies and partners, with the aim of maximising market uptake, strengthening competitive positioning, and ensuring long-term sustainability of the project results beyond the project lifecycle.

In addition, this deliverable provides a thorough assessment of the overall impact of the 6G-SENSES project. It evaluates the expected project contribution to values, linking them to European values and Sustainable Development Goals (SDGs). Key Performance Indicators (KPIs), impact metrics, and qualitative assessments are used to assess the impact of the project.

In summary, **D6.4** reports the activities of the project related to business planning, exploitation, and impact assessment. It aims to support the stakeholders of the project beyond the project lifetime in understanding the value proposition of 6G-SENSES innovations and provides actionable guidance for their successful transition from research outcomes to real-world deployment and commercialisation.

1 Introduction

The Digital Europe Programme (DEP), implemented by the European Commission (EC) [1], aims to strengthen the European Union (EU) leadership in advanced digital technologies by supporting research and innovation that enable the development and sustainable deployment of next-generation mobile networks. Within this context, 6G emerges as a transformative paradigm, expected to deliver unprecedented performance through capabilities such as immersive communication, massive connectivity, and high-reliability low-latency communications (HRLLC), alongside enabling technologies including integrated sensing and communication (ISAC), ubiquitous connectivity, and native integration of Artificial Intelligence (AI).

These technological advancements create the foundation for new forms of collaboration and value creation across industries. In particular, 6G ecosystems are expected to bring together stakeholders from Information and Communication Technology (ICT), vertical industries, and service providers, covering roles from design and manufacturing to deployment and operation. Through these interactions, innovative service offerings and value propositions can be developed, addressing both market demands and societal challenges, including sustainability objectives.

In order to fully leverage the potential of 6G infrastructures and services, new business models are required. These models define viable economic pathways that bridge advanced technological capabilities with market needs, enabling the realisation of 6G use cases. They encapsulate the priorities and value systems of diverse stakeholders, while ensuring alignment with technical feasibility, economic viability, and regulatory considerations.

Within 6G-SENSES, Task 6.3 focuses on the definition and consolidation of business models, the development of commercial exploitation strategies, and the assessment of project impact. This deliverable represents the culmination of these activities, presenting mature business plans and exploitation strategies associated with the KERs of the project, along with a comprehensive evaluation of 6G-SENSES overall impact.

More specifically, the work presented in this document includes:

- Refined business models that capture the value propositions of 6G-SENSES innovations within the emerging 6G ecosystem.
- Detailed commercial and technological exploitation strategies, developed per partner and per product, and integrated to identify synergies, optimize market opportunities, and maximize impact.
- A structured impact assessment that evaluates the contributions of the project across multiple dimensions, including effects on consortium partners, research and innovation uptake, technology adoption, and alignment with broader societal and policy objectives such as sustainability, EU priorities, and global frameworks, e.g., the United Nation (UN) SDGs.

In practice, the defined business models provide the foundation for the elaboration of exploitation strategies and activities, while jointly enabling a systematic assessment of the impact of the project over different time horizons and across different sectors.

1.1 Organisation of the document

Following this introduction, Chapter 2 presents the methodology describing the basic business modelling approach as a generic procedure in accordance to the project activities.

Chapter 3 discusses aspects of the 6G-SENSES Key Exploitable Outcomes (KEOs), the envisioned service provisioning environment, and the project implications for business modelling.

Chapter 4 presents the exploitation plans and activities per partner initially focusing on the project KERs.

Chapter 5 covers the overall impact assessment of the project, analysing its expected contributions across technological, economic, and societal dimensions using both quantitative and qualitative approaches.

Finally, Chapter 6 summarises the main findings of the work and outlines potential future activities.

2 Project Exploitation Outcomes Classification and Methodology

2.1 Exploitation Outcomes Classification

Considering the diversity of the partners who may participate in an EU funded project, ranging from academic to industrial sectors, different and usually complementary expertise and prospects are reflected to their exploitation strategy and activities. More specifically, Universities and Research Centres usually focus on exploitation activities regarding research items, while large companies and Small and Medium enterprises (SMEs) are mainly interested in the commercial exploitation of the project results in future products. At the same time, partners representing the stakeholders which are the potential consumers/users of the project outcomes mainly focus on the identification of the added value of the products/outcomes and the ways the latter can be adopted in their business processes, infrastructure, provided services, and so on.

Regarding the exploitable outcomes of a project, they can be classified in four (4) major categories; each one usually associated with some type of partner:

- **Product development** which includes the development of new products/features (together with a roadmap definition) as well as the product validation that increases the technology readiness level (TRL) towards its commercial exploitation. This category is mostly related to companies (large companies and SMEs).
- **Business development** which includes enhancement of existing business services/activities and/or the creation of new ones. This category is also related mostly to companies.
- **Standardisation contribution** which constitutes a very concrete step towards the sustainability of products, solutions, and services, as it reflects the consensus of the industry sector towards their development and commercial adoption. In the context of a project, partners that are actively involved in standardisation and regulatory activities may promote the results of the project as technical contributions to relevant standardisation bodies. Standardisation is not strictly associated with a certain type of outcome, but usually falls in the interest of commercial/industry entities.
- **Research achievements,** including theoretical studies and research prototypes, which can be further exploited/ extended by the research community (academic and industrial sectors), mainly when made available through publications and can be considered as the basis for further research/development. In general, academic and research entities focus on them.

In the 6G-SENSES project, Universities, Research Centres, large companies and SMEs are involved, with various expertise and areas of interest, focusing on various aspects/technologies/outcomes of the project according to their strategic (profitable or non-profitable) goals. In particular, the project outcomes have been classified in the following categories (keeping aside contributions to standardisation as they are closely monitored and tackled in the context of another project task):

- Research Achievements: including studies conducted by research/university partners.
- Product Development: including efforts performed by partners that focus on developing or enhancing specific products, by:
  - delivering them as prototypes - stand-alone products.
  - performing validation activities of the functionalities of specific products. These can be considered as exploitation activities aiming at increasing the TRL level of the associated products.
  - accompanying the validation activities with demonstrators in the field or in lab environment as Proof of Concept (PoC).

- Other Achievements, e.g., tools aiming at enhancing internal processes and assessment procedures related to the deployment of the technologies developed in the project.

2.2 Overview of Business Modelling and Exploitation Activities Methodology

Especially considering the project outcomes that fall in the type of Product Development, 6G-SENSES has defined a framework to guide their sustainability and commercial exploitation. This methodology integrates service evolution, technology analysis, and business modelling into a structured flow of activities (see Fig.2). The process leverages Value Proposition Canvas (VPCs) and Lean Canvas (LC) tools, ensuring alignment with market needs and technology trends.

In more detail, 6G-SENSES has defined a methodology for exploitation planning, which includes identifying the market and business environment driving 6G research, identifying the 6G-SENSES KERs and positioning them within the broader 6G business ecosystem. This involves mapping stakeholders and their roles, applying ecosystem modeling practices rooted in 5G/6G service provisioning theories, and formulating representative business models tailored to the use cases of the project. By aligning KERs with ecosystem entities, realistic pathways for exploitation can be defined for sustainable value creation and market adoption. The methodology considers applying structured tools such as the VPCs and LCs. These tools help capture customer needs, align technical innovations with market expectations, and outline steps for translating research output into viable business opportunities. This structured approach ensures that exploitation activities are systematic and measurable throughout the project lifecycle.

Concretely, the Methodology Phases are illustrated in Figure 2-1.

Phase 1 – Market and Service Foundations

- 6G and Beyond Targets Roadmap: Identification of future service targets and evolution paths.
- Market Analysis of Technology Domains: Assessment of technology trends relevant to 6G-SENSES.
- 6G Business Environment & Trends: Exploration of business ecosystems and emerging market dynamics.

Phase 2 – Business Modelling and KER Positioning

- Business Modelling Tools: Application of structured tools to define value propositions.
- KERs Identification & Positioning: Determination of KERs and their placement within the business ecosystem using VPCs.

Phase 3 – Exploitation Pathways

- KERs Exploitation Pathways: Development of exploitation strategies using LCs to translate KERs into actionable business opportunities.

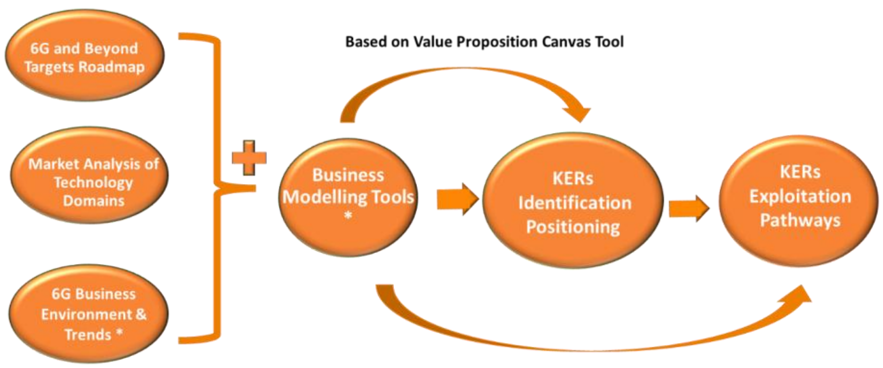

Figure 2-1 6G-SENSES Business Modelling and Exploitation Framework

Table 2-1 Technology readiness levels

TRL level	Description
TRL 1	Basic principles observed
TRL 2	Technology concept formulated
TRL 3	Experimental proof of concept
TRL 4	Technology validated in lab
TRL 5	Technology validated in relevant environment (industrially relevant environment in the case of key enabling technologies)
TRL 6	Technology demonstrated in relevant environment (industrially relevant environment in the case of key enabling technologies)
TRL 7	System prototype demonstration in operational environment
TRL 8	System complete and qualified
TRL 9	Actual system proven in operational environment (competitive manufacturing in the case of key enabling technologies; or in space)

The aim of this document is to report on the methodology and activities of Phase 1 and Phase 2. In practice, this document aims to establish the foundation for the exploitation strategy of the project by drafting preliminary business plans and initiating key exploitation activities. It focuses on identifying KERs, mapping them to relevant business models, and outlining pathways for market readiness and value creation, so to ensure that the project steers the effort of T6.3 to translating technical innovations into sustainable business opportunities.

2.3 Business Modelling for different TRL levels

Tailoring exploitation strategies to the TRL of each KER is critical for ensuring realistic and impactful outcomes. Aligning exploitation efforts with TRL ensures that resources are allocated effectively, risks are managed, and innovations transition smoothly from concept to market-ready solutions. At lower TRLs (1–3), where concepts are still being formulated or demonstrated in lab conditions, exploitation should focus on validating the value proposition, refining business models, and identifying potential markets through tools like VPCs. These early stages require strong emphasis on research partnerships, IP protection, and feasibility analysis rather than aggressive commercialisation. As KERs progress to higher TRLs (4–7), exploitation activities must shift toward more detailed modeling of business opportunities and business relationships to demonstrate viability in relevant environments. At this point **LCs** is considered a useful tool.

To this end, depending on the maturity of each KER, VPC or LCs will be used for the discussion on business models.

2.3.1 Value Proposition Canvas

The VPC is a strategic tool designed to align a product or service with customer needs and expectations and is split in two main conceptual sides, as explained below: Value Proposition and Customer Segment. The VPC defines the unique benefits that a solution delivers to its target audience, bridging the gap between what the company offers and what the customer truly values. It articulates why a customer should choose a specific product or service over alternatives, focusing on solving problems and creating meaningful gains. This definition ensures that innovation efforts are not just technology-driven but market-driven, increasing the likelihood of adoption and success.

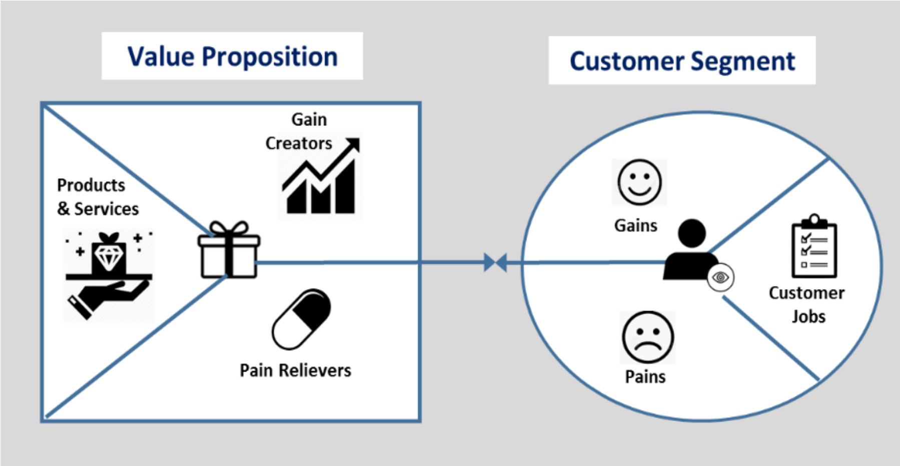

Figure 2-2 Value Proposition Canvas

On the value proposition side, the canvas breaks down the offering into three key aspects: Products & Services, Pain Relievers, and Gain Creators. Products & Services represent the tangible and intangible elements delivered to the customer. Pain Relievers describe how the solution addresses customer frustrations, inefficiencies, or risks, while Gain Creators highlight how to enhance outcomes, improve experiences, or add extra value beyond expectations. Together, these components form a compelling narrative that demonstrates how the solution not only meets functional needs but also delivers emotional and social benefits.

On the Customer Segment side, the canvas focuses on understanding the target audience through Customer Jobs, Pains, and Gains. Customer Jobs refer to the tasks, problems, or goals customers aim to accomplish, whether functional, emotional, or social. Pains capture the obstacles, risks, and negative experiences customers face in achieving these jobs, while Gains represent the desired benefits, improvements, or aspirations they seek. By mapping these elements, businesses can tailor their offerings to resonate deeply with customer priorities, ensuring that the value proposition is relevant, differentiated, and impactful.

2.3.2 Lean Canvas

The **LCs** is a powerful one-page framework designed to help innovators, startups, and project teams quickly capture, validate, and iterate on their business model (Figure 2-3). It is particularly useful for early-stage projects like 6G-SENSES, where clarity and adaptability are essential. It further elaborates on the VPCs providing a thinking space for businesses to further analyse aspects like business relationships, costs and revenues, as well as market obstacles or gaps.

Problem and Solution

The LC begins with identifying the Problem, which is the foundation of any successful business model. In this field the main customer problems are listed, ensuring that the solution under investigation addresses real pain points rather than perceived ones. This section also includes Existing Alternatives, which helps understand the competitive landscape and why customers currently rely on other solutions. Next is the Solution block, which describes how the product or service solves these problems effectively.

Unique Value Proposition and Unfair Advantage

At the center of the canvas is the Unique Value Proposition (UVP), which articulates the core reason why customers should choose the offering. The Unfair Advantage block captures what makes the solution defensible—something competitors cannot easily copy, such as proprietary algorithms, strong partnerships, or exclusive access to testbeds. This ensures that the solution / innovation is not only attractive but also sustainable in the long term.

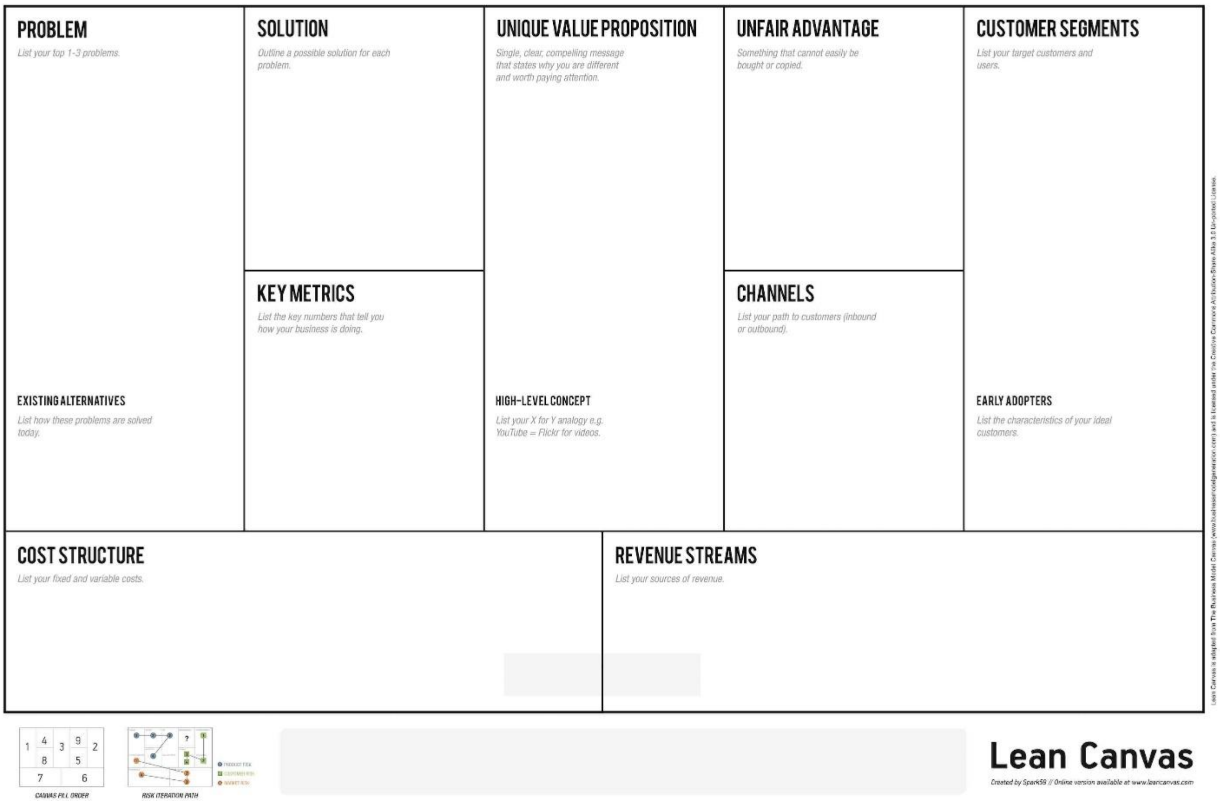

Figure 2-3 Lean Canvas

Customer Segments, Channels, and Financials

On the right side, Customer Segments define the target audience and early adopters. Channels describe how the business entity providing the solution can reach and deliver value to these customers, including marketing, distribution, and engagement strategies.

At the bottom, Cost Structure and Revenue Streams outline a coherent financial model—key costs to operate and expected income sources. Supporting blocks like Key Metrics ensure tracking of progress.

Together, these elements of the LC create a holistic view of how your innovation can succeed in the market.

2.4 Methodology of exploitation plans section

The unique setup of 6G-SENSES, characterised by the integration of advanced 6G technologies such as ISAC, Cell-Free Multiple-Input Multiple-Output (CF-MIMO), and Reconfigurable Intelligent Surfaces (RIS)-assisted connectivity, combined with AI-driven orchestration and Digital Twin (DT) capabilities, requires an exploitation approach that goes beyond conventional 5G exploitation pathways. The main goal is not only to maximize the impact and outreach of project results during its lifetime but also to ensure sustainability and long-term adoption of innovations beyond the project end.

The integrated exploitation plan for 6G-SENSES spans multiple dimensions, targeting multiple roles and corresponding stakeholders of an envisioned future 6G ecosystem. Depending on the maturity of the exploitable results of the project, different exploitation modes are considered.

2.4.1 Commercial Exploitation

This involves leveraging the technologies validated in 6G-SENSES for commercial deployment, in relevant network deployments – targeting future service scenarios like immersive services, HRLLC applications- and energy-efficient paradigms. It also includes offering the testbeds and platforms of the project to third-party experimentation and early adoption by industry stakeholders.

2.4.2 Technological Exploitation

Technological exploitation focuses on reusing the know-how gained to develop innovative 6G products and advanced services. Activities include:

- Building a knowledge base 6G-SENSES architectures and technologies.
- Integrating sustainable business models early in the development process.
- Designing integrated network blueprints for future services with high user acceptance considering the market landscape.
- Demonstrating and validating PoCs over 6G-SENSES testbeds, ensuring KPI compliance and alignment with IMT-2030 vision.
- Showcasing capabilities at major industry events and standardisation forums.

Additional activities may include systematic screening of innovative business models, market analysis for emerging 6G services, and validation of exploitation strategies of partners. These efforts aim to ensure sustainability and readiness of project outcomes for near-term market adoption.

2.4.3 Joint Exploitation Plans

The diverse ecosystem of 6G-SENSES, comprising telecom operators, technology vendors, SMEs, and research institutions, fosters cross-fertilisation and joint exploitation opportunities. R&D partners focus on research-driven exploitation, while industry players on bringing innovations close to commercialisation (depending on the TRL level). This collaborative environment creates opportunities for impactful partnerships and joint exploitation plans that have been explored throughout the course of the project.

3 KERs and Aspects of 6G Provisioning Business Environment

3.1 Overview of 5G Provisioning Roles

The evolution from 5G to 6G introduces a paradigm shift that extends beyond the Service-Based Architecture (SBA) of 5G. While 5G brought new processes and roles through virtualisation and disaggregation, 6G adds further complexity by incorporating sensing capabilities, AI-driven orchestration, and multi-domain resource management. These advancements create additional streams of information operating in parallel with traditional communication flows, requiring new roles and interactions within the ecosystem. 6G-SENSES builds on this foundation by enabling an extended layered service provisioning approach, illustrated in Figure 3-1, where new roles such as Sensing Data Provider and enhanced Radio Access Network (RAN)/Open RAN (O-RAN)/RIS functions are highlighted.

Moving beyond the traditional 5G service-provisioning model, the shift from 5G to 6G architectures—along with the introduction of new network segments and parallel information streams (such as those generated by sensing processes)—creates opportunities for additional roles within both 6G platforms (from a technical standpoint) and 6G ecosystems (from a stakeholder perspective). Integrating 6G-SENSES innovations into the 5G ecosystem enables an expanded, layered service-provisioning framework. Figure 3-1 illustrates the new roles introduced by 6G-SENSES, highlighted in orange, in contrast with the previous 5G ecosystem model.

Technically and functionally, 6G-SENSES builds on the disaggregation of RAN functionalities especially considering O-RAN architectures, the development of an intelligent control and management plane operating exclusively on top of the RAN, and the introduction of parallel data streams supported by RAN-based sensing (including RIS). As shown in Figure 3-1, these capabilities support multiple RAN provisioning models: (1) RAN as raw infrastructure resources, (2) RAN as virtualised resources, (3) RAN-captured, processed, and exposed data made available to Network Operators (NOPs) or even service customers. In conventional mobile systems, NOPs are essentially Mobile Network Operators (MNOs).

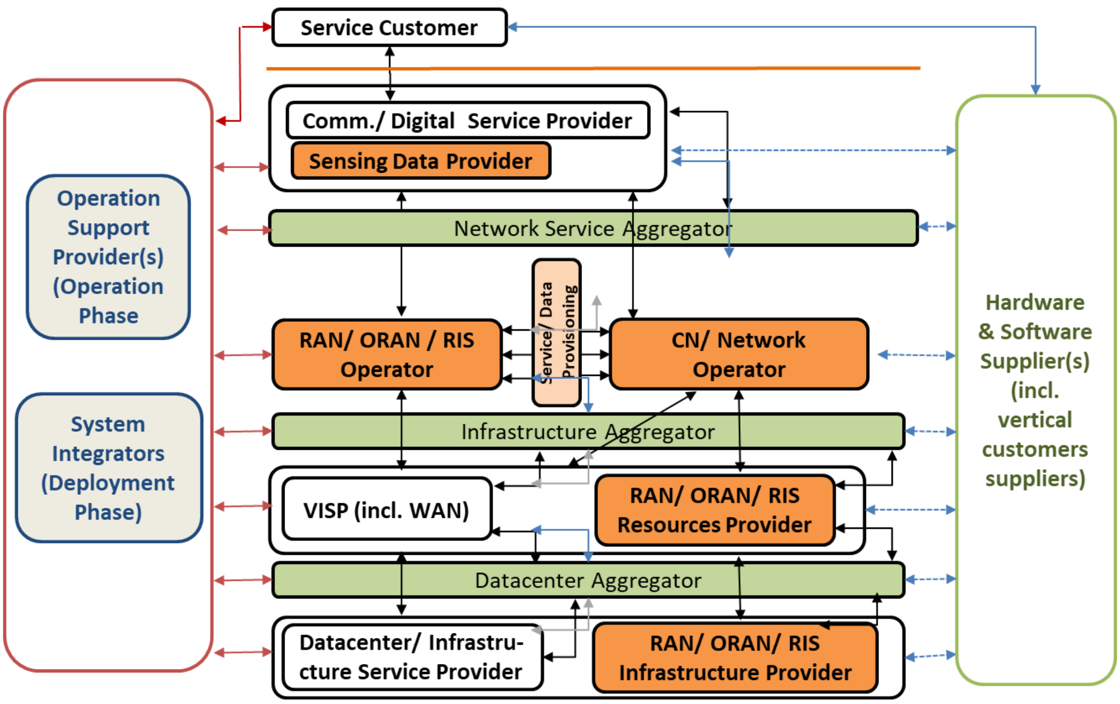

Figure 3-1 Revised Ecosystem view enabled by 6G-SENSES enhancements

In this setting, technological progress enables a broader ecosystem model (see the **orange** components in Figure 3-1) when compared with the 5G framework. Building on the established 5G ecosystem roles, the Service Provider (SP) remains a central actor, interfacing directly with end users and acquiring or coordinating resources from NOPs, Virtualization Infrastructure Service Providers (VISPs), and Datacenter Service Providers (DCSPs)—collectively referred to as Infrastructure Providers (InPrs). The SP role can further be categorised into:

i. a Communication SP (CSP) or Digital SP (DiSP), responsible for delivering conventional telecommunications services, and
ii. a provider of more advanced digital offerings, such as eMBB and IoT services tailored to different vertical sectors.

From a bottom-up view of service-provisioning layers, DCSPs/InPrs supply raw computing or connectivity (transport) resources. In 6G-SENSES, this role expands to include RAN/O-RAN/RIS infrastructure providers—entities owning RAN components (and potentially edge-computing assets) and offering them as raw resources to NOPs. This can be achieved by granting VISPs or NOPs full access to the control and management planes of RAN/O-RAN/RIS elements. Typical examples include public or commercial buildings where indoor RAN systems are deployed and owned by building owners or municipalities, especially as ICT cabling (copper/fibre) becomes standard in new constructions.

At the following service-provisioning layer, the VISP delivers virtualised networking and cloud/edge computing capabilities through Application Programming Interfaces (APIs), and traditionally functions as the cloud/edge infrastructure provider. In a 6G environment, this role can expand to include ownership of RAN components that are offered as shared access-network resources (O-RAN/RIS) to one or multiple NOPs.

At the network-operations layer, the NOP oversees a programmable infrastructure that covers radio or fixed access, edge, transport, and core network (CN) domains. This responsibility also involves managing virtualised resources obtained from other DCSPs/InPrs via APIs. With 6G-SENSES, the NOP role can be divided—both vertically and horizontally—into operators dedicated to RAN/O-RAN/RIS functions and those focused on the traditional CNs. The RAN/O-RAN/RIS operator is responsible for running RAN elements and making resources or advanced services – such as Radio Intelligent Controller (RIC) functionalities and sensing information – available to third parties, including CN operators, peer NOPs (to improve network delivery), or SPs (to enable sensing-driven services).

Finally, the SP role expands to provide services over both major streams: communication and sensing.

Additional roles may also emerge, such as Service Aggregators operating at various layers—for example, Network Service Aggregators, Infrastructure Aggregators, and Datacenter Aggregators. These entities orchestrate services across multiple domains within a given layer, such as across several NOPs (e.g., in mixed private/public network environments), multiple cloud/edge/RAN providers, or various infrastructure providers.

3.2 6G-SENSES Key Exploitable Results and Ownership

The exploitable outcomes of 6G-SENSES span pure research results, to individual products and further to integrated demonstrators. The exploitable outcomes list and classification is presented in Table 3-1 along with the corresponding owner and the addressed business role with view to the aforementioned 6G-SENSES Ecosystem.

Table 3-1 6G-SENSES KERs list

#	Topic	Innovation	Addressed Stakeholder/ Role	Owner	Start TRL	End TRL
1	CF-MIMO	Practical reciprocity calibration solution for distributed TDD/CF-mMIMO	RAN IP, Telecom Operator (Telco), Venue owner	**UC**	2	4
2	D-MIMO	Distributed Massive MIMO and RIS-assisted Beamforming Prototyping Platform	RAN IP Telco, Venue owner for surveillance	**TUBS**	1	4
3	O-RAN	Extension of O-RAN RIC for heterogeneous RATs for sensing capabilities support	O-RAN IP, Telco, Sensing Data Provider	**BR** / **UC**	2	4
4	ISAC enhanced O-RAN	O-RAN RIC Extensions for ISAC	Telco, End-User for end –user Apps	**ACC**	2/3	4
5	Antenna-in-package solution & mmWave FE Chipset	Low-voltage and low-power operation enabling battery operable multi-modal sensing and communication for highly efficient RF front ends	RAN IP, Telco, Other Vendors	**BI** / **IHP**	2	4
6	SM for mmWave	mmWave interfacing with O-RAN – integrated solution with an O-RAN 6G platform – 6G control fabric	Sensing Data Provider, Telco	**IHP** / **UC** (**BR**)	1	4
7	SM for Sub-6	Sensing Service Model (SM) for Sub-6 - Service based Interfacing with O-RAN	Sensing Data Provider, Telco	**IHP** / **UC** (**BR**)	1	4
8	Cross-domain AI Optimisation	SMO Intelligence plane	VISP, Telco, End-User	**ACC** (**IASA** / **UC**)	4	5
9	Wi-Fi Sensing	Human Presence Detection Using Wi-Fi Sensing	End-User, Venue owner, Other vendors - Consumer electronics Original Equipment Manufacturer (OEMs), particularly laptop manufacturers	**INT**	1-2	4
10	Network Digital Twin (NDT)	NDT Sandbox	Telco, End-User for end –user Apps	**ACC** / **UC**	2	3
11	DT for RSSI Fingerprint Maps	DT for RSSI Fingerprint Maps	End-User	**NTU**	2	3
12	ISAC enabled Transport	Programmable multi-technology transport infrastructure for joint support of communication and sensing services	Telco, VISP, RAN/O-RAN IP	**IASA**	**2**	**4**
13	Multi-O-RU Sensing	Multi-O-RU sensing aggregation and processing in centralised and distributed modes	Telco, Sensing Data Provider, Service Provider	**IASA**	**2**	**4**
14	PoC#1	Multi-Technology ISAC Platform	O-RAN/ RAN IP, Telco, Service Provider	Partners in PoC#1	2	4

15	PoC#2	CF-MIMO Prototype	RAN IP, Telco, Service Provider	Partners in PoC#2	2	4
16	PoC#3	NDT via RAN sensing	O-RAN IP, Telco, Sensing Data Provider, SP	Partners in PoC#3	2	4

It shall be noted that PoC#1, PoC#2, and PoC#3 essentially contribute to the advancement of the TRL of the technologies/KERs that they integrate rather than delivering a business value proposition at this stage. Therefore, they are not analysed via VP and LCs, but are included in the technological KERs list.

3.3 6G-SENSES Value Propositions of Product Development KERs and Mapping to 6G Ecosystem

The exploitable outcomes list and classification of the 6G-SENSES project are presented in Table 3-2 along with the respective Value Proposition.

Table 3-2 6G-SENSES Value Proposition for KERs

#	KER	Value Proposition
1	Practical reciprocity calibration solution for distributed Time Division Duplexing (TDD)/CF-mMIMO	This KER provides a practical reciprocity calibration solution for distributed TDD MIMO/CF-mMIMO USRP-based testbeds that allows for coherent downlink precoding based on 5G New Radio (NR) waveforms and improves Signal to Noise Ratio (SINR). The solution can be implemented with Universal Software Radio Peripheral (USRP) hardware and integrated with integrated into an OpenAirInterface (OAI) Radio Unit (RU) gNB.
2	Distributed mMIMO and RIS-assisted Beamforming Prototyping Platform	The developed Distributed MIMO Prototyping System is an instantiation of the so-called CF-mMIMO technology, focusing on beamforming and user terminal assignment. Built on the Emerson NI massive MIMO Prototyping System, the platform is modified to support the current 5G NR implementation of the OAI both on the wireless access as well as the CNs. Having access to the complete source code allows to modify the beamforming algorithms and implement distributed or cell-free beamforming algorithms. KPIs can be measured during bi-directional RT transmission of 5G NR packets. The Distributed mMIMO Prototyping System can be combined with our RIS System to showcase the joint optimisation of beamforming, user terminal assignments, and RIS element configurations. While the current setup reaches TRL4, a smaller form factor would allow to progress toward higher TRL levels.
3	Extension of O-RAN RIC for heterogeneous RATs for sensing capabilities support	This KER provides the capability to optimize RAN operation exploiting sensing information by performing preventive decisions. In highly demanding scenarios, this sensing-assisted communication capability allows improving the usage of radio resources using explicit surrounding information.
4	O-RAN RIC Extensions for ISAC	The O-RAN RIC extensions for ISAC provide telecom operators with a practical way to introduce sensing-aware intelligence into O-RAN network management. By combining xApp telemetry, ISAC-related information and NDT support, the solution allows RAN optimisation decisions to be assessed in a realistic digital environment before being enforced in the live network. This brings value by reducing the operational risk of AI-driven optimisation, especially for energy-saving and performance-management actions. Instead of treating sensing and communication as separate domains, the solution enables a more integrated control approach where environmental awareness can support smarter RAN

		decisions. In this way, the KER helps operators evolve towards future 6G-ready, context-aware and autonomous network operation.
5	Antenna-in-package solution & mmWave Front-End Chipset	This KER refers to the development of a scalable mmWave Industrial, Scientific and Medical Band (ISM)-band front-end system for ISAC applications. The chosen 60 GHz license free band hosts several indoor network standards offering an ideal platform for demonstrating ISAC in the mmWave range. The solution includes development of a novel ultra–low-power Bipolar Complementary Metal-Oxide Semiconductor (BiCMOS) chip operating at low DC voltage, serving as the core of a 1x4 phase array transceiver with four RF chains capable of beamforming and MIMO communication. The low power and low voltage operations make it attractive for battery operated mobile terminals. The transceiver module will enable both high-speed data transmission and environmental sensing, including identification and tracking of users. Its packaging and modular design are scalable, allowing easy extension beyond the 1×4 configuration which are not currently available in commercial systems. Baseband signaling and waveform generation will be handled by an RFSoC processor system, ensuring flexibility for advanced ISAC demonstrations.
6	mmWave interfacing with ORAN – integrated solution with an O-RAN 6G platform – 6G control fabric	This KER provides the means to make high resolution sensing information from mmwave radar readily accessible at the RT controller of the telecom operation. The developed solution permits adapting the temporal and spatial resolution of the sensing information, to simultaneously manage the additional communication capacity yielded by sensing flows.
7	Service based Interfacing with O-RAN	Development and validation of a sensing SM to integrate sensing information generated by sub-6 RAN elements. It can be integrated within a monolithic gNB or a Distributed Unit (DU) to make the sensing information accessible at the near-RT RIC.
8	SMO Intelligence Plane	The SMO Intelligence Plane provides an AI-driven orchestration capability for managing heterogeneous communication and sensing traffic in future O-RAN/6G environments. It allows operators and infrastructure providers to reason over different traffic types, resource constraints and service requirements from a higher-level management plane. Its unique value lies in connecting sensing-aware traffic characterisation with cross-domain optimisation decisions. Rather than optimising isolated network functions, the Intelligence Plane supports more coordinated decisions across RAN, SMO and service layers. This helps operators move towards autonomous, context-aware and service-driven network operation.
9	Human Presence Detection Using Wi-Fi Sensing	Wi-Fi sensing, as implemented by Intel on Personal Computers (PCs), improves the value proposition and user experience for a broad variety of usages. Since all PCs are equipped with Wi-Fi, this becomes an easy and low-cost method to enable sensing. Other alternatives based on dedicated sensors are possible, but they are more expensive (as Wi-Fi is already available in all PCs) and all have their own limitations which makes Wi-Fi sensing attractive for many usages.
10	NDT Sandbox	The NDT Sandbox provides a controlled 5G Standalone environment with O-RAN gNBs, an SMO layer and an NDT xApp for testing optimisation solutions before they are implemented in real networks. The value of the NDT Sandbox lies in reducing the operational risk associated with new xApps and RAN management algorithms. Instead of validating optimisation logic directly in production, telecom operators can first assess behaviour, performance impact and possible side effects in a repeatable sandbox environment. This

		makes the KER useful both for operational preparation and for research-oriented benchmarking of RAN optimisation methods.
11	Digital Twin for RSSI Fingerprint Maps	The proposed platform significantly reduces the overhead of repeated physical measurement campaigns by using an initial Received Signal Strength Indicator (RSSI) fingerprint database — collected once for a given environment — to generate a DT that supports ongoing simulation, algorithm development, and benchmarking without further physical intervention. This enables reproducible, environment-aware indoor wireless experimentation at scale, removing the need to repeatedly reconfigure hardware or re-enter physical spaces for each test cycle. The solution is deployable as a standalone tool, platform plugin, or testbed-as-a-service, making it accessible across research, network planning, and educational contexts.
12	Programmable multi-technology transport infrastructure for joint support of communication and sensing services	This KER provides a programmable multi-technology transport infrastructure capable of jointly supporting communication and sensing services in O-RAN-compliant ISAC deployments. It enables heterogeneous communication and sensing traffic generated by multiple O-RUs to be efficiently transported, orchestrated, and dynamically managed over a hybrid packet-optical transport network while satisfying the bandwidth, latency, and service-differentiation requirements of both traffic classes. By integrating packet switching and all-optical switching under a unified SDN control framework, the solution enables dynamic allocation of transport resources, logical isolation, and differentiated treatment of communication and sensing traffic.
13	Multi-O-RU sensing aggregation and processing in centralised and distributed modes	This KER provides a cooperative sensing framework that enables the aggregation and processing of sensing information generated by multiple sensing-enabled O-RUs. In the centralised sensing mode, range-Doppler maps from multiple sensing nodes are transported to a centralised sensing aggregation function and jointly processed using a hybrid Convolutional Neural Network–Long Short-Term Memory (CNN–LSTM) model for trajectory estimation. In the distributed sensing mode, the models are trained locally through Federated Learning, and only model updates are exchanged periodically. By supporting both sensing modes, the framework enables sensing operation to be adapted to communication and sensing requirements, transport resource utilisation, and compute availability, while balancing sensing accuracy and transport resource consumption.

3.4 KER#1 - Practical reciprocity calibration solution for distributed TDD/CF-mMIMO – Value Proposition Canvas

Value Proposition: A practical reciprocity calibration solution for distributed TDD MIMO/CF-mMIMO USRP-based testbeds that allows for coherent downlink precoding based on 5G NR waveforms and improves SINR. The solution can be implemented with USRP hardware and integrated with integrated into an OAI RU gNB.

Customer Segment: RAN IP, Telecom Operator, 6G research labs, SDR/testbed vendors, O-RAN/PHY prototyping teams, academic groups.

Customer Jobs Provide high-performance, high-quality network coverage at multi-layer indoor environments.

Pains:

- Phase and gain mismatches between Transmitter (Tx) / Receiver (Rx) paths in distributed MIMO systems.
- Calibration drift, long calibration time and overhead from bidirectional pilots.
- Mismatches when moving from simulation to USRP/Over the Air (OTA) experiments.

- Differences in intra- and inter-RU reciprocity calibration procedures.

Gains:

- Improved coherent combining at the downlink with higher SINRs at the User Equipment (UE).
- More reliable multiuser performance with almost uniform coverage, and a practical path from theory to prototype.
- Performance stable over time and reduced calibration overhead.
- Make TDD massive MIMO/CF-mMIMO coherent downlink precoding work possible in USRP-based hardware.

Products & **Services**:

- Argos-style intra-RU calibration + BeamSync-style inter-RU calibration.
- USRP-based prototype integrated into an OAI RU gNB.
- Protocol and calibration workflow for intra-RU and inter-RU calibration with a pilot/subcarrier multiplexing strategy for faster operation.

Pain Relievers:

- Compensates Tx-Rx phase mismatches allowing for TDD operation and coherent downlink beamforming.
- Reduces frequent recalibration procedures.
- Speeds up the reciprocity calibration procedure by multiplexing subcarriers in 5G-NR waveforms during bidirectional pilot transmissions.

Gain Creators:

- Improves SINR/EVM after calibration.
- Supports extension to multiple Access Points (APs)/RUs and UE.
- It can be deployed into a 5G NR/USRP testbed and integrated in OAI gNBs.

3.5 KER#2 - Distributed Massive MIMO and RIS-assisted Beamforming Prototyping Platform

Value Proposition - The platform provides a flexible and scalable OTA experimentation environment based on OAI and Software-Defined Radio (SDR) hardware. It enables: (a) Practical validation of distributed beamforming, (b) Investigation of near-field focusing, (c) Evaluation of RIS-assisted communication strategies, under controlled laboratory conditions. By offering full access to radio parameters, synchronisation mechanisms and PHY/MAC layer behavior, the platform bridges the gap between simulation-based development and real-world implementation constraints. This allows stakeholders to test, compare and refine novel radio concepts before moving to deployment or standardisation. As a research infrastructure, it fosters scientific collaboration, education and training, as well as technology transfer, while reducing risks in early-stage 6G system development.

Customer Segment: Equipment manufacturers, MNOs, Research institutions and universities, Industrial R&D labs, SDOs. Customers requiring validation environments for advanced 5G/ 6G radio technologies.

Pains

- Limited access to flexible experimental platforms for advanced 6G validation
- High cost and complexity of building distributed MIMO and RIS test environments
- Difficulty in validating theoretical algorithms under realistic OTA conditions
- Limited visibility into implementation constraints of SDR-based systems.

Gains

- Access to a real OTA validation platform for distributed beamforming and RIS-assisted communication
- Reduced uncertainty before large-scale deployment of new radio concepts
- Faster evaluation of algorithm performance under realistic hardware conditions
- Improved understanding of synchronisation, beamforming, and programmable radio environment challenges.

Products & Services

- Distributed mMIMO prototyping platform based on OAI and USRP SDR hardware
- Near-field beamforming experimentation with synchronised multi-antenna gNB deployment
- RIS-assisted transmission and multi-panel RIS control environment
- OTA validation framework for beamforming, synchronisation, and optimisation algorithms
- Experimental support for collaborative research, demonstrations, and technology validation.

Pain Relievers

- Reduces the need for costly large-scale field trials
- Simplifies evaluation in a controlled laboratory setup
- Identifies implementation limitations early
- Provides insights into synchronisation and hardware integration challenges.

Gain Creators

- Enables realistic validation before industrial deployment.
- Provides reproducible experimentation with full system control.
- Accelerates development of beamforming and RIS optimisation strategies.
- Facilitates collaboration between academia and industry.

3.6 KER#3 - Extension of O-RAN RIC for heterogeneous RATs for sensing capabilities support – Value Proposition Canvas

Value Proposition - Capability to optimize RAN operation exploiting sensing information by performing preventive decisions. In highly demanding scenarios, this sensing-assisted communication capability allows improving the usage of radio resources using explicit surrounding information.

Customer Segment: O-RAN IP, Telecom Operator, Sensing Data Provider.

Customer Jobs: Provide high-performance, high-quality network coverage optimising radio resources utilisation.

Pains:

- Unavailability of sensing information to enforce sensing assisted communications.
- Lack of technical integration of sensing data flows.
- Need to develop applications able manage semantics of sensing data.

Gains:

- Homogenous management of ISAC access network, i.e., RAN, entities.

- Realisation of sensing assisted communications to support services with extreme Quality of Service (QoS) requirements.
- Real time adaptation of sensing information based on sensing-service demand.
- Radio resources and energy saving from predictive decision making.

Products & Services:

- Sensing monitoring and control xApp able to shape the amount of sensing information.
- xApp able to adapt MAC scheduler operation based on sensing information.

Pain Relievers:

- Integration of sensing information within well-known RAN management system, i.e., O-RAN.
- Enabling taking preventive decision on radio resource management.
- Unified control solution for comms/sensing/ISAC devices.

Gain Creators:

- Explicit surrounding information at the near-RT RIC with varying precision.
- Dual sensing/comms xApp for MAC scheduling operation control.
- Reduction of the number of used Physical Resource Blocks (PRBs) for equal QoS.

3.7 KER#4 - O-RAN RIC Extensions for ISAC – Value Proposition Canvas

Value Proposition: The O-RAN RIC Extensions for ISAC provide telecom operators with a practical way to introduce sensing-aware intelligence into O-RAN network management. By combining xApp telemetry, ISAC-related information and NDT support, the solution allows RAN optimisation decisions to be assessed in a realistic digital environment before being enforced in the live network.

This brings value by reducing the operational risk of AI-driven optimisation, especially for energy-saving and performance-management actions. Instead of treating sensing and communication as separate domains, the solution enables a more integrated control approach where environmental awareness can support smarter RAN decisions. In this way, the KER helps operators evolve towards future 6G-ready, context-aware and autonomous network operation.

Customer Segment:

1st Customer Segment: The primary customer segment is represented by telecom operators deploying or experimenting with O-RAN-based networks, including future private/mobile network operators. These actors are responsible for operating programmable RAN infrastructures and are expected to benefit directly from enhanced RAN control, xApp-based automation and the integration of ISAC-related information into network management processes.

2nd Customer Segment: A secondary customer segment includes end-user application providers and vertical service owners, especially where service quality depends on reliable, adaptive and context-aware network behaviour.

Customer Jobs: Telecom operators need to operate and optimise increasingly complex RAN environments while maintaining service quality and controlling operational costs. In this context, they need to:

- optimise RAN behaviour based on real network and environmental conditions
- reduce energy consumption without negatively affecting QoS
- evaluate xApp or AI-driven optimisation decisions before applying them to the live network
- prepare their O-RAN infrastructure for future ISAC-enabled services.

Gains

The expected gains are linked to safer and more informed network automation. By using ISAC-related telemetry and NDT support, operators can improve the way RAN decisions are assessed and enforced.

Expected gains include:

- improved confidence in RAN optimisation decisions.
- reduced energy consumption.
- better context-awareness for network management.
- lower operational risk through pre-validation of actions.
- a first step towards sensing-aware O-RAN and future 6G services.

Pains

Current RAN optimisation processes often rely mainly on network-side telemetry, with limited awareness of the physical environment affecting radio conditions. This makes optimisation less accurate, especially in dynamic scenarios.

Main pains include:

- limited coordination between communication and sensing information.
- operational risk when applying new xApp or AI policies directly in the real network.
- difficulty balancing energy savings with coverage, reliability and user experience.
- lack of mature tools to validate sensing-aware optimisation decisions before deployment.

Products & **Services**:

The solution may comprise the following technical assets and service concepts:

- ISAC-enabled extensions to the O-RAN RIC framework.
- xApp-based telemetry collection and management mechanisms.
- NDT integration for pre-validation of optimisation actions
- AI-assisted RAN optimisation functions, with initial focus on energy efficiency
- Interfaces for using sensing-related information in RAN control decisions
- Know-how for deploying sensing-aware O-RAN control loops in experimental or future operational environments.

Gain Creators

- Enables safer deployment of AI/xApp-based RAN optimisation strategies
- Supports energy-efficient operation while preserving service quality
- Improves operator confidence by validating decisions through the NDT
- Provides a technical foundation for future ISAC-enabled O-RAN and 6G services.

Pain Relievers

- Reduces the risk of applying untested optimisation policies directly in the real network
- Addresses the lack of environmental/contextual awareness in current RAN optimisation
- Helps balance energy-saving objectives with QoS, coverage and reliability constraints
- Facilitates the integration of sensing information into O-RAN management workflows.

3.8 KER#4 – O-RAN RIC Extension for ISAC (by ACC) – Lean Canvas

<table>
<tr>
<td rowspan="2">Problem:
Telecom operators need to optimise increasingly complex O-RAN environments while reducing energy consumption and maintaining service quality. However, current RAN optimisation is often based mainly on network telemetry, with limited awareness of the physical environment and limited mechanisms to safely validate AI/xApp decisions before deployment.

Existing alternatives:
• Manual RAN optimisation and rule-based configuration.
• Conventional RIC/xApp control based only on network KPIs.
• Offline simulations that do not fully reflect the live network environment.
• Separate sensing systems not integrated into O-RAN control loops.</td>
<td>Solution:
Extend the O-RAN RIC framework with ISAC-aware capabilities, enabling sensing-related information and xApp telemetry to support RAN optimisation decisions. Through NDT integration, optimisation actions can be assessed in a realistic digital environment before being enforced in the live network.</td>
<td rowspan="2">Unique Value Proposition:

A sensing-aware O-RAN control solution that allows telecom operators to validate and apply AI-driven RAN optimisation decisions with lower operational risk, improved energy efficiency and better context awareness.

High level concept:

A NDT-assisted Intelligence Plane for ISAC-enabled O-RAN optimisation.</td>
<td>Unfair Advantage:
• Direct integration with dRAX (the name of the proprietary ACC solution) RIC/SMO capabilities.
• Project-based validation in the 6G-SENSES PoC#3 environment.
• Combination of O-RAN control, ISAC telemetry and NDT-based validation.
• Know-how from ACC and UC on xApps, telemetry, RIC extensions and network optimisation.</td>
<td rowspan="2">Customer segments:
• Telecom operators.
• Private network operators.
• O-RAN adopters and experimental 6G platform owners.
• Vertical service providers depending on reliable/context-aware connectivity.

Early adopters:
• Operators experimenting with O-RAN and AI-driven automation.
• Private 5G/6G network owners with energy-efficiency or automation targets.
• research and innovation (R&I) testbeds validating ISAC and O-RAN integration.</td>
</tr>
<tr>
<td>Key metrics:
• Energy consumption reduction.
• Accuracy/reliability of optimisation decisions.
• Number of validated xApp policies before live deployment.
• Impact on QoS, coverage and service continuity.
• Reduction of manual optimisation effort.</td>
<td>Channels:
• Pilot deployments with MNOs and private network owners.
• Integration into ACC’s dRAX RIC/SMO offering.
• 6G-SENSES PoC#3 demo.
• Joint trials with research partners and O-RAN ecosystem stakeholders.
• Technical workshops, SNS JU events and standardisation-oriented dissemination.</td>
</tr>
<tr>
<td colspan="3">Cost structure:
• Software development and maintenance of RIC/SMO extensions.
• Integration with NDT and sensing telemetry sources.
• Testing, validation and PoC operation.
• Engineering support for pilots and customer-specific deployments.
• Dissemination, standardisation and ecosystem engagement activities.</td>
<td colspan="2">Revenue Streams:
• Software licensing of ISAC-aware dRAX extensions.
• Professional services for integration, customisation and deployment.
• Managed service offering for AI-driven RAN optimisation.
• Consulting for O-RAN, ISAC and NDT-based network automation.
• Future platform modules for 6G-ready private/mobile networks.</td>
</tr>
</table>

3.9 KER#5 - Antenna-in-package solution & mmWave Front-End Chipset

Value Proposition – Development of a Low-voltage and low-power 60 GHz ISAC front-end platform enabling battery operable multi-modal sensing and communication for highly efficient RF front ends.

Customer Segment: RAN IP providers, Telecom operators, Other Vendors.

Customer Jobs:

- Provide high-performance, high-quality network services, based on sensing.
- Develop energy efficient ISAC transceiver systems.

Pains:

- Lack of high-resolution sensing information for demanding scenarios.
- Lack of energy efficient ISAC platforms supporting high speed communication with fined resolution sensing.

Gains:

- Bridge the gap between well-established telecom ecosystems and sensing data providers.
- Being able to exploit high precision sensing data by telecom operators.

Products & Services:

- Serves as a test platform for future ISAC waveforms and algorithms.

Gain Creators:

- Availability of technical foundations for future mmWave ISAC platforms.
- Improves telecom operator confidence through concept validations.

Pain Relievers:

- Facilitates rapid prototyping and evaluation of new ISAC algorithms.
- Lowers integration efforts through utilising on board antenna system.

3.10 KER#6a - mmWave interfacing with O-RAN – integrated solution with an O-RAN 6G platform – 6G control fabric – Value Proposition Canvas

Value Proposition – Solution providing the means to make high resolution sensing information from mmWave radar readily accessible at the RT controller of the telecom operation. The developed solution permits adapting the temporal and spatial resolution of the sensing information, to simultaneously manage the additional communication capacity yielded by sensing flows.

Customer Segment: Sensing Data Provider, Telecom Operator.

Customer Jobs: Provide high-performance, high-quality network services, based on sensing.

Pains:

- Technology providers cannot readily integrate their solutions.
- Lack of high-resolution sensing information for demanding scenarios.
- Lack of SMs for sensing information in general and mmWave data in particular.

Gains:

- Bridge the gap between well-established telecom ecosystems and sensing data providers.
- Being able to exploit high precision sensing data by telecom operators.
- Being able to integrate sensing data with other information sources at the RAN.

Products & **Services**:

- New SM able to transport high precision sensing information, with adaptable format and resolution.
- Integration within a well-established near-RT RIC (FlexRIC) and a simple monitoring xApp.
- Network controller algorithm that jointly considers traffic generated by high precision sensing devices and network capacity.

Gain Creators:

- Development of an O-RAN SM suited to carry sensing information generated by operational mmWave radar.
- Extension of the SM to allow control decisions over the sensing device to modulate the amount of sensing information (temporal and spatial resolution, as well as information format).
- Integrated algorithm to jointly handle sensing information generation and allocation of transport resources.

Pain Relievers:

- The integration cycle of high precision sensing solution is reduced.
- High-resolution sensing information becomes available at the RT RAN management ecosystem.
- Telecom operators can exploit existing solutions, i.e., near RT-RIC, to handle the generation of sensing the sensing data.

3.11 KER#7a - Service based Interfacing with O-RAN – Value Proposition Canvas

Value Proposition - Development and validation of a sensing SM to integrate sensing information generated by sub-6 RAN elements. It can be integrated within a monolithic gNB or a DU to make the sensing information accessible at the near-RT RIC.

Customer Segment: Sensing Data Provider, Telecom Operator.

Customer Jobs: Provide high-performance, high-quality network services, based on sensing.

Pains:

- Telecom operators cannot readily integrate sensing information from RAN elements
- Existing SMs are focused on radio information and are not designed to handle sensing semantics.

Even if RAN devices are able to provide sensing information, there is no settled means to exploit it.

Gains:

- Telecom operators can readily integrate sensing information within their management systems
- Network management operators can benefit from more comprehensive surrounding information.

Products & Services:

- Novel SM to handle sensing information from sub-6 RAN devices
- Integration and validation of the new SM within a well-known near-RT RIC (FlexRIC) and simple monitoring xApp.

Pain Relievers:

- Sensing capabilities of RAN elements can be readily exploited
- Semantics of SMs are extended beyond their current use.

Gain Creators:

- Reduction of integration cycle when RAN elements are equipped with sensing capabilities
- Possibility to further optimize RAN operation exploiting surrounding information.

3.12 KER#6b and KER#7b – Extended O-DU ad associated SM – Value Proposition Canvas

Value Proposition: As of KER#6 and KER#7

Customer Segment: Sensing Data Provider, Telecom Operator.

Customer jobs: Implementing Native-AI and sensing features in 6G networks and benchmarking advanced algorithms for channel estimation and equalisation.

Pains: Standard commercial offerings currently lack a high-fidelity data source.

Gains:

- Obtaining a high-fidelity data source by extracting I/Q sample of the received Sounding Reference Signal (SRS) from multiple RUs. Operating within a collaborative ecosystem against real-world radio data instead of pur

Products & Services:

- Extended O-DU and associated Sensing SMs.
- The models implement both O-RAN LLC E2 SM (E2SM) and custom sensing E2SM.
- A premier Research Infrastructure testbed for ISAC.

Pain Relievers:

- Solves the scarcity of data by retrieving received SRS signals and noise for channel inference via the E2 interface.
- Eliminates the reliance on purely simulated environments by providing real-world radio data for benchmarking.

Gain Creators:

- Validates the transport of data via the E2AP protocol on a millisecond scale.
- Drives standardisation discussions regarding the feasibility of transporting high-bandwidth raw I/Q data over open interfaces.

3.13 KER#6b and KER#7b – Extended O-DU ad associated SM – Lean Canvas

<table>
<tr>
<td rowspan="2">Problem:

There is a scarcity of high-fidelity data sources in standard commercial offerings.

Existing alternatives:

• Standard commercial offerings that lack raw data extraction capabilities.
• Purely simulated environments.</td>
<td>Solution:

ISAC-enabled O-RAN platforms featuring sub-millisecond control loop capabilities at the RIC level.

Extraction of I/Q samples of received SRS signals from multiple Radio unit

Validated transport of data via the E2AP protocol on a millisecond scale.</td>
<td rowspan="2">Unique Value Proposition:

A robust enabling platform allowing network equipment manufacturers and third-party xApp developers.

High level concept:

Establishing a premier Research Infrastructure for ISAC.</td>
<td>Unfair Advantage:

• Closed source.</td>
<td rowspan="2">Customer segments:

• Operators and vendors looking to implement Native-AI
• Third-party xApp developers
• Network equipment manufacturers.

Early adopters:

IHP and UC.</td>
</tr>
<tr>
<td>Key metrics:

• Minimum accuracy
• Max mobility range
• User performance improvement</td>
<td>Channels :

• Advanced consultancy services and software licensing
• High-impact scientific publications and technical workshops.</td>
</tr>
<tr>
<td colspan="3">Cost structure:
• Operating Expenditure (OPEX): Testbed maintenance and Consultancy & R&D Personnel
• Capital Expenditure (CAPEX): Establishing the hardware and platform's requirements for the Research</td>
<td colspan="2">Revenue Streams:

• Software licensing
• Funding
• Consultancy fee</td>
</tr>
</table>

3.14 KER#8 – SMO Intelligence plane – Value Proposition Canvas

Value Proposition: The SMO Intelligence Plane provides an AI-driven orchestration capability for managing heterogeneous communication and sensing traffic in future O-RAN/6G environments. It allows operators and infrastructure providers to reason over different traffic types, resource constraints and service requirements from a higher-level management plane.

Its unique value lies in connecting sensing-aware traffic characterisation with cross-domain optimisation decisions. Rather than optimising isolated network functions, the Intelligence Plane supports more coordinated decisions across RAN, SMO and service layers. This helps operators move towards autonomous, context-aware and service-driven network operation.

Customer Segment: The main customer segment includes telecom operators and virtualised infrastructure/service providers that need to manage heterogeneous communication and sensing traffic across programmable network domains. A secondary segment includes vertical service owners and end-users that depend on predictable network behaviour, especially for services with strict latency, reliability or sensing-data requirements.

Customer Jobs

Operators and infrastructure providers need to coordinate different types of traffic flows while maintaining service quality and efficient resource usage. In the 6G-SENSES context, this includes communication traffic and sensing traffic, which may have different requirements depending on the sensing source configuration and the level of processing applied.

- Manage heterogeneous communication and sensing traffic.
- Optimise resource allocation across RAN, edge and service domains.
- Support AI-driven orchestration decisions from the SMO layer.
- Prepare networks for sensing-aware and AI-native 6G operation.

Gains

The expected gain is a more intelligent and coordinated management layer able to optimise network behaviour across multiple domains. This supports better use of resources and creates a stronger basis for future ISAC-enabled services.

- Better coordination of communication and sensing traffic.
- Higher resource efficiency across RAN, transport, and compute (lower cost/energy).
- New revenue from ISAC and differentiated SLA-based services.
- Improved readiness for AI-driven automation.
- More scalable and predictable support for ISAC and vertical use cases.

Pains

Current management approaches are not well prepared for networks where sensing data becomes part of the operational traffic mix. Operators may lack sufficient models, telemetry and decision-support mechanisms to understand the impact of sensing flows on network performance.

- Communication and sensing traffic still handled separately.
- Limited understanding and modeling of sensing traffic.
- Increased load leading to higher CAPEX/OPEX.
- Inefficient static/reactive resource allocation under dynamic demand.
- Complex QoS management across heterogeneous services.

- Difficulty in validating/explaining AI-driven decisions.
- Scalability and bottlenecks (especially with centralised sensing data processing).

Products & Services

- SMO Intelligence Plane functions for cross-domain AI optimisation.
- AI models for communication/sensing traffic management.
- Sensing traffic characterisation models.
- Interfaces towards dRAX RIC/SMO components.
- Integration with NDT-assisted validation and PoC#3 experimentation.
- Know-how for deploying AI-native orchestration in ISAC-enabled networks.

Gain Creators

- Coordinated optimisation of communication and sensing services.
- More efficient use of network, compute, and sensing resources.
- Enables new ISAC services (e.g., localisation, detection) and revenue opportunities.
- Supports proactive, AI-driven optimisation using sensing context.
- Enables differentiated services via slicing and intelligent orchestration.
- Builds reusable AI/traffic models for 6G evolution.

Pain Relievers

- Reduces fragmentation between communication and sensing management.
- Lowers CAPEX/OPEX via efficient resource allocation and adaptive processing.
- Mitigates fronthaul/backhaul load through distributed intelligence.
- Improves SLA fulfilment with proactive AI-driven decisions.
- Simplifies multi-domain orchestration (RAN, transport, compute) via hierarchical AI.
- Reduces manual effort and improves understanding of sensing impact.

3.15 KER#8 SMO Intelligence plane – Lean Canvas

<table>
<tr>
<td rowspan="2">Problem:
Future O-RAN/6G networks will need to manage communication and sensing traffic together, but current orchestration approaches are not designed for this level of cross-domain complexity. Operators need better ways to characterise sensing traffic, understand its impact, and optimise resources without degrading communication services.

Existing alternatives:
• Manual or rule-based network configuration.
• Domain-specific optimisation at RIC or network-function level.
• Generic AI orchestration not aware of sensing traffic.
• Offline simulations with limited connection to operational SMO/RIC workflows.</td>
<td>Solution:
The SMO Intelligence Plane introduces AI-driven cross-domain optimisation functions that jointly consider communication and sensing traffic requirements. It supports traffic characterisation, resource-aware decision-making and integration with dRAX RIC/SMO capabilities to enable more intelligent network control.</td>
<td rowspan="2">Unique Value Proposition:

An AI-native SMO Intelligence Plane that helps operators coordinate communication and sensing traffic across network domains, improving resource efficiency, service assurance and readiness for ISAC-enabled 6G operation.

High level concept:

“Cross-domain AI brain for sensing-aware 6G network orchestration.”</td>
<td>Unfair Advantage:
• Integration path with Accelleran’s dRAX RIC/SMO platform.
• 6G-SENSES PoC#3 context combining ISAC, NDT and RAN intelligence.
• Collaboration between ACC, IASA and UC on AI optimisation, traffic modelling and O-RAN experimentation.
• Early know-how on sensing traffic behaviour and its effect on network orchestration.</td>
<td rowspan="2">Customer segments:
• Telecom operators.
• Virtualised Infrastructure Service Providers.
• Private network operators.
• O-RAN/6G testbed owners.
• Vertical service providers requiring reliable sensing-aware connectivity.

Early adopters: Operators experimenting with O-RAN automation.

• Private network providers targeting industrial or campus deployments.
• Research testbeds validating AI-native 6G architectures.</td>
</tr>
<tr>
<td>Key metrics:
• Resource utilisation improvement.
• Communication/sensing traffic prediction accuracy.
• Service QoS/Quality of Experience (QoE) stability.
• Reduction in manual orchestration actions.
• Number of AI optimisation policies validated or deployed.</td>
<td>Channels:
• Integration into ACC’s dRAX RIC/SMO roadmap.
• 6G-SENSES PoC#3 demonstrations.
• Joint pilots with operators and private network stakeholders.
• SNS JU events and technical workshops and other activities.
• Research collaboration with IASA, UC and external testbeds.</td>
</tr>
<tr>
<td colspan="3">Cost structure:
• AI model development and maintenance.
• Integration with SMO, RIC, telemetry and NDT components.
• Data collection and sensing traffic characterisation.
• PoC validation and customer-specific pilots.
• Engineering support, documentation and dissemination.</td>
<td colspan="2">Revenue Streams:
• Software licensing of Intelligence Plane modules.
• Professional services for AI/SMO integration.
• Consulting for ISAC-aware network automation.
• Future commercial modules for 6G-ready dRAX deployments.</td>
</tr>
</table>

3.16 KER#9 - Human Presence Detection Using Wi-Fi Sensing – Value Proposition Canvas

Value Proposition

Wi-Fi sensing, as implemented by Intel on PCs, improves the value proposition and user experience for a broad variety of usages. Since all computers are equipped with Wi-Fi, this becomes an easy and low-cost method to enable sensing. Other alternative based on dedicated sensors are possible, but they are more expensive (as Wi-Fi is already available in all PCs) and all have their own limitations which makes Wi-Fi sensing attractive for many usages:

- ***Cameras***: This is easily the most capable sensor, but it has significant privacy concerns for always-on sensing (and is closed by many users when not needed for this reason), does not work when the lid is closed/angled downwards, and can require significantly more power for processing.
- ***Infrared and time-of-flight sensors***: These additional sensors are usually not present on a PC and increase both bill-of-material and integration costs (require space, electrical, mechanical etc.).
- ***Radar and Ultra-WideBand (UWB) sensors***: These are specialised sensors that are costlier and increase wireless coexistence issues as well since they may operate in similar/adjacent bands to Wi-Fi and Bluetooth.

Customer Segment

There are a few different customer segments, based on different Wi-Fi sensing usages.

1st Customer segment: The widest set of customers are all PC users who make use of computers at homes, offices, workspaces, etc. With broad usage of computers across every personal and business usage, this effectively encompasses most of the population. Since Wi-Fi is available on every computing platform, this sensing modality is provided for “free” with no integration or materials cost.

- **Pains**:
  - One of the key pain points for customers is security of the data on the PC. To prevent unauthorised access to the data, most devices lock after a period of unuse. However, this still allows access during the time window before lock (typically around 5 minutes). By automatically detecting when the user leaves the computer, it can lock much faster, improving the security of the system, especially in shared and public spaces. For businesses, this can alleviate concerns related to information security.
- **Gains:**
  - By not relying on the user to manually lock the device, the equipment security level increases significantly while improving the experience of the user and compliance. Similarly, by detecting the presence of the user in all situations, including when the person is sitting silently, the device can avoid accidental locks and remain responsive, thus offering an improved QoE.
  - Battery lifetime can significantly improve since the device can use human presence detection to sleep/wake much more accurately while balancing power consumption and responsiveness. Given a typical person walks away from a device multiple times during a day, combined with 5 minute default timeouts currently, this translates to 30-60 minutes or more of battery lifetime that can be potentially recovered in a day.
  - New forms of interaction such as gesture detection, especially in cases where the reach of the user or quick response may be needed. As an example, controlling a presentation, or basic commands such as changing the volume/screen brightness could improve the user experience.

2nd Customer segment: Another customer segment, narrower than the previous one, includes healthcare or aging-in-place vertical sectors. Always-on sensing can be useful for providing broader contextual information, such as physical activity levels, vital sign monitoring such as breathing, fall detection, etc. The proposed Intel Wi-Fi solution can provide the sensing platform on which these applications could be developed.

- **Pains**
  - Privacy-aware sensing is critical for in-home applications, and Wi-Fi sensing excels at that. In addition, the wide variety of deployed Wi-Fi devices could enable very good sensing coverage across such indoor environments
- **Gains**
  - Fall detection is a hard problem, as cameras cannot be used due to privacy concerns, and compliance issues may become relevant with wearable devices that may be forgotten. Wi-Fi sensing enables the privacy-aware ambient sensing as a solution to this problem.

Products & Services

Intel has launched the human presence detection feature that utilizes Wi-Fi sensing. This is available on a select set of computers and is currently being expanded across a broader section of the market. The current offerings are being used to gauge the user acceptance and testing for more mainstream deployment. Currently, every Intel Wi-Fi platform offers at least limited support for Wi-Fi sensing features which can in theory enable this usage to be rolled out across the PC board.

Future products that are being envisioned include gesture detection and improved security features such as detecting multiple people in the vicinity for privacy control. Given Intel's position in the PC industry, these features have the potential to be very broadly deployed, e.g., in several million of pieces per year.

Healthcare and aging-in-place usages could use Intel computing/edge/Wi-Fi platforms in the future, or may even be built on other platforms utilising the Wi-Fi sensing technical innovations and results that have been developed in this project.

Pain Relievers

- Lower security concerns with no intervention from users
- Removes the need to add additional cost and hardware to achieve the same requirements. Earlier specialised sensors such as Infrared (IR) or Time-of-flight (TOF) sensors were added for this purpose.

Gain Creators

Human presence detection achieves better security and power management of the devices with no extra hardware requirements. Some of the advantages include:

- Reduced walk-away detection time from 5 minutes to 10 seconds or so, improving battery lifetime by 30-60 minutes per day of usage
- Improved security of the device since it remains unlocked for only a few seconds after the customer has walked away (when the device is typically still within view)
- New interaction forms such as gesture detection could improve user experience and device control.

Results on breathing detection and improved sensing accuracy that have been demonstrated in the 6G-SENSES project could be building blocks for wellness/healthcare usages that use ambient sensing without requiring any wearables.

3.17 KER#9 - Human Presence Detection Using Wi-Fi Sensing – Lean Canvas

<table>
<tr>
<td rowspan="2">Problem:

Enhance computer context awareness and human presence detection to optimize platform power management and improve security features.

Existing alternatives:

• Current solutions rely either on simple timeouts to lock devices after 5+ minutes of no input from a person, or they use specialised one-off sensors such as Time-of-Flight sensors, IR sensors, etc. The latter solutions increase Bill of Material (BOM) and integration costs, as well as require some additional power for sensing.</td>
<td>Solution:

Wi-Fi sensing effectively detects human presence, approach and walk-away without requiring any additional sensor. It can lock down the PC with high accuracy within 10 seconds of a person departing, saving both power and improving security.</td>
<td rowspan="2">Unique Value Proposition:

Improved user experience with no additional cost of hardware and integration.

High level concept:

Wi-Fi sensing detects (1) Approach: Bringing up PC ready to use, (2) Constantly detecting human presence making sure system is responsive and available, and (3) Walkaway, locking PC within seconds of a person departing.</td>
<td>Unfair Advantage:

• Intel has developed a unique monostatic (radar-like) sensing technique that has been implemented over all Intel Wi-Fi NICs. In addition, specialised algorithms can detect things like approach, walkaway, human presence, gesture etc. so as to make the system responsive and bring to market new methods of interaction.</td>
<td rowspan="2">Customer segments:

• Premium segment: Leading edge of sensing featured such as gesture detection in addition to presence detection
• Mainstream segment: Requires no additional sensors and improves user experience based on the presence detection feature for value-conscious users

Early adopters:

Different OEMs are incorporating this feature into more platforms over time.</td>
</tr>
<tr>
<td>Key metrics:

• The key KPIs are missed detections and false locks which directly translate to user experience.
• Increased battery lifetime is another metric (e.g. 5 mins of saving every time someone departs X number of departures over a day, typically 5+)</td>
<td>Channels:

• The solution has been implemented over Intel Wi-Fi NICs and is productised via partner OEMs such as Dell, HP, Lenovo, etc.</td>
</tr>
<tr>
<td colspan="3">Cost structure:

• Primary CAPEX is development cost of Wi-Fi sensing which is a new feature in the Wi-Fi industry and requires significant R&D expenditure. Engineering costs to productize and test are also significant in the initial period.</td>
<td colspan="2">Revenue Streams:

• Increased sales of Intel Wi-Fi due to these premium features in addition to higher Average Selling Price (ASP). PC manufacturers are implementing these features in different market segments (premium/mainstream/budget) in different ways to maximize revenue opportunities.</td>
</tr>
</table>

3.18 KER#10 – Network Digital Twin Sandbox– Value Proposition Canvas

Value Proposition: The NDT Sandbox provides a controlled 5G Standalone environment with O-RAN gNBs, an SMO layer and an NDT xApp for testing optimisation solutions before they are implemented in real networks. Its value lies in reducing the operational risk associated with new xApps and RAN management algorithms. Instead of validating optimisation logic directly in production, telecom operators can first assess behaviour, performance impact and possible side effects in a repeatable sandbox environment. This makes the KER useful both for operational preparation and for research-oriented benchmarking of RAN optimisation methods.

Customer Segment: The main customer segment is represented by telecom operators and end-user application providers that need to test RAN optimisation solutions before applying them in operational networks. This KER is mapped to Telecom Operator and End-User for end-user Apps, with ACC / UC as owners.

Customer Jobs

Telecom operators need to improve network operation while avoiding unnecessary risk in live deployments. They need an environment where optimisation logic, xApps and management decisions can be assessed before being applied to real infrastructure.

- Test RAN optimisation solutions before live deployment.
- Benchmark xApps and network-management algorithms.
- Reduce the risk of service degradation in operational networks.
- Support experimentation over realistic O-RAN/5G SA environments.

Gains

The NDT sandbox provides a controlled environment where operators and researchers can validate optimisation approaches before real-network implementation. This improves confidence in new algorithms and reduces the gap between simulation and deployment.

- Safer validation of optimisation solutions.
- More reproducible benchmarking of RAN algorithms.
- Better understanding of expected network impact.
- Faster transition from research prototype to deployable solution.

Pains

Operators are cautious when introducing new optimisation algorithms, especially when they may affect coverage, QoS, energy consumption or service continuity. Testing directly in a live network can be costly, risky and difficult to repeat.

- Limited safe environments for validating RAN optimisation actions.
- Difficulty benchmarking xApps under reproducible conditions.
- Risk of negative impact when moving from simulation to real networks.
- High effort required to test new optimisation logic in operational setups.

Products & Services:

- Operators are cautious when introducing new optimisation algorithms, especially when they may affect coverage, QoS, energy consumption or service continuity. Testing directly in a live network can be costly, risky and difficult to repeat.
- Limited safe environments for validating RAN optimisation actions.
- Difficulty benchmarking xApps under reproducible conditions.

- Risk of negative impact when moving from simulation to real networks.
- High effort required to test new optimisation logic in operational setups.

Gain Creators:

- Enables pre-validation of optimisation solutions before real-network use.
- Improves repeatability of experiments and benchmarking.
- Helps operators evaluate the impact of xApps and RAN control policies.
- Supports faster and safer maturation of RAN optimisation algorithms.

Pain Relievers:

- Reduces the risk of testing new optimisation logic in live networks.
- Lowers the effort required to reproduce network-management experiments.
- Helps identify performance or QoS issues before deployment.
- Bridges the gap between offline simulation and operational network validation.

3.19 KER#10 – Network Digital Twin Sandbox – Lean Canvas

Problem:

Telecom operators and application stakeholders need to validate optimisation solutions before introducing them into real networks. However, live-network testing is risky, costly and difficult to reproduce, while pure offline simulation may not provide enough confidence for deployment decisions.

Existing alternatives:

- Direct testing in live or pre-production networks.
- Offline simulation environments.
- Manual validation of xApp behaviour.
- Isolated testbeds with limited SMO/O-RAN integration.

Solution:

The solution provides an NDT sandbox where optimisation algorithms, xApps and RAN management decisions can be tested in a controlled 5G SA/O-RAN environment before implementation in real networks. It supports assessment and benchmarking of RAN management algorithms, including reusable simulation components.

Key metrics:

- Number of optimisation algorithms/xApps tested.
- Accuracy of sandbox results compared with real-network behaviour.
- Reduction of failed or risky live-network trials.
- Experiment repeatability.
- Impact on QoS, coverage, energy consumption.

Unique Value Proposition:

A NDT sandbox that allows telecom operators and researchers to test, benchmark and de-risk RAN optimisation solutions before deploying them in operational networks.

High level concept:

Test before touching the real network.

Unfair Advantage:

- Built around the 6G-SENSES PoC#3 context.
- Integration of 5G SA, O-RAN gNBs, SMO layer and NDT xApp.
- Direct link with ACC/UC work on RAN optimisation and O-RAN experimentation.
- Reusable components for research benchmarking and future development.

Channels:

- 6G-SENSES PoC#3 demonstrations.
- Integration into ACC/UC experimental activities.
- Open-source or shared simulation/emulation env.
- Research workshops and SNS JU dissemination.
- Direct engagement with operators &O-RAN partners.

Customer segments:

- Telecom operators.
- O-RAN testbed owners.
- xApp/rApp developers.
- End-user App providers requiring reliable network behaviour.
- Research organisations working on RAN optimisation.

Early adopters:

- MNOs experimenting with O-RAN automation.
- 6G/5G testbed owners.
- R&D teams validating xApp-based optimisation.
- Private network stakeholders needing safer validation environments.

Cost structure:

- Development and maintenance of NDT/xApp components.
- Operation of the 5G SA/O-RAN sandbox.
- Integration with SMO and gNB components.
- Data collection, testing and benchmarking activities.
- Engineering support for pilots and experimentation.

Revenue Streams:

- Consulting and integration services for NDT-based validation.
- Software licensing of sandbox/NDT components where applicable.
- Custom pilot deployments for operators or private network owners.
- Research collaboration and testbed-as-a-service activities.
- Support services for xApp benchmarking and optimisation validation.

3.20 KER#11 - Digital Twin for RSSI Fingerprint Maps – Value Proposition Canvas

Value Proposition The platform significantly reduces the overhead of repeated physical measurement campaigns by using an initial RSSI fingerprint database — collected once for a given environment — to generate a DT that supports ongoing simulation, algorithm development, and benchmarking without further physical intervention. This enables reproducible, environment-aware indoor wireless experimentation at scale, removing the need to repeatedly reconfigure hardware or re-enter physical spaces for each test cycle. The solution is deployable as a standalone tool, platform plugin, or testbed-as-a-service, making it accessible across research, network planning, and educational contexts.

Customer Segment Network operators, telecom vendors, smart building solution providers, and academic/industrial research teams working on indoor localisation, radio propagation, and ISAC algorithm development in 5G/6G environments.

Customer Jobs Planning and optimising indoor wireless networks, developing and benchmarking indoor localisation and sensing algorithms, and conducting radio propagation studies to support 5G/6G deployment decisions.

Pains

- Physical measurement campaigns are expensive, slow, and constrained by lab/site availability.
- Results are hard to reproduce, undermining fair algorithm comparison.
- Iterative development is slowed by repeated hardware reconfiguration.
- Smaller organisations and early-stage researchers lack affordable access to realistic indoor wireless environments.

Gains

- Large-scale, repeatable experiments without physical infrastructure constraints.
- Fair, standardised benchmarking of competing algorithms.
- Faster R&D cycles and reduced time-to-publication.
- Cross-institutional collaboration through shared open datasets.

Products & Services

- DT generating synthetic RSSI fingerprint maps from a real multi-AP lab environment.
- Indoor wireless simulation engine supporting 5G/6G and ISAC use cases.
- Virtual testbed-as-a-service for remote algorithm testing and benchmarking.
- Open labelled RSSI datasets for cross-institutional research.

Pain Relievers

- Removes dependency on continuous physical measurements.
- Enables fully reproducible experimental conditions.
- Eliminates hardware reconfiguration between test cycles.
- Lowers access barriers for students and early-stage researchers.

Gain Creators

- Accelerates research output through rapid, repeatable simulation-based experimentation.
- Supports publication-ready results via standardised, shareable simulation conditions.
- Facilitates cross-institutional collaboration through open datasets.
- Extends utility into education and professional training without physical lab dependency.

3.21 KER#12 – Programmable multi-technology transport infrastructure for joint support of communication and sensing services – Value Proposition Canvas

Value Proposition: A programmable multi-technology transport infrastructure capable of jointly supporting communication and sensing services in O-RAN-compliant ISAC deployments. The solution enables heterogeneous communication and sensing traffic generated by multiple O-RUs to be efficiently transported, orchestrated, and dynamically managed over a hybrid packet-optical transport network.

Customer Segment: Virtualised Infrastructure Service Providers, Telecom Operators, and RAN/O-RAN Infrastructure Providers.

Customer Jobs: Provide end-to-end support for ISAC services by efficiently transporting and dynamically managing communication and sensing traffic over shared transport resources.

Pains

- Communication and sensing traffic have different bandwidth, latency, and service-differentiation requirements.
- Sensing I/Q streams introduce high and variable transport-capacity requirements.
- Static transport-resource allocation cannot adapt efficiently to changing communication and sensing demands.
- Separate control of packet and optical technologies complicates coordinated transport management.

Gains

- Joint transport of communication and sensing traffic over shared transport resources.
- Dynamic allocation of transport resources according to service requirements.
- Logical isolation and differentiated treatment of communication and sensing traffic.
- Reduced transport-resource consumption while preserving communication connectivity and sensing functionality.

Products & Services

- Programmable multi-technology packet-optical transport infrastructure.
- Integration of packet switching and all-optical switching under a unified SDN control framework.
- Centralised transport orchestrator for coordinated management across heterogeneous transport domains.
- Sensing-aware transport optimisation framework.

Pain Relievers

- Dynamically allocates network resources according to communication requirements, sensing demands, and optical transport constraints.
- Jointly determines O-RU–O-DU associations, routing, wavelength assignment, and optical transport capacity.
- Discards sensing streams below the required SNR threshold.
- Prevents unnecessary transport of sensing information that cannot contribute to reliable target detection.

Gain Creators

- Enables programmable transport control through SDN.
- Improves network-resource utilisation while maintaining communication service continuity and sensing performance.

- Supports low-latency transport of sensing I/Q streams.
- Enables end-to-end support of ISAC services over O-RAN-compliant infrastructures.

3.22 KER#13 – Multi-O-RU sensing aggregation and processing in centralised and distributed nodes – Value Proposition Canvas

Value Proposition: An adaptive cooperative sensing framework that enables aggregation and processing of sensing information generated by multiple sensing-enabled O-RUs. It supports a centralised sensing mode, where range-Doppler maps from multiple sensing nodes are jointly processed using a hybrid Convolutional Neural Network–Long Short-Term Memory (CNN–LSTM) model for trajectory estimation, and a distributed sensing mode based on Federated Learning, where the same model is trained locally and only model updates are exchanged. The availability of both modes allows sensing operation to be adapted to communication and sensing requirements, transport resource utilisation, and compute availability.

Customer Segment: Telecom Operators, Sensing Data Providers, and Service Providers offering sensing-enabled applications.

Customer Jobs: Provide accurate and scalable cooperative sensing services by aggregating and processing sensing information generated by multiple O-RUs.

Pains:

- Individual O-RUs provide only partial sensing observations because of their location and observation geometry.
- Aggregating raw sensing information from multiple O-RUs can create high transport-capacity requirements.
- Centralised collection of raw sensing information creates scalability and data-privacy concerns.
- A single sensing-processing approach cannot efficiently address all sensing, transport, and compute conditions.

Gains:

- Improved sensing (trajectory-estimation) accuracy through multi-view sensing observations.
- Support for both centralised and distributed multi-O-RU sensing processing.
- Reduced transport-resource consumption when sensing processing is distributed.
- Improved scalability and preservation of local sensing data.
- Greater flexibility in adapting sensing operation to available network and compute resources.

Products & Services:

- Multi-O-RU sensing aggregation capability.
- Centralised fusion and joint processing of range-Doppler maps.
- Hybrid CNN–LSTM model for trajectory estimation of moving targets.
- Distributed sensing based on Federated Learning and FedAvg.
- Support for adaptive selection between centralised and distributed sensing modes.

Pain Relievers:

- Combines sensing observations from multiple O-RUs to improve sensing accuracy.
- Enables distributed model training without transporting all raw range-Doppler maps.
- Reduces fronthaul and backhaul requirements by exchanging model updates instead of high-volume sensing data.

- Provides centralised and distributed sensing alternatives to address different communication and sensing requirements and resource availability conditions.

Gain Creators:

- Exploits spatial diversity and complementary Doppler and range perspectives from multiple sensing-enabled O-RUs.
- Uses Convolutional Neural Network (CNNs) to extract spatial features from range-Doppler maps and Long Short-Term Memory (LSTM) Neural Network to capture their temporal evolution.
- Improves trajectory-estimation accuracy through joint processing of multi-view sensing observations.
- Reduces fronthaul and backhaul bandwidth requirements while preserving data privacy.
- Allows sensing processing to operate in either centralised or distributed mode.

4 Individual and Joint Exploitation Plans

The following tables contain the 6G-SENSES exploitation plan devised individually or jointly between 6G-SENSES partners, addressing the identified KERs presented in the previous section, as well as other outcomes and results of the project.

Table 4-1 IHP's Exploitation Plan

#1 **IHP**		Exploitation activity
Exploitation framework		
Commercial (Individual)	**SW/ applications / service concepts & know-how for consulting and future deployments**	Provision of ISAC capabilities to multiple SDR-based wireless access technologies (**KER#3**) and integration of the ISAC software portfolio for postprocessing of I/Q signals as sensing processing function xApps. Extension and adaptation of the software (**KER#6** and **KER#7**) for different deployments, frequency bands, etc.
Scientific (individual)	**Education & Qualification**	Train highly skilled PhD students and young scientists in these technical areas with special emphasis on hands-on training using cutting-edge equipment available at IHP.
	Networking & Research Community e.g. Publications	Promote collaboration targeting top-tier conferences, workshops, and journals in the field, to present the outcomes of the project, as well to the public by means of talks, demos, and the communication channels of the Institute. Exploit results academically via IHP annual summer school, and lectures given at Universities in Berlin as well as through the graduate school for PhD students at IHP.

Table 4-2 BI & IHP's Joint Exploitation Plan

#6 **BI** & **IHP**		Joint Exploitation activity
Exploitation framework		
Commercial (Individual)	**SW/ applications / service concepts & know-how for consulting and future deployments**	The projected 60 GHz ISM-band ISAC front-end transceiver will be leveraged for a tangible scientific impact. Instead of a direct product-oriented setup (based on **KER#5**), the strategy is centered on PoC validation, experimental evaluation, and technology transfer to relevant research and development sectors. The mmWave sensing hardware will provide a practical RT test environment for baseband algorithms, waveform designs, synchronisation approaches, and MIMO configurations under realistic wireless conditions hence enabling a benchmarking of the future commercial mmWave solutions. The tight integration between sensing and communication also makes it possible to study how communication performance degrades through the joint architecture and how sensing data can be utilised to upgrade the link quality. The platform is also useful for external stakeholders like network operators, equipment vendors, and research labs that need a realistic testing environment before committing full-scale developments. **BI** and **IHP** will continue to publish measurement results, implementation insights, and interoperability findings that can realistically fed into future mmWave and ISAC specifications and standards. The results will be shared through conference demos, workshops, technical talks, and scientific publications, with a clear focus on engaging companies working in telecommunications, industrial IoT, and automotive sensing. Parts of
Scie ntifi	**Education & Qualification**	

	Networking & Research Community e.g. Publications	the developed platform and selected measurement datasets covering different sensing configurations such as range and resolution settings will be made available to interested research and industry groups on request. This is intended to support further experimentation and allow to build on the work with reduced efforts and resources. At a broader level, having a scalable and reconfigurable mmWave testbed strengthens the institutes' position for future European and national funding proposals, especially in 6G-related consortia where experimental credibility is important. BI and IHP already collaborate with universities, e.g., TU Dresden and TU Berlin in teaching and training programs, the projected ISAC system will be giving researchers and students direct exposure to RF hardware, SDR integration, MIMO systems, and synchronisation challenges in a real setup rather than just simulations. The goal is to keep the results usable across research, education, and early-stage industrial validation, while also supporting collaborative projects and publications.

Table 4-3 IASA's Exploitation Plan

#2 IASA **Exploitation framework**		**Exploitation activity**
Commercial (Individual)	**SW/ applications / service concepts** **& know-how for consulting and future deployments**	IASA's exploitation strategy focuses mainly on knowledge transfer, research-driven consulting, and the use of the developed methods and expertise as a basis for future collaborative research and innovation activities. IASA will leverage its expertise in programmable multi-technology transport infrastructure for joint support of communication and sensing services (**KER#12**), Multi-O-RU sensing aggregation and processing in centralised and distributed nodes (**KER#13**); as well as AI-driven cross-domain orchestration for ISAC services (**KER#8**). Although direct commercialisation is not currently envisaged, these capabilities will strengthen IASA's scientific and technical profile, support collaboration with academic and industrial partners, and improve its competitiveness for future European and national research funding in 6G, O-RAN, optical networking, and ISAC.
Scientific (individual)	**Education & Qualification** **Networking & Research Community e.g. Publications**	IASA has disseminated project-related results through multiple scientific publications [14]-[20] on optical and multi-technology transport networks, ISAC, and AI-assisted optimisation for Beyond-5G and 6G networks. The knowledge and expertise gained through **KER#12**, **KER#13**, and **KER#8** will continue to inform future scientific publications and research activities on programmable transport for communication and sensing services, centralised and distributed multi-O-RU sensing, and AI-driven cross-domain orchestration for ISAC. These outcomes will also be exploited after the end of the project through future research collaborations, new PhD and MSc research topics, and enriched postgraduate teaching material.

Table 4-4 UC's Exploitation Plan

#3 UC **Exploitation framework**		**Exploitation activity**
Commercial (Individual)	**SW/ applications / service concepts** **& know-how for consulting and future deployments**	Considering the "mmWave sensing solution: Interfacing with O-RAN – integrated solution with an O-RAN 6G platform – 6G control fabric" (**KER#6**), the integration will be exploited to analyze the performance of traffic management solutions aiming to ensure timely delivery of sensing data. In addition, the developed sensing SM will be made publicly available through code repositories to allow experimentation. Besides, a dataset of the sensing information will be generated for different sensing configuration (i.e., resolutions and processing levels). Considering the "Sub-6 sensing solution" (**KER#7**) the implemented E2 SM will be made available through public repositories using an opensource implementation of a near-RT RIC. Furthermore, datasets will be generated considering different sensing configurations.

Scientific (individual)	Education & Qualification Networking & Research Community e.g. Publications	The "USRP-Based Platform for Distributed Reciprocity Calibration in Cell-Free Massive MIMO Systems" platform (**KER#1**) strengthens UC's competitive positioning for securing future European and national project funding, where demonstrable experimental capabilities in emerging 6G technologies such as CF-mMIMO represent valuable assets for consortium building and proposal development. As part of the exploitation plan of KER #1 the reciprocity calibration algorithms and OTA PoC will be published as a reproducible calibration framework. This calibration package might be offered as a module to be used for downlink precoding, multiuser testing, and performance benchmarking. The testbed offers significant value to external stakeholders—including telecommunications equipment manufacturers, network operators, and research institutions—requiring practical evaluation environments for distributed synchronisation technologies before committing to large-scale implementations. Finally, the platform fulfils academic objectives by providing graduate telecommunications students with hands-on experience in advanced topics, including software-defined radio programming, distributed MIMO architectures, and synchronisation techniques. This multi-pronged exploitation strategy aligns with the European Commission's definition of KERs as results with clear potential for scientific, educational, and commercial use beyond 6G-SENSES. As far as the "Extension of O-RAN RIC for heterogeneous RATs for sensing capabilities" (**KER#3**) is concerned, the main exploitation goal is for research. In particular, it will consist on the development of the extended functionalities over open-source near-RT RIC implementation and making it open-source for the research community. Moreover, UC will leverage the NDT-based xAPP for assessing and benchmarking RAN management algorithms. Release as open-source simulation/emulation NDT components to be further exploited by the research community. Last but not least, considering the "Cross-domain AI optimisation" (**KER#8**), exploitation is focused on the generation of research outcomes related to the joint management of communication and sensing traffic. Furthermore, the models of sensing traffic will be included in network simulators (i.e. ns-3) and made available through open repositories.

Table 4-5 ACC's Exploitation Plan

#4 ACC		Exploitation activity
Exploitation framework		
Commercial (Individual)	SW/ applications / service concepts & know-how for consulting and future deployments	ACC's development of the ISAC-enabled Intelligence Plane within its dRAX platform (**KER#4**) unlocks a new commercial pathway for intelligent RAN control and optimisation. By extending dRAX with northbound interfaces for NDT integration and southbound telemetry ingestion for ISAC, the platform evolves into a modular, sensing-aware orchestration layer. These capabilities provide operators and integrators with actionable insights for energy-efficient, coverage-optimised, and context-aware network management. In the short term (≤1 year), ACC will exploit this innovation through pilot deployments, and software extensions to its dRAX RIC/SMO suite, enabling partners to experiment with AI and sensing-assisted automation. In the long term (≤5 years), these extensions will mature into commercial-grade Intelligence Plane modules forming the basis for 6G-ready, cognitive, zero-touch private network solutions offered as licensed software, extended features or managed services.
Scientific (individual)	Education & Qualification Networking & Research Community e.g. Publications	The dRAX Intelligence Plane with ISAC integration provides a tangible research framework to explore the fusion of sensing and communication data for network intelligence. The PoC#3 implementation demonstrates how RAN telemetry and NDT models can be used to create self-adaptive orchestration mechanisms, fostering research on AI-driven network twins, ISAC data fusion, and energy-aware optimisation algorithms. In the short term (≤1 year), ACC will contribute its findings to joint publications, open workshops, and technical sessions within the SNS JU ecosystem, strengthening its visibility in the research community. In the long term (≤5 years), the company aims to extend collaborations with academia and standardisation bodies, leveraging the Intelligence Plane as an educational and experimental reference architecture for future research on AI-native 6G systems.

Table 4-6 OTE's Exploitation Plan

#5 OTE Exploitation framework		Exploitation activity
Commercial (Individual)	SW/ applications / service concepts & know-how for consulting and future deployments	OTE as a leading telecommunications provider and the primary investor in telecom infrastructure in Greece continues to play a central role in advancing next-generation network technologies and services. With a strong track record of innovation and market leadership, OTE leverages its participation in 6G-SENSES to strengthen its strategic positioning in the evolution towards 6G systems and services. Within the framework of the project, and in alignment with its operational priorities and long-term strategy, OTE has achieved several key outcomes that form the basis of its exploitation activities. These outcomes are particularly significant in areas where focused effort has been applied, namely: **Advanced technical expertise and know-how:** OTE has acquired in-depth knowledge on the challenges associated with deploying and operating DTs in O-RAN-based environments, particularly in relation to handling and utilising real network datasets (as demonstrated in PoC#3). This knowledge enhances OTE's internal capabilities for network optimisation, automation, and data-driven decision-making. **Exploration of novel architectural approaches:** Through continuous monitoring and evaluation of project prototypes and solutions, OTE has identified emerging architectural options and deployment strategies for integrating ISAC functionalities into future network infrastructures. These insights support strategic planning for incorporating sensing capabilities into commercial network offerings. **Development of a techno-economic analysis tool:** A major outcome of OTE's contribution is the design and implementation of a fully parameterised techno-economic analysis tool (as reported in D2.3). This tool enables the systematic evaluation of large-scale network deployments, incorporating a wide range of parameters such as geographic characteristics, traffic evolution, service requirements, infrastructure availability, and scaling considerations over time. The tool supports the assessment of alternative deployment scenarios for ISAC-enabled 6G networks, enabling the identification of cost drivers and optimisation opportunities at early planning stages. By modelling access, transport, edge, and CN segments, and by integrating cost elements such as CAPEX, OPEX, and Total Cost of Ownership (TCO), the tool provides a comprehensive foundation for pre-deployment decision-making. It also facilitates the evaluation of different technology mixes, sensing configurations, and functional placements, ensuring that deployments are both economically viable and operationally efficient. The associated techno-economic methodology follows a structured approach that includes: • Definition of deployment scenarios, coverage requirements, and service demands; • Modelling and dimensioning of network segments (RAN, transport, edge, core) across time; • Incorporation of cost models and scaling rules; • Iterative analysis of alternative deployment configurations to extract optimisation insights and deployment guidelines. The outcomes derived from this work provide actionable input for OTE's future activities related to ISAC and O-RAN deployment strategies. In particular, they support the reduction of deployment complexity, minimisation of operational risks, acceleration of time-to-market, and overall cost efficiency. Importantly, the knowledge, tools, and insights generated within the project are already being disseminated across relevant business and technical units within the OTE Group. This ensures their integration into internal processes, strategic planning, and future network evolution initiatives. Overall, through its participation in 6G-SENSES, OTE is well-positioned to exploit project results by enhancing its technological capabilities, optimising network deployment strategies, and enabling the introduction of innovative 6G services in line with emerging market and societal needs.

Table 4-7 UNIROMA's Exploitation Plan

#6 UNIROMA1 Exploitation framework		Exploitation activity
Commercial (Individual)	SW/ applications / service concepts & know-how for consulting and future deployments	UNIROMA1 is developing novel Wireless Edge Caching (WEC) strategies specifically tailored to sensing use cases at the network edge. The objective of this research is the introduction of caching strategies in a completely new scenario, enabling significant performance improvements across a wide range of use cases. The main outcome of this work has been the creation of a novel caching algorithm which is able to adapt to dynamic use-case scenarios at the edge. These strategies have the potential to be exploited both by industry and research community to optimize data availability and network bandwidth usage. Complementary to these algorithmic results, UNIROMA1 is developing a comprehensive evaluation and testing framework built in ROS and Gazebo.
Scientific (individual)	Education & Qualification Networking & Research Community e.g. Publications	The proposed framework constitutes a realistic and modular environment in which not only the already proposed solution can be implemented, but also new ones, thus providing a reusable framework suitable to researcher and developers to continue developing new caching strategies.

Table 4-8 TUBS' Exploitation Plan

#7 TUBS Exploitation framework		Exploitation activity
Commercial (Individual)	SW/ applications / service concepts & know-how for consulting and future deployments	The exploitation of the Distributed MIMO and RIS-assisted Beamforming Prototyping Platform (KER#2) is primarily centred on its role as an advanced experimental research infrastructure for validating next-generation wireless communication concepts. The platform enables the practical investigation of distributed beamforming, near-field focusing, and RIS-assisted transmission strategies under real OTA conditions using an OAI-based 5G NR implementation. Within the project, the platform supports the integration and evaluation of algorithms and functionalities developed by project partners, including: Distributed calibration procedures, Advanced beamforming strategies, RIS control mechanisms. This allows indirect contributions to future commercial products by providing a PoC validation environment prior to industrial deployment. Beyond the project, the platform offers external stakeholders—including Telecom equipment manufacturers, MNOs, Research institutions, SDOs- the opportunity to evaluate novel radio concepts, implementation strategies, and architectural extensions in a controlled and reproducible environment. This strengthens knowledge transfer activities and supports future consulting services as well as collaborative research opportunities in the fields of: 6G radio systems, distributed-MIMO, Programmable radio environments.
Scie ntifi	Education & Qualification	The prototyping platform serves as a research and teaching infrastructure, providing students and early-stage researchers with access to a fully operational 5G NR-compliant

	Networking & Research Community e.g. Publications	network. It offers full visibility into: System parameters, KPIs, SDR-level implementation details. By combining OAI source code access with real SDR hardware, the platform enables hands-on education in advanced topics such as: distributed-MIMO architectures, Synchronisation techniques, Beamforming methods, TDD operation, RIS-assisted communication. The platform supports Bachelor, Master, and PhD research activities by enabling experimental validation beyond simulation-based studies. Furthermore, it contributes to the qualification of students in SDR development and experimentation with wireless systems. These competencies are highly relevant for future academic and industrial careers in 6G research. Considering further exploitation of project results in research, the platform provides a strong foundation for scientific dissemination through: conference papers, journal publications, technical workshops, collaborative demonstrations with project partners It enables reproducible OTA experimentation for distributed beamforming and RIS-assisted communication, supporting high-quality validation of research results under realistic laboratory conditions. In addition, the testbed strengthens the institute's position in future national and European research proposals, where demonstrable experimental capabilities in emerging 6G technologies are a key factor for: consortium building and proposal competitiveness The platform also facilitates collaboration with external academic and industrial partners by providing a shared environment for joint experimentation and technology validation.

Table 4-9 BR's Exploitation Plan

#8 **BR** **Exploitation framework**		**Joint Exploitation activity**
Commercial (Individual)	**SW/ applications / service concepts** **& know-how for consulting and future deployments**	Regarding the KERs related to "mmWave sensing solution" and the "Sub-6 sensing solution" (**KER#6** and **KER#7**), the primary exploitation strategy focuses on the commercialisation and transfer of know-how regarding ISAC-enabled O-RAN platforms in sub-millisecond (<1ms) control loop capability at the RIC level. Specifically, the developed Extended O-DU and the associated Sensing SMs (implementing both O-RAN LLC E2SM and custom sensing E2SM) represent a significant market differentiator. These assets will be exploited to offer advanced consultancy services and software licensing to operators and vendors looking to implement Native-AI and sensing features in 6G networks. The capability to extract I/Q samples of received SRS signals from multiple Transmission Reception Points (TRPs) prior to channel estimation offers a high-fidelity data source that is currently scarce in standard commercial offerings. By validating this extraction mechanism and the transport of data via the E2AP protocol on a millisecond scale, the technology will be positioned as a robust enabling platform for third-party xApp developers (such as **IHP**/**UC**) and network equipment manufacturers aiming to integrate sensing without disrupting critical traffic
Scientific (individual)	**Education & Qualification**	From a scientific perspective, the exploitation is centred on establishing a premier Research Infrastructure for ISAC. By providing the underlying testbed and the novel ISAC SM. The architecture developed—specifically the method of retrieving received SRS signals and noise for channel inference via the E2 interface—will be disseminated through high-impact scientific publications and technical workshops. Furthermore, the LLC O-RAN SM and the custom extensions for SRS UL data extraction will be utilised to drive standardisation discussions regarding the feasibility of transporting high-bandwidth raw I/Q data over open interfaces. By maintaining this testbed, we facilitate the work of academic partners (like **IHP**/**UC**) and foster a collaborative ecosystem where advanced algorithms for channel estimation and equalisation can be benchmarked against real-world radio data, rather than purely simulated environments.
	Networking & Research Community e.g. Publications	

Table 4-10 INT's Exploitation Plan

#10 INT **Exploitation framework**		Exploitation activity
Commercial (Individual)	SW/ applications / service concepts & know-how for consulting and future deployments	The primary exploitation plan for "Wi-Fi active sensing technology" (KER #11) centers on integration with next-generation laptops in collaboration with key OEM partners. By embedding Wi-Fi sensing directly into consumer laptops, manufacturers are enabled to extend their offering with intelligent features such as automatic presence detection, enabling functionalities like battery saver modes, instant lock/unlock, and secure, touchless wake-up. For example, the laptop can automatically turn off the display or enter low-power mode when the user leaves, and instantly reactivate when the user returns, optimising battery life and enhancing device security. These features are already deployed in a select set of PCs and are rapidly expanding across the industry to more computing devices/segments over 2026-2028. Further security features (such as detecting multiple people in the vicinity) or new forms of interaction such as gesture detection are also being developed as part of the future product roadmap. Platforms that will incorporate limited gesture detection capabilities are being targeted to be released in 2027. In parallel, our solution is being positioned as a scalable software platform that can be licensed to OEMs for inclusion in their device ecosystems, ensuring broad compatibility with commercial Wi-Fi chipsets. Beyond laptops, the system will be able to offer a flexible feature set that can be adapted for deployment in other market sectors, such as smart buildings. Security and surveillance operators will also be in the position to leverage the same presence and activity detection capabilities to enhance situational awareness and automate access control. In healthcare, it will allow passive monitoring of patients in non-intrusive ways, supporting applications in elderly care or remote health monitoring, as well as providing more long-term contextual information, such as physical activity tracking, gait monitoring etc., with the advantages of ambient sensing (no compliance / forgetfulness issues that are challenging for wearables-based monitoring of elders). By focusing first on consumer laptop integration and then scaling to additional verticals and services, the sensing methodology we have developed is positioned as a foundational technology for privacy-friendly, RT presence and activity detection across multiple markets.
Scientific (individual)	Education & Qualification	Scientific exploitation is targeted by leveraging on the 6G-SENSES know-how for future innovation activities by INTEL.
	Networking & Research Community e.g. Publications	

Table 4-11 NTU's Exploitation Plan

#11 **NTU** **Exploitation framework**		Exploitation activity
Commercial (Individual)	SW/ applications / service concepts & know-how for consulting and future deployments	The solution can be developed into a software platform enabling reproducible, location-aware wireless signal simulation and indoor localisation testing without continuous reliance on physical measurements. This capability supports commercial applications in indoor positioning, wireless network planning, robotics, IoT, smart buildings, and Extended Reality (XR) systems, significantly reducing deployment costs, development time, and experimental uncertainty. The DT can be offered as a standalone simulation tool, as an integrable module

Scientific (individual)		within existing DTs and network design platforms, or as a virtual testbed-as-a-service for algorithm benchmarking and scenario evaluation.
	Education & Qualification	The environment enables students and early-stage researchers to interact with realistic, reproducible wireless scenarios, supporting hands-on learning in DTs, indoor localisation, and radio propagation without dependence on continuous physical experiments. The platform can be integrated into university curricula, laboratory courses, and professional training programmes, allowing controlled experimentation and repeatable assessments.
	Networking & Research Community e.g. Publications	It enables reproducible, environment-aware experimentation for indoor localisation and wireless signal analysis, addressing a key challenge in empirical research. The approach supports high-quality scientific publications by allowing controlled evaluation, benchmarking, and comparative studies without continuous physical measurements. The methodology and datasets can be shared with the research community to foster collaboration, replication, and cross-institutional studies.

5 Impact Assessment

5.1 Impact Definition and Classification

Impact assessment refers to the systematic identification, analysis, and evaluation of the effects generated by the innovations across multiple dimensions, activities, and results of the project. These impacts extend beyond the technical domain, encompassing economic, societal, environmental, and strategic value creation at different levels and time horizons.

More specifically, impact assessment in the context of this project considers:

- **Impact on project partners and their activities,** including capability building, innovation potential, market positioning, and new business opportunities, evaluated across different time scales (during and after the project lifecycle).
- **Impact on R&I and technology adoption,** reflecting contributions to the advancement of 6G technologies, standardisation efforts, and the acceleration of uptake in industry and vertical sectors. The KPIs related to this impact factor are essentially the dissemination and standardisation activities KPIs of the project. These are analysed in section 5.2.
- **Impact on values,** including sustainability, resilience, inclusiveness, and efficiency, addressing broader societal challenges and long-term development goals. This aspect of impact is considered in line with the UN SDGs, the SNS-JU strategic research and innovation agenda, and broader EU policy priorities.

Given the multidimensional nature of impact, different impact assessment methods need to be used, depending on the specific type of impact being assessed.

At the core of impact assessment lies the concept of value creation, which originates from the outcomes of the project, including technologies, services, methodologies, and knowledge assets. These outputs act as enablers for generating measurable and non-measurable impacts when adopted, exploited, or further developed by stakeholders. The transition from value creation to impact depends on successful exploitation, market uptake, and integration within broader ecosystems.

To ensure a structured and comprehensive assessment, impacts are classified across multiple dimensions:

Scale of Impact

Impact can be analysed depending on its geographical and systemic reach:

- Local impact: Effects on specific organisations, pilot sites, or local ecosystems where solutions are tested or deployed.
- Regional impact: Contributions to regional innovation capacity, industrial clusters, and cross-border collaboration within Europe.
- Global impact: Influence on international markets, global standards, and worldwide technological and societal developments in the 6G domain.

Time Horizon of Impact

Impact evolves over time and is therefore assessed across different temporal dimensions:

- Project lifecycle impact: Immediate outputs and benefits generated during project execution (e.g., prototypes, collaborations, knowledge sharing).
- Short-term impact: Outcomes realised shortly after project completion, such as early commercialisation activities, pilot deployments, or follow-up initiatives.

- Long-term impact: Sustained effects including market transformation, large-scale adoption of 6G technologies, and long-lasting societal and environmental benefits.

Sectoral and Value-Based Impact

In alignment with global and European policy frameworks, impact is further categorised according to the type of value that is generated, such as:

- **Environmental impact:** Contributions to sustainability goals, including energy efficiency, reduced emissions, and support for green digital transformation.
- **Societal impact:** Enhancements in quality of life, accessibility, inclusiveness, and support for critical societal services (e.g., healthcare, education, public safety).
- **Personal impact:** Benefits experienced at the individual level, such as improved user experience, enhanced connectivity, and new digital services enabled by 6G technologies.
- **Economic impact:** Value generation for businesses and markets, including new revenue streams, job creation, increased competitiveness, and growth opportunities for European industry.

Overall, this structured approach to impact definition and classification enables a holistic evaluation of the 6G-SENSES project, ensuring that its contributions are properly captured across technical, economic, societal, and environmental dimensions, while also supporting alignment with strategic European and global objectives.

5.2 Impact on 6G-SENSES Partners and Activities

6G-SENSES has generated significant impact on participating partners, both during the project lifecycle and in terms of longer-term positioning within the evolving 6G ecosystem. This impact is reflected not only in technological advancements but also in measurable economic and operational benefits. Key indicators of this impact are:

KPI#1: Economic Support for Partners During the Project Lifecycle

6G-SENSES has delivered substantial financial support to participating partners, enabling them to fund research activities and cover personnel-related costs throughout the project duration. This support has been particularly critical for SMEs and research organisations, which often face limitations in securing independent funding for high-risk, advanced R&D initiatives.

Through EC funding, partners have been able to accelerate the development of innovative 6G technologies, gain access to state-of-the-art experimentation infrastructures, and participate in collaborative environments that foster knowledge exchange and co-creation. This has significantly reduced entry barriers to cutting-edge research while strengthening partners’ technical capabilities and innovation capacity.

In addition, the availability of project funding has contributed to human capital growth within partner organisations (see Table 5-1), supporting the recruitment of new personnel dedicated to 6G-related activities. Indicatively, and based on the impact reporting of the project, several partners have expanded their workforce during the project lifecycle as follows:

Table 5-1 Increase in Partners’ Workforce

Partner	Workforce	Comments
ACC/ Firecell	0	Despite no new personal has been hired, training activities in AI coding, and the support for new AI-aided coding techniques has been included in the company to increase the performance and quality of solutions, while aiming to reduce time-to-market of research-based solutions.

BI	1x Full time researcher	Development of the workforce towards advanced antenna design.
UC	1 Pre-doctoral researcher	A PhD student (Neco Villegas) was granted a competitive scholarship to carry out his PhD. His research topics are aligned with the work that UC has been doing within the project. In particular, the exploitation of sensing information to promote enhanced radio resource management is one of the main aspects of his PhD.
IASA	1 Post-doctoral researcher	A post-doctoral researcher was hired to conduct research in AI-driven network slicing in support of ISAC services.

KPI#2: Costs Avoided for Integration and Technology Validation Activities

A second key economic impact for partners relates to cost savings achieved through the collaborative framework of the project, particularly in the context of integration and validation activities. Partners have been able to combine their individual technologies, components, and solutions into end-to-end system environments, enabling comprehensive testing and validation.

This approach has allowed partners to:

- Verify interoperability between components and systems,
- Validate interfaces and functional performance,
- Assess solutions under realistic deployment and operational conditions.

Such activities are inherently complex and resource-intensive. Outside the project context, partners would typically need to rely on separate bilateral collaborations, dedicated test infrastructures, or commercial agreements with telecom operators to achieve similar validation outcomes. These alternatives would involve significant additional costs, extended timelines, and increased operational complexity.

In 6G-SENSES, these expenses have been effectively mitigated, as integration and validation efforts are supported through project funding—particularly within **WP5** (Technology Integration and Live Demonstrations), as reflected in the financial reporting of the project.

As a result, partners benefit from reduced development and testing costs, faster validation cycles, and lower risks associated with technology readiness and market introduction. This KPI underlines the importance of collaborative R&D environments in enabling efficient and cost-effective innovation within complex ecosystems such as 6G.

KPI#3: Number of Synergies achieved

6G-SENSES has created added value for partners through the establishment of synergies within the consortium and with external initiatives. These collaborations enable the combination of complementary expertise and technologies, supporting the development of integrated solutions and strengthening partners' exploitation potential.

Key synergies include:

- Intra-consortium collaborations, leading to joint developments and aligned exploitation plans,
- Interactions with other SNS JU and 6G initiatives, facilitating knowledge exchange and strategic alignment,
- Business-oriented partnerships across roles (e.g., vendors, operators, research entities), fostering ecosystem-level solutions.

The number of synergies serves as the main KPI, reflecting both the level of collaboration and the potential for joint market opportunities. In particular, we report the ones listed in Table 5-2.

Table 5-2 Synergies achieved within the project lifecycle

Synergies	Partners/ Companies	Comments
Intra-consortium collaborations	IHP - BI	The expertise sharing has resulted in the joint development of the mmWave hardware. The joint-exploitation plans have been aligned for academic utilisation and academia–industry demonstrations.
	IHP-UC	Collaboration on the integration of sensing solutions within system-level O-RAN system for the realisation of sensing-assisted.
	IASA - BR	The collaboration resulted in an enhanced ISAC testbed at IASA's premises, combining IASA's existing testbed and expertise in optical transport networks and O-RAN experimentation with BR's cloud-native O-RAN platform. The resulting testbed will be further exploited for future research activities, graduate and postgraduate education.
	IASA- IHP	Research collaboration in O-RAN, ISAC, and next generation wireless network experimentation, leading to numerous joint publications ([18]-[20]).
	TUBS-UC	Strong research partnership on RIS (leading to numerous joint publications) and joint development of a USRP-based CF-MIMO platform.
	OTE - ACC IHP - UC - ACC/FC	The setup developed in PoC#3, has created an O-RAN 5G ready setup for indoor outdoor testing with RIS capabilities, for research and develop new solutions.
Business-oriented partnerships	IHP - BI	The TRL advancement of the hardware solutions involving IC from IHP and Antenna from BI will result in further opportunities for both partners. This could include participation in industry-led projects with higher TRL as well as exploitation of the hardware solution in advanced solutions.
	INT - major PC manufacturers (HP, Dell, Lenovo, etc.)	Established Wi-Fi sensing features and roadmap that are being rolled out by many PC manufacturers.
Interactions with other SNS JU and 6G initiatives (excluding participation in SNS JU WGs)	BeGREEN – 6G-SENSES	The Intelligent Plane has been conceived and evolved from the initial planning in BeGREEN to the actual status in 6G-SENSES providing collaborations with intra-consortium IHP-ACC partners, and extra including I2CAT.
	6G-SENSES - MultiX	The sensing -related knowhow and technologies/prototypes developed by IHP-UC, IASA, BR, INT have been fused and leveraged on to the next phase SNS-JU project MultiX.

While several synergies have already been established during the project, their number and impact are expected to grow further after project completion, as partnerships mature and move towards commercialisation.

KPI#4: Impact on 6G Ecosystem – Enablement of new Ecosystem Roles

6G-SENSES contributes to shaping the emerging 6G ecosystem by extending the traditional 5G service provisioning model and enabling new roles, interactions, and value chains. Building on the virtualisation and disaggregation principles of 5G, the project introduces additional capabilities such as integrated sensing, AI-driven control, and multi-domain orchestration, which fundamentally enrich the ecosystem structure.

A key aspect of this impact is the introduction and validation of new stakeholder roles, including Sensing Data Providers and enhanced RAN/O-RAN/RIS operators. These roles enable the creation of parallel data streams—beyond conventional communication flows—supporting new types of services and business opportunities. At the same time, existing roles such as NOPs), VISPs, and SPs are expanded and further specialised, particularly through the separation of RAN and CN functions and the exposure of programmable interfaces and data.

In addition, 6G-SENSES promotes a layered and flexible service provisioning framework, where infrastructure, platform, and service layers become more modular and interoperable. This facilitates the emergence of new entities such as service and infrastructure aggregators, capable of orchestrating resources across multiple domains and providers.

Overall, the impact reflected in **KPI#4** lies in the ability of the project to enable new ecosystem roles via a more scalable, open, and data-driven 6G ecosystem, supporting innovation, cross-domain collaboration, and the development of new value propositions that combine communication, sensing, and computing capabilities.

This KPI refers to long term, global scales and can be justified (but not validated) during the project lifecycle.

5.3 Impact on Values

Traditionally, advancements in ICT have been largely guided by performance indicators and market-driven requirements. In recent years, however, there has been an increasing emphasis on aligning technological progress with broader societal priorities, addressing both global and regional challenges as reflected in frameworks such as the UN SDGs, the EC's strategic agenda, the European Green Deal, and more recently the ITU International Mobile Telecommunications 2030 (IMT-2030) vision. Within this evolving context, technological innovation is expected to go beyond fulfilling technical specifications and user needs, and instead actively contribute to positive societal, environmental, and individual outcomes. This shift towards value-oriented innovation represents a significant transformation for both industry and academia, and is now a core focus of European research initiatives, including the SNS programme.

To establish a shared understanding of how SNS projects contribute to value-driven innovation, the concepts of Key Values (KVs) and Key Value Indicators (KVIs) have been introduced. These serve as structured mechanisms to link ICT research outputs with measurable impacts across short-, medium-, and long-term horizons. The concept was initially introduced by the Hexa-X project, the flagship initiative of the SNS JU, which incorporated KVs into its research approach. Building upon this foundation, Hexa-X-II further advanced the concept by proposing an end-to-end 6G system blueprint centred on sustainability, inclusiveness, and trustworthiness, aligning closely with Corporate Social Responsibility (CSR) principles across social, economic, and environmental domains. In parallel, other SNS JU projects—beginning from the programme's early phases—have actively worked to refine and harmonize their interpretation of values, impacts, and KVIs.

In this context, the Societal Needs and Value Creation (SNVC) subgroup was established within the Vision and Societal Challenges Working Group of the 6G Industry Association (6G-IA). Its objective is to integrate insights from SNS projects, industry stakeholders, and external experts—particularly from the social sciences—in order to provide guidance on aligning technological development with value-based objectives. SNVC has developed a structured framework to support the design and evaluation of value-driven next-generation ICT solutions. This framework continues to evolve through contributions from several funded projects and other initiatives.

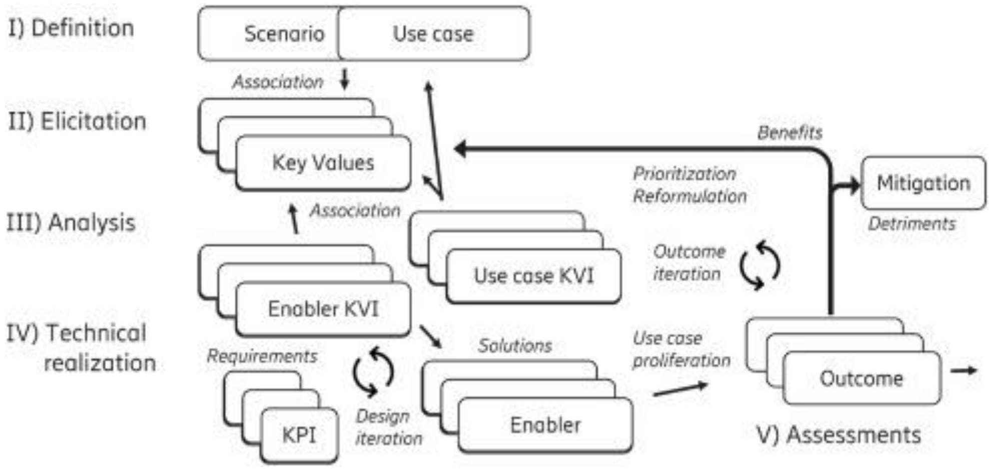

Figure 5-1 SNS KVIs definition methodology

It should be noted that current approaches to defining KVs and KVIs distinguish between two complementary types of impact. The first is direct impact, which examines the intrinsic properties of technologies, including resource consumption and environmental footprint (often referred to as Sustainable ICT or Sustainable 6G). The second is indirect impact, which assesses the effects of technology adoption across other sectors, commonly described as ICT for Sustainability or 6G for Sustainability. Both perspectives are actively explored within SNS JU projects at different stages of research and development.

The SNVC framework for KVs and KVIs introduces a stepwise methodology that evolves alongside the maturity of technological solutions, as reflected in TRLs and Society Readiness Levels (SRLs). 6G-SENSES adopts this framework, tailoring it to its own objectives by identifying the relevant KVs, KVIs, and associated validation approaches.

The methodology comprises several key steps (as outlined in Figure 5-1).

Step 1- Definition of scenario and use cases; where the global scenario and the separate use cases addressed by the technological solution are defined.

This document fulfils these steps (in the following chapters), by elaborating on 6G-SENSES scenarios and use cases.

Step 2- Elicitation of KVs as criteria and as outcome that are affected -in any way- by the instantiation and the proliferation of the use case. This step provides a linkage between the KVs, both as criteria and outcomes, to the vision and objectives of R&D activities.

KVs as criteria could include a range of values, often framed at a high level within Environmental Sustainability, Economical Sustainability and Societal Sustainability, following relevant directions from UN SDGs adopted by policy or funding agencies of international, EU, national or community level. These KVs however need to be nailed down to the scope of the ICT/6G project and the ICT industry. The sources used for KVs definition are primarily the mandate of R&D program and the R&D project description of work and various groups of stakeholders.

These sources for KVs definition are also used in the context of 6G-SENSES. This step is also fulfilled in this document at this low TRL/SRL stage, by elicitating on KVs as criteria and outcome and KVIs on a per use case basis.

Step 3 - Analysis of outcome on value domains. This step includes a more thorough analysis of the impact on value domains and the derivation of KVIs as absolute or relative, quantitatively (preferably) or qualitatively measures of the impact of technology solution on the identified KVs (under the notion of 6G for

Sustainability). Essentially, for each of the KVs identified as relevant for a specific use case, certain use-case specific KVIs should be formulated.

The impact can be beneficial or adverse, direct or indirect, at various timeframes and for various use case proliferation stages. Appropriately selected use case KVIs can be either utilised to demonstrate or validate that a developed technology usage is in the direction mandated by the international/EU/local, etc., policies on values.

This step is performed iteratively throughout the technology development and deployment/project lifecycle and at more mature stages it includes a more speculated view on the KVI as outcome and more valid estimations of use case proliferation/ foreseen acceptance at various time scales.

This step is also fulfilled in this document at this low TRL/SRL stage, by elicitating on KVIs on a per KV and use case basis in the following chapter. According to the methodology, this work has been refined along the project lifecycle, and the updates have been reported in the context of the Impact Assessment activities of the project (in Work Package 6 – **WP6**).

Step 4 - Technical realisation, involving identification and specification of enablers (i.e., ICT solutions). This step is closely associated with the technical realisation (under the notion of Sustainable 6G solutions), and design iterations towards meeting the KPIs as a pre-condition for achieving the target KVIs (under both the notion of 6G for Sustainability and Sustainable 6G). In the context of 6G-SENSES, this step has been implemented by using the KPIs and KVIs definitions to co-steer the implementation WPs of the project.

Step 5 – Assessment. This step includes the activities to be followed subsequently to monitor and evaluate KVIs following various methodologies depending on the TRL, SRL and use case proliferation stage. This step has been fulfilled as part of the 6G-SENSES project Impact Assessment activities.

Following these steps, in brief, the use cases envisioned within 6G-SENSES are the following:

- **Use Case #1**: **Sensing enabled Services**, focusing on exploiting sensing information to improve communication services (sensing-aided communication), and on enabling active sensing with Wi-Fi system. This use case highlights the work of the project on Sensing and in particular on Multi-WAT sensing & integration in 6G RAN. From the vertical perspective the proposed capabilities can enable numerous Immersive Services, while being applicable in future use cases.
- **Use Case #2**: **Ubiquitous Connectivity & Immersive Services**, focusing on storylines exploiting the cell-free mMIMO and RIS capabilities combined with sensing. This use case highlights the work of the project on RIS assisted CF-mMIMO for coverage and localisation. From the vertical perspective, the proposed capabilities can enable numerous Immersive Services, while high reliability/availability services are also in focus.
- **Use Case #3**: **Network DT**, focusing on storylines enabling Network Optimisation and Energy Saving, exploiting Network Intelligence. This use case highlights the work of the project on network digital twinning serving for optimising capacity, availability and Energy Efficiency (EE) via AI/ML at Orchestration, Network & User layers. From the vertical perspective the proposed capabilities can enable numerous Immersive Services, while vertical level digital twinning is considered – essentially highlighting that digital twinning can be a service for various network and service provisioning layers.

As identified in deliverable **D2.1** [3], the KVs and KVIs that are expected to be impacted from the proliferation of the 6G-SENSES use cases are listed in Table 5-3. Beyond this step, Table 5-4 provides a structured mapping of the identified KVs to their corresponding KVIs, along with associated target metrics, evaluation approaches, and temporal and spatial impact dimensions.

In particular, the selection of **target values** and associated metrics is driven by a combination of State of the Art (SoTA) benchmarks, expected gains from enabling technologies, and feasibility at the current TRL level of the project. In particular, technologies such as ISAC, AI/ML, and O-RAN have been widely recognised in the literature and within SNS projects as capable of delivering incremental but measurable improvements in energy efficiency, coverage, and service performance. Therefore, indicative ranges (e.g., 10–30% EMF or TCO reduction, 20–60% coverage or service improvements) reflect realistic yet ambitious expectations, ensuring that projected impacts remain credible while still demonstrating innovation potential. Furthermore, targets are expressed using standardised and measurable indicators (e.g., percentage improvement, kWh/site/year, QoE metrics), which enables comparability across use cases. Where direct quantification is not yet possible (e.g., early-stage immersive services adoption), relative growth indicators (e.g., increase in number of services or coverage) are used, reflecting the exploratory nature of certain use cases. The selected targets aim to capture the anticipated long-term impact associated with the proliferation of the use cases and can serve as a reference baseline for future impact assessment of 6G technology adoption.

The **evaluation methodology** has been selected based on the maturity level (TRL/SRL) of each use case and the availability of validation environments. For KVIs that are highly associated with technological KPIs (e.g., EMF, energy consumption efficiency, etc.) PoC validations and trials are used as the primary means of assessment. These enable empirical validation under realistic conditions, ensuring that measured KPIs and KVIs reflect system-level behaviour. In contrast, for future-stage or more conceptual aspects (e.g., large-scale service adoption, societal impact), concept validation is primarily considered as the validation methodology. These approaches allow the exploration of scalability, performance trends, and potential ecosystem effects, which cannot yet be fully demonstrated experimentally. Additionally, the use of the techno-economic tool (**D2.3**) provides a structured and quantitative method for evaluating economic KPIs (e.g., TCO), supporting robust scenario-based comparisons.

The assignment of **time horizons** (short-, medium-, and long-term) reflects the expected pathway from research outcomes to real-world deployment and impact realisation. Short–Medium term impacts (e.g., TCO reduction, initial coverage improvements) correspond to technically mature solutions that can be realistically adopted or influence early 6G deployment strategies shortly after project completion. Medium-term impacts are associated with incremental deployment and scaling of technologies such as ISAC and RIS, where benefits become visible as integration into network infrastructure progresses. Long-term impacts reflect systemic changes that depend on widespread adoption of the envisioned use cases, ecosystem maturity, and alignment with policy and market evolution.

This temporal classification also aligns with the SNS framework, where value creation evolves progressively with TRL/SRL advancement, and where certain impacts—especially societal and industrial—require longer timeframes to materialize at scale.

Table 5-3 6G-SENSES KVs/ KVIs

Key Value	KV as Outcome	KVIs	UC/ Scenario	Technology enablers
Environmental Sustainability	Stakeholder: Providers & Users Effect on: State of Being KVI 1: Low EMF. KV2 description: Lower Energy Consumption	KVI 1: Optimisation of EMF for given coverage. KVI 2: Optimisation of Energy Footprint for given services	UC#1 - Sc#1 & UC#1 - Sc#2	ISAC enabling coverage optimisation and energy minimisation at RAN
Quality Education & Reduced Inequalities	Stakeholder: Users Effect on: Activities KV1: Remote/Live Participation in education. KV2 description: Economically efficient participation in education and cultural products	KVI 1: Increase in # of educational/cultural products available as immersive services. KVI 1/KVI 2: Increase in # of educational/cultural products available as immersive services. KVI 3: Increase in areas (population/coverage) having access to these products	UC#1 - Sc#1 & UC#1 - Sc#2	ISAC enabling Immersive services
Quality of Living & Inclusion; sustainable cities and communities	Stakeholder: Users Effect on: Activities KV1: Remote/Live Participation in various events (enabled by Immersive services support)	KVI 1: Increase in # events available as immersive services KVI 2: Increase in areas (population/coverage) having access to these events	UC#1 – Sc#1 & UC#1 - Sc#2	ISAC enabling Immersive services
Quality Education & Reduced Inequalities	Stakeholder: Users Effect on: Activities KV1: Remote/Live Participation in education. KV2: Economically efficient participation in education and cultural products	KVI 1/KVI 2: Increase in # of educational/cultural products available as immersive services KVI 3: Increase in areas (population/coverage) having access to these products	UC#2	ISAC and RIS enabling Ubiquitous coverage with sufficient performance for Immersive Services
Quality of Living & Inclusion	Stakeholder: Users Effect on: Activities KV1: Remote/Live Participation in various events (enabled by Immersive services support).	KVI 1: Increase in # events available as immersive services. KVI 2: Increase in areas (population/coverage) having access to these events.	UC#2	ISAC and RIS enabling Ubiquitous coverage with sufficient performance for Immersive Services
Sustainable cities and communities	Stakeholder: Industries Effect on: Activities KV1: Enablement of Industry 5.0 (enabled by Immersive services support) – Effective	KVI 1: Increase in # processes enabled by immersive services. KVI 2: Energy savings enabled via introducing Collaborative services in manufacturing.	UC#2	ISAC and RIS enabling Ubiquitous coverage with sufficient performance for Immersive Services

Key Value	KV as Outcome	KVIs	UC/ Scenario	Technology enablers
	Manufacturing. KV2: Resource efficient Manufacturing			
Economic Sustainability	Stakeholder: Providers & Users Effect on: State of Being KV1 description: Economically efficient solution. KV2 description: Economically efficient service provisioning to end users	KVI 1: Reduction of TCO for service provisioning	UC#3 - Sc#1	AI/ML and sensing plane, combined with O-RAN enabling coverage optimisation and cost minimisation
Reduced Inequalities	Stakeholder: Users Effect on: Activities KV1: Connecting the unconnected thus fostering inclusion of remote populations in digital services	KVI 1: Increase in coverage footprint	UC#3 - Sc#2	AI/ML and sensing plane, combined with O-RAN enabling Energy Efficient coverage optimisation
Environmental Sustainability	Stakeholder: Providers & Users Effect on: State of Being KV1: Lower Energy Consumption. KV2 description: Lower Energy Resources utilisation	KVI 1: Optimisation of Energy Footprint for given services	UC#3 - Sc#2	AI/ML and sensing plane, combined with O-RAN enabling Energy Efficient coverage optimisation

Table 5-4 6G-SENSES KVs/ KVIs Target Values and Means for Evaluation

Key Value	KVI	Target Values & Metrics	Evaluation Approach	Time Horizon	Scale
Environmental Sustainability	Optimisation of EMF for given coverage	10–30% EMF reduction	PoC#1 validation	Medium term	Local → Regional
Environmental Sustainability	Optimisation of Energy Footprint (UC#1)	15–40% energy reduction, kWh/site/year, energy/bit	PoC#1 validation	Medium–Long term	Regional → Global
Quality Education & Reduced Inequalities	Increase in immersive educational/ cultural services	20–50% service availability increase, number of immersive sessions	concept validation	Medium–Long term	Global
Quality Education & Reduced Inequalities	Increase in population/coverage access	Percentage population coverage increase	concept validation	Medium–Long term	Regional → Global

Key Value	KVI	Target Values & Metrics	Evaluation Approach	Time Horizon	Scale
Quality of Living & Inclusion; Sustainable Cities	Increase in immersive events	20–40% event availability increase	concept validation	Medium term	Regional → Global
Quality of Living & Inclusion; Sustainable Cities	Increase in coverage of immersive events	Percentage coverage increase	PoC#1 validation	Medium term	Regional
Quality Education & Reduced Inequalities	Increase in immersive services (UC#2)	30–60% coverage improvement	concept validation	Medium–Long term	Regional → Global
Quality Education & Reduced Inequalities	Improvement in QoE (latency, throughput)	QoE metrics improvement (latency, throughput)	PoC#2 validation	Medium term	Regional
Quality Education & Reduced Inequalities	Increase in population/ coverage access (UC#2)	Percentage coverage increase	concept validation	Medium–Long term	Regional → Global
Quality of Living & Inclusion	Increase in immersive events (UC#2)	30–50% coverage/service increase	concept validation	Medium term	Regional → Global
Quality of Living & Inclusion	Increase in population access / QoE	QoE improvement indicators	PoC#2 validation	Medium term	Regional
Sustainable Cities & Communities	Increase in industrial processes enabled	20–40% process efficiency increase	Concept validation	Long term	Regional → Global
Sustainable Cities & Communities	Energy savings in manufacturing	10–25% energy savings	Concept validation	Long term	Regional
Economic Sustainability	Reduction of TCO	10–30% TCO reduction, CAPEX and OPEX optimisation	Techno-economic tool (D2.3), scenario comparison	Short–Medium term	Operator → Global
Reduced Inequalities	Increase in coverage footprint	20–50% coverage extension	PoC #3 Trials & Evaluation Results	Medium term	Regional → Global
Environmental Sustainability	Optimisation of Energy Footprint (UC#3)	20–40% energy reduction	PoC #3 Trials & Evaluation Results	Medium–Long term	Regional → Global

More specifically, the KVIs that are meant to be conceptually validated have been evaluated based on third parties' forecasts, expectations of the network capabilities and quality with the relevant 6G-SENSES technologies. The analysis of these KVIs is presented below. Based on the combination of SoTA research on 6G and immersive communications, empirical evidence from 5G deployments and adoption trends, and well-established projections on connectivity-driven service expansion and digital inclusion, it was validated that the selected target ranges for the KVIs are realistic and well grounded. The relevant analysis is provided in the following paragraphs on a per KV/KVI basis. The verification of the impact can only be assessed in retrospect in the medium- and long-term future.

Use Case #1

KV: Quality Education & Reduced Inequalities

KVI: Increase in immersive educational / cultural services

The 6G-SENSES use cases (UC#1 and UC#2) justify the expected increase in immersive educational and cultural services through the integration of ISAC, RIS, and high-capacity communication technologies, which collectively enable large-scale deployment of immersive applications such as Virtual Reality (VR)-based classrooms, remote laboratories, and cultural digitisation platforms. These technologies ensure high throughput, ultra-low latency, and reliability, which are critical for supporting RT immersive interactions and thus directly contribute to increasing the number of such services that can be effectively delivered.

This expectation is supported by external studies indicating that next-generation connectivity (6G and beyond) can significantly expand immersive learning environments, enabling substantial growth in service availability and accessibility. For instance, research highlights that immersive communication technologies will "profoundly change" education delivery, enabling widespread adoption of virtual and augmented reality learning experiences. At the same time, practical analyses of 5G-enabled education environments already anticipate significant increases in digital learning service availability and adoption, driven by improved connectivity, scalability, and content delivery capabilities. Based on these trends, the projected 20–50% increase in immersive educational services is aligned with realistic expectations derived from both current 5G deployments and anticipated 6G evolution ([4], [5]).

KV: **Quality Education & Reduced Inequalities**

KVI: Increase in population / coverage access

The increase in population and coverage access is directly enabled by 6G-SENSES through RIS-assisted propagation, ISAC-based optimisation, and AI-driven network planning, which collectively improve coverage efficiency and extend connectivity to underserved areas. These technologies allow networks to adapt dynamically to environmental conditions, increasing both reach and reliability, and enabling previously unconnected populations to access high-quality digital services, including education.

This is strongly supported by existing evidence on next-generation networks reducing inequalities. Studies show that technologies such as 5G can bridge the digital divide by significantly improving coverage and access in rural and underserved regions, enabling broader participation in online education and other services. Additionally, research on the digital divide indicates that lack of connectivity remains a primary barrier for up to a significant proportion of the population, directly impacting educational outcomes and access. As next-generation networks expand, measurable improvements in connectivity coverage (often reported in tens of percentage points in rollout studies and policy forecasts) are expected. Therefore, the assumption of ~20–50% coverage increase is consistent with observed improvements in network expansion scenarios and aligns with the anticipated impact of 6G capabilities at scale. ([6], [7], [8])

KV: **Quality of Living & Inclusion; Sustainable Cities**

KVI: Increase in immersive events

The 6G-SENSES use cases enable immersive events (e.g., live virtual participation in concerts, sports, cultural experiences) through the combined use of ISAC, RIS, and immersive communication frameworks, which support RT, multi-sensory interaction across distributed users. These capabilities allow users to participate in events independently of geographical constraints, significantly increasing the number and reach of such experiences and contributing to social inclusion and improved quality of life.

This projection is reinforced by industry and research insights indicating that 6G will enable immersive shared experiences as a core use case, including mixed reality events accessible globally. Furthermore, smart-city-oriented studies highlight that immersive digital services, enabled by advanced connectivity, can drive substantial increases in user engagement and participation in social and cultural activities. As immersive platforms gain maturity and infrastructure improves, adoption curves indicate strong growth trajectories, justifying expected increases such as 20–40% in event availability and participation, particularly in urban and connected regions. ([9], [10])

Use Case #2

KV: **Quality Education & Reduced Inequalities**

KVI: Increase in immersive services

The UC#2 use case in 6G-SENSES, focusing on RIS-assisted CF-mMIMO and ISAC-enabled connectivity, directly enables the large-scale deployment of immersive services such as VR/Augmented Reality (AR)-based education, collaborative virtual environments, and RT cultural applications. These services require ultra-high throughput, very low latency, and consistent QoS, which are supported by RIS-enhanced propagation and distributed antenna systems. As a result, UC#2 provides a strong technical foundation for increasing the availability and scalability of immersive services across different environments.

External research confirms that 6G networks and immersive communications are expected to significantly increase the deployment and usage of such services. Immersive communications, combining XR, holography, and RT interaction, are identified as a core 6G use case with transformative impact across education and society. Furthermore, next-generation connectivity is expected to enable substantial improvements in service delivery capacity and quality, allowing immersive services to scale efficiently to a wider audience. Based on this, a 30–60% improvement in service availability and coverage is consistent with expected gains from advanced technologies such as RIS and cell-free architectures. ([4])

KV: **Quality Education & Reduced Inequalities**

KVI: Increase in population / coverage access

The UC#2 use case justifies the increase in population and coverage access through the use of RIS and advanced connectivity mechanisms, which improve signal propagation, reduce dead zones, and extend network reach in challenging environments. RIS enables the reconfiguration of the wireless environment itself, improving coverage in areas where traditional deployments are inefficient or costly. Combined with CF architectures, this leads to more uniform coverage and enhanced accessibility to high-quality services, including digital education applications.

This is aligned with broader findings showing that advanced wireless technologies can significantly reduce the digital divide by improving access to connectivity in underserved areas. Studies on educational inequality further confirm that lack of access to digital infrastructure is a major barrier to participation and outcomes. Additionally, RIS technology has been widely recognised for its capability to enhance wireless coverage and capacity through intelligent control of signal propagation, which supports large-scale connectivity improvements. Therefore, the assumed percentage increase in coverage is justified by both technological advancements and observed trends in next-generation network deployments. ([7], [11])

KV: Quality of Living & Inclusion

KVI: Increase in immersive events

Within UC#2, immersive events are enabled through ubiquitous, high-performance connectivity supported by RIS and ISAC, allowing users to participate in events such as concerts, social interactions, and public gatherings in virtual or hybrid formats. The ability to provide consistent performance across wide geographical areas allows these services to scale, increasing their availability and accessibility. This directly supports improved quality of living and inclusion by enabling broader participation in cultural and social experiences, regardless of physical location.

Industry and research projections confirm that 6G will enable immersive shared experiences as a key application domain, including RT mixed-reality events accessible globally. Additionally, smart city studies highlight that advanced connectivity and immersive technologies will significantly increase user participation in digital services and events, contributing to social inclusion and engagement. These projections support the expectation of a 30–50% increase in event coverage and service availability, reflecting the combined effect of improved infrastructure and growing demand for immersive experiences. ([9], [10])

Use Case #3

KV: Sustainable Cities & Communities

KVI: Increase in industrial processes enabled

The UC#3 use case in 6G-SENSES, focusing on NDT, AI/ML-based orchestration, and sensing-enabled optimisation, directly supports the enablement of advanced industrial processes. By providing RT visibility, predictive analytics, and intelligent optimisation across network and operational layers, UC#3 facilitates the deployment of Industry 5.0 applications, including remote control, collaborative robotics, and adaptive manufacturing systems. These capabilities allow industries to digitalize and automate processes that were previously impractical due to latency, reliability, or coordination constraints, thus increasing the number of processes that can operate efficiently in distributed and intelligent environments.

This is aligned with broader research indicating that 6G technologies, particularly AI-driven and DT-based systems, will significantly enhance industrial efficiency and enable new operational paradigms. Studies emphasize that 6G-enabled DTs can optimize industrial operations by providing RT monitoring, simulation, and predictive decision-making, leading to substantial efficiency improvements in production environments. Additionally, 6G is expected to support advanced industrial use cases such as autonomous systems and intelligent manufacturing processes, enabling higher levels of automation and coordination. Based on these trends, the expected 20–40% increase in process efficiency is consistent with the anticipated impact of AI- and DT-driven optimisation in next-generation industrial systems ([12]).

KV: Sustainable Cities & Communities

KVI: Energy savings in manufacturing

The UC#3 use case contributes to energy savings in manufacturing through AI/ML-driven optimisation, network-level intelligence, and sensing-enabled resource management. By leveraging DTs and RT analytics, industrial systems can dynamically adjust production processes, optimise resource allocation, and reduce inefficiencies in energy consumption. For example, predictive maintenance, adaptive load balancing, and intelligent scheduling enabled by UC#3 can significantly lower unnecessary energy usage while maintaining or improving productivity levels.

External evidence supports the strong link between advanced connectivity, digitalisation, and energy efficiency improvements in industrial environments. Research on smart cities and Industry 4.0/5.0 systems shows that AI-driven optimisation and connected infrastructures can reduce energy consumption by optimising processes and enabling data-driven decision-making. Furthermore, studies on next-generation networks highlight that integrating sensing, communication, and computation allows for more efficient resource utilisation and reduced operational waste, contributing directly to sustainability goals. These findings justify the projected 10–25% energy savings, which fall within realistic ranges observed in digital optimisation and smart manufacturing scenarios ([12], [13]).

A key outcome of the 6G-SENSES long term KV-/KVIs-based impact assessment is the clear distinction between conceptually validated KVIs and those that can be empirically verified within the project lifecycle. In this context, while several KVIs (particularly those related to large-scale societal adoption, service proliferation, and long-term ecosystem effects) are assessed through conceptual validation based on SoTA research and forecasts, a significant subset of KVIs—especially those closely linked to technical performance and system behaviour—are explicitly designed to be validated through the PoCs of the project.

More specifically, KVIs related to EE, EMF optimisation, QoE improvements, coverage enhancement, and system-level performance are directly associated with measurable KPIs and are therefore assessed through PoC#1, PoC#2, and PoC#3 trials and experimental results. These PoCs provide realistic and controlled environments where the combined effects of enabling technologies (e.g., ISAC, RIS, AI/ML, O-RAN, and DTs) can be observed, quantified, and validated against the defined target ranges. Through this approach, the project ensures that the anticipated impact is not purely theoretical, but is grounded in experimental evidence and real-system behaviour.

At the same time, for KVIs that inherently depend on large-scale deployment, user adoption, and long-term ecosystem evolution—such as immersive service proliferation, societal inclusion, and industrial transformation—the validation remains conceptual within the project duration, while their full verification is expected to materialize beyond the project timeline.

Overall, this dual validation approach—combining PoC-based empirical validation with concept-based foresight analysis—ensures a robust, credible, and methodologically sound assessment of impact, bridging present technological capabilities with future 6G adoption scenarios.

6 Conclusions

This deliverable consolidates the final outcomes of the 6G-SENSES project related to business planning, exploitation strategies, and impact assessment. Building on the technical achievements of the project, D6.4 has defined a structured pathway for translating research results into sustainable scientific, technological, and commercial opportunities. Through a combination of business modelling methodologies, exploitation planning frameworks, and impact assessment activities, the consortium has identified how the innovations developed within 6G-SENSES can create value for multiple stakeholders across the future 6G ecosystem.

A key achievement of this work has been the systematic identification and positioning of the KERs of the project. The project has delivered a diverse portfolio of outcomes ranging from research advances and experimental platforms to enabling technologies and integrated PoCs. These include innovations in ISAC, RIS-assisted communications, CF-MIMO, O-RAN extensions, AI-driven orchestration, NDTs, Wi-Fi sensing, and sensing-enabled SMs. For each KER, a clear value proposition and exploitation pathway has been defined, taking into consideration technology maturity, target stakeholders, market opportunities, and long-term sustainability prospects.

The exploitation analysis confirms that the 6G-SENSES outcomes have relevance for a broad range of actors, including telecom operators, infrastructure providers, equipment vendors, software developers, research organisations, and vertical industries. The developed VPC and LC analyses have enabled partners to identify customer needs, market gaps, competitive advantages, and potential revenue streams associated with their innovations. Furthermore, the deliverable highlights several joint exploitation opportunities among consortium partners, demonstrating how complementary expertise and technologies can be combined to enhance future market uptake and maximize the overall impact of the project.

From an ecosystem perspective, 6G-SENSES contributes to the evolution of future 6G service provisioning by extending current 5G models with sensing-native capabilities, AI-driven intelligence, and programmable infrastructures. The project promotes the emergence of new ecosystem roles, such as Sensing Data Providers and sensing-aware RAN operators, while enabling more open, modular, and interoperable platforms. These developments support the long-term vision of 6G as a unified communication, sensing, and computing environment capable of addressing both industrial and societal needs.

The impact assessment performed in this deliverable demonstrates that 6G-SENSES has generated and can generate value across technological, economic, societal, and environmental dimensions. During the project lifecycle, partners benefited from access to funding, advanced experimentation environments, reduced validation costs, workforce development, and the creation of strategic collaborations. Beyond the project duration, the developed technologies are expected to contribute to improved energy efficiency, enhanced network coverage, immersive service delivery, industrial process optimisation, and reduced operational costs. The project therefore aligns strongly with the objectives of the SNS JU programme, the European digital agenda, and broader sustainability frameworks, including the UN SDGs.

Particular emphasis has been placed on the adoption of the KVs and KVIs framework. The assessment shows that 6G-SENSES technologies have the potential to contribute to environmental sustainability through reductions in energy consumption and electromagnetic exposure, to economic sustainability through TCO optimisation, and to societal objectives through improved accessibility, enhanced immersive services, digital inclusion, and support for sustainable industrial transformation. The defined KVI target ranges have been justified through a combination of project outcomes, SoTA research, industry forecasts, and technology adoption trends.

An important outcome of the project is the establishment of a robust impact validation methodology. Technical KVIs closely linked to measurable system performance are validated through the PoCs and experimental infrastructures of the project, while wider societal and industrial impacts are assessed through concept validation and long-term projections. This dual approach ensures that the impact assessment remains both scientifically credible and aligned with the long-term nature of 6G adoption. The project therefore not only demonstrates technological feasibility but also provides a framework for evaluating the future value created by next-generation communication and sensing technologies.

In conclusion, 6G-SENSES has successfully laid the foundations for the exploitation, adoption, and long-term impact of its innovations. The business plans, exploitation strategies, and impact assessment presented in this deliverable provide a coherent roadmap for moving from research results to real-world deployment. Through its technical advances, ecosystem contributions, and value-driven approach, the project strengthens EU's position in the development of future 6G technologies and offers a solid basis for future research, standardisation, industrial collaboration, and commercialisation activities

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8 Acronyms

Acronym	Full Form
5G	Fifth Generation Mobile Network
6G	Sixth Generation Mobile Network
AI	Artificial Intelligence
AP	Access Point
API	Application Programming Interface
BiCMOS	Bipolar Complementary Metal-Oxide Semiconductor
CF-MIMO	Cell-Free Multiple Input Multiple Output
CN	Core Network
CSP	Communication Service Provider
CSR	Corporate Social Responsibility
DC	Direct Current
DCSP	Datacenter Service Provider
DEP	Digital Europe Programme
E2	E2 Interface
EU	European Union
FE	Front End
HRLLC	High Reliability Low Latency Communication
ICT	Information and Communication Technology
IMT-2030	International Mobile Telecommunications 2030
IP	Infrastructure Provider
ISAC	Integrated Sensing and Communication
ISM	Industrial, Scientific and Medical Band
IoT	Internet of Things
IP	Intellectual Property
KER	Key Exploitable Result
KPI	Key Performance Indicator
MNO	Mobile Network Operator
NDT	Network Digital Twin
NOP	Network Operator
NR	New Radio
O-RAN	Open Radio Access Network
OAI	OpenAirInterface

OEM	Original Equipment Manufacturer
OTA	Over-The-Air
PoC	Proof of Concept
PRB	Physical Resource Block
RAN	Radio Access Network
RAT	Radio Access Technology
RF	Radio Frequency
RFSoC	Radio Frequency System-on-Chip
RIC	RAN Intelligent Controller
RIS	Reconfigurable Intelligent Surface
SDG	Sustainable Development Goal
SMEs	Small and Medium-sized Enterprises
SMO	Service Management and Orchestration
SNCV	the Societal Needs and Value Creation
SP	Service Provider
SRS	Sounding Reference Signal
TCO	Total Cost of Ownership
TDD	Time Division Duplex
TRL	Technology Readiness Level
UE	User Equipment
URLLC	Ultra-Reliable Low Latency Communication
USRP	Universal Software Radio Peripheral
VISP	Virtualisation Infrastructure Service Provider
Wi-Fi	Wireless Fidelity
eMBB	Enhanced Mobile Broadband
gNB	Next Generation Node B
mmWave	Millimetre Wave