Horizon Europe Framework Programme

CENTRIC

Towards an AI-native, user-centric air interface for 6G networks

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D5.1 Early results on KPIs/KVIs, testing methodologies and benchmarking

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ABSTRACT

In order to evaluate the merits of the technologies developed in CENTRIC for future 6G networks, it is of crucial importance to define a set of measures that can help quantify their performance under different conditions. In addition to performance characterization, 6G aims to provide other indirect benefits to society at large, e.g., in the context of the United Nations Sustainable Development Goals. Such societal benefits should also be assessed.
In this deliverable, we address the identification of Key Performance Indicators (KPIs) and Key Value Indicators (KVIs) that will be used to assess both types of

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impacts –performance impact and societal impact, respectively—generated by the techniques proposed in CENTRIC. We first review the state-of-art on KPI and KVI definition in relevant bodies and projects, then identify and define those that are relevant for CENTRIC activities and, to finalize, we link each of the technologies developed in the project to the KPIs and KVIs that are specifically relevant for them. The resulting set of KPIs and KVIs will be revised in deliverable D5.3, where in addition assessment methodologies for them will be proposed.

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Executive summary

The aim of this document is to identify the Key Performance Indicators (KPIs) and Key Value Indicators (KVIs) that are relevant to assess the impact of the artificial intelligence (AI)-enabled air interface technologies being researched in CENTRIC. KPIs are defined in order to assess the communication performance of CENTRIC developed enablers, whereas KVIs are used to evaluate their indirect impact in society at large. This identification and definition exercise is an initial step in establishing a benchmarking and testing framework for the AI-enabled air interface.

To perform an informed selection of KPIs and KVIs, we first review relevant work in the area of KPIs and KVIs for beyond 5G and 6G systems. Specifically, we cover the outcomes of the flagship project Hexa-X, work done by 5th Generation Infrastructure Public Private Partnership (5GPP), the 6G Industry Association (6G-IA), the 3rd Generation Partnership Project (3GPP), as well as regulatory bodies in the area of electromagnetic field (EMF) exposure. A selection of CENTRIC relevant KPIs and KVIs defined by these ventures are presented and used as input to define our own set of project KPIs and KVIs.

In terms of KPIs, we select and defined KPIs belonging to 3 main categories:

- **Conventional KPIs:** these are conventional communication KPIs, similar to those defined for previous systems such as 5G, used to characterize the performance of the air interface.
- **Common AI KPIs:** these comprise a set of common KPIs to assess performance and complexity aspects of air-interface techniques relying on AI models.
- **EMF-related KPIs:** these are KPIs that assess the EMF radiation incurred in humans due to wireless networks.

In addition to the above, we also identify a few **enabler-specific KPIs** that are used only in particular technologies as a way to characterize the intermediate performance –as opposed to end-to-end performance—of some particular methods.

In terms of KVIs, we focus on indicators that are related to the sustainability of the 6G network itself, and which we classify into the following subsets:

- **Environmental sustainability KVIs:** they assess the impact that CENTRIC technologies will have on different environmental aspects, such as the carbon footprint of future 6G networks, or the potential reductions in the amount of disposed materials.
- **Economic sustainability KVIs:** these are defined to evaluate impacts on the total cost of ownership (TCOs) for 6G infrastructure and service providers.
- **Societal sustainability KVIs:** they are used to qualify the trustworthiness of 6G networks as experienced by society at large.

The defined KPIs and KVIs are then mapped to the technological enablers developed in CENTRIC that will have impact on them. The purpose of this mapping is to identify which performance measures are of particular importance for each of the CENTRIC techniques, as well as which key values the methods will mainly impact.

The outcome of this deliverable, i.e., the identified set of KPIs, KVIs, and their links to the CENTRIC enablers, will be used to propose a testing and benchmarking framework for the developed technologies in the project. This will be the subject of deliverable D5.3, due at the end of 2024.

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Abbreviations

5GPPP	5th Generation Infrastructure Public Private Partnership
3GPP	3rd Generation Partnership Project
6G	6th generation
6G-IA	6G Industry Association
AI	Artificial Intelligence
AI-AI	artificial intelligence enabled air interface
CSI	Channel state information
EC	European Commission
EMF	electromagnetic field
ICNIRP	International Commission on Non-Ionizing Radiation Protection
ICT	information and communication technology
KPI	key performance indicators
KV	Key Values
KVI	Key Value Indicators
MOS	mean opinion score
NR	New radio
QoE	Quality of Experience
SAR	energy absorption rate
SDG	sustainable development goals
UN	United Nations
WPs	work packages

1 Introduction

CENTRIC's vision considers that the artificial intelligence enabled air interface (AI-AI) will be the essential fabric of future wireless connectivity systems. The project places the user's communication needs and environmental constraints as the starting point so that, by leveraging advanced artificial intelligence (AI) methods, an air interface can be automatedly configured to optimally deliver the required services and applications. A pictorial summary of CENTRIC's objectives is depicted in Figure 1.

Figure 1: Centric Objectives

To validate that the developed AI-AI methods do indeed achieve the desired goals, it is of crucial importance to identify the key performance indicators (KPIs) that will be the optimization target of the technological enablers developed in the project. Based on a proper definition of KPIs, assessment and validation methodologies can then be formulated to measure said KPIs, compare the results with the expected targets, and draw conclusions on the performance and/or complexity gains attained by the developed methods.

Ultimately, however, the 6th generation (6G) of mobile communications aims at more than simply enhancing the communication performance of 6G applications and use-cases. The 6G vision, as established by the 6G Industry Association (6G-IA) and the European Commission (EC), should as well contribute to broader societal values [1] aligned with the sustainable development goals (SDGs) formulated by the United Nations (UN) [2]. Such societal values are given the terminology of Key Values (KV), and the extent to which 6G technologies will contribute to them will be assessed based on what has been termed Key Value Indicators (KVIs).

The purpose of this deliverable is to identify both the main KPIs and the main KVIs that the technologies developed in CENTRIC will target. For this, we first review state-of-the-art work on KPIs and KVIs by other projects and bodies, such as 5th Generation Infrastructure Public Private Partnership (5GPPP), 6G-IA, 3rd Generation Partnership Project (3GPP), and more. Based on this review, we then select and define the KPIs and KVIs that CENTRIC will focus on and map them to the technological enablers developed in other work packages (WPs) in the project.

Using the outcome of this deliverable, CENTRIC will develop validation methodologies to quantify and assess the KPIs and KVIs defined in this deliverable for the different technological enablers. These will be documented in CENTRIC's deliverable D5.3, due at the end of 2024.

2 State-of-the-art on KPIs for 6G

Several research projects in Europe and other regions started to investigate the new cellular communication system, 6G, that is expected to be commercially available by 2030. 6G is expected to bring a significant enhancement in data speed, jitter reliability, system availability, power efficiency, cost, network coverage and many others. These new enhancements will happen through the deployment of different technologies such as artificial intelligence, machine learning, etc. and it will assist in the deployment of different scenarios and applications such as coverage from space to the ground, 100% geographical coverage, high mobility, microsecond latency, robotic machine, high touch virtual reality and many more.

To support these new applications, new requirements are needed such as wide bandwidth, large number of antennas, etc. KPIs are essential to understand the performance of the new technologies deployed in CENTRIC and will provide measurable criteria to monitor and evaluate them. In the below section, we will provide an overview of the KPIs that have been discussed by different European projects and bodies such as Hexa-X [3], 5G-PPP, 6G-IA [4] [5], and 3GPP [6]. In addition, we discuss the state-of-art on KPIs related to electromagnetic field (EMF) exposure at the end of the section.

2.1 5G-PPP Testing, Measurement and KPI Validation Work Group KPIs

5G-PPP is a collaborative effort between the European commission and European information and communication technology (ICT). The third phase of the 5G-PPP began in June 2018 in Brussels, when numerous new initiatives were introduced. Solutions, architectures, technologies, and standards for the widely used next generation communication infrastructures of the upcoming ten years will be provided by the 5G-PPP. 5G-PPP, in Test Measurement and KPIs Validation Working Group, provides insights about the KPIs of Beyond 5G/6G [4]. In the below section, we summarize the list of KPIs discussed within this project.

Peak data rate: Peak data rate is defined as the maximum data rate that can be achieved under ideal conditions. Ideal conditions are assumed for one single mobile station where the received bits are error free and all assignable radio resources for the corresponding link are utilized. The peak data rate is expressed in (bit/s) as below:

$$R_p = W \times SE_p \qquad (1)$$

Where W denotes the channel bandwidth and SE_p denotes the peak spectral efficiency.

User experience data rate: User experienced data rate is the 5% point of the cumulative distribution function of the user throughput where user throughput is defined as the number of correctly received bits. User experienced data rate is given as follows:

$$R_{user} = W \times SE_{user} \qquad (2)$$

Where W denotes the channel bandwidth and SE_{user} denotes the 5th percentile user spectral efficiency.

Area traffic capacity: Area traffic capacity is defined as the total throughput served per geographic area and it is expressed in Mbits/s/m^2. The area traffic capacity C_{area} is related to average spectral efficiency SE_{avg} through the below equation:

$$C_{area} = \rho \times W \times SE_{avg} \qquad (3)$$

W denotes the channel bandwidth and ρ the transmission and reception points (TRxP) spatial density (TRxP/ m^2).

Bandwidth: Bandwidth is defined as the maximum aggregated system bandwidth that is supported by single or multiple radio frequency carriers. The required bandwidth is 100 MHz for low frequency bandwidth, and it can go up to 1 GHz for higher frequency bandwidth (above 6 GHz).

Connection Density: The total number of connected and/or accessible devices fulfilling a specific quality of service per unit area. It is expressed as number of Device/km^2. As an example, for some massive IoT use-cases the minimum requirement for connection density is 1 000 000 devices per km^2.

Latency: Latency is defined separately for the user and the control-planes:

- **User-plane latency** is defined as the time needed to successfully deliver an application layer message in either the uplink or the downlink assuming that the mobile station is in the active state. The minimum requirements for user plane latency in 5G networks are:
    - 4 ms for eMBB
    - 1 ms for URLLC
- **Control-plane latency** is the transition time from the idle state to the active state (data transfer). The minimum requirement for control plane latency is:
    - 20 ms and it is encouraged to lower it to 10 ms

Reliability: Reliability is the capability of transmitting a specific amount of traffic within a predetermined time duration with high success probability. As an example, for a given use-case the minimum requirement could be formulated as 1-10^{-5} success probability of transmitting a layer of 2 PDU of 32 bytes within 1 ms.

Peak Spectral Efficiency: Spectral Efficiency is defined as the maximum data rate under ideal conditions where the maximum data rate is the received data bits assuming error free conditions. The minimum requirements for peak spectral efficiencies are given as follows:

- Downlink peak spectral efficiency is 30 bit/s/Hz
- Uplink peak spectral efficiency is 15 bit/s/Hz

5th Percentile User Spectral Efficiency: The 5th percentile user spectral efficiency is defined as the 5% point of the CDF of the normalized user throughput where the normalized user throughput is defined as the number of correctly received bits. The minimum requirements of the 5th percentile user spectral is given in the below table:

Table 1: 5th percentile user spectral efficiency

Test environment Downlink	Downlink (bit/s/Hz)	Uplink (bit/s/Hz)
Indoor	0.3	0.21
Dense	0.225	0.15
Urban	0.12	0.045

Energy Efficiency: Energy efficiency is defined as the ability to minimize the radio access network energy consumption in relation the traffic capacity provided. Energy efficiency supports the below two scenarios:

- Efficient data transmission in a loaded scenario
- Low energy consumption for no data transmission scenario

Quality of Experience: The Quality of Experience (QoE) is subjective as it is related to the end user experience and his point of view. It is defined by ITU-T as “*The overall acceptability of an application or service as perceived subjectively by the end user”.* Objective parameters are needed to measure the QoE. Factors that affect the QoE are bandwidth, jitter, delay, and packet loss rate. The mean opinion score (MOS) is an example of a subjective measurement method in which users rate the service quality by giving five different point scores, from 5 to 1, where 5 is the best quality and 1 is the worst quality. Quality can be classified as Bad [0 – 1], Poor [1 – 2], Fair [2 – 3], Good [3 – 4] and Excellent [4-5]. The minimum requirement is to have MOS values > 4.3.

Higher Accuracy Positioning: High requirements of positioning accuracy are essential for different applications such as self-driving cars to avoid collisions and locating moving objects on a factory floor. 6G should support higher accuracy positioning. UEs shall be able to share positioning information between each other e.g., to a controller if the location information cannot be processed or used locally. Below are some requirements needed for high positioning accuracy:

- Position acquisition time: 500 ms
- Survival time: 1 s
- Availability: 99.99%
- Dimension of service area: 500x500x30m
- Position accuracy: 0.5 m

2.2 KPIs defined by Hexa-X

Hexa-X is a European project with 25 partners that provides a 6G vision where it enables technology of connecting humans, physical and digital world [3]. The ambition of Hexa-X includes developing key technologies enablers in the below areas:

- Fundamentally new radio access technologies at high frequencies and high-resolution localization and sensing.
- Connected intelligence through AI-driven air interface and governance for future networks.
- 6G architectural enablers for network disaggregation and dynamic dependability.

In this section, we will focus on the KPIs of Hexa-X related to AI-driven air interface as presented in [7]. The KPIs related to AI-driven air interface design are divided into 3 categories as shown below.

- Conventional communication KPI
- ML-related KPI
- Environmental characteristics

Each category defines a set of several KPIs as depicted in the below tables.

Table 2: Hexa-X Conventional KPIs [7]

Conventional communication KPI	
KPI	**Brief definition**
Latency	it is defined as the time elapsed between the beginning and the end of the air interface functionality.
Bandwidth	It is defined as the difference between the highest and lowest frequency for a continuous frequency band and it is expressed in MHz.
Bit rate	It is defined as the number of transmitted bits per unit time.
Outage probability	It is defined as the probability that an outage will occur during a time period.
Energy efficiency	It is defined as the energy needed to send a number of bits, and it is expressed in bits / joule.
Signalling overhead	It is defined as the number of radio signals that needs to be transmitted in order to finalize a specific functionality. As an example, the number of pilot signals that need to be transmitted to estimate the channel.
Backhaul / fronted capacity:	It is defined as the capacity of the backhaul link or the fronthaul link.
Spectral efficiency	It is defined as the number of bits that can be transmitted per unit bandwidth.

Table 3: Hexa-X KPIs related to ML [7]

ML related KPI	
KPI	**Brief definition**
Convergence	it is defined as the loss function value that is settled with increasing training epochs.
Flexibility	It is defined as the ability of adaptation of the ML model to different conditions and environment in a timely fashion.
Data quality	it is related to data quality for model training. Assuming higher quality data achieve better ML convergence model.
Complexity gain	It quantifies the decrease in the complexity of the system compared to a conventional system (non-ML method).

Table 4: Hexa-X KPIs related to environmental characteristics [7]

Environmental related KPI	
KPI	**Brief definition**
Coverage	it is defined as the monitored area by the LiDAR sensors

Sensing resolution	Resolution of the LiDAR sensors
Connecting density	Number of connected devices in an area
Positioning accuracy	Position estimation accuracy

2.3 KPIs defined by 3GPP Rel-18 RAN1 Study (38.843)

Rel-18 RAN1 focuses on Artificial Intelligence (AI)/Machine Learning (ML) for new radio (NR) air interface along with evaluations (from several proponents) on AI/ML based algorithms for the use cases considered (channel state information (CSI) feedback enhancement, beam management, positioning accuracy enchantments). To get a better understanding of the attainable gains and associated complexity requirements, the study included identification of *common* and *use-case specific* KPIs [6].

The scope included:

- Performance, inference latency and computational complexity of AI/ML based algorithms should be compared to that of a state-of-the-art baseline.
- Overhead, power consumption (including computational), memory storage, and hardware requirements (including for given processing delays) associated with enabling respective AI/ML scheme, as well as generalization capability should be considered.

Below is the list of KPI proposed by RAN1 where several KPIs are depicted for the above use cases along with common KPIs related to AI.

Table 5: 3GPP Common KPIs related to AI [6]

Environmental related KPI	
KPI	**Brief definition**
Performance	Intermediate KPIs, Generalization performance
Over-the-air Overhead	Overhead of assistance information, overhead of data collection, overhead of model delivery/transfer, overhead of other AI/ML-related signalling
Inference complexity, including complexity for pre- and post-processing	Computational complexity of model inference: TOPs, FLOPs, MACs, Computational complexity for pre- and post-processing, Model complexity: e.g., the number of parameters and/or size (e.g., Mbyte), Complexity shall be reported in terms of "number of real-value model parameters" and "number of real-value operations" regardless of underlying model arithmetic
Training complexity	-
LCM related complexity and storage overhead	Storage/computation for training data collection, Storage/computation for training and model update, Storage/computation for model monitoring, Storage/computation for other LCM procedures, e.g., model activation, deactivation, selection, switching, fallback operation.

Table 6: 3GPP AI-related KPIs considered in CSI feedback enhancement [6]

KPI related to CSI feedback enhancement	
KPI	**Brief definition**

Capability/complexity	Floating point operations (FLOPs), AI/ML model size, number of AI/ML parameters
AI/ML memory storage	Storage in terms of AI/ML model size and number of AI/ML parameters
CSI compression	Intermediate KPIs: SGCS and/or NMSE to evaluate the accuracy of the AI/ML output CSI
CSI prediction	Intermediate KPIs: calculated for each predicted instance if AI/ML model outputs multiple predicted instances

Table 7: 3GPP AI-related KPIs considered in beam management [6]

KPI related to beam management	
KPI	**Brief definition**
Model complexity and computational complexity	NA
Beam prediction accuracy	with 1dB margin for Top-1 beam, Top-1 (%): the percentage of "the Top-1 genie-aided beam is Top-1 predicted beam", Top-K/1 (%): the percentage of "the Top-1 genie-aided beam is one of the Top-K predicted beams", Top-1/K (%) (Optional): the percentage of "the Top-1 predicted beam is one of the Top-K genie-aided beams
CDF of L1-RSRP difference for Top-1 predicted beam	NA
Average L1-RSRP difference of Top-1 predicted beam	Top-1 genie-aided Tx beam (baseline definition): the Top-1 genie-aided Tx beam is the Tx beam that results in the largest L1-RSRP over all Tx and Rx beams, or Top-1 genie-aided Tx-Rx beam pair (baseline definition): The Tx-Rx beam pair that results in the largest L1-RSRP over all Tx and Rx beams

Table 8: 3GPP AI-related KPIs considered in Positioning accuracy enhancements [6]

KPI related to Positioning accuracy enhancements	
KPI	**Brief definition**
Model complexity	number of model parameters, and computational complexity, e.g., FLOPS
For AI/ML assisted positioning	an intermediate performance metric of model output
Model generalization capability	NA

2.4 EMF-related KPIs

In the below section we provide an overview of the standards related to electromagnetic field (EMF) exposure, since the EMF-related KPIs must be correlated to the limits of the associated standard.

2.4.1 ICNIRP Guidelines

The baseline document for the European Commission and national regulators for radiation limits for the exposure of EMF are the International Commission on Non-Ionizing Radiation Protection (ICNIRP) guidelines in 1998 [8] and their update in 2020 [9]. These guidelines cover the frequency range from 100 kHz to 300 GHz. ICNIRP is an independent scientific commission, whose members are experts in the field of non-ionizing radiation protection from all relevant scientific domains. Therefore, the ICNIRP guidelines are internationally recognized and accepted for radiation limits of EMF. ICNIRP is the key international body for evaluating scientific studies and to set radiation limits as basis for regional and national regulations. The ICNIRP guidelines apply to occupational and general public exposure and are frequency dependent. ICNIRP has developed two types of limits: basic restriction and reference level.

Basic restrictions are defined as ‘’restrictions on exposure to time-varying electric, magnetic, and electromagnetic fields, which are based directly on established health effects and biological considerations’’ [8]. The physical quantities used to specify these restrictions are the specific energy absorption rate (SAR), and the absorbed power density (*Sab*) for time averaged exposure > 6 min, or the specific energy absorption (SA) and the absorbed energy density (U_{ab}) for time averaged exposure > 0 and < 6 min.

Reference levels for limiting exposure are measures related to the internal measures of exposure and expressed in terms of directly measurable quantities of external exposure. These reference levels are defined as ‘’levels which are provided for practical exposure-assessment purposes to determine whether the basic restrictions are likely to be exceeded’’ [8]. The ICNIRP reference levels of occupational and general public exposure are the electric field strength (*E*), magnetic field strength (*H*), magnetic flux density (*B*), and equivalent plane wave power density (*S*). In any particular exposure situation, measured or calculated values of any of these quantities can be compared with the appropriate reference level. Compliance with the reference level will ensure compliance with the relevant basic restriction. If the measured or calculated value exceeds the reference level, it does not necessarily follow that the basic restriction will be exceeded. However, whenever a reference level is exceeded, it is necessary to test compliance with the relevant basic restriction and to determine whether additional protective measures are necessary.

2.4.2 European Commission Recommendations

The council of the European Union has published Recommendation 1999/519/EC of 12 July 1999 [10], including frequency-dependent reference levels for general public exposure, which are considered as limit values. These limits are identical to the ICNIRP limit values for general public exposure the ICNIRP Guidelines 1998 [8]. Many European countries implemented these recommendations, and thus the ICNIRP guidelines, in their legislations. However, in the implementation of these limits additional security margins are considered, which may differ from country to country.

2.4.3 ITU-T Electromagnetic field compliance assessments for 5G wireless networks

ITU, Telecommunications Sector (ITU-T) provides basic guidelines for the assessment of 5G and RF-EMF exposure [11] . These recommendations for 5G can be used as an example for the extension towards 6G and Terahertz systems. ITU-T is also referring to the ICNIRP guidelines in 1998 [8].

2.4.4 IEC Standards

The IEC issued several standards and reports concerned with the evaluation of the human EMF exposure due to RF fields to ensure compliance with the national regulations or ICNIRP guidelines.

IEC standards can be divided into two categories; those concerned with the assessment of the RF field strength, power density and SAR near base stations, and those concerned with the evaluation of the RF field produced by mobile and handheld devices.

3 State-of-the-art on KVIs for 6G

6G is expected to provide enormous benefits to citizens, societies, and industries. Key performance indicators are used to evaluate the development of new technologies in order to meet standards. To evaluate and validate the contributions of 6G on human needs and its impact on society key value indicators will be used for this purpose. KVI are proposed to reflect the societal demands brought by 6G. Hexa-X program originated the concept of key value indicators and has generated several deliverables [12] [7] [13] and insights about KVIs in 6G and how 6G will improve the quality of life, provide economic growth, and promote digital equity towards building a sustainable society. Several countries around the world like USA, China, Japan, UK and many others have identified a set of priorities to improve the quality of life, connecting the unconnected, to investigate sustainability, security, and privacy within the framework of programs such as 6G sandbox [14], Next G Alliance's [15], Hexa-X 6g flagship [3], and many others. Two years after introducing the concept of KVI, researchers have not put KVIs discussion in position where discussions are still open to quantify and evaluate the societal and ethical impact of new technologies proposed by current and new communication systems. In other words, addressing the societal impact along technology enhancement of 6G is required.

United Nations Sustainable Development Goals:

Sustainability revolves around meeting the needs of the present generation without compromising or jeopardizing the future generations to meet their own needs. The United Nations (UN) plays an important role in advancing and promoting sustainable developments throughout the globe where sustainability is central to the mission of the UN. In 2015, UN adopted 17 Sustainable Development Goals (SDGs) [2], in which they cover three areas: *environmental sustainability*, *societal sustainability,* and *economic sustainability* as illustrated in Figure 2. These 17 goals are mapped to a set of 169 targets where they cover critical aspects related to people, planet, prosperity, peace, and partnership.

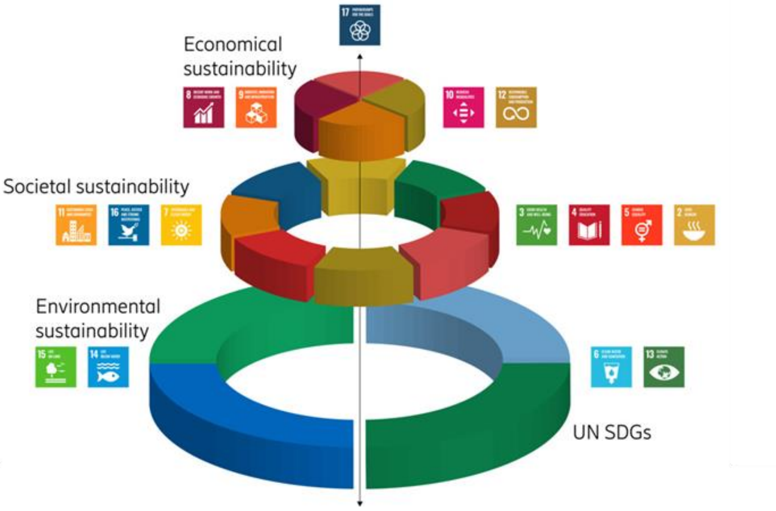

Figure 2: Illustration of UN SDGs (source: [2])

Along with UN SDGs different organizations and projects are investigating the societal impact of the new communication systems such as Next Generation Mobile Networks Alliance (NGMN) [15], Hexa-X [3] and many others. CENTRIC project will offer services to human end users and to industries in many sectors of society where the technologies provided by CENTRIC will directly improve the quality of life through providing a cheaper and better access to wireless systems and empowering us in the society. Technology is considered of societal value if it enables impact on society. For this purpose, addressing the benefits of CENTRIC on end users and society is essential through key value indicators. KVIs differ from KPI where they provide an insight into factors related to society and humans while KPIs evaluate the enhancement in terms of tech perspectives such as data rate, coverage, throughput, latency, interference, etc.

In CENTRIC, we are investigating, evaluating, and quantifying the impact of new technologies on humans, economy, education and on society by introducing new key values (KV) and evaluating them using key value indicators. In the below section, we discuss the KVI presented by 5GPPP and Hexa-X while in section 4 we present the KVIs related to CENTRIC.

3.1 KVIs approach by Hexa-X

2030 and beyond the world will face tremendous opportunities and challenges of sustainable growth. The Hexa-X vision is to connect human, physical and digital worlds with a fabric of 6G key enablers [3]. It enables new radio access technologies at high frequencies and high-resolution localization and sensing as well, it connects intelligence through AI-driven air interface and governance for future networks. Hexa-X is the first project to present the concept of KVI besides to the KPIs where it addresses different set of KVIs divided into different categories as given below:

- **Sustainability:** where it considers two aspects on sustainability for the 6G itself and sustainability for other sectors that are enabled by 6G.
- **Inclusion:** where it refers to the capability of a person or group to use a service, including the ease of access to the service.
- **Flexibility:** refers to the ability of the system to adapt to changes in its environment and utilization, considering the incurred costs. It is related to the dependability and the resilience of the system. AI-based mechanisms for management and orchestration are the main enablers.
- **Trustworthiness:** where it covers many aspects such as security, privacy, and dependability (availability, reliability, etc.)
- **AI/ML air interface related KVIs:** related to KVIs enabled by the usage of AI air interface.

The first four categories relate to the general KVIs defined for 6G [12], whereas the latter one is specifically defined for the use of AI in the air interface [7] [13]. Each of these categories consists of other sets of KVIs. The below tables summarize the definition of each KVI that belongs to each category with the key enabler.

Table 9: Hexa-X KVIs for sustainable 6G and key enablers [12]

KVI for sustainable 6G	
KVI	**Selected enablers**
Energy consumption during operation	Extending sleep modes to compute, Joint optimization
Energy consumption at zero load	Advanced sleep modes (MIMO muting), low/zero energy devices, complexity reduction in signalling
Signalling overhead	AI-based orchestration, functional decomposition, and reduced signalling
Energy consumption per bit	Control computation communication co-Design

Table 10: Hexa-X KVIs for inclusion and enablers [12]

KVI related to inclusion	
KVI	**Selected enablers**
Increase in addressable workforce	Novel HMIs, DTs
Perceived quality of work	Novel HMIs, DTs
Ease of use	NA
Percentage of population reached	NTN
Reduction in wait time	NA
Percentage of target area covered	NTN and zero Energy devices
Spatial and/or temporal resolution	NTN and zero energy devices

Table 11: Hexa-X KVIs for flexibility and enablers [12]

KVI related to flexibility	
KVI	**Selected enablers**
Convergence time	Flexible source allocation
Detection Time	Handling unexpected situations, error detection
Re-configuration overhead	Architectural enablers for flexible networks
Re-configuration capability / related to scalability	Enablers for flexible resource managements
Re-use / sharing of spectrum	Flexible spectrum management

Table 12: Hexa-X KVIs for trustworthiness and enablers [12]

KVI related to trustworthiness	
KVI	**Selected enablers**
AI privacy	Privacy preserving clustering differentially private federated learning

AI agent availability and reliability	Prediction of mobility, workload movement optimization, prediction of impairments in connectivity

Table 13: Hexa-X KVIs for AI enabled air interface [7] [13]

KVI related to AI driven air interface design	
KVI	**Brief definition**
Generalizability	AI-based models should perform affectively to unseen scenarios
Deployment flexibility	The ability to deploy same AI model to multiple scenarios without the need to modify the model.
Service availability	Being able to resist the adversarial attacks and to perform without any downtime
Distributed learning with frugal AI	Being able to train the model without the need to acquire expensive data and based on small amount of data.
Data privacy protection	The data used for model training should adhere to ethical obligations
Trustworthiness	The AI model should perform optimally without any manipulation
Resistance to adversarial attacks	Being capable to perform as intended during adversarial attacks

3.2 KVIs approach by 6G-IA

The 6G-IA is the voice of European Industry and Research for next generation networks and services where it represents the private side in both 5GPP and the Smart Networks and Services Joint Undertaking (SNS JU). In [1], 6G-IA provides an initial set of KVIs where they map the key values to each use case and provide the related KVIs and the enablers as summarized in the below table.

Table 14: 6G-IA defined KVs, KVIs, and enablers [1]

KVI related to AI driven air interface design		
KV examples	**KVI example**	**KV enabler example**
Societal sustainability	Reduced emergency response time, increased operational efficiency of intervention; average cost health saving in health care system per patient; travelling/commuting time reduction; access to job market, etc.	Flexible network fabric with dynamic network and service orchestration and automation; Mobile ad-hoc networking; TN/NTN convergence, System resilience; Ecosystem adaptation and integration; Zero-touch system, Ubiquitous coverage for basic MBB, etc.
Environmental sustainability	Increased area of protected and surveyed natural habitats and climate preserves; Environmental footprint of urban transport of persons and goods, etc.	Energy-efficient monitoring sensors, Flexible analytics services, and network automation, TN/NTN convergence; Precise positioning / localization, etc.
Personal health and protection from harm	Increased operational efficiency for saving lives in emergencies; Reduced injuries in PPDR missions, Access to	Joint communication and sensing; Safe and easy to use XR devices; Network and service automation for low-

	autonomous health monitoring service; etc.	latency; Medically safe on-body devices with long autonomous operation time;
Trust	Reported confidence in advanced digital devices, systems, and services in critical missions; Reported trust level for autonomous e-health components; etc.	Rugged and robust devices; Secure and trustworthy AI; System E2E privacy and security; Secure and trustworthy AI; etc.
Simplified life	Access and ease of use of public transport; Time savings in agricultural activities	Multimodal interconnectivity services; AI for detection of threats and action
Privacy and confidentiality	Reported user control of medical data for storage transmission and processing	System E2E privacy and security; Decentralized processing / offloading to devices, edge, etc.
Cultural connection	Access to cultural products, and cultural events	Extended service coverage with sufficient QoS
Digital Inclusion	Access to internet in communities and areas	Ubiquitous coverage for basic MBB
Knowledge	Access to quality education, to digital libraries, and to knowledge groups	Merged reality and multimodal communication services
Personal freedom	Degree of influence over your daily activities; Degree of personal mobility	System resilience
Democracy	Access to / active participation in administrative and political functions	Ubiquitous coverage for basic MBB; Merged reality and multimodal communication services

4 Definition of KPIs and KVIs in CENTRIC

Using the state-of-art analysis presented in Section 2 for KPIs and Section 3 for KVIs, we now present in this section a selection of KPIs and KVIs that will be used by CENTRIC to assess the benefits of the technological enablers developed in the project.

CENTRIC's primary goal is to develop technologies and enhancements to the air interface to be potentially applied in 6G networks. These technologies have the goal to improve latency, throughput, spectral efficiency, etc, of the 6G air interface. Therefore, they will be evaluated using ***conventional KPIs*** typically applied to air-interface components. In addition, the key enabling technology allowing for such advances is AI, which entails a set of characteristics that are substantially different to the signal processing and optimization tools that have been classically used in the design of air interface techniques. In order to characterize the specific performance aspects that commonly affect AI models in different air-interface tasks and components, we define as well a set of ***common AI KPIs.*** Another of the key differentiators of CENTRIC is the emphasis on developing EMF-aware air-interface techniques. To assess the validity of those methods, we further propose a set of ***EMF-related KPIs*****.** Finally, there are some technical advancements in CENTRIC which will also be evaluated using intermediate KPIs that are only applicable to those specific methods. These, we coin ***enabler-specific KPIs*****.**

On the other hand, KVIs are essential to address the societal values which complements the KPIs that are used to understand the technology performance brought by CENTRIC. KVIs will allow for assessing any impact on societal key values enabled by CENTRIC. The presented KVIs are related to sustainability and categorized into 3 categories: **environmental**, **economic** and **societal sustainability** KVIs.

The aim of this deliverable is providing early and preliminary insights and analysis of KPIs and KVIs that are within the scope of CENTRIC work. In order to explicitly connect these KPIs and KVIs to the particular AI-enabled air interface components developed in the project, we also provide a mapping between the technological enablers developed in the project and the KPIs that will be used to assess their performance. Furthermore, we also present a qualitative indication of how each particular enabler will contribute to the KVIs that are in the CENTRIC scope.

These KPIs and KVIs will be revised and verified in deliverable ***D5.3***, due December 2024, where methods for their assessment will be described.

4.1 CENTRIC KPIs

As mentioned above, CENTRIC KPIs are classified into four categories: **conventional KPIs, common-AI KPIs, EMF-related KPIs** and **enabler-specific KPIs.** In the following, these are separately introduced and defined.

4.1.1 Conventional KPIs in CENTRIC

Below is the list of conventional KPIs selected for CENTRIC, provided along with their definitions.

Table 15: Conventional KPIs

KPI	KPI description
Latency	Time elapsed between the beginning and the end of the air interface functionality.
Bandwidth	Maximum aggregated system bandwidth that is supported by single or multiple radio frequency carriers.
Bitrate	Number of transmitted bits per unit time
Outage probability	Probability that an outage will occur during a time period
Energy efficiency	Number of information bits that are transmitted per unit energy consumed, expressed in bits / joule
Signalling overhead	Number of radio signals that needs to be transmitted in order to finalize a specific functionality; as an example, number of pilot signals need to be transmitted to estimate the channel.
Spectral efficiency	Number of information bits that can be transmitted per unit bandwidth.
Reliability	Capability of transmitting a specific amount of traffic within a predetermined time duration with high success probability.
Positioning accuracy	Position estimation accuracy.
Connection Density	Total number of connected and/or accessible devices per unit area
Bit error rate	Number of bits in error relative to the total number transmitted bits
Block error rate	Probability that an entire block of transmitted data contains at least one

4.1.2 Common AI KPIs in CENTRIC

In addition to conventional communication KPIs, the table below describes the list of common KPIs related to AI models developed in CENTRIC.

Table 16: Common AI KPIs

KPI	KPI description
Training complexity	Number of real-valued of operations needed for training an AI model until convergence (assuming fixed input data distribution?).
Inference complexity	Number of real-valued of operations needed for pre-, post-processing, and inference of in an AI model. Can also be characterized as the number of real-valued model parameters.
Storage and computation for life-cycle management	Quantification of storage and computation needed for: training data collection, model update, model monitoring, activation, deactivation, selection, switching, etc.
Model generalization capability	A model's ability to perform under unseen scenarios / data distributions.
Over-the-air overhead	Overhead incurred for assistance information, data collection, model delivery/transfer, and other required signalling.
Simulation-to-real fidelity	The accuracy of a virtual model of a communication network as a function of the computational resources available at the virtual system.
Training complexity	Number of real-valued of operations needed for training an AI model until convergence (assuming fixed input data distribution?).
Inference complexity	Number of real-valued of operations needed for pre-, post-processing, and inference of in an AI model. Can also be characterized as the number of real-valued model parameters.

4.1.3 Relevant EMF-related KPIs in CENTRIC

Based on the state-of-art analysis in Section 2.4, the EMF-KPI here proposed are:

Specific Absorption Rate (SAR, W/kg): which is the power absorbed per mass unit and measure for the absorption of electromagnetic fields in materials. *SAR* can be specified over different masses to better match particular adverse health effects; for example, SAR_{10g} represents the power absorbed (per kg) over a 10-g cubical mass, and whole-body average *SAR* represents power absorbed (per kg) over the entire body. *SAR* is defined as:

$$SAR = \frac{\delta}{\delta t}\left(\frac{\delta W}{\delta m}\right) = \frac{\delta}{\delta t}\left(\frac{\delta W}{\rho \delta V}\right) \qquad (4)$$

i.e., the time derivative of the incremental energy consumption by heat, δW, absorbed by or dissipated in an incremental mass, δm, contained in a volume element δV, of a given mass density of the tissue (kg/m^3), ρ, and is expressed in watt per kilogram (W/kg).

Dielectric properties of biological tissues or organs are generally considered as dielectric lossy material and magnetically transparent because the relative magnetic permeability (μ_r) is 1. Therefore, the *SAR* is usually derived from the following equation:

$$SAR = \frac{\sigma |\boldsymbol{E}|^2}{\rho} \qquad (5)$$

where σ is the conductivity (S/m) and $\boldsymbol{E}$ is the internal electric-field (root mean square (rms) value).

Absorbed power density (S_{ab}, W/m^2): provides a measure of the power absorbed in tissue that closely approximates the superficial temperature rise. A formula for absorbed power density is based on the Poynting vector ($\boldsymbol{S}$):

$$S_{ab} = \iint_A Re[\boldsymbol{S}] \cdot d\boldsymbol{s}/A \qquad (6)$$

Where $Re[\boldsymbol{S}]$ denotes the real part of the Poynting vector and $d\boldsymbol{s}$ is the integral variable vector with its direction normal to the integral area A on the body surface.

Electrical field strength (*E*, V/m): which is the unperturbed root mean square (rms) values of the incident electric field strength.

Magnetic field strength (*H*, A/m): which is the unperturbed root mean square (rms) values of the incident magnetic field strength.

Power density (*S*, W/m^2): which is the power per unit area normal to the direction of propagation and is related to the electric and magnetic fields by the expression:

$$S = \boldsymbol{EH} = \frac{|\boldsymbol{E}|^2}{377} = 377|\boldsymbol{H}|^2 \qquad (7)$$

The EMF-related KPIs are summarized in the table below:

Table 17: EMF-related KPIs

KPI	KPI description
Specific Absorption Rate (SAR, W/kg)	power absorbed per mass unit and measure for the absorption of electromagnetic fields in materials
Absorbed power density (Sab, W/m^2)	power absorbed in tissue that closely approximates the superficial temperature rise

Electrical field strength (E, V/m)	unperturbed root mean square (rms) values of the incident electric field strength
Magnetic field strength (H, A/m):	unperturbed root mean square (rms) values of the incident magnetic field strength
Power density (S, W/m^2):	power per unit area normal to the direction of propagation

4.1.4 Mapping of CENTRIC KPIs to the Technological Enablers Developed in CENTRIC

Using the KPIs defined in Table 15, Table 16, and Table 17, the following table shows the most relevant KPIs for the different technological enablers developed in CENTRIC WP2, WP3, and WP4. In addition, for some of the enablers we also include other intermediate KPIs that are only relevant to that particular enabler.

Table 18: Mapping between Technological Enablers developed in CENTRIC and their relevant KPIs.

Work Package	Technological enabler	Conventional KPIs (see Table 15)	Common AI KPIs (see Table 16)	EMF-related KPIs (see Table 17)	Enabler-specific KPIs
WP2	**Model predictive control**	Latency, energy efficiency, reliability	Inference complexity, simulation-to-real fidelity, model generalization capability		
	In-context learning	Spectral efficiency, signalling overhead	training complexity, inference complexity, simulation-to-real fidelity, model generalization capability		
WP3	**AIML-enabled CSI compression**	Spectral efficiency, signalling overhead,	Training complexity, inference complexity, model generalization capability		Squared generalized cosine similarity (SGCS), compression ratio
	ALML based MIMO precoding	Bitrate, spectral efficiency	Training complexity, inference complexity, model generalization capability		
	Joint sensing and communication	Bitrate, block error rate	Training complexity, inference complexity.		
	Multi-user MIMO Neural Receiver	Block error rate	Training complexity, inference complexity, model		

			generalization capability		
	ML-enabled symbol modulation	Bitrate, spectral efficiency, energy efficiency, bit error rate	Training complexity, inference complexity, model generalization capability		Symbol-error rate
	AIML aided Beam management	Latency, spectral efficiency, block error rate	Training complexity, inference complexity, model generalization capability		Beamforming gain
WP4	**DCI compression**	Spectral efficiency	Inference speed		Lossless compression ratio
	Emerging multiple-access protocols for specialized services	Bitrate	Training & inference complexity		Collision rate
	Task-oriented cognitive wireless scheduling	Uplink bitrate, latency of control-commands	Inference speed at UEs		Success rate of robotic task
	ML-based sub-band selection	Bitrate	Training loss, robustness to scenario generalization		interference, SINR
	Probabilistic Time Series Conformal Risk Prediction	Bitrate (geomean), latency, energy-efficiency			
	EMF reduction via AI-enabled cell-free networking			Modulo of Electric Field, Power Density, Specific Absorption Rate (SAR)	

4.2 CENTRIC KVIs

As discussed in Section 3, most key values that will be targeted by 6G need to be evaluated and assessed in relation with a particular use-case. This is due to the fact that the beneficial and adverse effects that 6G networks will have on global society will mostly be realized through the end-user applications that they will enable. With CENTRIC being a use-case agnostic project which focuses mainly on generic technological enablers rather than on specific 6G use cases (e.g., holographic communications or telemedicine), it will be difficult for CENTRIC to assess the impact of our developed technologies on societal Key Values. In CENTRIC's view, such an assessment should instead be taken upon by other projects, like Hexa-X II, that have a stronger focus on use-cases and deal with a more holistic, end-to-end view.

An exception to the above reasoning is the Key Value of Sustainability. CENTRIC's vision has a strong emphasis on developing technological enablers that contribute to the goal of a sustainable 6G network. Such sustainability can be understood from, mainly, three dimensions:

- **Environmental sustainability**
- **Economic sustainability**
- and **Societal sustainability**

4.2.1 Environmental sustainability

By environmental sustainability, we include the impact that CENTRIC technologies will have on different environmental aspects, such as the carbon footprint of future 6G networks, or the potential reductions in the amount of disposed materials and/or materials that can be circularly re-used. Hence, in relation to the key value ***Environmental Sustainability,*** we define two KVIs:

- **Energy efficiency improvements:** energy efficiency refers here to the overall energy used to deliver a given 6G service to the user. Since CENTRIC's focus is on the air interface, energy efficiency gains should be measured as the amount of energy required to deliver a given number of information bits. In addition, CENTRIC should focus on quantifying two main sources of energy consumption: 1) the energy radiated by wireless transceivers, and 2) the energy devoted to training, managing, and performing inference tasks in the researched AI models.
- **Material efficiency improvements:** material efficiency is defined here following the ITU Recommendation ITU-T L.1023 [16], which proposes a methodology to identify an information and communication technology (ICT) good's circularity. It is evaluated according to three aspects: 1) the ICT good durability, 2) the ICT good ability to be recycled, repaired, reused, and upgraded, and 3) the manufacturer's ability to recycle, repair, reuse and upgrade the ICT good put into the market.

4.2.2 Economic sustainability

Economic sustainability refers here to reductions of the total cost of ownership (TCOs) for 6G providers. In particular, two KVIs are targeted:

- **CAPEX reductions:** CAPEX refers to the sum of capital expenditures, that is, the one-time costs incurred when deploying a network.
- **OPEX reductions:** OPEX refers to the operational expenditure, that is, the recurring costs that are incurred in operating and maintaining a network.

4.2.3 Societal sustainability

In terms of societal sustainability, we focus on the trustworthiness of 6G networks as experienced by society at large. For this, we focus on the following KVIs:

- **EMF-aware networks:** even if public concerns about alleged health hazards of exposure to electromagnetic fields generated by mobile networks may not be justified, it is undeniable that this aspect has eroded the trust of a significant segment of society.

Hence, the ability to show that EMF exposure concerns are taken into account in their design will improve the trustworthiness of future 6G networks.

- **User data protection and privacy:** another public concern that should be addressed by CENTRIC is that of the user's data protection and privacy. Especially when dealing with AI and ML algorithms that are trained fully or partially on data collected in the field, it is important to reassure users that their privacy and personal data are appropriately protected.

To conclude this section, in Table 19 we present the qualitative contributions that the technological enablers developed in CENTRIC, classified by WP, can make to the above-identified KVIs. Whenever possible, we also include possible proxy KPIs that can be used to, at least partially, quantify the contribution towards the target KVIs.

Table 19: Contribution of CENTRIC technological enablers to sustainability KVIs

Work Package	Technological enabler	KVI contributions	Proxy KPIs to assess contribution
WP2	**Model predictive control**	**- Energy efficiency improvements**: Model predictive control at the digital twin allows the proactive allocation of resources, anticipating changes in connectivity and traffic requirements that may cause a spike in usages of energy and spectral resources.	Reduction in energy and spectral requirements
	In-context learning	**- OPEX reductions:** In-context learning is a data-efficient, "universal", form of meta-learning that does not require explicit optimization, e.g., gradient descent, at run time. Via in-context learning, the network can quickly adapt to changing conditions, reducing sample and computational complexity.	Reduction in number of pilots and computational complexity
WP3	**AIML-enabled CSI compression**	**- Energy efficiency improvements**: CSI compression will reduce the amount of information that needs to be transmitted between the UE and gNB. The smaller CSI payload will lead to decreased energy consumption at both the UE and gNB. -**CAPEX reductions**: CSI compression will result in reduced bandwidth requirement for CSI feedback translating to minimized need for spectrum licenses.	- Compression ratio - Spectral efficiency
	ALML based MIMO precoding	- **Energy efficiency improvements**: AIML based MIMO precoding will reduce unnecessary radiation and hence, energy consumption. This will result in increased energy efficiency. - **CAPEX reductions:** AIML based MIMO precoding will enhance spectral efficiency translating to reduction in capital investments for acquiring more spectrum.	-Bit rate -Spectral efficiency
	Joint sensing and communication	- **Energy efficiency improvements:** AI enabled JSAC can dynamically adjust resource usage for sensing and	-Bit rate -Spectral efficiency

		communication according to real-time channel environment conditions. This will lead to more efficient operation and hence, energy savings. Also, AI will enable energy-efficient sensing operations by intelligently optimizing energy usage while collecting information. - **CAPEX reductions**: JSAC will reduce the need for separate networks and devices to perform communication and sensing tasks translating to CAPEX reductions via elimination of the investment required to deploy and maintain separate communication and sensing systems.	
	Multi-user MIMO Neural Receiver	- **CAPEX reductions:** the developed neural receiver will improve the system's spectral efficiency, translating to reduction in capital investments for acquiring more spectrum.	-Block error rate
	ML-enabled symbol modulation	- **Energy efficiency improvements**: The ability to adapt symbol modulation to channel conditions will result in enhanced spectral efficiency and minimized retransmission.	- Spectral efficiency
	AIML aided Beam management	- **Energy efficiency improvements:** dynamic adjustment of beam directions and power will result in reduced radiation and energy consumption. - **CAPEX reductions**: AIML optimised beam management will lead to improved coverage in specific areas translating to a reduction in the need for additional gNBs or infrastructure to cover the same area.	Beamforming gain Spectral efficiency
WP4	**DCI compression**	- **Energy Efficiency improvements**: DCI compression techniques will reduce the bandwidth needed to transmit the same control data. - **OPEX reductions**: DCI compression will increase network capacity and help the network serve more users in the same bandwidth. Operating margins will thus grow.	-Compression ratio. -PDCCH coding rate.
	Emerging multiple-access protocols for specialized services	- **CAPEX reductions**: The ability to automatically produce protocols to solve a concrete use-case will reduce development efforts significantly.	-Protocol performance (e.g., task success rate).
	Task-oriented cognitive wireless scheduling	- **Energy Efficiency improvements**: The ability to extract abstract semantic concepts from complex use-cases reduces the amount of data that needs to be transmitted for control purposes. This implicitly reduces transmit power.	-Control-Plane bitrate. -Task success rate.
	ML-based sub-band selection	- **Energy Efficiency improvements**: Smart subband selection strategies will minimize the collision rate, and with it, the energy wasted in unnecessary transmissions.	-Collision rate -Geometric mean of network bitrate -SINR statistics

		Interference will also be reduced, thus reducing the power needed to achieve a target signal quality.	
	Probabilistic Time Series Conformal Risk Prediction	- **Energy Efficiency improvements**: The ability to predict confidence in point predictions will necessarily improve control algorithms in multiple fields, among them, radio resource allocation.	-HARQ energy efficiency -Throughput -Delay
	EMF reduction via AI-enabled cell-free networking	- **Energy Efficiency improvements** and **EMF-aware networks**: Smart clustering of cell-free access points will optimize the transmit power needed to achieve a target capacity, while minimizing unnecessary radiation and energy waste.	-Transmit power -SAR -Data rate

5 Conclusions and Future Work

In this deliverable, we provided an exploration of KPIs and KVIs the we propose as tools for measuring and evaluating the enhancements provided by CENTRIC project. The selection and measurement of these indicators will enable CENTRIC track progress and identify areas for improvement brought by the new technologies developed throughout the project. We have exposed critical insights into the unfolding technologies of 6G systems. We have provided a comprehensive analysis of different KPIs and KVIs presented by several European projects and standards such as Hexa-X, 5G-PPP, 3GPPP, etc. This analysis provides a snapshot of the current state and serves as a benchmark for the trajectory of 6G advancements.

We have analysed the traditional KPIs brought by different projects such as the latency, bandwidth, bit rate, spectral efficiency, energy efficiency, etc. We have as well analysed the KPIs provided by artificial intelligence such as model performance, inference complexity, training complexity, overhead, etc. Additionally, we have provided insights into the KVIs presented in several projects that are mainly focused on sustainability such as societal, environmental, and economic sustainability. We have shown that most KVIs are derived and focused on the United Nations Sustainable Development Goals (UN-SDG).

In CENTRIC, we leverage the integration of AI where it will play a pivotal role in enabling air interface. This integration of AI demands in providing new KPIs and KVIs. In our approach, we provided four different lists of KPIs: conventional KPIs, common AI-KPIs, EMF-related KPIs, and enabler-specific CENTRIC-KPIs. Furthermore, we presented a new list of KVIs related to sustainability as follows: economic sustainability, environmental sustainability, and societal sustainability.

Furthermore, our dedication to continuing research will enhance the improvement of KPIs and KVIs, guaranteeing their continued applicability in the face of technological breakthroughs. Strict testing procedures, such as controlled experiments and real-world simulations, will be essential to confirming and strengthening the resilience of the recognized indicators. These will be one of the focus of the work in WP5 of CENTRIC, and the outcome will be documented in the sequel of this deliverable, D5.3, which will be due by the end of 2024.

With this commitment, we aspire to contribute significantly to the realization of a resilient and high performance 6G that meets the demands of the interconnected world.

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