Grant Agreement No.: 101139070 (SNS JU)
DOI number: 10.5281/zenodo.14592217

6G4SOCIETY

D1.1 SOCIETAL ASPECTS IN 6G TECHNOLOGY: CONCERNS, ACCEPTANCE MODELS AND SUSTAINABILITY INDICATORS

Revision: v.1.0

Work package	WP 1
Task	Task 1.1, Task 1.2, Task 1.3
Due date	30/09/2024
Submission date	15/11/2024
Deliverable lead	CEL
Version	1.0
Authors	Margot Bezzi (CEL, main author Section 3) Lucas Pereira Carwile (CEL, main author Section 5,6) Luigi Briguglio (CEL, Section 6), Carmela Occhipinti (CEL, Section 6) Katrina Petersen (PSCE, main author Section 4)
Reviewers	Eleni Chamou (NOVA), Anna Aseeva (D4P), Giota Lilli (eBos)
Abstract	This document consists of a foundational analysis to address societal dimensions of 6G technology development. This is done through focusing on three main concepts: societal impact, values, and social acceptance. The intention is twofold; on the one hand to explore the complexity of the notion of acceptance in the 6G specific technological context; on the other hand, introducing reflections and tools to support the integration of sustainability and

Co-funded by the European Union

Project funded by
Schweizerische Eidgenossenschaft
Confédération suisse
Confederazione Svizzera
Confederaziun svizra
Swiss Confederation
Federal Department of Economic Affairs, Education and Research EAER
State Secretariat for Education, Research and Innovation SERI

social considerations into 6G development from the outset. In line with the three concepts explored, the work provides an overview of broader societal transformations connected to 6G; an exploration of how KVIs are already being used in 6G innovation; an approach to define Key Sustainability Indicators (KSIs); an assessment of the analysis of current controversies related to the 5G technology; and a method called Social Acceptance of Technology (SAT), to analyse social acceptance in the context of 6G. Drawing on experiences from 5G and current technological trends, the analysis equips stakeholders with practical tools and guidance to integrate societal and sustainable values into 6G development from the beginning, accounting for societal needs and impacts. Aligned with EU priorities, this work promotes responsible technological innovation by embedding social and environmental considerations into technology development processes. It also supports the EU's goals for digital sovereignty, inclusive governance, and societal benefits, fostering transparent public engagement and participation. The deliverable's findings and tools lay a foundation for the SNS community's future research, particularly in areas related to sustainability, social acceptance, and stakeholder engagement. They ensure that 6G advancements align with European values, ultimately contributing to broader societal objectives.

Keywords 6G, societal concerns, social acceptance, societal values, values indicators, sustainability

Document Revision History

Version	Date	Description of change	List of contributor(s)
V0.1	11/04/2024	Creation of the document with the ToC	CEL
V0.2	22/06/2024	Progressive development of all sections	CEL, PSCE
V0.3	30/09/2024	Finalised content insertion for all sections	CEL, PSCE
V0.4	22/10/2024	Restructured ToC and order of sections and of paragraphs; continuous improvement of contents and internal coherence.	CEL, PSCE
V0.7	28/10/2024	Version incorporating comments and improvements from authors' internal cross-reading	CEL
V0.8	30/10/2024	Finalisation of the document for peer-review process	CEL, PSCE
V1.0	14/11/2024	Final release	CEL
V1.0	15/11/2024	Submission	MAR

Project funded by

Co-funded by the European Union

Schweizerische Eidgenossenschaft
Confédération suisse
Confederazione Svizzera
Confederaziun svizra
Swiss Confederation

Federal Department of Economic Affairs, Education and Research EAER
State Secretariat for Education, Research and Innovation SERI

The 6G4SOCIETY project has received funding from the Smart Networks and Services Joint Undertaking (SNS JU) under the European Union's Horizon Europe research and innovation programme under Grant Agreement No 101139070. This work has received funding from the Swiss State Secretariat for Education, Research and Innovation (SERI).

Project co-funded by the European Commission in the Horizon Europe Programme		
Nature of the deliverable:	**R**	
Dissemination Level		
PU	*Public, fully open, e.g. web (Deliverables flagged as public will be automatically published in CORDIS project's page)*	✓
SEN	*Sensitive, limited under the conditions of the Grant Agreement*	
Classified R-UE/ EU-R	*EU RESTRICTED under the Commission Decision No2015/ 444*	
Classified C-UE/ EU-C	*EU CONFIDENTIAL under the Commission Decision No2015/ 444*	
Classified S-UE/ EU-S	*EU SECRET under the Commission Decision No2015/ 444*	

* R: Document, report (excluding the periodic and final reports)

DEM: Demonstrator, pilot, prototype, plan designs

DEC: Websites, patents filing, press & media actions, videos, etc.

DATA: Data sets, microdata, etc.

DMP: Data management plan

ETHICS: Deliverables related to ethics issues.

SECURITY: Deliverables related to security issues

OTHER: Software, technical diagram, algorithms, models, etc.

EXECUTIVE SUMMARY

6G represents a profound shift; not merely an upgrade from 5G, but a transformation of human experience across the dimensions of space, time, body-technology interaction, and social dynamics. Grounded in lessons learnt from 5G, and on the overarching goal of better understanding the dynamics underpinning social acceptance, this document aims at better describing the relationship between 6G and society. This is done through focusing on three main concepts: societal impact, values, and social acceptance. The intention is twofold; on the one hand to explore the complexity of the notion of acceptance in the 6G specific technological context; on the other hand, introducing reflections and tools to support the integration of sustainability and social considerations into 6G development from the outset. In line with the three concepts explored, the work results in three key contributions: an overview of broader societal transformations connected to 6G; an approach to define Key Sustainability Indicators (KSIs); and a framework to analyse social acceptance in the context of 6G.

As concerns impact, the exploration of broader socio-cultural transformations driven by 6G technological advancements, beyond its intended technical benefits, is critical to anticipate issues possibly connected with social sustainability. Through the examination of emerging technological and social trends triggered by digital communication, and of their socio-cultural implications, the research stresses how changes in information and communication environments transform society at a deep level. Key 6G features, such as digital hyperconnectivity and immersive communication, are explored for their sociological significance. These technologies have the potential to transform perceptions of time, space, and human sensory experiences, ultimately reshaping self-identity, human interaction dynamics, and societal structures. These evolving dynamics demand careful consideration, for their possible implications on social and right dimensions such as individual autonomy, privacy, social inclusion, well-being. In this sense, understanding impact helps ensuring technology acceptability, while facilitating social acceptance. The analysis then prompts reflection on the values and assumptions guiding 6G's design and their alignment with societal aspirations, pointing out how orientation or design choices are never neutral, and how assumptions - often taken for granted and acting beneath the threshold of awareness - affect the vision of the future, the criteria for setting priorities and objectives, problem-solving approaches, and implementation paths.

The work on values focuses especially on the current effort of SNS (Smart Networks and Services) projects in incorporating key values into 6G technological development, with a view to elaborates the background necessary to build a framework for Key Sustainability Indicators (KSIs). Recommendations are made for further clarifying the goals and process by which values are translated into action for 6G, acknowledging the different ways value can be understood and become part of technology, and assessing the current activities within SNS projects working with Key Value Indicators (KVIs). The section then presents the steps required in order to build a framework of Key Sustainability Indicators (KSIs), which addresses environmental, economic, and societal sustainability in an integrated manner. This framework outlines a preliminary ontology of societal sustainability, mapping key values and their interrelationships, addressing overlaps and gaps between policy, strategy, and public sentiment. Recommendations clarify how these values translate into actionable goals for 6G, emphasising the importance of aligning Key Performance Indicators (KPIs) with these societal goals, drawing on lessons from similar sectors. The section also addresses the issue of trade-off between different values, pointing out how a true holistic approach to value integration shall overcome conflicts or hierarchies between values, towards a system where sustainability becomes foundational for, and inseparable from, the value proposition – as it is the case for values such as security or privacy.

The exploration on social acceptance of 6G starts by examining the relationship between emerging technologies and society through the lens of public controversies, with particular focus on the 5G experience. In particular, by reflecting on 5G's public trust issues and controversies, the analysis underlines the importance of inclusive governance and transparent communication for 6G acceptance. The analysis reveals how 5G controversies evolved into fundamental governance challenges, highlighting tensions between national objectives and local autonomy, the complex interplay between legitimate dissent and misinformation, and the critical role of public trust and communication. Through case studies from France, Switzerland, and Italy, the section demonstrates how infrastructure-based innovations like 5G require collective rather than individual acceptance, emphasizing the need for inclusive decision-making processes. Misalignment between public and industry perspectives on risk and values, such as health concerns and privacy, posed challenges that offer essential insights for 6G.

These learnings informed the development of the Social Acceptance of Technology (SAT) framework, a tool designed to analyse and evaluate acceptance across four dimensions: Social Disruptiveness, Value Impact, User Experience, and Trust. The framework intends overcoming a notion of acceptance based on adoption metrics and individual interactions, widening the exploration to broader societal implications, systemic shifts, value system considerations, and the influence of dynamics on the public and democratic sphere. Also, the framework introduces a nuanced approach to stakeholder identification that goes beyond traditional metrics of power, legitimacy, and urgency, to include consideration of potential harm, ensuring representation of passive stakeholders who may be impacted by the technology but lack direct influence over its development. The SAT framework, through its anticipatory approach and its attention to the wider governance and social environment, puts forward an interpretation of acceptance as a complex process, rather than a fixed outcome. The framework is designed to be both modular and scalable, allowing for application across different levels of analysis from systemic to individual, and adaptable to various stages of technology development. In the context of 6G, it supports the alignment between technology development, societal values, and the EU's goals for sustainability, inclusivity, and digital sovereignty.

As a main contribution, this document seeks to open a discussion for further research and reflection, sparking curiosity, prompting questions, and be an initial step towards a more thorough exploration of societal and environmental sustainability within the context of 6G technology development. Through a multi-perspective analysis of the concepts of impact, values and acceptance, and by synthetising them into actionable frameworks, it provides actionable insights for the SNS community and other stakeholders. It lays a strong foundation for integrating EU-aligned values into 6G's development, ultimately ensuring that this emerging technology resonates with public interests and contributes to long-term societal benefits.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

ABBREVIATIONS

3GPPP	Third Generation Partnership Project (The Mobile Broadband Standard)
5G	Fifth generation mobile network
6G	Sixth generation mobile network
AI	Artificial Intelligence
AIE	Associazione Italiana Elettrosensibili (Italian Electrosensitive Association)
AR	Augmented Reality
ATIS	Alliance for Telecommunications Industry Solutions (USA)
CA	Consortium Agreement
CSA	Coordination and Support Action
DG CONNECT	Directorate General for Communications Networks, Content and Technology of the European Commission
DMP	Data Management Plan
DoA	Description of Action
DOI	Diffusion of Innovation
EC-GA	European Commission Grant Agreement
ELSA	Ethical, Legal and Social Aspects
EMF	Electromagnetic field
ETNO	European Telecommunications Network Operators' Association (now Connect Europe)
EU-US TCC	EU-US Trade and Technology Council
FOMO	Fear of Missing Out
GDPR	General Data Protection Regulation (EU 2016/679)
GMO	Genetic Modified Organism
GSMA	GSM Association
HCI	Human Computer interaction
IAIA	International Association for Impact Assessment
IARC	International Agency for Research on Cancer
ICNIRP	International Commission on Non-Ionizing Radiation Protection
ICT	Information and Communication Technologies
IoT	Internet of Things
ITU	International Communication Union

KPIs	Key Performance Indicators
KSIs	Key Sustainable Indicators
KVIs	Key Value Indicators
LEED	Leadership in Energy and Environmental Design
LBS	Location-based service
ML	Machine Learning
NTN	Non-terrestrial Network
OECD	Organisation for Economic Cooperation and Development
PPP	Public-private partnership
RF-EMF	Radiofrequency - Electromagnetic field
RRI	Responsible Research and Innovation
R&D	Research and Development
R&I	Research and Innovation
SAT	Social Acceptance of Technology
SDGs	Sustainable Development Goals
SNS-JU	Smart Network System - Joint Undertaking
SSH	Social Sciences and Humanities
STEM	Science, Technology, Engineering and Mathematics
STS	Science and Technology Studies
TAM	Technology Acceptance Model
TRA	Theory of Reasoned Action
TRL	Technology Readiness Level
UAM	Urban Air Mobility
UN SDGs	United Nations Sustainable Development Goals
UTAUT	Unified Theory of Acceptance and Use of Technology
UX	User Experience
VR	Virtual Reality
XR	Extended Reality

1 INTRODUCTION

This document addresses the need for a better understanding of 6G (sixth generation mobile network) technology in its relationship with the wider societal context where technology is expected to nest. The deliverable has been identified in the Description of Action (DoA) as 6G4Society Deliverable D1.1 "Societal aspects in 6G Technology: Concerns, acceptance models, and sustainability indicators", and elaborates on the results of three distinct tasks, focusing on three interconnected aspects of the complex relationship between technology and society: T1.1 "Societal impact of 6G Technology", T1.2 "Technology Acceptance Models for 6G Technology" and T1.3 "Key Sustainability Indicators for 6G Technology".

The primary goal of this document is to offer the 6G-IA community and society at large a comprehensive analysis, incorporating perspectives from the Social Sciences and Humanities (SSH), to understand the societal impact of 6G technology and promote a new development mindset focused on core dimensions such as responsible research and innovation, societal values, social acceptance, and sustainability.

The analysis highlights concerns, challenges, theories, and models through an extensive literature review. Its aim is to help in interpreting current policy objectives and public debates, highlighting areas that require further research or reflection. In particular, the authors believe that the reflections initiated here can constitute a first fruitful step to feed a more comprehensive reflection on the concepts of societal and environmental sustainability in the framework of other projects in the SNS community, identifying potential concerns affecting the trustworthiness of the 6G value chain, and proposing countermeasures for its development based on responsible innovation principles.

1.1 RELATION TO PROJECT WORK

The general indications for the project deployment have been defined in the European Commission Grant Agreement (EC-GA), the Description of Action (DoA), the Consortium Agreement (CA), the Project Handbook (D5.1), the "Ethics and Legal Guidelines" (D5.4) and the "Data Management Plan" (D5.5). As a result, the present deliverable D1.1 "Societal aspects in 6G technology: concerns, acceptance models and sustainability indicators" does not replace any of these established agreements and outcomes, and partners should abide by the following order of precedence:

- European Commission Grant Agreement (EC-GA)
- Commission Rules
- Consortium Agreement (CA)
- D5.1: Project Handbook
- D5.4: Ethics and Legal Guidelines
- D5.5: Data Management Plan (DMP)
- D1.1: Societal aspects in 6G technology: concerns, acceptance models and sustainability indicators (present document)

1.2 STRUCTURE OF THE DOCUMENT

The document is divided into 7 sections, the references and four annexes.

TABLE 1: STRUCTURE OF D1.1. SOCIETAL ASPECTS IN 6G TECHNOLOGY

	Section title	Summary
Section 1	**Introduction**	A brief explanation of the objectives of the deliverable, its relation to other project documents and structure of the present deliverable.
Section 2	**Methodology and approach**	This section describes the methodology and approach behind the study carried out by the present deliverable.
Section 3	**Societal impact of 6G**	This section identifies and analyses potential impacts of 6G technology on society, based on the analysis of the transformations concerning the information and communication context.
Section 4	**6G, sustainability, and societal Values**	This section identifies and analyses societal values to be considered within a responsible development and innovation of 6G for ensuring sustainability.
Section 5	**Understanding acceptance through controversies on the public sphere**	This section identifies and analyses factors impacting social acceptance of mobile network technologies, through a collection of representative controversies on the public sphere.
Section 6	**6G and social acceptance**	This section describes models and theories of technology acceptance from the literature review, identifying limits and improvements, therefore promoting a new social acceptance of technology methodological framework.
Section 7	**Key findings and conclusions**	This section closes the document with relevant findings of the activities on societal perspectives carried out during the first months of the 6G4Society project.
	References	This section provides the list of references to scientific publications used for the present deliverable
Annex I	**A glimpse on specific application scenarios**	This annex provides a glimpse on specific application scenarios in the following sectors: health-care and well-being, digital and online learning, entertainment and media consumption, industrial and business sector

Co-funded by the European Union

Annex II	**Health and safety debate around 5G**	This annex provides a summary of the ongoing debate regarding the potential health impacts of 5G technology
Annex III	**Examples of 5G controversies in the EU**	This annex provides three examples of 5G controversies in France, Switzerland, Italy.
Annex IV	**A common example of mistrust and distrust**	This annex provides the description of a petition against 5G antennas, authored by a community in Italy.

2 METHODOLOGY AND APPROACH

The ability to understand the variables and dynamics that influence social acceptance of emerging technologies, as well as to contribute effectively to the development of a sustainable digital supply chain, has garnered increasing attention in recent years, particularly within EU-funded research. In the context of 6G, as the standardisation phase approaches, these topics have become even more relevant, especially given the global waves of discontent that accompanied the rollout of 5G. Recognising these challenges, the SNS JU issued a call for projects to specifically address the complex relationship between technology and society. Key areas of focus include social acceptance, the societal impacts of 6G, the integration of societal values into technology development, and the promotion of better governance in information and communication processes to bridge the gap between expert knowledge and the general public.

Building on the overarching goal of studying social acceptance and identifying the variables and dynamics that shape it, the work of *6G4Society* addresses these challenges. This deliverable, in particular, provides an initial exploration of these issues by combining the findings from three different tasks, as outlined in the introduction. It focuses on three key, interrelated aspects that influence the relationship between technology development and society: (i) societal impact (covered in section 3); (ii) values (discussed in section 4); and (iii) social acceptance, including the dimension of controversies (covered in sections 5 and 6). While each section focuses on one of these aspects based on the findings from specific tasks, these dimensions are interconnected and mutually influence each other.

The following sections will make these relationships more explicit, clarifying the relevance and contribution of each dimension to the challenge of understanding and improving the governance of the complex interplay between technological development and its adoption by society.

2.1 IMPACT AND VALUES

Values and impact are particularly significant in the development of 6G, as it is expected that 6G will integrate certain values from the outset and aim to create societal value (i.e., generate positive societal impact). As concerns their interplay, we identify two principal relationships.

Societal values play a crucial role in shaping the impact of technology on society. Values influence technological development, as they underpin the overall direction of technological progress, through the choices of research priorities, policy objectives, industrial strategies and ultimately of use-cases. These choices – often unconsciously – reflect the broader value system and the assumptions ingrained in a particular culture. For instance, current technology development objectives - such as the pursuit of ubiquitous connectivity - result from a culture that considers hyperconnectivity as a value in itself, following the dream of universal connection originated in the Silicon Valley. Another underlying value and assumption orienting innovation priorities is the prioritisation of “quantity” and “more” —more devices, more data, more access. Yet another example is the focus on automation in many sectors, which is based on the values of efficiency and productivity over human-centred considerations like job preservation or impact on well-being. Similarly, when prioritising certain use cases over others, or setting specific objectives for these use cases, these decisions are guided by one's broader underlying value system. Finally, when evaluating the impacts of a technology— determining what constitutes a negative externality, weighing trade-offs, or setting thresholds for what outcomes are acceptable or not — we do so, based on a hierarchy of values. In this way, values shape the criteria used to define what is considered a positive or negative impact.

The relationship between impact and values is explored in detail in section 4, while the potential societal impacts of 6G are discussed in section 3.

Technology can influence and transform societal values. One way to interpret technological innovation is by analysing the cultural changes it drives at the value level. For example, the advent of hyperconnectivity has led to significant shifts in societal values. The frictionless capacity to access a wide abundance of digital contents, combined with the interaction dynamics shaped by social media platforms, translated into the redefinition of the concept of privacy and personal space, changing our perception of what is allowed to be shared in public. The emancipation from the obligation to perform certain tasks in certain specific places, led to different interiorised expectations as to the balance between work and personal life. Frictionless digital interaction changed our perception as to the privileged position that face-to-face interaction used to hold in society. The overabundance of hyper-accessible content or experiences, diminished the value and significance of any given cultural object or product in the digital sphere. The velocity of interactions, the immediacy of responses and the habit to instant gratification changed our perception as to what is a reasonable time to invest in activities or persons. The interaction logic promoted by social platform, - valuing interactions, followers or sharing rate – promote popularity as the first measure of cultural value.

This aspect is addressed in section 3.

2.2 IMPACT AND ACCEPTANCE

The impact of technology influences social acceptance. A perceived positive impact tends to foster greater acceptance, while a perceived negative impact —often related to environmental or social sustainability, particularly health concerns— can lead to challenges in social acceptance and controversies within communities. Understanding impact-related concerns or possible undesired impacts can support decisions at the design, development or deployment phase, in directions that may be conducive to higher acceptance. For this reason, the concept of impact—in the form of social disruptiveness—serves as a key variable in our proposed framework for studying the social acceptance of technology.

The relationship between impact and acceptance is explored in detail in section 6, while section 3 delves deeper into the specific societal dimensions affected by the evolving technological landscape. Moreover, section 5 deals with controversies as a means to understand acceptance.

2.3 VALUES AND ACCEPTANCE

Values can enhance social acceptance. The value dimension plays a key role in shaping acceptance, as it is often easier to gain acceptance when there is a perceived alignment with a particular value system. Technologies that consciously incorporate and reflect values that are deemed important by a specific user group or social community are more likely to be accepted.

A detailed analysis of the values relevant to the 6G development process is provided in section 4, with a particular focus on ongoing research within the SNS community on Key Value Indicators. This work lays the foundation for more advanced research on Key Sustainability Indicators for 6G, particularly investigating the relationship between these two frameworks. Section 6 further explores how values must be considered when analysing factors influencing acceptance.

Acceptance helps in exploring values. Exploring the complex phenomenon of acceptance can provide insights into the values that are important to a particular user or social group. Similarly, analysing controversies reveals the values and priorities that are perceived as neglected or marginalised. In this sense, controversies can help us understand the values that are most significant and prioritised by certain societal groups.

The relationship between values and acceptance is discussed in section 6, where it is positioned as a key variable in our framework for studying the social acceptance of technology. Section 5 examines controversies surrounding science and technology, showing how their analysis can help interpret public friction as a clash between different value systems and priorities across various social groups and forces.

This work aims to provide an initial, non-exhaustive exploration of concepts and theories that can aid in understanding and interpreting current policy objectives and challenges in the domain of 6G. The original contribution of this work can be identified in several key areas:

- Bridging different stakeholder worlds—academia, industry, the public, and policymakers—as well as integrating different fields of knowledge, such as the humanistic and sociological perspectives on technology with the engineering-focused approach of the industry.
- Applying sociological interpretations to the specific field of 6G, which remains largely unexplored from a sociological standpoint. Most available studies tend to address broader topics such as the digital transformation, the Internet, or hyperconnectivity in general.

This deliverable’s intention is not to provide definitive answers or solutions, which is challenging given the complexity of the environment we are working in and the scope of this work. Instead, it aims at showing directions for further research and reflection, taking the first steps toward a more comprehensive examination of societal and environmental sustainability within the framework of other projects in the SNS community.

3 SOCIETAL IMPACT OF 6G

The 5G Infrastructure Association [1] defines 6G as "one of the basic foundations of human societies of the future." This vision highlights the pervasive and profound impact 6G will have on society. Pervasive, because it will be embedded in every aspect of life, transforming all levels of infrastructure, services, and applications through an intertwined ecosystem of technologies. Profound, because it will reshape the boundaries between human beings and technologies, ultimately dissolving them. 6G is poised to finalise the digital transition of society, "targeting massive of societal and business processes through intelligent connectivity across the human, physical, and digital worlds." [2]

The societal impact of 6G extends far beyond its technical functionality and intended applications. This section explores these impacts, beginning with an overview of existing descriptions of 6G impact (section 3.1), then illustrates the expected outcomes as conceived by industrial stakeholders involved in 6G's design and development (section 3.2). The analysis then shifts to a social science perspective (section 3.3), establishing the project methodology to contribute to ascertain the social impact of 6G technology in terms of mega-trends and related socio-cultural transformations due to the adoption of 6G, with particular reference to two big aspects defining 6G: ***hyperconnectivity*** and ***immersive communication***. Finally, through a relativising lens, section 3.4 questions whether the assumptions and values driving current technological development truly align with the future society we aspire to, revealing that design choices are not neutral. These decisions deeply affect human experience, shaping identity, relationships, ethical principles, and perceptions of desirability.

3.1 GENERAL OVERVIEW OF EXISTING ANALYSES OF 6G IMPACT

The complexity and unpredictable nature of societal variables make it very challenging to fully understand or anticipate the impacts that technologies (especially emerging ones) may produce in a broader sense, beyond their intended use and applications. The co-evolution and interplay between technology and society makes it so that the infinite and unique combinations of situations and settings where such technology will be used (e.g., specific use-cases, territorial contexts, and users) generate unpredictable outcomes, and chains of broader societal implications. These by definition cannot be outlined with certainty, nor can risks be quantified or identified specifically.

Despite these challenges, the following explores the wide and pervasive transformative power that the modification of the information and communication infrastructures may trigger in society. In particular, the current document aims to illustrate the extent to which 6G developments are relevant in terms of their impact on the human dimension. It underscores the sensitivity and importance of approaching the development of this technological system with a heightened awareness and a thoughtful, well-informed exchange of ideas and perspectives.

In the monitoring and evaluation practice, especially the one used to evaluate strategies, policies, programmes or projects in the international cooperation sector, impact is an evaluation criterion defined through a number of different oppositional and possibly overlapping concepts: **direct/indirect**; **intended/unintended**; **expected/unexpected**; **short-**

term/long-term. Following the OECD definition, impact can be defined as “the extent to which the intervention has generated or is expected to generate significant positive or negative, intended or unintended, higher-level effects” [3]. Also, impact seeks to capture the “social, environmental and economic effects of the intervention that are longer term or broader in scope”, and go beyond the immediate results of the intervention, assessed under the effectiveness criterion. The aspects that this definition stresses more are the “indirect, secondary and potential consequences of the intervention” and the “ultimate significance and potentially transformative effects of the intervention”, to be sought at a holistic and structural level, by “examining the holistic and enduring changes in systems or norms, and potential effects on people’s wellbeing, human rights, gender equality, and the environment”.

Currently, a rich corpus of 6G-related documents and studies focuses on intended and/or possibly expected effects of 6G, stressing especially (although not only) the wide-ranging anticipated benefits and immediate positive outcomes promised by technological advancements, at the level of the global economy or of the environment. These effects are mostly linked to intended purposes, as conceived in the visions and intentions of technology developers and designed during industrial research and innovation processes. Normally, they are directly attributable to the *actions* of these technologies: they may concern direct effects of improved technological performances (e.g., enhanced communication and network performances) as well as impacts generated in specific economic sectors (e.g., health, the environment, education, and labour) through specific sectoral applications and services. Overall, these impacts tend to paint an optimistic picture of seamless connectivity, heightened efficiency, and unprecedented convenience.

As concerns secondary effects (externalities, or footprints), they are identified and mentioned. However, for instance in the framework of Hexa-X-II work, the project explains that their work intentionally confines its analysis scope to only first and second-order effects of technology, acknowledging how “due to the complexity of social, economic, and ecological systems, [and] due to infeasible predictability and uncertainty, higher-order effects can take many paths and may be subject to rebound effects and other externalities […]. Additionally, most handprints and footprints depend on the final use that people will give to the technology. Therefore, the impacts listed emerge from the foreseeable potential usage scenarios the proposed use cases will enable” [4].

Regarding reflections on broader social impacts, a thorough work exists on 6G [5], based on exploratory, alternative scenarios revolving around the combination of key drivers and uncertainties identified by a group of experts. Three are the main societal dimensions explored: markets, ICT technologies, and technology regulations and policies, with a particular attention to the evolution, sustainability, and value creation of telecommunications business models. The approach has the merit of highlighting some complex interrelationships amongst different stakeholders’ worlds and interests, as well as the repercussions of these evolutions on society at large. The perspective at the basis of the work, however, is primarily focused on business, and is aimed at stressing the opportunities linked to the evolution of business and market aspects of 5G and 6G by describing what technology will enable across macro-sectors of society (i.e., with broad generalisations concerning the variety of social groups and needs). As such, this work seems to build on several underpinning assumptions that normally go unchallenged in the R&I domain, like the presumption that technological development shall find its way to market and be widely adopted, or that technological innovation is poised to produce positive relapses at the societal level.

In general, the prevailing approach to smart network development focuses on the immediate and intended benefits derived from the improvements of speed and quality. In turn, the wider impact on the human and social sphere linked to the widespread uptake of certain technological innovation are less addressed, due to their challenging and uncertain nature. The following list captures the impact categories raising more challenges or less explored:

- **Indirect, longer-term and broader socio-cultural impact.** From a socio-technical perspective, the transition to 6G is expected to trigger significant, often unintended changes in individual and societal dynamics. Among these, unintended impacts may manifest as social disruptions, ethical dilemmas, or environmental consequences that could shape our future society. A more reflexive and critical approach would help in examining the broader, long-term societal implications of this technology. This approach aims to identify and address potential drawbacks, such as societal externalities or problematic aspects in human and social spheres, before they fully emerge.
- **Unexpected negative impacts.** Outside the specific category of positive and intended impacts, negative impacts should be taken into account. Some negative impacts may be predictable, taking the form of negative externalities of a process (e.g., environmental), and calling for the necessity to trade-off between conflicting values (e.g., security and data management vs privacy). However, other negative impacts are not predictable and emerge overtime as a complex interplay among societal variables. Some of these, with proper analysis can be anticipated, necessitating a proactive and comprehensive approach to studying their long-term effects.
- **Social impact**. Following the definition of the International Association for Impact Assessment (IAIA), social impact includes all intended and unintended social consequences, both positive and negative, of planned interventions and any social change processes intended by those interventions. The concept of social impact, by definition, covers a wide-ranging set of aspects, comprising both immediate effects and broader or more indirect societal implications. Key dimensions of social impact include:
    - culture (shared beliefs, customs, values and language);
    - way of life (how people live, work, play and interact with one another; the quality of their relationships);
    - social cohesion and stability (including the presence of services and facilities);
    - democratic aspects (democratisation level; equity; governance, decision-making and participatory aspects);
    - quality of the environment, including of water, air, food, level of hazard or risk;
    - health and wellbeing, meant as a complete physical, mental, social and spiritual wellbeing;
    - personal and property rights (including access to resources) security and safety (real or perceived)

3.2 THE INDUSTRY'S OVERARCHING VISION

A first step to understanding the societal impact of a technology is to outline the vision related to the intended purpose and expected contribution of technology to society, as conceived by the community driving its development. We will do that starting from the account done in the framework of the European industry working on 6G, drawing from the documents describing the higher-level overarching vision and the explored use-case scenarios, mostly deriving from the results of 5G-PPP or SNS JU projects.

Within the framework of technology development, from an industry perspective, the transformative potential of 6G on society is described **predominantly in a positive way. The impacts described are in general, directly attributable to technological characteristics** in terms of design, functionality, performance (e.g. reduction of energy consumption; resilience; connectivity; security), or explicitly connected to the specific purposes of application across vertical sectors (radiofrequency management, healthcare, transports). In other words, those are impacts that are intended and expected, and are relatable to how 6G technology is intended to work (technical performance combined with sustainability) and to what we expect 6G to do to improve services and citizens' everyday life (use-case applications). Finally, impacts related to expected business opportunities complete the picture.

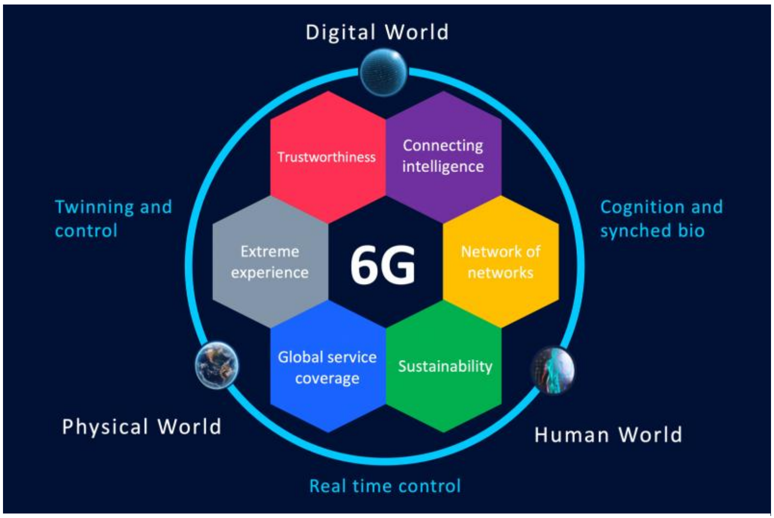

FIGURE 1: 6G AND UNIFICATION OF PHYSICAL, DIGITAL AND HUMAN WORLDS

The overarching vision accompanying 6G development is that of a pervasive, distributed and intelligent network, acting as a service provisioning and access platform, ensuring connectivity, and based on capacities such as computing, processing, actuating, sensing, data and intelligence. In particular, the vision statement of Hexa-X, the European flagship project on 6G, states that "we envision a future in which everyday experience is enriched by the seamless unification of the physical, digital, and human worlds, achieved through the new network and device technologies [6]", assigning a clear and **positive value to the seamless convergence and interconnection** between digital sphere, human physical sphere (our body), and objects of the material world.

In this vision, the role of technology in society is cross-cutting, permeating, embedded, enabling, and interpreted as a key enabler for the enhancement of human capacities. 6G is seen as an *actant* that "shall assume a crucial role and responsibility for large-scale deployments of intelligence in the wider society [...] transforming AI/Machine Learning (ML) technologies into a vital and trusted tool for significantly improved efficiency and service experience, with the human factor ("human in the loop") integrated" [7].

The promise of a pervasive and intelligent technology and communication network is expected to entail revolution across economic sectors and industries, while also supporting sustainable development. In general, 6G is associated with the potential for increased productivity across industries, and for strengthening the economy in a way that is respectful for and inclusive of people's needs and well-being, and for the environment. The next paragraphs highlight the major transformations that the industry prioritises in its approach, to describe the societal impact of the 6G technology.

3.2.1 Highly transformative technological features

As compared to 5G or previous generations of networks, 6G industrial vision includes a number of elements of discontinuity, in terms of enabling technological features as well as of design approach. Some of these elements stand out for their capacity to impress broader impacts at the societal level, triggering change at a conceptual and very fundamental, paradigmatic level. As illustrated in the next subsections, they can be summarised as follows:

1. hyperconnectivity and seamless convergence;
2. intelligence;
3. values and sustainability.

3.2.1.1 A hyperconnected, immersive and seamless experience

The 6G, as an umbrella technological framework, will "connect the unconnected". A real-time and seamless integration between cyber and physical spaces is expected, closing the loop between three "worlds": the human physical world (human body and brain), the objects' physical world (e.g., objects and devices connected through the Internet of Things – IoT) and the digital world. Technology is expected to be embedded in every aspect of life and dimension of reality (pervasive communication). All objects, individuals, or territories currently unserved will be connected (massive and ubiquitous connectivity).

The notion of connectivity will extend its current meaning. The interconnection of objects and individuals will extend into the digital realm, further blurring the lines between the physical world and virtual experiences. By leveraging virtual and augmented reality technologies, a three-dimensional virtual representation of both human and physical environments will be created. Proposed scenarios envision "holo-presence systems […] capable of projecting realistic, full-motion, real-time 3D digital twin images of distant people and objects into a room, along with real-time audio communication, achieving a level of realism that rivals physical presence. Images of remote people and surrounding objects will be captured and transmitted over a 6G network and projected using laser beams in real time" [5]. This will change the nature and possibilities of interpersonal distance communication.

Research is also oriented to transcend and overcome physical boundaries between human body and communication devices, redefining human-computer interaction. The centrality of some traditional communication devices, such as the mobile phone, may be revisited or resized, in favour of a more immersive, and therefore invisible and ubiquitous communication capacity. This would represent, after almost 50 years since the first cell phones appeared, a paradigmatic change in the way humans communicate through devices and media (or without them).

This will also include brain-machine interfaces, which constitutes radical communication tools enabling direct communication links and interoperability between the brain's electrical activity and an external device - computer, platform, robotic limbs. This approach could revolutionise the human experience in communication, not only overcoming the separation between the human body and devices, but also between two human bodies, opening novel ways to connect people and the biological world. All these technological features, which are related to how people communicate, have implications at both the human and societal levels that extend beyond the specific technology itself. These implications will be analysed in the following subsections.

3.2.1.2 An intelligent reality

AI and data will gain an even more central role, with a mutually reinforcing interaction. The quantity of data processed will exponentially grow, while a wider variety of data typologies (quality) will be collected by sensors, from people and from the environment. This will enhance machine learning capacities, by constituting the nourishment for AI. The transformation of the way data is collected, shared and analysed in real-time will impact on the way we produce new knowledge and conduct research.

The inference and reasoning capabilities of AI, as a native feature of 6G, will control sensors and IoT devices, further enhancing the overall capabilities of the network. "With advances in artificial intelligence, machines can transform data into reasoning and decisions that will help humans understand and act better in our world." In particular, generative AI may play a significant role in generating and interpreting the semantic messages to be communicated. This is especially crucial in applications involving massive IoT, where numerous devices continuously exchange data, as well as for new forms of communication between humans and machines, which could overcome traditional device mediation (e.g., brain-to-machine communications based on mapping and interpreting neural signals). The assumption is optimistic and somehow deterministic, suggesting that AI-supported reasoning can guide humanity toward a better future.

3.2.1.3 A comprehensive approach to values and sustainability

6G's design paradigm goes beyond traditional technical performance metrics to include value-oriented objectives focused on social and sustainability perspectives.. As explicitly mentioned in the vision of the project Hexa-X-II "to fully embrace such a vision, Hexa-X recognises the necessity to expand the fundamental network design paradigm from mainly performance-oriented to both performance- and value-oriented. Here value entails intangible yet important human and societal needs such as sustainability, trust, and inclusion. This will lead to a new class of evaluation criterion, i.e., Key Value Indicators (KVIs) that must be understood, developed, and adopted in the network design towards 6G." This approach, which constitutes an innovation in itself, aims at ensuring a responsible innovation, namely through achieving net-zero emissions, respecting human rights, and avoiding undesired externalities.

The main values underpinning the conception of 6G (aside from sustainability) are privacy protection, operation resilience, reliability, and security. These are expected to build trust among consumers and enterprises for wireless networks and their enabled applications. Also, EU technological sovereignty is pursued, as an overarching meta-value able to foster an open, trustworthy, and democratic Europe. In addition to these values, the vision of 6G currently being developed is that of a technology designed around the value of sustainability, in both the levels of “sustainable ICT” and “ICT for sustainability”, applied in the three aspects of economic, social and environmental sustainability. While in ICT for sustainability a technology is aimed at solving sustainability issues in society, in sustainable ICT sustainability is a requirement of the technology itself: a technology is expected to work and perform in a sustainable manner through sustainability by design, and “negative impacts must be minimised regardless of whether there are positive impacts as an output value or side effects of executing a use case [8]”.

The HEXA-X-II project, the current EU flagship for 6G research, explicitly emphasises the importance of creating a value-oriented ecosystem and addressing all three pillars of sustainability in 6G design. This focus reflects a growing awareness of the significant societal impact anticipated from a pervasive and ubiquitous system such as 6G. To achieve this, Hexa-X-II plans to evaluate all 6G use cases across the so-called “triple bottom line”, combining the three sustainability dimensions: persons (society), planet (environment) and profit (economy). The approach aims at estimating and accounting for the full societal costs and gains of economic choices and actions across the three pillars, with the intention to identify and analyse risks, capture challenges, and understand both potential benefits and unintended negative consequences, to develop mitigation strategies. Environmental sustainability, in particular, holds a priority place in terms of ambitions. Major efforts are currently directed towards maximising energy efficiency, and diminishing energy consumption, for network operations, reducing carbon footprint through a capillary impact wave effect throughout the many industries and sectors that the network enables.

The work of the project HEXA-X-II gives us a glimpse of how this general vision is being transformed into concrete use-cases. The definition of concrete use-cases represents a fundamental phase to understand how the technology will be used, what desired functions shall be envisioned, and to define the right requirements and performance indicators. In the case of 6G, use-cases are defined as “taking a comprehensive view on sustainability”. This is translated into the following process features:

- The work is guided by three questions that help in reappraising and resising the traditional primacy of technology-driven considerations in setting the way forward for technological development, putting forward the needs of end-users and society: 1) *What end-user problem and need are we addressing?; 2) Why are current technologies not enough to solve the problem?; 3) What innovation should 6G bring?*
- The key values of environmental, social, and economic sustainability are expected to influence the work on use-cases at different levels: i) selection of use cases; ii) definition of the approach on how to address or solve user-needs, sustainability goals and issues within a use-case; iii) identification through a sustainability analysis of the environmental, social, and economic impacts of each use-case.
- Finally, each use-case is accompanied by a sustainability analysis showing all positive acquisitions linked to use-case projections (handprints, or benefits), together with possible negative impacts (footprints, or costs).

Such an approach certainly represents a meaningful change of perspective as to the capacity of industry to care and engage within more holistic societal challenges. On the other hand, the actual extent to which the set of values and priorities belonging to the social and environmental pillars will influence the overall 6G system vision and the core business of 6G stakeholders, is still to be fully understood. 6G stakeholders' expectations are expected to play an important role in this, with a cascade influence on drivers and use cases, up to the definition of requirements and technology solutions [8].

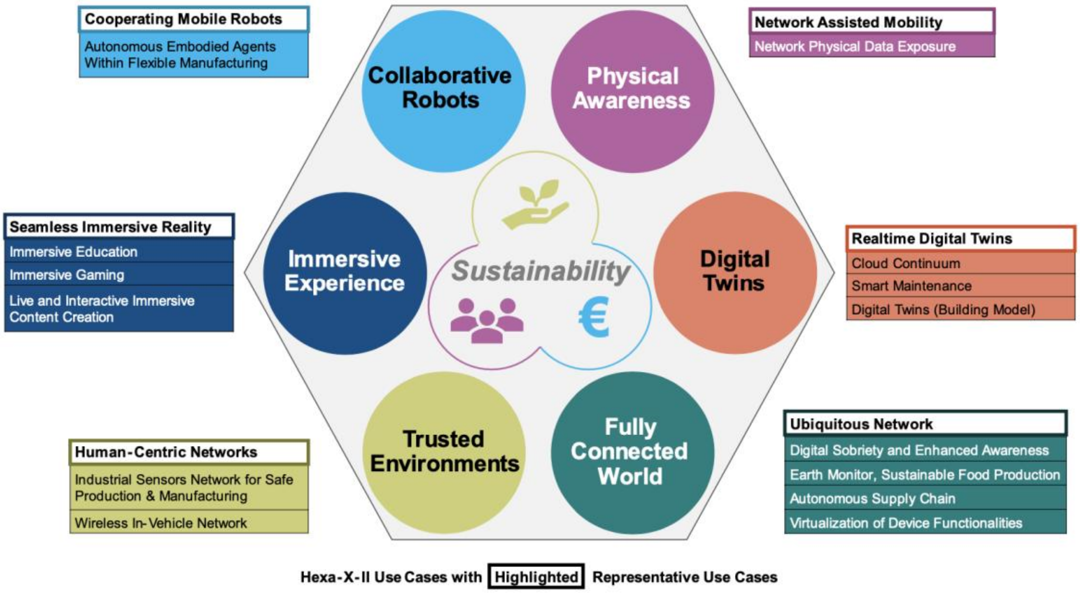

FIGURE 2: INITIAL SET OF 6G USE-CASES IDENTIFIED BY HEXA-X-II

3.3 THE SOCIAL SCIENCES AND HUMANITIES PERSPECTIVE

Since other EU projects, such as Hexa-X-II, have already thoroughly explored the specifics of use cases, their expected positive impact, and potential footprint, the following sections will instead focus on aspects not typically covered in such analyses—particularly socio-cultural dimensions. **The mission of the 6G4Society project is to bridge the technical approach to 6G innovation with an analysis of the ongoing transformative trends from a sociological perspective.** Challenges of anticipatory thinking in the 6G context

In today's fast-paced technological innovation environment, the ability to understand the profound social implications of emerging technologies has become increasingly strategic. When key societal variables are disrupted by transformative pressures, structures—such as legal frameworks, social norms, beliefs, and conventions—may be reshaped, and societal imbalances may arise. This is why te evolving relationship between humans and technology, combined with a radically altered landscape for communication and information exchange, has exposed significant challenges for institutions, regulators, and governance systems. These challenges lie in their limited capacity to anticipate and effectively manage transformations, from the social and ethical implications of digitalisation to the conflicts arising within public and democratic spheres [9]. Therefore, **critical and forward-looking thinking** about these transformational processes is essential to identifying potential losses—such as valuable skills or protections of human rights—and to proactively govern these changes before unintended consequences emerge.

Recent decades have seen a growing recognition of the need to critically understand the implications of pervasive technologies at both individual and societal levels. This has led to a much-needed increase in **focus on methods that enhance our anticipatory understanding of the potential human and socioeconomic impacts of technologies**. The merit and objectives of such approaches are to support decision-making and governance processes in implementing timely preventive or adaptive measures. In practice, this involves anticipating future areas of concern and proactively addressing and governing them through reflexive, inclusive, and deliberative processes that engage relevant stakeholders beyond the community of “usual suspects” [10]. Additionally, it includes developing regulatory and privacy frameworks that prioritise societal well-being over short-term gains. At the level of EU research and innovation policies, programmes, and processes, for example, these concerns and awareness have found a theoretical and operational framework within the **Responsible Research and Innovation paradigm** [11] [12].

Regarding 6G, understanding its potential societal impacts is both interesting and essential, although it presents considerable challenges for at least three key reasons that define the scope of our analysis:

- **The type of relationship occurring between technological innovation and the broader societal effects it triggers** (both intended and unintended). The relationship between technology and society is dynamic and reciprocal. Technology shapes society by introducing new tools, systems, and modes of interaction, influencing culture, economics, politics, and human behaviour. Society, in turn, shapes the development and application of technology based on its values, norms, and needs, as well as through original, bottom-up interpretations that emerge from specific contexts of use. Grasping this interplay remains essential for evaluating how technology affects different areas of society, including education, healthcare, governance, and the economy. This understanding enables informed decisions to leverage technology for positive social change while mitigating potential negative impacts.
- **The difficulty to understand the long-term and broader societal implications of something that is still being developed**. In the specific case of technologies that are both *emerging* (still in their conceptual stage) and *enabling* - such as 6G is – the capacity to consider long-term implications is particularly sensitive. Firstly, because emerging enabling technologies i) are expected to generate a broad, structural and cross-cutting transformational impact on society and the economy; ii) Secondly, because these technologies still offer a window of opportunity to proactively guide and shape technological development in a timely and appropriate manner, before they become deeply interwoven with other technologies and entrenched within society. If this proactive approach is neglected, potential negative impacts may only become evident when it is too late to address them effectively, echoing the challenges posed by the Collingridge dilemma on multiple levels.

> **The Collingridge dilemma** describes the challenge of managing the impacts of new technologies. It highlights a paradox: in the early stages of technology development, when changes are easier to make, the effects of the technology are often not fully understood. However, once the technology is widely adopted and its effects become clear, it becomes much harder to change or regulate. This may be relevant for different aspects of technology-related impacts: regarding infrastructures, once a technology is built into societal infrastructure (like transportation, energy, or communication systems), changing it can be extremely costly and disruptive; industries and economies

can become dependent on certain technologies, making it difficult to shift away without significant economic consequences; concerning legal and regulatory frameworks, once conceived around a technology, adapting them to new understandings or challenges can be lengthy and contentious. Also, technologies can shape social habits and behaviours, making it hard to reverse these patterns once they are ingrained. Some of these habits and behaviours may include possible negative marginalities of innovation with a societal relevance. Issues related to wellbeing, mental health, social cohesion, later result in burdens for the social or governmental sectors, which shall later address them through policy measures.

Anticipatory approaches support this goal by employing various techniques for foresight, forecasting, and futures studies. These include anticipatory scenarios (such as techno-moral or techno-ethical scenarios, trend analysis, expert panels using the Delphi method, horizon scanning, and technology assessment methods), as outlined by Brey [13] in the framework of ethical analyses of emerging technology. It is important to stress that the aim of these techniques is not to predict the future. The real contribution that anticipatory approaches can provide to STEM research, besides giving some anticipation about plausible and possible futures, is their capacity to identify path dependencies and causal relations among societal ecosystem variables. For instance, they can identify contingencies, constraints and unintended consequences in the development and use of emerging technologies and their relation with the emergence of certain ethical issues or social transformation [13].

- **The nature of 6G, a multilayer technological ecosystem**, encompassing infrastructures, enabling technologies, and applications, all interacting dynamically, functioning both as enablers of the system and as components enabled by it. This makes it challenging to identify univocal connections between single elements of the technological landscape and any potential societal impact. No specific influence can be attributed to a single technology alone; instead, it is the entire technological system that activates various trends and dynamics that will impact, through the communication environment, the whole broader social ecosystem.

3.3.1 Approach, methodology and theories for the analysis of 6G social impacts

Despite the above-described challenges, and following the **anticipatory approach** illustrated in section 0, 6G4Society adopts a **methodology** for analysing the broader future possible social effects of 6G, starting from a **critical inventory of trends** [14]. Trends (section 3.3.2) are societal tendencies and forces that have not necessarily convincingly emerged yet, nor necessarily have clear boundaries, but nonetheless influence social dynamics. Understanding trends is a necessary step in order to meaningfully frame possible future impacts and to be able to interpret their socio-cultural effects (section 3.3.3). Considering the complexity of societal transformations, it is important to highlight that:

- The objective is not to identify the precise effects or consequences of these dynamics: any interpretation relates more to understand the nature of these dynamics, the threads, the trajectories, the relationships with other trends and dynamics, and their significance at the societal level.
- Given the fine-grained combination of gain and losses, and the subjectivity through which the benefits of changes could be interpreted, it is often difficult to appreciate what scenario is best to have.

In terms of background theories, the analysis is anchored in the broader discussions on societal transformations and implications related to the spreading of digital ICTs, as addressed by the philosophical, sociological and media studies literature. In particular, the reflection will focus on two concepts, deeply intertwined in their genesis and definition: **digital hyperconnectivity**, and **immersive communication**. Both these concepts represent constitutive elements of the technical and social vision related to 6G. Within the 6G framework vision they find a synthesis and an ecosystem where their mutual influence and interdependence are destined to grow. The attempt here is to highlight their sociological significance in the context of 6G and to describe the nature and importance of their mutual relationships as well as of the important societal impact they have entailed. More in particular:

- The concept of *hyperconnectivity* can count on a considerable bulk of studies, derived especially from Internet studies, providing very interesting insights to interpret its impact at the societal level.
- The study of *immersive communication*, particularly in the context of emerging technologies like 6G and through a sociological lens, is an emerging field. Scholars are only beginning to investigate the profound societal impacts of these technologies, and current literature offers limited analyses from communication and social theory perspectives. Specifically, few studies examine how technology, society, and the human sphere intersect, or identify which dimensions of human and social experience are structurally transformed, and why. This makes immersive communication a particularly compelling and promising area for exploration, aligning closely with the categories traditionally addressed by medium theory and calling for a refreshed interpretative framework.

According to medium theories, and in particular media ecology theories **[15]**, the media environment we live in influences and shapes our cognition of the world, because each media creates and provides us with specific symbolic environments, structures and codes, through which we exchange sense (we communicate) and make sense of the world we live in.

This analysis aims to demonstrate the extent and depth to which shifts in information and communication technologies can impact society. By raising awareness of the multitude of social, human, and governance aspects that warrant attention, it underscores the importance of timely investigations into technological and innovation processes from humanistic and sociological perspectives.

None of the following reflections should be interpreted in a deterministic way. It is well understood that socio-cultural transformations are not solely the product of rational decisions, nor are they merely the result of random, incidental forces. Rather, there exists a continuum between technological design choices—such as the values and promises embedded within their creation—and the societal impact these technologies produce, especially within the interplay between society's micro and macro levels. This continuity arises because the value systems, priorities, and objectives embedded in policy and industrial decisions shape particular visions of the future, thereby reinforcing specific transformative trends and tendencies. In the words of Brubaker: "networked digital technologies do not determine the uses we make of them, though they do have certain 'affordances' that open up new possibilities and foreclose others, making some actions easier, others more difficult [16]. The social transformations set in motion by digital hyperconnectivity are not preordained by the nature of networked digital technologies themselves; they emerge rather from how these technologies, and the practices growing around them, are culturally understood, socially organised, legally regulated, and politically contested" [17].

A chain of micro-choices and decisions happening in the intricate interplay between technologies and social forces (culture, social organisations and structures, regulatory frameworks, and the democratic arenas) orients the construction of the final technological setting, with its uses, capabilities, purposes, standards and constraints. Taking this into account, the following analysis aims at highlighting the importance of anticipatory reflection, on the one hand, and on the other hand of a more informed, proactive and multi-stakeholder governance, suggesting that the journey to 6G is not just a technical endeavour but one that is shaped by various social, cultural, and ethical factors.

Rather than finding conclusive answers, or providing an exhaustive elaboration, the work intends highlighting relevant questions, representative issues, references and perspectives. In particular, in the framework of the 6G4Society project, but also in the wider community of SNS projects, these reflections have the ambition to represent a first founding base to reflect especially on the values underpinning technological development, as well as on the concept of societal sustainability.

3.3.2 Mega-trends and Socio-Cultural Implications

The impact of ICTs extends far beyond the technical realm, becoming a force that reshapes the very foundations of human societies. No longer confined to a specific sector, ICTs are now central to how we interact, communicate, and understand our world. As Van Dijk [18] asserts, "networks are becoming the nervous system of our society," with ICTs influencing everything from personal identity to global political structures. 6G represents the next stage of this transformation, bringing unprecedented levels of hyperconnectivity that will blur the lines between the physical and digital worlds, creating both opportunities and challenges for societies across the globe.

As defined in the methodology (section 0), with the aim of foreseeing possible future impacts and being able to interpret their social effects, 6G4Society analysis starts from identifying the principal trends characterising the information and communication landscape. The following subsections will provide an overview of the main transformational effects linked to the digital transformation, grounding the analysis on two main concepts identified in section 0, i.e., *hyperconnectivity* and *immersive communication.*

3.3.2.1 The Digital Turn and the Leap to Hyperhistory

Throughout history, the evolution of Information and Communication Technologies (e.g., writing, telegraph, telephone) has driven societal change by transforming information exchange patterns. Information and communication technologies (ICTs), more than other technologies, penetrated deeply into the societal structure, impressing profound changes, and representing a founding infrastructure for the development of human civilisation. From communication, to institutions, to economic models and political structures, **any change in the communication and information landscape, pushes forward changes in societies, at all levels of human life.**

> The word technology is not meant here in the currently prevalent and common meaning of artifact enabled by computing and digitisation. It is used, instead, in its etymological and literal meaning. Composed of techne (meaning art, skill, craft, or the way, manner, or means by which a thing is gained) and logos (meaning word, the utterance by which inward thought is expressed), technology hence refers in this context to a discourse about the way things are gained. It refers to the ensemble of tangible and intangible rules, codes, representations and mechanisms that human civilisation has invented, throughout history in order to transfer meanings throughout time and space. Such extensive meaning is recurrent in Floridi's work [19].

The digital revolution, marked by the rise of ICTs, represents a more fundamental shift. **The digital code has become a meta-language into which all previous analogue languages and codes could be translated**. In addition, digital ICTs have become the backbone of all other technological fields, preliminary and critical for the reliable running of all other sectoral technologies. Philosopher Luciano Floridi [19] describes this transition as the passage to "hyperhistory", where societies become vitally dependent on information as a fundamental resource. This has two main consequences:

- on the one hand, it increases our dependability from these technologies;
- on the other hand, society will undergo a process of deep and pervasive transformation determined by the instructions, values, habits or implied rules ascribed in these technologies.

> Following the interpretation of philosopher Luciano Floridi, we can identify three main ages of human civilisation, determined based on ICTs related innovations: prehistory; history; hyperhistory. If the invention of writing marked the passage from prehistory to history, providing the infrastructure to record and transmit information to future generations, the advent of digital ICTs has now marked the passage to hyperhistory.

3.3.2.2 Hyperconnectivity as a Societal Force

Hyperconnectivity goes beyond technological and infrastructure achievements, fundamentally altering human communication and our lived experience. By connecting individuals to an exponentially growing network of people, sensors, and digital content, accessible anytime, anywhere, at a planetary scale, hyperconnectivity transforms our societal structure (including our individual "structure") at a very deep level, As Brubaker highlights, hyperconnectivity represents a "total social fact", and "a defining fact of our time", permeating every aspect of human life. More specifically, Brubaker defines **hyperconnectivity as a meta-infrastructural quality of our information and communication environment**; a terrain, a mode, a way through which we experience communication, and consequently our life, to which all other transformations can be reconducted.

The 6G vision aims to fully actualise hyperconnectivity [20] by creating seamless, real-time connections across physical and digital environments. Such integration extends beyond technical infrastructure to reshaped social relationships, cultural production, economic structures, and the mechanisms of governance, raising fundamental questions about privacy, human attention, and the concentration of digital power. Indeed, as an entity, hyperconnectivity is referred to by Brubaker as a complex sociotechnical assemblage comprising communication networks, computational procedures, material artefacts, social practices, embodied habits, organisational forms, economic incentives, and legal frameworks. **Reading 6G through the concept of hyperconnectivity will allow us to shed light on the complex interplay between technological advancements and societal changes**, recognizing it not as just a technological advancement, but as a force that will fundamentally alter our relationship to ourselves, to others, and to the world.

3.3.2.3 Immersive communication: a new media paradigm

Closely tied to hyperconnectivity is the concept of immersive communication, which represents a paradigm shift in how individuals will interact with technology and one another. This communication modality is proper and exclusive of the hyperconnected communication environment enabled by 6G, through enhanced virtual and augmented reality, ubiquitous connectivity and sensing, ultra-reliable machine-to-machine communications, and AI-native networks with distributed intelligence. This shift will make communication feel more natural, integrating the digital and physical worlds to an unprecedented degree.

Immersive communication will act upon and transform our experience in the fundamental categories of space, body, and reality perception, addressing the challenge of realising an increasingly intelligent, pervasive ambient technology, invisibly, silently embedded in the environment, providing a seamless integration of physical and digital worlds, and transcending current device-mediated exchanges, by embedding technology invisibly into the environment, creating frictionless interactions. As Li [21] describes, immersive communication marks the “third media age,” where individuals experience communication beyond the boundaries of time and space, and through a seamless integration of physical and digital worlds. Immersive experiences offered by technologies like augmented and virtual reality (AR/VR) will likely reshape cultural production and consumption patterns, altering how we engage with entertainment, art, and each other. This will create opportunities for deeper engagement but also lead to significant shifts in cognitive experiences, social norms around communication, and interpersonal relationships.

Two are the major qualitative breakthrough features in immersive communication environments. They relate to the ways in which technologies and humans meet and cross each other’s boundaries through a two-way process. They especially pin over the dimension of ubiquity and of senses:

- **we assist to the evanescence of the mediation**, through the disappearance of artefacts and devices.
- **technologies get closer or even cross the threshold of the human body**, more or less invisibly, either through brain-machine interfaces, or through “bringing” the body into the dimension of virtual reality (holograms, metaverse). People integrate with their surroundings, and the physical world integrates with the virtual world.

In Li interpretation, the “first media age” refers to the unidirectional, one-to-many mass communication age; the “second media age”, theorised by Poster, to the two-way, focused communication age; and the third media age relates to the immersive and “ubiquitous mass” communication age, where the individual is at the centre of all ultra-precisely customised, one-to-one personalised and tailored information services. As to the “second media age”, in 1995, Nicholas Negroponte presciently argued that human society had entered the post-information era: “The transition from an industrial age to a post-industrial or information age has been discussed so much and for so long that we may not have noticed that we are passing into a post-information age” (1996 p. 163). In the post-information era, people and the media blend with each other. Information becomes extremely personalised, mass communication turns from broadcasting to narrowcasting, and individual narrowcasting can be turned into broadcasting instantly through media.

In summary:

- **Digital** → provides a meta translational language for all existing languages and codes as well as technological infrastructures.
- **Hyperconnectivity** → provides an ecology of communication, the structure of relations amongst entities, with a strong impact on identities and societal structures
- **6G** → provides the vision and constitutes the framework for a pervasive technological landscape, deployed at a planetary scale and across sectors, into which bringing to full realisation the capabilities that were, so far, only anticipated and glimpsed on the horizon, or experienced in small and specific technological, or socio-technical contexts.
- **Immersive communication** → constitutes a paradigmatic change in communication from the qualitative point of view, pushing forwards the changes brought by internet-mediated communication, acting on the categories of space, time, on our physical/body dimension, and on the concept of "medium". It opens the way for further explorations in terms of impacts on social development.

3.3.3 Socio-Cultural Transformations

The combined forces of hyperconnectivity and immersive communication present far-reaching implications for society, triggering transformations in human work, interaction, and identity formation. This subsection focuses on the broader potential impacts and transformational effects of 6G technology on society beyond the specific use cases and determined industrial purposes, to introduce a broader view in terms of time span and chains of consequences regarding impact dynamics and possible paths. In particular it will examine key features related to technological innovation, pinpointing how deeply they get to trigger profound societal transformations.

3.3.3.1 Evolving Sense of Space and Time

Over the past decades, the convergence of mobile internet technologies has redefined human experience of space and time, enabling communication from anywhere at any time. Suddenly, communication was able to **fully bridge distance and transcend time in new ways**: it became possible to experience and choose **synchronous, semi-synchronous, or asynchronous communication in any preferred communication form and format, from anywhere and anytime**: writing (email, SMS, individual or group chats), voice (phone call, and later voice messages), or video (video call, teleconference, videos), and all through the same devices (phone; computer), that becomes a unique hub for communications.

Such a proliferation of possibilities transformed in a few years the way we behave and interact socially and privately, build relationships, (re)shaping social norms. They resulted in lowered boundaries for communication and interaction processes, acting on different aspects of the human experience, and especially in our way to perceive space and time, or to be (more or less) bound to them. **The constraints of space and time were overcome in several ways:**

- **Mobile phone connectivity overcame the constraint of *place* for synchronous (tele)communication**, and made us reachable from anywhere and anytime, as single individuals (the use of the telephone was previously bound to specific physical locations, and the device was not personal, but shared with other persons). By means of electronic communication, mobile communication achieves omnipresence.

- **The Internet freed us from the influence and limitations of *proximity*-related communities,** offering the possibility to structure new socialites (and identities) based on networks and communities of interest. This became quickly true also for the performance of conceptual works activities, which broke their association with the work-place.
- **The Internet also broke the barrier of *synchronicity* for distant communication** (the telephone - the only medium allowing to bridge the distance, required synchronicity), allowing the first forms of asynchronous (emails) or semi-synchronous (chats) communication.

The dimension of *space* is the one most profoundly impacted by convergence and hyperconnectivity. In particular, electronic media have broken the original connection between "physical place" and "social place". 6G technology will further blur these boundaries, enabling new forms of remote collaboration and immersive interactions through virtual telepresence. Physical co-location becomes less significant as an immersive communication environment allows individuals to interact as if sharing the same space, regardless of geographical distance. This shift challenges traditional notions of presence, creating new dynamics between physical and virtual worlds, where the notion of space and that of media will progressively converge. Integrating real and virtual environments raises questions about privacy, security, and the emotional consequences of living in a constantly connected, digitally augmented reality. This transformation of the notion of space opens up to a series of considerations:

- **Virtual telepresence as a new communication mode and medium.** The sense of space, already strongly transcended by previous media evolution, will acquire new meanings. The concept of virtual telepresence and immersive communication will acquire the role and meaning of a medium, since they will represent a way to communicate, enabling effective remote collaboration through realistic audio-visual reconstruction of participants and their environments.
- **Immersive communication enhances the sense of social presence** – the feeling of being "with" others in a mediated environment. Social presence is crucial in understanding how media influences our social interactions and relationships. Through immersive experiences, individuals can feel more connected and engaged, reducing the perceived distance between themselves and others.
- **No more difference between symbolic works and works implying tangible, concrete processing.** Activities that constitute the last bastion of tangibility or of in-presence necessity, will be possibly developed in a distance, opening up new possibilities, but also liabilities, challenges, habits, etc.
- **Online, offline; imaginary, real.** The distinction between online and offline has already proven obsolete in the definitionof our identity, social interactions and life experience. Now, Virtual Reality (VR) raises new questions regarding new boundaries being bridged. Knowing that the immersive potential of VR technology generates vivid experiences and real emotions, questions have been raised regarding what would be the relationship and type of interaction between physical, virtual and imaginary space,

including the relationship between physical and virtual social space. Excessive engagement in the virtual world may create detachment from reality, and difficulty in distinguishing between virtual and real-life experiences, potentially leading to confusion or disconnection from one's physical surroundings and social relationships. Such a reflection could raise relevant questions (also ethical) as concerns the development of contents in the gaming and real games industry, if we consider impacts on the processes of self-creation, identification, or the risks of emulation.

3.3.3.2 Body and Senses in Immersive Communication

Immersive communication incorporates, for the first time, the full sensory experience into distant interactions, simulating physical presence through technologies such as photorealistic avatars and holographic projections. **In the immersive communication context, for the first time after the invention of any medium, the physical and sensorial dimension of the body (beyond hearing and sight) will be introduced into the models of distant communication**. This represents a fundamental departure from previous communication technologies, which largely “disembodied” human interaction, and will act as breakthrough shift in terms of how social interaction and exchanges are made possible in a distance. It will transform the way we perceive ourselves and our body in space and in relation to distance, as well as the way through which we exchange and produce meanings and sense during a human interaction, opening interesting reflection paths in terms of communication theory and models.

The potential to recreate physical presence, while opening new possibilities for tangible social exchanges, introduces concerns. While immersive environments like virtual and augmented reality enhance social interactions by making remote communication more embodied, they also present risks of excessive immersion, leading to challenges such as cognitive overload, mental fatigue, addiction, emotional detachment from physical reality, and the erosion of real-world skills.

3.3.3.3 Immanent and evanescent media

For the first time in the history of media evolution, the development of 6G technologies is overcoming the physical dimension of devices towards a vision where technology become immanent, invisible, hidden, quiet. Using the sensing and semantic capabilities of the network, the environment or space turns into the medium and becomes completely mediated. At the same time, human communication will be enhanced by virtual senses experiences and human biological systems. The physical and virtual world, humans and objects, the media and the environment will be fully integrated into each other, with no need for screens or interfaces.

The capacity to enact communication through virtualised “devices” represents an opportunity for inclusion, potentially enabling disabled individuals who could not benefit from this phase of the digital transition. Brain sensing technology, for example, promises to interpret the brain signals into actions and intended objectives. These signals might be interpreted and connected to exoskeletons or artificial arms/leg (brain-to-machine communication), overcoming disabilities due to a damaged nervous system. With the development of biological media, people *become* the media ontology, embedding both human nature and a digital personality.

With the mediated environment of immersive communication, as remarked by Li, “it seems that we are returning to the original state of human existence, going in a circle from the end to the starting point” [21]. Of course, this “naturalisation” of communication is only apparent. Although silent and immanent, the mediation still exists and acts, participating in the process of meaning creation. Despite the wide and thorough literature, the symbolic or meaning generation mechanisms underpinning traditional and new media, and therefore their influential power on society, still goes for the most part unperceived, unacknowledged, if not denied - making their influential capacity even stronger.

The evolution of media, according to Levinson, can be read as a series of steps aimed at, on the one hand, extending our outreach beyond the limits of space and time (including to posterity), and on the other hand recapturing all the nuances and elements of the natural world (image, voice, images, colours, movement) that have been lost in the first mediated communication, that is, writing. In particular, “the overall evolution of media can be seen as an attempt, first, to fulfil the yearnings of imagination by inventing media that extend communication beyond the biological boundaries of hearing and seeing (thus, hieroglyphics and the alphabet and the telegraph each in its way extends words thousands of years and/or thousands of miles), and, second, to recapture elements of the natural world lost in the initial extension (thus, photography recaptures the literal image lost in writing, and the telephone, the phonograph, and radio recapture the voice).” **[22]**

3.3.3.4 Self-Image and Identity in a Hyperconnected World

In the hyperconnected digital sphere, there is no discontinuity between our online and offline selves. They are the extension of one another, in continuous constructive and mutually determining dialogue. Hyperconnectivity has transformed the complex dynamics underpinning self-creation and projection, creating a continuous feedback loop between self-presentation and social interactions. All of us can continuously produce images of ourselves, and become continuously exposed to the image of us (our objectified self) that is projected and reflected online (we can see ourselves from outside), including through interaction and feedback with other users. Digital platforms, besides enabling identity curation and display, also introduce external influences – such as algorithms and social feedback – that have a role in shaping self-perception: algorithms contribute to creating a version of ourselves, based on the quantification and elaboration of the digital traces we leave behind across the digital social sphere (actions, contents) under the forms of data.

The main forces, springing from the hyperconnected socio-technical environment, acting on identity and self-creation are: abundance (of stimuli and information); quantification (through data); construction of our online identities through algorithms; ubiquity. These tendencies are expected to be further reinforced in immersive and ubiquitous media environments. The immersive nature of these media can make the experience of self-representations more impactful, as users “live” through these experiences. As such, the power of immersive media in challenging or reinforcing cultural narratives and identities, including stereotypes, will be reinforced. For example, in a VR simulation, the way environments, characters, and stories are designed can either perpetuate stereotypes or offer more diverse and inclusive representations.

More specifically:

- **Abundance** refers to the quantity of stimuli, mediated experiences, possibilities and potentialities we have access to. This allow us to explore new ways of being, overcome constraints coming from family roles or ideologies from local communities, and reconjoin with persons felt like similar, overcoming feelings of unfitness, social stigmatisation or isolation and freeing the individual from the unchosen obligatory community. On the other hand, however, the abundance of possibilities and infinite exposure and comparison with other possible selves (who we might become, who we would like to become) make us introject a multitude of potentials as well as differing and conflicting criteria of self-evaluation. Individuals can continuously compare their lives, achievements, and appearance with others. Even in a conscious and proactive process of self-creation, this constant exposure to curated images and narratives may bring unsettling feelings and fuel feelings of inadequacy, envy, freezing, doubts, and a sense of low self-esteem and insufficiency, as individuals compare themselves to idealised online personas. These feelings may ultimately trespass into negative psychological outcomes such as depression and social anxiety. Finally, the omnipresence of digital interactions and virtual identities in online spaces may contribute to identity fragmentation, as individuals navigate multiple personas across different social platforms and contexts. This fragmentation can lead to dissonance or dissociation between one's online and offline selves, potentially impacting self-concept, authenticity, and interpersonal relationships.

- Concerning the **datafication** of self and the subsequent correlations, relationships, predictions and assumptions on us produced by **algorithms**, they can also intervene at other, more intimate and unconscious levels, influencing our choices and actions online. This is done in a way that is functional to the social media economy and business models, and is possible through the way social media platforms are engineered, to capture our attention and exploit psychological vulnerabilities (that they themselves create and reinforce). For example, we are pushed towards becoming more dependent on others' gaze and recognition, feeling the need for a constant *attunement* of our online representation. The creation of this perception of scarcity (a paradox, in the online world, characterised by abundance), and of the need to communicate and produce more and more, leads to soft and insinuated forms of behavioural control or nudge, disguised behind the illusion of self-choices. The capacity to influence individuals' choices and identity will be further explored in the paragraph about power dynamics.

3.3.3.5 Interaction, Social Life, and Culture

6G will further blur the lines between private and public spaces, fostering an environment where individuals can engage in activities from anywhere. This increased permeability between spaces, accelerated by the COVID-19 pandemic, changes how we experience social and public life. Immersive technologies will enhance these experiences but also challenge traditional norms of privacy and boundaries. Attention will be further fragmented as people engage in multiple communication flows simultaneously, contributing to cognitive overload. The "attention economy" thrives on this, turning human focus into a commodity, while also accelerating the tempo of life, raising questions about the sustainability of such a pace. The following examples, not exhaustive, aim to provide a window into the radical and pervasive ways in which our social fabric is being rewoven in the digital and hyperconnected age. All these dynamics are expected not only to remain relevant in 6G-enabled immersive environments, but evolve further, needing close monitoring.

- **Permeability and continuity between private and public life.** The boundaries between private and public spaces have become increasingly permeable as activities can now be performed from any location, detaching them from specific physical spaces like home, work, or social venues. Public space can be lived as private, whenever we detach from it, make ourselves unapproachable, and immerse ourselves in our device-mediated activities and network of distant relationships. At the same time, our private space opens up to "public" activities whenever we perform public activities from home. Immersive realities and holographic communications will add up an additional layer to such permeability, raising concerns on how privacy and security aspects will be considered, especially when dealing with sensing of special categories of personal data. Such increased continuity between the two spheres raises questions on the need to re-conceptualise these two aspects in the light of a hyperconnected society and of immersive communication environment, with a direct impact on the whole ethics and legal framework.

- **Fragmented attention and routinised interruptibility.** When connected, our attention becomes divided across multiple and parallel communication and information flows. We multi-communicate and multitask across emails, social media, personal chats, administrative tasks, and shopping platforms. This fast-paced communication environment has translated into a routinisation of interruption: we have become chronically intruded by asynchronous communication inputs, results of technologies (notifications, messages and online contents from apps and platforms) designed to stimulate action and constantly prompt us to react, contribute, reply, agree.

  Two main mechanisms, one technological and the other one psychological, underpin these tendencies. On the one hand, the perceived low switching cost, allowed by the centralisation of all functions over the same device, made it possible to softly push our attention towards multiple and parallel foci: since we perform all activities from the same device, we tend to perceive the effort to switch across various technological functions as minimal, and to underestimate the costs of diversion, in terms of attention, focus, energy. On the other hand, we act out of an interiorised obligation to reply or give feedback: we assume the expectation of immediate availability, and continuous reachability and responsiveness.

  On the cognitive and psychological level:

  - relentless switching between activities changes our ways to relate to people, or to a subject: we more rarely experience "immersive" and profound focused experiences, with a direct effect on skilling or individual culture.
  - The fragmentation of attention span contributes to cognitive overload, which diminishes cognitive resources, leading to attention deficits and impeding concentration. This may in turn lead to stress, frustration, decreased productivity or learning issues.
  - Finally, interiorised expectation and pressure has results into increased burden and anxiety.

  In terms of socio-technical considerations, with attention becoming a more and more scarce resource, its value progressively increased, up to creating entire business models revolving on maximising engagement through attracting and retaining users' attention on the platform: the "attention economy".

- **The never-ending race towards efficiency gain.** It is by now evident that the promise of efficiency – that is, using technologies to do more in less time, and to free out time - did not realise. The time gained through more efficient processes quickly filled in, since the overall number of activities supposed to be attended grew exponentially, neutralising possible efficiency gains. From the point of view of human well-being, this hyper-filled time means an overall acceleration of "the tempo of life" [23] and the intensification of time pressure.

  On the cognitive and psychological level, the permanent tendency towards efficiency gain raises questions as to which extent such a pace is suitable and sustainable for human well-being, and about where the real boundary between empowerment and burden stands.

- **Overabundance of contents and the limits of choices.** The superabundant stock and ceaseless flow of digital and hyper-accessible contents of all sorts have reshaped our engagement with cultural goods. We can easily encounter more content and culture, with which however we engage more superficially, since our attention shrunk. This process transforms our skills and capacities from boht qualitative and quantitative points of view, in a continuous and complex process of re-skilling and deskilling.

  On the cognitive and psychological level:

  - The overabundance of choices tends to paralyse choices, and reduces, rather than enhances, well-being [24].
  - Instant and continuous access to a wide array of contents can increase our exposure, in terms of quantity and continuity, to violent media or sensationalised news, and to associated negative emotions. Prolonged exposure to such content may desensitise individuals to real-world violence, foster apathy or desensitisation towards human suffering, and contribute to feelings of distress, helplessness, or moral disengagement [25].

  In terms of socio-technical considerations, these trends may strengthen the tendency to delegate the burden of choice by relying on outsourced choices, accepting the personalised choices offered by algorithms.

- **A constant prompt for micro-sociality and micro-communication.** The convenience, frictionless and effortless nature of digital interaction, combined with variegated and expanding range of communication forms (text, voice, image, video, emoji, GIF, memes) has generated a superabundant flow of micro social interactions and ultra-minimal communicative acts. This type of sociality is in fact channelled and oriented by the specific interface and social architecture choices of each application or platform. The way prompts and notifications are formulated and chosen, the specific types of interaction buttons made available, the range of activity choices we are offered, the way templates are constructed, ultimately stimulate, channel, modulate and shape our actions within a pre-established and limited set of possibilities, including emotional responses, which reflect a certain system of priorities and values.

  On the cognitive and psychological level,

  - The immersive and interactive experiences enabled by 6G can potentially **enhance human cognition** by providing highly interactive, real-time learning environments.

For instance, virtual simulations in education or healthcare could offer experiential learning that mimics real-life scenarios, improving cognitive retention and problem-solving skills.

- The endless flow of interactions may generate feelings of **stress and overload**, due especially to the flow of micro-decisions associated with such actions.
- Prompted connectivity may deepen societal reliance on digital devices, potentially leading to increased screen time, **Internet addiction, and related mental health issues**, such as anxiety, depression, and attention disorders.
- The immediacy of information dissemination enabled by advanced connectivity may intensify the **fear of missing out (FOMO)**, a pervasive fear of being excluded from social experiences or opportunities. Individuals may feel pressured to constantly monitor their devices, participate in online conversations, and stay updated on news and events, leading to heightened stress, insecurity, and an inability to fully engage in present-moment experiences.
- As physical and digital realities merge, people may **struggle with identity and the authenticity of relationships.** Enhanced connectivity, may paradoxically erode face-to-face interactions, interpersonal relationships, and community cohesion, leading to feelings of loneliness, social disconnection, and reduced empathy. Social isolation, in turn, could increase if individuals become more comfortable interacting within immersive virtual environments than in the real world, leading to a fragmentation of communities.

  In terms of socio-technical considerations, this approach raises questions on the effects of non-transparent forms of behaviour influence.

➲ **Perceived hierarchy and approachability.** The use of electronic media has altered the social role and status of people. The online space of social media for example contributed to weaken the sense of perceived hierarchy and spreading a sense of closeness and of easier approachability, making all people (from the politicians, to the movie stars, to lay citizens) look the same under the presentation logic of a profile, and putting all at the same level.

3.3.3.6 Power Dynamics and Autonomy

The rapid adoption of 6G can challenge existing cultural norms and ethical standards, requiring societies to adapt to new ways of living and interacting. This includes addressing ethical concerns related to AI decision-making, data-ownership, and the environmental impact of widespread 6G deployment. In the new interactive and interaction scenarios of immersive communication, new dimensions and nuances of control and surveillance will enter the scene, with platforms collecting vast amounts of data on new aspects of users' behaviours and preferences, such as for example emotional responses or movements.

In the era of 6G, data will be a dominant economic resource, leading to new power imbalances. While increased data collection, tracking and monitoring can enhance security and operational efficiency, it also raises questions about who owns and controls this data, how data is used, and how much agency or autonomy people retain over their digital lives. Platforms and corporations will wield significant influence by controlling data and algorithms, potentially manipulating users' choices and reinforcing biases. As data continues to grow in importance, we are witnessing new forms of inequality, surveillance, and control, with users becoming more and more exposed to the risks of exploitation or manipulation. Users' autonomy may diminish as anticipatory design removes their need to make decisions, creating a more passive digital experience. This shift challenges the concept of freedom and agency, raising questions about the impact of algorithm-driven choices on personal autonomy, and about the role of governance, ethics, and societal equity in this rapidly evolving landscape. Similarly, the societal implications of increased surveillance must be carefully managed to prevent the erosion of trust and ensure that individuals rights are protected. Finally, societal attitudes towards privacy may evolve as individuals weigh new conveniences against potential risks. Some of the main transformation trends triggered by the data economy are described in the following paragraphs.

Impact of data economy on power structures. The dominant business model of the internet is built on the extraction, collection, storage, aggregation, analysis and trade of ever more fine-grained data about any aspects of user behaviour. This management of data, as a key economic asset, is known as data economy. Through their control and analytical capacity over vast amounts of data, a small number of corporations can tailor services, target advertising, and influence consumer behaviour, exerting a power that outpaces that of nation-states. Through behavioural data collection, companies can predict and manipulate consumer choices through targeted advertising, offering discounts, or promoting certain products at the right time. As concerns the democratic sphere, this capacity to manipulate can extend to influence public opinions and political choices, as seen in the influence of fake news, misinformation, and the manipulation of public opinion during elections or crises (e.g., COVID-19). This model is expected to expand even more in the ubiquitous paradigm of 6G and immersive communication.

It is to be noted also how opportunities in accessing data and the tools to extract value from it are not equally distributed also at the geopolitical level, with wealthier nations having greater access to data infrastructure (e.g., cloud storage, high-speed internet, and machine learning tools). As a result, data-driven innovation and wealth creation are concentrated among a small number of actors, widening global inequality.

Datafication, algorithms and personal autonomy. Algorithms show us how to influence users' behaviour through the power of data; at the same time, they show us many levels in which processes based on data may lead to biases. Algorithm influence users' behaviour by giving the impression of choice, while silently directing our choices, as well as making the need to choose unnecessary.

- In the first case, by proposing contents based on previous behaviours, or clickbait considerations, algorithms actively guide users towards a set of preconfigured, circumscribed, formalised choices (leaving us the illusion of free choices). Users' freedom of choice is only apparent, since it is possible only within a limited range of options, defined upstream through non-transparent criteria and commercially-driven considerations. This potentially limits people's exposure to diverse ideas or products. Individuals may be trapped in filter bubbles or echo chambers that reinforce existing preferences and biases. Over time, this affects how individuals perceive reality, subtly limiting their cognitive autonomy.

- In the second case, algorithm-governed processes get to influence our behaviour by making users' choices more and more unnecessary, by choosing on our behalf and instead of us. This tendency is concretised through anticipatory design, a combination of marketing strategies and technology design, whose aim is to ultimately liberate users from the burden of "needless choices" (eliminating the so-called "decision fatigue") [26]. Such a vision is based on a value system that aims at removing any friction from the activity flow, prioritises convenience over choices, and efficiency over freedom.

This influence of algorithms raises concerns about the potential manipulation of human behaviour and erosion of individual autonomy, calling for an ethics reflection on fairness, biases, autonomy, and transparency. Also, the lack of transparency, and the undermining of users' awareness of autonomy, leads to companies acquiring indirect cultural power. These mechanisms may reinforce the creation of a fragmented cultural environment, characterised by filter bubbles and echo chambers.

3.3.3.7 Digital Divide and Inclusion

6G, like other socially disruptive technologies, may lead to an unequal distribution of costs, benefits and risks. It has the potential to both reduce or exacerbate existing digital inequalities, impacting social mobility and access to opportunities, and potentially widening the gap between different groups in society. This raises significant questions of justice.

The development of 6G revolves around a vision of ubiquity, which is closely tied to the ambition of delivering affordable, high-quality broadband internet and network access across the globe, particularly targeting underserved or unconnected areas such as remote rural regions. Achieving full global service coverage would represent a significant step toward equity and social inclusion, ensuring equal and universal access to services and information worldwide. This will entail reshaping balances between urban and rural communities, allowing marginalised and underserved communities to participate in digital spaces that transcend the barriers of the physical world. In these social contexts, 6G is expected to enable advanced digital services even in areas with limited infrastructure, enabling equal access to education, healthcare, and essential services, irrespective of physical location. In education, for example, immersive technologies could bridge geographical gaps, allowing students in rural areas to virtually access museums and cultural events, or experience quality education despite limited local resources. Also, the creation and availability of more contents in languages other than English, will foster greater inclusivity. Finally, universal access will also have geopolitical implications, altering power dynamics between developed and developing nations, highlighting the need for enhanced decision-making processes and regulations around data, information, and network usage.

However, while the vision of connectivity for all offers great promise, every evolution in communication technologies brings with it the risk of deepening existing social inequalities. Without deliberate action, the gap between those with access to cutting-edge technologies and those without could widen, raising concerns about fairness and equal access. The absence of equitable access to 6G networks may further exclude marginalised groups from economic, educational, and social opportunities, exacerbating the very inequalities that 6G seeks to address. Risks of widening existing inequalities are connected to several factors related to access, infrastructure, and the broader socio-economic impacts that can accompany the rollout of advanced technologies:

Infrastructure and competitiveness disparities. While 6G promises global coverage, including remote and rural areas, the initial rollout will likely favour urban centres and affluent regions where investment in infrastructure is more economically viable. This transition period might temporarily widen the opportunity gap between early adopters and those left behind. Regions with limited infrastructure—especially in developing countries—might struggle to access or afford 6G technology, deepening the gap between digitally connected and disconnected populations. Regions or communities without access to these technologies may miss the economic opportunities that 6G facilitates. This uneven access could exacerbate existing economic inequalities within and between countries, reinforcing the socio-economic stratification that already exists.

Cost barriers and affordability. While the vision for 6G includes making broadband affordable, the initial costs of accessing this technology, including device purchase and subscription fees, could still be prohibitive for lower-income populations. Access to these cutting-edge technologies will likely be limited to those who can afford them. The cost of 6G-compatible devices, as well as the fees associated with high-speed data plans, may be out of reach for many individuals in both developing and developed countries. This could limit participation in the digital economy for poorer communities, exacerbating existing inequalities between those who can afford to access 6G services and those who cannot. Missed opportunities for leveraging the full potential of 6G technology [27] not only limit the realisation of socio-economic potential benefits for all, but also results in environmental and economic costs that could have been avoided with broader adoption.

Cultural hegemony. These disparities may rebound at the cultural level. For example, if the global digital content market will continue to prioritise the dominant languages and cultures of wealthier regions, smaller language groups or cultures that do not have the technological means to produce and disseminate content at the same scale, will be increasingly marginalised. Without deliberate efforts to promote linguistic diversity and cultural inclusivity, 6G could inadvertently reinforce cultural hegemony.

Digital sovereignty, data privacy and security risks. Developing nations that cannot keep up may find themselves reliant on foreign-owned 6G technologies, which could compromise their digital sovereignty and increase dependency on external powers. This could lead to unequal access to the benefits of 6G, as well as the potential exploitation of weaker nations in matters of data sovereignty and digital governance. Other disparities may arise globally as concerns the risk of unequal data protection practices. Wealthier countries or individuals might have access to stronger data privacy protections, while poorer or less connected regions may be more vulnerable to exploitation or surveillance. This creates an inequality in how different populations can protect their personal data and digital rights, which could disproportionately affect marginalised groups.

Work dynamics and skills. The labour market in general is likely to undergo substantial transformations. Enhanced connectivity may erode traditional boundaries between work and personal life, influencing work structures, remote work practices, and work-life balance. For instance, the rapid adoption of 6G may lead to job displacement, as automation and AI integration become more prevalent. Workers in traditional sectors may find their roles obsolete, necessitating reskilling and adaptation to new job markets. This economic upheaval could widen the gap between tech-savvy populations and those with limited access to new training opportunities.

Mental health and cognitive capabilities. The rapid exchange of vast amounts of data facilitated by high-speed networks may overwhelm individuals, leading to cognitive overload, decreased attention spans, and difficulties in information processing, which could impact decision-making and critical thinking skills. Brubaker even highlight the paradox through which cultural abundance not only becomes overwhelming, but at times even impoverishing, as in the never-ending content flow we are exposed to, “we come to know less and less about more and more” [23]. Different social groups react in different ways to the information overload. Analysis of these differences are needed to protect vulnerable groups that may be affected negatively by it.

The balance between digital engagement and physical activities also represents a significant rising challenge. Overuse of immersive reality technologies may lead to individual isolation and alienation, disrupting the essential human need for physical contact and social interaction.

3.3.3.8 Concluding thoughts on navigating the future of 6G

The transformative potential of hyperconnectivity and immanent media will reshape how we interact, construct our identities, and understand space, time, and privacy. These developments offer great potential for inclusion and innovation, but they also pose profound ethical, psychological, and social challenges. The ability of 6G to seamlessly integrate human experience into digital environments will require careful governance to ensure that technology serves society’s broader goals, such as equity, privacy, and autonomy. As we move into this future, it is key to critically examine the underlying assumptions driving these technologies and explore alternatives that prioritise societal well-being. These reflections lead us to sub-section 3.4, where the need to relativise the development of 6G will be addressed, recognising that technological progress is not neutral, and the choices we make today will shape the future we live in tomorrow.

3.4 ‘RELATIVISING’ THE PATH TO 6G

This section aims to **contextualise and examine the development of 6G technology within a broader framework**. This involves recognising that the journey toward 6G is not linear or absolute but rather influenced by various factors, such as societal values, stakeholder perspectives, and cultural contexts.

As emphasised by Science and Technology Studies (STS) and the Responsible Research and Innovation (RRI) approach, research and innovation occur within specific socio-technical contexts shaped by actors, networks, norms, and cultural values. These contexts include implicit assumptions that reflect the interests, goals, and priorities of specific stakeholder groups (e.g., industry or institutions), and which guide the direction of technology development. These assumptions comprise visions, paths, and priorities that influence problem-solving approaches. In addition, they often operate unconsciously, taken for granted beneath our awareness threshold. The evolution of mobile generations and the convergence of telecommunications, data, and media has largely been driven by an underlying, unchallenged belief that universal connectivity is inherently beneficial and should be a primary goal.

STS and RRI literature call for critical reflection on such assumptions, questioning paths that may seem inevitable and revealing them as products of specific cultural and historical contexts. Recent initiatives in Digital Humanism stress the need to reassert control over technology development, challenging the assumption that technological innovation automatically equates to progress. Two key narratives come under scrutiny: the belief that digitisation is universally beneficial and the notion that technological advancement is naturally guided by market forces toward better futures.

The following subsections put in practice the reflexive approach as defined in the RRI framework. First, a number of founding assumptions are identified, (section 3.4.1) which guide our research and innovation system; then, the relevance of the use-case level is highlighted (section 3.4.2), as a moment where an underpinning value-systems may orient priorities and choices; the section concludes (section 3.4.3) by examining the degree to which the narrative surrounding the rapid pace of technological advancements and the future we aim to achieve through 6G may align with the perspectives, aspirations, social needs, and projections of diverse social groups.

3.4.1 Positive assumptions: deciding where we head to

In line with the above-described premises, this sub-section aims to make explicit a number of mechanisms and assumptions that influence actions and decisions within the research and innovation sector. From the RRI perspective, the vision proposed must be understood as one amongst other possible or desirable visions. Therefore, in relation to the specific vision outlined by industry about 6G, the following assumptions influence research and investment orientations at the following levels:

- **The concept of innovation.** Innovation –meant as the process through which discoveries and novelties are transposed into societal value– depends primarily on technology advancement.
- **The value attributed to technological advancement.** The new features and capabilities connected to technological advancement are often viewed as inherently good and desirable *per se*. *New* and *more* constitute values in themselves. This is particularly true concerning a number of features underpinning 6G, as for instance:
  - **Hyperconnectivity**: a primary underpinning statement behind the 6G vision concerns a positive assumption about hyperconnectivity, presented as *the* value.
  - **Artificial Intelligence**: the assumption about artificial intelligence is positive as well as deterministic, for the capacity of AI to lead humans towards a better future, through supporting reasoning: "With advances in artificial intelligence, machines can transform data into reasoning and decisions that will help humans understand and act better in our world" [28].
- **The relationship between technological advancement and the economy.** The driving criterion to orient economic strategies and investment decisions is the technological feasibility. The economy and related investments go where technology brings them, since technological advancements are considered means to generate new

applications and services that would translate into new customer needs, new markets and economic growth.

- **The needs and expectations of customers/end-users, and the need to build certain sectoral applications.** As far as questions like "*What end-user problem and need are we addressing?"* or *"Why are current technologies not enough"* are raised, assumptions are made regarding the capacity of new services and applications to respond to the needs, demand and expectations of end-users, and about the direction that innovation shall take in certain sectors.
- **The hierarchy between values in a trade-off setting.** The necessity for establishing trade-offs arises from potential conflicts between different values. In the context of 6G, we might question whether the values associated with technological advancement or competitiveness occupy a privileged status as essential and non-negotiable priorities. If so, these values would serve as pivot points around which other values revolve and may be traded off, including crucial domains like climate, ecosystems, biodiversity, and human health. The tipping point of this balance depends on an implicit hierarchy of values. Different cultures, societies, or even social groups may recognise and prioritise values that diverge from those centred on technological advancement.
- **The relationship between technological progress and societal progress**. The envisioned scenarios and applications for 6G emerge from a specific understanding of the relationship between technological advancement and social development. This perspective tend to position technological progress as an inherent driver of societal improvement, suggesting that social challenges find their solutions through technological innovation. Such an approach implies that societal value emerges as a natural consequence of economic growth driven by technological advancement. This assumption deserves critical examination, as it frames social progress primarily as a by-product of economic growth and technological development rather than a distinct objective requiring independent consideration. It is indeed to be recognised how 6G has introduced important innovations to the process of technological development, with leading companies recognising the necessity to expand the design paradigm from mainly performance-oriented to both performance- *and* value-oriented. The explicit questions introduced about the role of technological innovation (*Why are current technologies not enough to solve the problem*? *What innovation should 6G bring?*) and a more active approach towards environmental and societal goals (*What end-user problem and need are we addressing?*) **are first concrete steps forward in relativising the importance of technological development, in favour of a more complex set of drivers.** Some points have, however, to be highlighted in this regard.

When viewed through the lens of the Responsible Research and Innovation framework, the current approach to envisioning the future of 6G highlights some areas for reflection. It appears that this vision may be shaped by a focus on technological feasibility and economic marketability, sometimes at the expense of exploring a broader range of possibilities in terms of societal desirability. Additionally, there seems to be a tendency to justify the use of existing technologies rather than considering new solutions that align with our collective aspirations as a society. This perspective suggests that there may be unintentional biases in how we outline our future and choose its foundational elements, including technological ones.

To better understand the significance of this approach, it is useful to explain some of its implications in relation to 6G, as follows:

- At the global and geopolitical level, a choice has been made that society needs to go towards hyperconnectivity. This constitutes a very foundational baseline choice regarding the role of technology within society (e.g., the six usage scenarios described by ITU). This choice, made on a global scale based on criteria reflecting the priorities and vision of a specific group of stakeholders, raises several important issues, related to the diversity of stakeholders involved, the decision-making process, and the adaptability of the vision to evolving societal needs, etc.
- The dominant vision about the network and media environment of the future, and the global race throughout the different generations of mobile networks towards 5G and 6G, pursuing better performances and features, and a change of pace, always in incremental terms, are a coherent expression of a specific technology-driven paradigm, rooted in the quest for competitiveness, and considering hyperconnectivity as a primary goal and intrinsic, undiscussed value.
- With 6G conception, considerations regarding social desirability and values important for society have been made more explicit in the description of use-case scenarios and related target applications, marking a positive shift in the way technology shall be conceived. In this context, the commendable goal of integrating the desirability criterion (primarily through social and environmental sustainability) represents a significant step forward. However, while meaningful, it is not yet sufficient to fully reshape a conceptual framework that has so far been strongly based on technology-driven and performance-oriented use scenarios. This addition contributes to a more balanced and thoughtful approach but still requires further efforts to be genuinely transformative.

3.4.2 Use-cases: deciding the *destination* of technologies

The passage from vision to specific use-cases fills a key strategic relevance for the shaping of the societies of the future. From the selection of goals to be achieved to the determination of specific approaches or concepts for addressing those goals, our choices are founded on implicit assumptions. These assumptions guide the setting and creation of the specific priorities, functions, tools, appliances, and resources we will be able to count on in the future.

For instance, the choices and priority made to shape the entertainment, cultural and creative sector will directly influence our cultural, symbolic and value universe. Similarly, when new technological capabilities to allow precision agriculture and farming emerge, we may direct them towards scenarios valuing sustainability and wellbeing, or we may opt to reinforce instead existing systems where productivity is prioritised [29]. Therefore, the crucial passage from a technology's generic capability to the specific design of a use-case has a direct creative influence in terms of imprinting a direction to our future society. For this reason, it is important to acknowledge with awareness the criteria and priorities that really lead the process, as well as whose idea of future is being nourished and actualised. We must also consider the actual influence of technology-driven or commercial criteria within the broader context, and examine the assumptions that underpin the selection of specific solutions for particular problems.

For instance, in this regard it is worth noting how the intrinsic necessity to compromise between the three pillars of sustainability is openly acknowledged in Hexa-X-II: "It is undeniable that not all observed 6G drivers derive from clearly defined sustainability goals but rather originate from technology requirements and business demands. In Hexa-X-II all use cases will be evaluated based on the three pillars of sustainability, looking at both potential benefits and any unintended negative consequences that need to be understood in order to develop mitigation strategies. The initial sustainability analysis presented in this section will be complemented in future deliverables with an elaborate in-depth analysis, the introduction of sustainability challenges, risk analysis, mitigation strategies, and the development of KVIs" [4].

In the same deliverable, it is also stated how "it is important to underline that the social sustainability's potential footprints consider a scenario where no additional policies or legislations for a smooth transition to the new technologies are put in place, nor other tools to prevent and minimise any misuse of the technology. Appropriate mitigation strategies will be suggested in future deliverables" [4]. This sentence implies two important statements:

- The pervasive effect of technologies on society is recognised, calling for the need to adjust regulations and policies to address the possible unbalances inevitably created among the entities of an ecosystem ("to ensure a smooth transition"), as well as to address any intentional but unintended uses of technologies (misuse).
- "Social sustainability's potential footprints", i.e., the negative externalities caused by technologies on society is defined as something that happens when adequate policy adjustments or measures are lacking to mitigate their impacts. This implicit statement invites debate about which relevant actors - such as industry and policymakers - should be held accountable or responsible for the impacts and consequences of technology deployment on society and societal values.

To conclude, **understanding the driving assumptions that underpin a developmental approach and its associated vision of the future** allows us to recognise that the paths we pursue are always relative and reflect the vision of **only a segment of society.** Consequently, we should ask whether all stakeholder groups, driven by different combinations of values, priorities, and interests, feel fully or partially represented by such visions and expectations; and this may have **a direct influence on acceptance dynamics.**

3.4.3 Relativism in priorities and ideas of the future

In light of the above, and with the aim of fostering an environment conducive to public trust and open dialogue with society, we should consider the extent to which the proposed narrative about the rapid pace of technological advancements and the future we aspire to realise through 6G aligns with the perspectives, aspirations, and projections of various social groups. Additionally, we must examine how this narrative corresponds to perceived societal needs, ensuring that it does not overlook issues deemed critical by the public. One approach to addressing this is to engage in discussions about values. When concerns arise, they often stem from the fact that **different interest groups prioritise certain values differently, reflecting the relative nature of value systems**. Indeed, value systems are relative: value prioritisation can shift based on different social or interest groups, or even within an individual depending on the various roles they occupy (for instance, a professional may prioritise different values than a parent). What driving values serve as pivot criteria when navigating conflicts between values and interests? Based on which values do we find the tipping point when seeking balance and trade-offs among social, environmental, and economic interests? **This will be further explored in section 4 dedicated to 6G and societal values.**

In light of this, there is an increasing call for a stronger and more proactive multi-stakeholder approach in shaping technology, capable of reconceptualising how technology is perceived, rather than treating it as a given. Following the European Declaration on Digital Rights and Principles, the market is urged to share this responsibility with other relevant stakeholders, prompting society as a whole to reimagine the approach to technological innovation and production. This should be grounded in a renewed and shared recognition that every design choice made lays the foundation for a particular future society, consciously choosing which human principles may be strengthened and which may be diminished. In the words of Paul Timmers, former Director of the Digital Society, Trust & Security Directorate in the DG CONNECT of the European Commission, “Digital technology is now in the veins, heart, and brains of our society. Yet, the idea that we can put technology into our hands to shape reality, rather than taking technology as a given, has still not been embraced by policy-makers. [...] we can and should give a stronger steer on technology to construct the kind of reality and in particular the kind of sovereignty we aspire to” [30]. By overcoming the limitations of technology systems that are often taken for granted - typically designed with a focus solely on commercial success or profit - societal aspects at the conceptual and design levels can be integrated and addressed. This would enable the realisation of a genuinely human-centred (or even better, planet-centred) approach to innovation [31].

To summarise, the current section examined the societal impact of 6G, highlighting how some of its significant consequences such as *hyperconnectivity* and *immersive communication* are poised to transform human interaction, identity, and social structures. While these changes present exciting new opportunities, they also introduce ethical and governance challenges that necessitate thoughtful consideration. Moving to Section 4, the focus shifts to the critical analysis of sustainability and societal values within the development of 6G. This section will explore how integrating sustainability into the 6G ecosystem is essential for aligning technological advancement with societal needs and environmental responsibilities. It will outline the intersection of values and sustainability with 6G innovation, establishing a framework that prioritises, in particular, long-term well-being for both society and environment.

What is proposed is that the discussions about what society values, desires, or considers sustainable - both socially and environmentally - can benefit from broader exploration beyond the current frameworks. While the existing governance structures and strategic assumptions create a defined range of possibilities for debate, dissent, and choices, expanding this spectrum could foster more inclusive conversations. Recognising that the boundaries of what is possible or acceptable may often go unnoticed presents an opportunity for enhanced technology governance. This suggests that decisions regarding society's future needs and its shape can evolve to better represent diverse perspectives and needs from the wider population. By engaging more stakeholders in these discussions, potential acceptance issues can be addressed, similar to those seen in the context of 5G-related protests, leading to more broadly supported outcomes.

4 6G, SUSTAINABILITY, AND SOCIETAL VALUES

As part of addressing the impact of 6G technology, it is imperative to incorporate, prioritise, and realise values that are important for sustainability. Part of the current 6G strategy within Europe is to proactively integrate societal values and sustainability policy objectives into 6G innovation to ensure the challenges and experiences that define sustainability is core to 6G as it is designed and deployed [32]. Such an approach not only ensures future environmental resources, health, and human well-being, but builds trust, aligns innovation activities with societal interests, and creates a foundation for acceptance [33]. It is especially important to establish how to integrate sustainability into 6G innovation because the next round of 6G standardisation study work has already started. So, how can a societal, environmental, and economic perspective be brought to technological development?

To do so, we must develop an understanding of how value drivers and technology enablers are intertwined to create impact, including how actions in one are only as effective as the connection to actions in another. When principles are leveraged without a rich understanding of the values they encompass or how they matter to and create an impact in the world around 6G, **priorities are often decided based on business interests, cultural biases, or technological capabilities**. This disconnect creates a frame where performance criteria such as hyperconnectivity, speed, or cost, are given the greatest weight, under the assumption that improved performance or decreased expense will have greater value than other attributes that might impact people or places.

Working towards value integration and new forms of impact, this section elaborates on the background necessary to build a framework for Key Sustainability Indicators. It elaborates on the synergies and incongruities in how value and sustainability get used in the 6G ecosystem, describing the various processes by which values become embedded in technology. It summarises key 6G strategy and European policy in which high-level values are articulated, exploring the implications of different classifications and priorities used by different actors related to 6G. With this foundation, we explore how Key Value Indicators (KVIs) are already being used in 6G innovation to bring sustainability into view and outline the next steps to enhance this process from a social science perspective. Finally, from this we establish the steps and criteria to build a framework of Key Sustainability Indicators (KSI).

4.1 WHAT IS MEANT BY SUSTAINABILITY?

Sustainability is defined as “state of the global system, including environmental, social and economic aspects, in which the needs of the present are met without compromising the ability of future generations to meet their own needs,” where the three dimensions of sustainability interact and are interdependent [34]. It requires a simultaneous assessment of present state and anticipated outcomes and impacts. Despite this general agreement high-level agreement to engage sustainability, **what elements, values, and priorities underpin sustainability vary depending on the perspective policy takes and the context of the intervention**. Understanding how values drive sustainability “to identify, convey, delivery, and capture, but also protect and sustain” over the long term is central to this effort [35]. As the framework and drivers for 6G get solidified, understanding how the various objectives collide and interact will increase the potential for 6G to reach its sustainability potential.

4.1.1 Sustainability as championed by the United Nations

The United Nations (UN)'s Sustainable Development Goals (SDGs) call for actions to protect the planet, to end poverty, and support peace and prosperity for all. **All three dimensions of sustainability - economic, environmental, social - are to be engaged in an integrated manner**, where "action in one area will affect outcomes in others, and that development must balance social, economic and environmental sustainability" [36]). To reach these sustainability goals, the UN's Agenda 2030 requires structural transformation, leaving no-one behind, and building resilience [37], [38]. For example, national local planning processes around poverty reduction need to integrate ecosystem and biodiversity values [39]. Sustainability from this perspective is not just about energy and carbon reductions but about environmental conservation. It is "people-centred, gender-sensitive, based on human rights, with a particular focus on the poorest, most vulnerable and those furthest behind" [40]. Sustainability remains a major challenge for 6G, where tasks like measuring the enablement effect (e.g., towards greenhouse gas emissions) or tracing the life cycle of a 6G solution (e.g., greenhouse gas emissions across all solution life stages) remain elusive and difficult.

Exacerbating this challenge is that, despite the global nature of these values, what they mean in practice is population-, place- and needs-dependent. The UN acknowledges such when offering guidance for developing national SDG strategies. they write:

> *"Every country needs to determine, for itself, how best to approach the preparation and implementation of its national sustainable development strategy depending upon the prevailing political, historical cultural, ecological circumstances. A "blueprint" approach for national sustainable development strategies is neither possible nor desirable" [41].*

Guidance from the UN further notes that national differences in priorities, processes, and definitions can be so different that many of the indicators are not able to be compared across countries [42]. For the purpose of 6G, this could also apply to use cases applications in different countries. Thus, 6G's approach to sustainability needs to be simultaneously top-down to develop a frame for comparability and bottom-up to support grounded and stakeholder-accepted impacts.

4.1.2 Key Policy and Strategy drivers around sustainability in 6G

A series of regulations and policies explicate elements of sustainability. These include the European Green Deal, the ESG taxonomy regulation, the United Nations' Sustainable Development Goals, and the EU ESG Taxonomy Regulation. **These not only describe key aspects of ensuring the health of the environment for future generations, but also all tie such actions directly to social and economic well-being, putting care for the environment into direct connection with care for people and economics**. For instance, fairness, competitiveness, education, poverty, consumption and production, and equality are part of the same policy as protecting nature, climate action, resource use, and emissions reduction. **While each is an individual value, sustainability compounds them.**

EU ESG Taxonomy

Climate change mitigation
Climate change adaptation
Sustainable use and protection of water and marine resources
Transition to a circular economy
Pollution prevention and control
Protection and restoration of biodiversity and ecosystems

European Green Deal

No net emissions of greenhouse gases by 2050
Economic growth decoupled from resource use
No person and no place left behind
Protection of planet and health
Fairness
Strengthening competitiveness
Cost effective
Tackling inequality
Enhanced skills
Openness
Enhance quality of life
Improve the reuse and recycling
Reduce greenhouse gas emissions
Foster digitalisation
Nature restoration

UN Sustainable Development Goals (SDGs)

No poverty
Zero hunger
Good health and well-being
Quality Education
Gender equality
Clean water and sanitation
Affordable and clean energy
Decent work and economic growth
Industry, innovation and infrastructure
Reduced inequalities
Sustainable cities and economies
Responsible consumption and production
Climate action
[Care for] Life below water
[Care for] Life on land
Peace, justice and strong institutions
Partnership for the goals

FIGURE 3: LIST OF VALUES DESCRIBED WITHIN KEY EU SUSTAINABILITY REGULATIONS AND POLICIES, SHOWING THE BREADTH OF ELEMENTS THAT MAKE UP SUSTAINABILITY

The European Green Deal similarly acknowledges that the various dimensions of sustainability are “strongly interlinked and mutually reinforcing” and that “careful attention will have to be paid when there are potential trade-offs between economic, environmental and social objectives” [43]. In this light, to ensure environmental or economic foci do not overpower social elements, the Green Deal specifically notes that it should be tied with the European Pillar of Social Rights and Europe’s Green Deal Industrial Strategy pairs the green and digital transition [44]. Policies like the Digital Transition, The Digital Decade, and the Declaration on Digital Rights and Principles, while they only minimally mention environmental aspects (though they do highlight fighting climate change, promoting the sustainability of digital futures), elaborate the kinds of values that make up sustainability beyond energy and net-zero [20], [43], [44], [45]. **Overall, these policies show the depth of how the European approach to sustainability ties together the three dimensions of sustainability and the breadth of values contained within.**

The European Pillar of Social Rights

Education, training
Gender equality
Equal opportunities
Secure and adaptable employment
Work-life balance
Healthy, safe and well-adapted work environment and data protection
Childcare
Social protection
Minimum income
Old-age income and pensions
Healthcare
Inclusion of people with disabilities
Long-term care
Access to essential services

Digtial Transition

Empowering people, businesses and administrations
Benefit everyone
Technological advancement
People first
Trustworthy
Open and democratic society
Vibrant and sustainable economy
Fight climate change
Achieve the green transition

Digital Decade

New ways to learn, entertain, work, explore, and fulfil ambitions
Reach out beyond physical communities, geographical locations, and social positions
No one is left behind
Everyone enjoys freedom and protection
Fairness
Everyone has the skills to use everyday technology

European Declaration on Digital Rights and Principles

Putting people and their rights at the centre
Supporting Solidarity and inclusion
Ensuring freedom of choice online
Fostering participation in the digital public space
Increasing safety, security and empowerment of individuals (especially young people)
Promoting the sustainability of the digital future

FIGURE 4: LIST OF VALUES INCLUDED WITHIN THE POLICY THAT ARE INTERLINKED WITH THE GREEN DEAL, HIGHLIGHTING ASPECTS BEYOND THE ENVIRONMENT THAT POLICY CONSIDERS IMPORTANT FOR SUSTAINABILITY

In relation to 6G, sustainability (environmental, societal, and economic) is explicitly highlighted by the European Commission as a key priority [39]. In terms of environmental sustainability, EU policy briefs on 6G focus on increased energy efficiency and reduced energy consumption to reduce emissions. Security, privacy, accessibility, openness, inclusiveness, enhanced connectivity, and protection from external actors are key to societal and economic sustainability. It is interesting to note that **the more detailed list of priority values within the EU 6G strategies only minimally overlaps with the EU sustainability policies**.

Also, implicit within these 6G strategies are further policy priorities that have the potential to create trade-off challenges, such as increasing the pervasiveness of digital possibilities and machines, improving the availability of broadband, and becoming a leader in the area [20].

4.1.2.1 National Priorities and Definitions around Sustainability

As further noted by the OECD, “in the context of a specific country, defining end-values should be the result of a process that considers the **political, economic, social and environmental circumstances** of each country” [46]. This can be seen in the variations in what nations focus on when applying these policies to their national contexts. Understanding these differences are key to both clarifying a stakeholder’s priorities, particularly when that stakeholder is a project’s trial user, as well as assessing how international frameworks, like SDGs can be transposed to activities at a smaller scale. Some examples are below.

In Spain, **equality** is further elaborated as non-discrimination, child protection, protection of persons with disabilities and elderly, including guaranteed accessibility of digital environments [47]. In Wales, ‘**Equality’** becomes the ability for people to fulfil their potential no matter what their background or circumstances, such as adults with qualifications, fair pay, people living in poverty, people with access to services, young children developing the right skills [48], [49].

Germany prescribes specific **energy efficiency and environmental criteria** to public procurement, such as costs for energy consumption, lifecycle costs, and cost of emissions over lifecycle [50]. France's national perspective on the **circular economy**, including repairability, use of recycled material, recyclability, and the presence of precious metals or dangerous substances, also considers the amount of **data used and the related emissions** [51]. Belgian strategy includes values that support **social cohesion** and the UK's Social Value Act considers social, economic, and environmental **well-being** [52], [53].

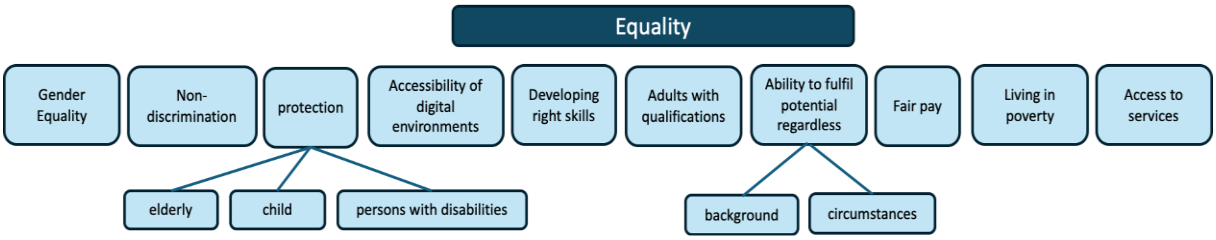

FIGURE 5: EXAMPLES OF ELEMENTS OF EQUALITY AS EXPRESSED IN SPANISH AND WELSH LAW

Different countries also include different key features in their national strategies. Greece's Just Transition Plan includes health, inclusivity (e.g., inequality, job insecurity), energy security, climate change, and environmental sustainability. Italy's National Energy and Climate Plan prioritises inclusivity (e.g., inequality, job insecurity), energy security, climate change, and environmental sustainability, but not health. Hungary's National Sustainable Development Framework Strategy highlights health, aging populations, inclusivity (e.g. inequality, job insecurity), and environmental challenges. Norway's Energy Strategy focuses on energy security, climate change, and environmental sustainability. Poland's National Energy and Climate Plan emphases energy security and climate change.[1] Italy's Corporate Responsibility Directive 254/2016, focuses on environmental, social, personnel management, human rights and anti-corruption. While all covering sustainability, they prioritise different aspects [54].

Understanding these differences can support proper prioritisation of indicators and impacts in a given project.

4.1.3 Sustainability as defined by the 6G community

The SNS JU describes sustainability, economic growth, and trustworthiness as the priority areas for 6G efforts [55], specifically highlighting energy efficiency as a key impact priority [55]. It often, though not exclusively focuses sustainability on 4 SDG goals: 8: decent work and economic growth; 9: industry innovation and infrastructure; 11: sustainable cities and communities; and 13: climate action.

The three dimensions of sustainability, related to the triple bottom line, have been further elaborated in the 6G-IA position paper as "Sustainable 6G" and "6G for sustainability" as [32]:

- **Environmental sustainability**: "Targeting the minimisation of environmental impact", including usage of natural resources, reduction of consumed and emitted energy, reduction of carbon footprint of manufacturing and operation of 6G networks, circular

[1] Summaries of these initiatives can be found at: https://stip.oecd.org/stip/interactive-dashboards/policy-initiatives

economy, and decreased environmental impact of other industries enabled by 6G. resource sharing principles, trust, transparency.

- **Societal sustainability**: ", aiming at providing value to people and society thanks to new use cases powered by 6G", including safety, security, trustworthiness, inclusiveness, and health.
- **Economic sustainability**: "where 6G will be an enabler for business value", including economic value-added, jobs, production of public funds, productivity gains, flexibility, supply-chain diversity, fair allocation of costs, and improved opportunity for development.

6G use-case-based values were further elaborated by a white paper and the 5GPPP working group, drawing additionally on the European Green Deal, Human-centred design, as well as the broader European values of strategic autonomy and technological sovereignty, to include, as large categories, environmental sustainability, societal sustainability, and economic sustainability and innovation. It also lists SDG-related values of democracy, cultural connection, knowledge, privacy and confidentiality, simplified life, personal freedom, personal health and protection from harm, and trust [56].

Informed by the Environmental, Social, and Governance (ESG) materiality assessments, the European Green Deal, Life cycle assessment processes, and the United Nation's Sustainable Development Goals (SDGs), other industry groups have also described sustainability values that matter to the next generation of connectivity. Primary across all are energy efficiency, direct and indirect emissions reductions and reduced carbon footprint without compromising performance [57], [58], [59], [60], [61], [62], [63], [64]. Some also specify lowering energy use and consumption.

Others, still highlight the need to improve the circularity of what goes into making 6G work, from infrastructure to device [57] , [58]. Included with this are sustainable materials, e-waste, networks, and manufacturing processes, focusing on impacts both land and water [58], [59], [65]. The Alliance for Telecommunications Industry Solutions (ATIS) and the 6G Smart Networks and Services Joint Undertaking (SNS JU) also stress the need for improved handprints, via enabling other areas to improve their sustainability. Also, along with ITU, they raise mitigating biodiversity loss [66], [67]. In addition, ITU includes literacy and training as key to these priorities. As concerns cross-Atlantic collaborations, the EU-US Trade and Technology Council (EU-US TCC) together with ATIS and the SNS JU, refer to societal sustainability comprising affordability, accessibility, inclusion, closing the digital divide, societal resilience, justice and inclusivity [68], [66]. The EU-US TCC also underlines priorities around trust, data privacy, security and resilience as key to this. However, only a few industry groups include in their definitions elements referring to societal sustainability or to the Just Transition Mechanism [58]. ITU includes the need to include literacy and training. Connect Europe (ex ETNO, voice of the leading providers of connectivity networks and services in Europe) and 3GPP (Third Generation Partnership Project) consider security and resilience systems that support economic sustainability, competitiveness, and wellbeing [64], [69]. Indeed, environmental and societal/economic issues – like digital equity, trust, economic growth, quality of life –are often treated separately enough that they are structured into two separate working groups under ATIS (Next G Alliance) [70].

TABLE 2: FREQUENCY OF DIFFERENT SUSTAINABILITY VALUE TERMS APPEAR IN INDUSTRY STRATEGY

Environmental Sustainability	Societal Sustainability	Economic sustainability
Energy Efficiency	Security	Economic Growth
Reduction in direct and indirect GHG emissions	Data privacy	Innovation
Circular Economy	Affordability	Investment
Environmentally friendly materials in supply chain	Accessibility	Education
Enable other industries to reduce their footprint	Inclusivity/inclusion	Labor
Sustainable use of water, energy, and materials	Trust/Trustworthy	Equal Access
E-waste	Resilience	Reduce costs
Adaptation to climate change	Digital equity	New markets/applications
Sustainability along product entire life cycle	Availability	New revenue streams
Sustainable ecosystem	Closing digital divides	Increase capacity
Circular and Sustainable cities and communities	Justice	Economic competitiveness and well-being
Reduced footprints (Sustainable 6G)	Quality of Life	Openness
Improved handprints (6G for sustainability).	Training and literacy	Economic viability and jobs
Biodiversity loss and its mitigation	Quality of experience	Resilient economies
	Safety	
	Resilient societies	

The general spread of sustainability values (i.e., the frequency with which different sustainability value terms appear in industry strategy, assessed over a variety of documents across eight organisations) is summarised in Table 2, with the most commonly mentioned values in darker blue and the less mentioned in lighter blue.

Summarising, there is a broad acknowledgement across industry groups of the various elements of sustainability represented in EU policy, with focus on different ranges of sustainability issues. However, it also emerges the tendency to prioritise values connected to previously existing industry priorities – such as energy efficiency, security, privacy, affordability, trust, economic growth, and innovation – while the call to action for towards many sustainability areas remains limited. **This suggests that while awareness is there, further support is needed to push sustainability action into more holistic approaches.**

4.1.4 Where does the public sit on sustainability and 5G/6G?

As concerns instead the public perception of value in relation to 6G, research with different communities across Europe show that public often seeks 5G and related technology to support socio-economic flourishing, giving more prominence to the elements of sustainability. While some segments of the public are concerned about the health effects of the telecom sector, most see 5G as having greatest potential to impact, both positively and negatively, social and economic well-being. Of particular importance are improved lifestyle and daily experiences [71]. This includes improvements in levels of loneliness and isolation, harm, unwasted time and resources, improved social connections and mental health, physical health, improved practices that support business innovation and growth including decent work, public safety, autonomy and choice, sustainable cities and communities, responsible consumption, and resilience of connected communities [72], [73], [74]. The public also values privacy, non-discrimination, and national and European security [75]. These values, however, were not uniform. In the studies above, **key values and their meanings changed depending on location, gender, age, level of education, income, occupation, etc.** This suggests, for example, that traditional techno-economic factors (e.g. good jobs, digital availability) do not always correlate to improved well-being. As importantly, these studies also found that the public is concerned by the possibility that the respect of their values may be subordinated to or traded off in favour of the reasons of technology advancement.

Considering these values, it is important for the 6G community to balance the strategic articulation of sustainable values with the public's lived needs in relation to the policy priorities. Below is a diagram showing a rough ontology of societal sustainability values across these domains, as described within these texts. This raises a series of questions about what values and priorities should drive 6G work, including what are the implications of differences in what public values, industry values, and policy perspectives. Should 6G innovation focus on the areas of overlap, focus on a specific branch, or develop its own taxonomy? Looking at policy and strategy alone does not create a clear enough picture or consistent enough terminology and definitions to establish the necessary Key Value frame for sustainability. Developing this further to create a baseline value framework would support projects in understanding how different values are a) further defined by the different communities; b) expected outcomes that are connected to the values for different stakeholders; and c) offer insight into clusters of values that could be strengthened if they were approached together. These differences also demonstrate the need for multidisciplinary teams to develop the ontology for 6G, so that the different priorities and needs across stakeholder perspectives will be incorporated into the final taxonomy created. Without this inevitably industry will drive one way and the public another, and they will meet very little in the middle, as demonstrated in Figure 6.

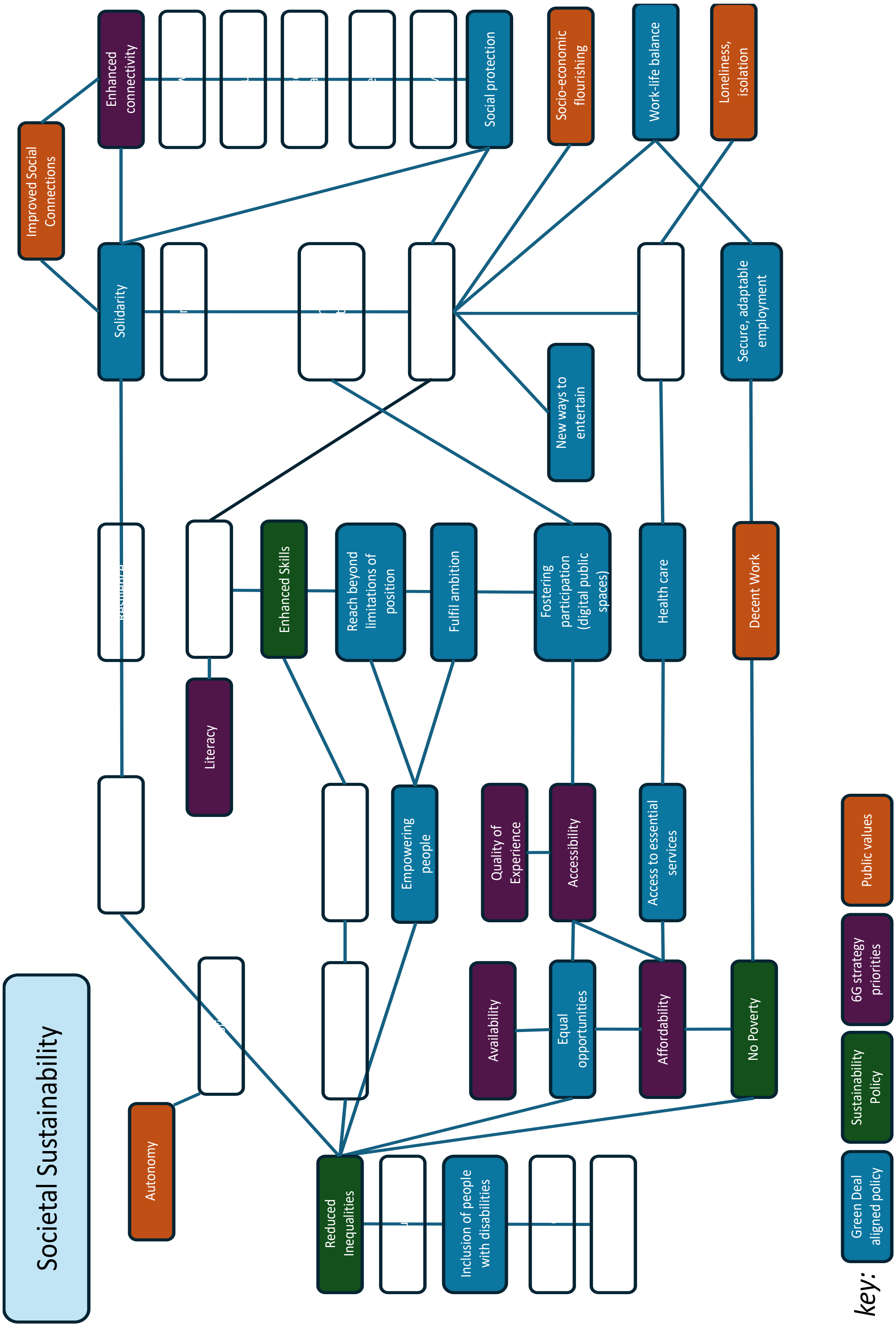

FIGURE 6: DRAFT ONTOLOGY OF SUSTAINABILITY VALUES BASED ON HOW THEY ARE PRESENTED BY THE VARIOUS STAKEHOLDERS

4.2 HOW TO APPROACH THE VALUES THAT UNDERPIN SUSTAINABILITY?

Despite the pervasiveness of these values and sustainability across Europe as principles, what they mean in practice is neither simple nor uniform. As concerns values and desirable ends at a high level – such as safety, freedom, equity, economic security, health, etc. – it can be affirmed that they are more or less held by all. However, they become contested when exploring what they imply for a specific group of people, for an individual, or when applied towards a specific goal. Even more, controversies arise when these values are specified into norms [76]. This is especially the case when values become prescriptions for action and codes for conduct. As the definitions become operationalised, different groups and goals will not always agree on how they are translated into concrete actions or outcomes. Controversies emerge because the passage from a more abstract definition of a value, and its concretisation into specific objectives, implies the possibility of different interpretations and of different specific applications, which do not transfer across time/place. **What constitutes a value in action, how it is understood or enacted, and what values are prioritised, depends on context**. What is considered representative or a way of achieving a value can change depending on country, economic status, cultural history, and social status. This is one reason why it is t important to balance insights with individuals/stakeholders with broader considerations of value. What matters to one group or person might not to another. What matters to society might not be expressed or prioritised the same way for a community or individual and vice versa. If the normative elements and principles become too rigid in their meaning, they will inevitably give rise to conflict [77].

Context is needed to both understand and define how values matter or are prioritised. Lessons from the European Value Study, a multi-national multi-decade study of key values in European society that aims to understand how and what values are shared across Europe and how they change over time and place, are important qualifiers here. There are very few values that are understood or defined equally across Europe. As an example, results show that Western Europe has high interpersonal trust, whereas Eastern Europe has low levels of trust. Similarly, the survey found that in Georgia, 90% of people want income equality, but in Denmark, only 50%. This is likely not because of a lack of valuing equality in Denmark, but rather because in Denmark there is already a high-level of income equality, while there is not in Georgia [78]. **Differences in how values are prioritised and understood across groups could result from unique needs within those groups, which might not all have the same mainstream needs or reap the same benefits.** Another example regards environment. Whether environmental well-being is considered a luxury or a health threat, can depend on the economic stability of a region: a community whose basic needs are fulfilled will focus on non-economic goals, such as self-expression, quality of life, or quality of air and environment; otherwise all what falls outside of immediate survival (food, shelter, physical security) and necessity could be considered a luxury [78].

> Thus, it is important to ask: is environmental sustainability in this context about the reduction in energy use by ICT? Or does the region care more about the quality of their water? Is public safety about having police on every street or building strong community ties? Is well-being about good housing, access to health care, social interactions, or unpolluted environments? Is fairness about equality or equity? **KVIs need to support explicit articulation of values in ways that allow for these debates as the values are put into practice in specific contexts.**

Values also change over time. For example, during the Coronavirus pandemic – about the typical innovation cycle within an SNS project – values that were prioritised within society changed. At the beginning of the pandemic, in Europe and the US, health & safety and economic well-being were key priorities discussed in the media, dropping as the pandemic progressed to give way to a prioritisation of discussions around socio-economic equality. However, these trends did not always hold across the rest of the globe or in lower-income countries, and some have reversed as the pandemic eased and the situations/context changed [79]. "It is unlikely that the new digital world can embrace precisely the same values and established principles that have governed our non-digital history" [31]. The question is understanding what values to keep and protect, and where to embrace new or adapted principles.

4.2.1 "Value" itself has many undertones

In the context of sustainability, 'value' can have multiple interpretations, stemming from values as principles, values as benefits experienced by society, and value-for-money dimensions. These affect what makes a good indicator towards value and where and how bias is seen in the choices made around indicators.

Different disciplines have taken distinctive approaches towards value, how it connects to communities, and how it is connected to sustainability [80]. Definitions range from value as worth (e.g. monetary), value as a societal goal (e.g. SDGs, human rights), to value as a moral driver within society (e.g. ethics). Looking at how we talk about values can **clarify the actual project behind sustainability,** helping to identify the actual scope of sustainability, **which aspects might be impacted,** and **who are the stakeholders**. It also helps reveal the assumptions behind trade-off logics – since **what might be prioritised in a trade-off scenario changes depending on which approach to value is taken and the biases we encounter.**

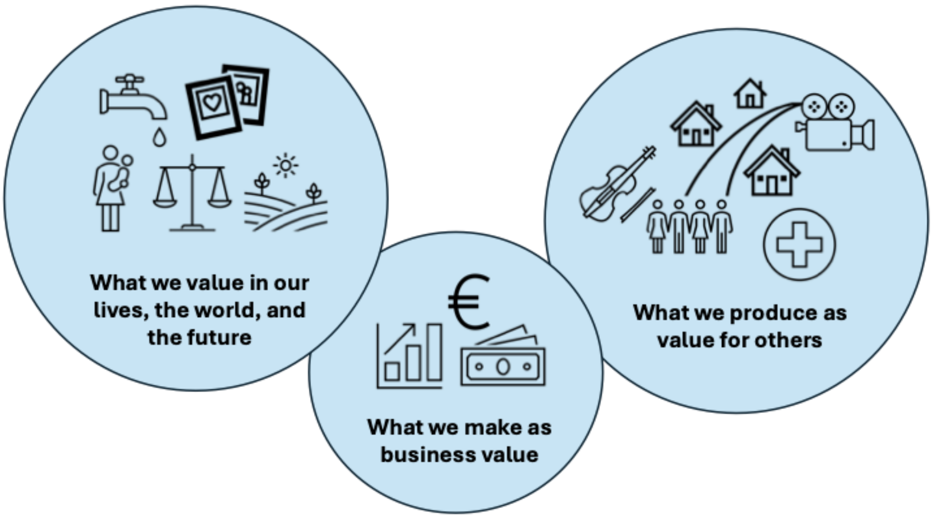

FIGURE 7: THREE DIFFERENT UNDERSTANDINGS OF VALUE AS A CONCEPT RELATED TO 6G

4.2.1.1 Societal Values: what we value in our lives and the world

Values, as part of society and culture, are foundations for human actions, integration into communities, and social decision-making. The EU, as enshrined in The Treaty of Lisbon

(2007), defines societal values as those which **support improved well-being of individuals and communities as well as those that promotes justice, belonging, inclusiveness, tolerance, non-discrimination, and cohesion**. Sociology and cultural studies define values as abstract concepts that inform ideal or desired futures. Organisations like *Social Value International* define social value **as making positive change to the world or people's lives and well-being in ways that are important to communities and society as a whole**. **This requires understanding specific contexts, cultures, politics, economics, places, and times.** From these perspectives, these are motivating values that guide contributions towards society, decisions taken towards specific objectives, and criteria for evaluating if actions are good or bad based on what is needed for a society to survive [81]. These are often codified into policy or strategy drivers. Wikström et al. [56] call these "*values as criteria and goals*".

In this frame, societal and personal values are not the same thing, and even more, they can often clash. Thus, relying on individuals alone (e.g. user interviews) can often mis-represent societal needs.

4.2.1.2 Value Added: What we produce as value for others

Value is created by some activity and is brought to society now or in the future. Here**, value is an end goal, like a mathematical equation, additive in nature**. Value is achieved if the output has societal relevance (e.g. useful and beneficial) and societal impact (demonstrable contribution towards such use and benefit) [82].

Value added is often treated as an economic calculation that looks at costs of production (e.g. materials and labour) in relation to intermediate consumption (e.g. how much is sold and at what price) [83]. However, it can also look at other aspects like added quality, convenience, choice, effectiveness, or accessibility [84]. In the general discourse around 6G, such value is regularly defined via a belief in the inherent positive value of increased connectivity and hyperconnectivity, efficiency, speed and market expansion, emphasising constant access to information. In sustainability strategy around 6G, this could include better health outcomes, nature restoration, decreased pollution, reduced inequalities, enhanced skills, improved social cohesion, or improved living environments. Procurement policies that focus on social return on investment, like those found in The Netherlands, engage this form of value [85]. Wikström et al. [56] term this form of value "*values as outcomes"*, as enabled benefits or harms resulting in what 6G does or how 6G is used.

4.2.1.3 Value-for-Money: what we make as a business value

This form of value is traditionally about net earnings and competitive advantage, e.g. value-for-money. It is about the value created within a business activity, improving market reach, adding new consumers, and finding new applications. Cost-benefit analyses often use this form of value. However, in the last two decades this concept of value has been pushed to include shared societal impacts [86]. The OECD, for instance defines value-for-money as including "social considerations such as respect for human rights, labour rights including non-discrimination, and gender mainstreaming, as well as promoting economic opportunities for long-term unemployed people, minorities and people with disabilities" [87]. It suggests more socially-aware models such as Responsible Business Conduct [88], where businesses build a greater understanding of what is at stake for the communities with which they are engaged. As it puts its resources towards the problems that emerge from these understandings it will have more opportunities to create greater impact and shared value for those communities [89], [90]. Cost is just one indicator that needs to be treated in relation to others, not overlook long term reach of benefits [91].

4.2.2 How Value Becomes Part of Technology

Values creep into technology in different ways and moments, leaving implicit bias in design and business decision, and affecting thus the trajectory of technology development (in our case, of 6G. From who is involved in the conception phase, to how target audiences are chosen, what is prioritised in the design, and what promises are made about 6G, all these choices embed values. During different intervention points, different biases can emerge as a result of how values interplay with innovation, including: 1) selection bias of which priorities, stakeholders, and data are considered; 2) confirmation bias where information that confirms one's pre-existing beliefs is unintentionally favoured while disregarding information that contradicts these assumptions; 3) response bias in how data is collected such that it influences the responses; and 4) cultural bias: where data is interpreted through the lens of one's own cultural norms, values, or assumptions.

This process is not without consequences. As already described in the way technologies create impact, the interaction between value and technology transforms technology into a political and moral actor in and of itself [92]. For example, a speedbump is constituted by material on the ground, which creates a bump that can be driven over safely if a car goes slow. Besides this, it also forces those around it to act in specific ways, being imbued with the value of safety [93].

it forces cars to slow down; .it allows pedestrians to cross roads with little fear; it helps keep children playing in the street from harm; and ultimately, it communicates the norm that human safety is more important than faster commutes. **6G is no different: it encourages humans to act in specific ways imposing rules as to what is appropriate behaviour and what is an acceptable outcome** [94].

Understanding these dynamics, therefore, 1) makes it possible to outline different points of intervention in innovation where values can be productively engaged; and 2) suggests different times and forms in which value can be monitored and measured depending on the point of intervention. Also, it demonstrates that engaging values involves more than just addressing what can be included within project scenarios, which can carry the biases described above, especially cultural biases). It requires taking into account societal broader and longer-term objectives, based on diverse societal visions of the future. The two things may not agree with each other and their interactions need therefore to be explicitly addressed, in order to avoid bias or, at least, to be transparent about the biases within.

Unconscious values	Conscious values	Values impacted by	
Trajectory priorities Target audience assumptions Corporate culture that structures what is possible Vision of good life that informs what	Trajectory choices Target audience choices Choices created by funding Capabilities and limitations put into policy	Why audience is prioritised	Conception
Tastes that inform design Design choices Data/evidence and models used What becomes a tech requirement or KPI Who is involved in design	Priorities put into policy Whose input is included and at what stages of design What kinds of deliberations are taken Design decisions	Material, environmental, and labour resources used	Design
Who ends up gaining access and benefits What has to change infrastructurally or environmentally for it to work	Promises made Who is given access Who is intended to gain benefit	Narratives shared Power dynamics in the have and have nots	Diffusion
The applications it is able to used for	Intended area of use Relationship sought to be made because of the solution Types of decisions than can be taken	Interactions, relations supported New practices that emerge New mental models about the daily life New policies required (to control or spur)	Use/user

FIGURE 8: VALUE PATHWAYS INTO TECHNOLOGY

4.2.2.1 Values unconsciously embedded into technology

People create technologies. People who are from specific places and times, who are motivated by specific cultures, societal problems, power dynamics, resource flows, beliefs, biases, expectations, and interests [67], [85]. Often taken for granted or unspoken, this includes how designers get paid, who controls the narratives, who and what data is included in design processes and design goals, and how we teach technology design [95]. These people include technologists, funders, and governments. These socio-cultural and normative influences unconsciously drive our daily decisions about what we buy, how we govern, what becomes public imaginary, and what is considered a normal approach to activity [76]. They become unconsciously embedded in the technology people make, the narratives and public imagination they produce around them, inevitably shaping its design and functionality.

These unconscious values impact ideas about what technology should be made, who the target audience is, including their needs and tastes, and who deserves the technology first. It also impacts conceptions of what data is needed to prove a value is being addressed, and whose voices should be included in these discussions. Technology created within a society that values individualism may emphasise features that support personal customisation and autonomy (e.g. remote work capabilities prioritised over equity in access to those capabilities), while a society that values personal attainment may emphasise novel gadgets over support for a blind person. It is why many companies are now seeking diversity in their workforce. Not paying enough attention to unconscious values can lead to the same challenges faced by AI, a technology increasingly tied to 6G, further disconnecting technology narratives from real impacts and harms [96]. **KVIs that focus on the activities that inform conception and design can both mitigate biases that could emerge and become an opportunity to be more transparent about driving narrative of how a given innovation brings benefits.**

AI systems can learn bias from a range of source: training data that carry with them the values behind what data should be collected; models which carry normative assumptions in everything from smoothing decisions to how qualitative relates to quantitative; shifting an algorithm designed towards one goal – with one set of values –towards another goal and value set [97]. Well documented, if unintentional, acts of discrimination have emerged in systems meant to be the social fabric of society. The Dutch tax authority AI system misidentified benefit fraud, unfairly penalising thousands, resulting from value judgements that informed the training data and models [98]. Danish child protection used AI decision-support to similarly enacted inequalities and discrimination [99]. Moreover, the previously unspoken aspects of how AI is produced, from natural resource extraction to low-wage labour, have been shown to offer challenges for equality and democratic governance [96].

4.2.2.2 Values consciously embedded in technology

Values can also be consciously and proactively embedded into technology in response to explicit institutional requirements or societal demands. For example, SDGs and Green Deal advocate for technologies that promote sustainability. These values are actively translated into design choices, technical requirements, Key Performance Indicators (KPIs), and evaluation processes. Prime examples are ongoing 6G efforts to work towards digital inclusivity or climate mitigation. Specific design decisions are being made that support different segments of society to access and benefit from 6G and to improve the recyclability and longevity of services to reduce pollutants in the environment. Value-Sensitive Design is a useful method to support such conscious approaches to value**. This is the approach to value that KVIs are seeking to achieve. Understanding how values can be proactively embedded from conception to use can open up the variety of KVIs being created, beyond project outputs.** For instance, how are demographics prioritised in target audiences across projects relative to general populations and whose input is included in the design process?

4.2.2.3 Values impacted by technology

While values can impact technologies and how they function in society, technologies can also have concrete effects on people, environments, and economies. By using or regularising a technology, values can be transferred to and even transform society reshaping societal norms and expectations [100]. This has been readily seen resulting from the use of mobile phones, social media, cars, and even electricity, as already well elaborated in the impact chapter.

The rise of social media platforms has significantly altered communication norms, affecting what it means to ensure privacy, equity and accountability. This, in turn, has impacted what is considered acceptable ways of talking to others (e.g. increasing bullying) and who it is appropriate to talk to in order to participate in democratic processes (making echo chambers the norm). increasingly able to tailor information to individual preferences, it can lead to new forms of self-identification, challenges in collective identity and community cohesion [100] .

It is not just an individual's activities that can be impacted. It can impact mental models (transformative change), relationships and connections or power dynamics (relational change), and policies, practices, or resource flows (structural change) [101]. The promises and narratives around 6G can impact what communities imagine as a good future, which in turn legitimise specific ways of acting, and impact how values are enacted and prioritised [102]. **Anticipatory KVIs that bring into view changes in community relationships or resource flows can offer insight into these impacted values.**

4.2.3 Implications for 6G

Values exert a significant role across different stages of technological development, from conception to user interaction. During the conception phase, implicit assumptions about the purpose and impact of technology are made, often reflecting the creators' cultural context and values. In the design phase, values are embedded, whether intentionally or unintentionally, through the choices made by developers. As technology diffuses, it carries these embedded values, influencing user behaviour and societal norms. At the user interaction stage, individuals engage with technology based on their own values, which can shape how technology is utilised and perceived, and vice versa. **Early on, innovation is most malleable and thus can better address values as part of design not just as a result of design** [103]. In 6G, these interactions between value and technology affect:

- which technologies will society have or not
- orientations we give to research (we invest in this tech instead of this)
- prioritisation of technologies, or even before, prioritisation of problems and audiences
- which effects are sought from the design, which are not considered
- what stories and promises we make and vision of a good life
- what and who gets funding
- what gets regulated
- who gains benefits and how that aligns with design intentions
- what both publics and designers value in society
- what both publics and designers accept in a technology.

In other words, just focusing on inclusivity alone or energy consumption alone will not support these goals nor likely mean that the actions will produce the benefits and outcomes desired, as they will have consequences or contingencies in other areas that need to be acknowledged and addressed. Moreover, to contribute to such social values, work needs to have an explicit focus on desirable ends, otherwise work will simply be avoiding harms [104].

Addressing these embedded values necessitates adopting human-centred, planet-centred, and value-based approaches to 6G innovation. This requires:

Actions related to values:

- Explicit articulation of what is desirable and acceptable within society [76];
- Understanding of what is at stake and for whom in the definitions chosen, and where controversies or disagreements might exist in relation to them;
- Providing context, in order to understand both what values mean and do in practice, and define how values matter or are prioritised;
- Codifying values in a way that considers how they change over time;
- Including bias mitigation and transparency activities throughout the innovation process;

Actions related to stakeholders and governance:

- Treating people not as a monolith, but with an understanding towards diversity;

- Including the diversity and representativeness of diverse stakeholders in deliberations around values to balance the innate values and biases we all have [105];
- Working with stakeholders to articulate the bigger picture (e.g., goals, context, situation, ecosystem dynamics) and the greater good being worked towards [56];
- Engaging forums for deliberation that include the widest possible range of experts, public, innovators and policymakers, where they can agree upon the choice of a value within those activities, its definitions and the impacts of engaging that value in order to inform those processes and governance [106];
- Developing systems for assessing echo chambers in design, development, and use [105];
- Building a robust process and governance for ensuring the value is applied across the innovation chain;
- Translating high level-values and their objectives into selection criteria for funding [106];

Actions related to technology development:

- Addressing values before design even starts, at the conception phase and within the teams involved;
- Educating designers and developers to be more aware of the possible bias they can inject into technology based on their personal priorities and values, as well as how to acknowledge and address them [105];
- Engaging foresight processes to consider the technology as a concept, the technology as a material and procedural artefact in context, and the applications towards goals [107];
- Considering technology not just as an enabler but as an *actant* that differently affects the world at different scales and contexts [100];
- Ensuring a careful balance between critique and alternative approaches to empower those involved in the innovation chain to act [95].

4.3 CURRENT APPROACHES TO SUSTAINABILITY VALUES WITHIN SNS PROJECTS

Currently, SNS projects approach sustainability through KVIs. This value-driven approach aims to guide technology development and clarify project goals and contexts of use. The aim is to put the person, planet, and prosperity at the centre to demonstrate and validate how technology is contributing to those values. These are currently being used both proactively, to inform conception and design, and reactively, to evaluate existing technology to build baselines and understand where change might be needed in the future. Developed as a complement to Key Performance Indicators (KPIs) that focus on technological functions and states, KVIs seek to ensure responsibilities towards society by identifying, monitoring and validating the impact that development can contribute towards. In relation to 6G, Wikström et al. [33] define them as

> *"quantitative or qualitative indicators for gauging effects on values as outcomes. The purpose of KVIs is to gauge the impact from the execution of a use case in terms of economic, social and/or ecological benefits (gain) or detriments (loss)."*

Key Value Indicators exist in other research areas, such as finance, governance and health, and similar value-based indicators exist, under different names, for procurement and responsible business practices [46], [85], [87], [88], [108]. As a whole, these kinds of indicators aim to measure the outputs and outcomes achieved, creating an evidence base for the impact claims, informing strategic objectives, shaping use case conception and implementation, as well as acting as steps toward validating assumed enabler correlations. They can also inform policy to promote specific objectives and targets [66]. Used well, KVIs are a way to converge the strategic objectives of companies, policy-makers, and stakeholders [109].

KVIs become a way to declare what values drive 6G innovation. Intended to be transparent and clear in the goals and evidence, they can be a way of working with methods that are societally accountable. Practically, KVIs:

- can be used to map features of the ecosystem the innovation is entering into to better assess and acknowledge impacts, both positive and negative,
- help to create a pre-defined frame of benefit assessment,
- can be used to identify points where the design team has the mandate, control, or power to intervene,
- are a way to remind us of all the aspects of sustainability we should be considering.

It is important to note that they are not tools designed to only ensure business value or market spaces but are assessment tools to ensure what is made can, with evidence, improve the intangible yet essential elements of life [28]. By concretely demonstrating societal priorities, they can be a part of an integrated model of interdependent correlations and a toolset to facilitate stakeholder's acceptance of the outputs and outcomes [109].

KVIs are grounded in a priority set of Key Values, that inform what impacts an innovation is trying to make. Identifying the "key values requires a mix of bottom-up analysis of use cases, ambitions, and stakeholders with a top-down engagement with strategy and policy. The indicators can then be quantitative and qualitative **output targets** that are measurable/assessable or **outcome enablers** that have the potential to support the value further down the road [33]. They can then be evaluated objectively, such as expert assessments or system measurements, or subjectively, such as interviews, questionnaires, or focus groups [56].

> ! Currently, there is too much diversity to select a specific priority subset of Key Value Indicators from project activities. This is exacerbated by the fact that projects are still in the process of evaluating the KVIs within their activities as effective, meaningful, and anticipatory. However, project activities offer insight into how values are currently addressed and provide a variety of potential indicator forms which can be very useful for engaging sustainability and looking past technical KPIs towards impact.

4.3.1 Sustainability KVs covered

Currently SNS projects cover a range of sustainability values. This results from a few things: 1) the variety of policies and strategies informing sustainability; 2) the limited definitions existing within high-level policy and strategy as to how to interpret the values for action; 3) the variety of applications, use cases, and verticals that projects are working with. **Error! Reference source not found.** shows the spread and frequency of the Key Values covered within SNS projects. Darker blue represents most common themes. Lighter blue themes only appear in one or two projects only with limited dimensions. A Majority of projects developed these in relation to verticals, either via general thematic area or via individual use cases.

TABLE 3: THE SPREAD AND FREQUENCY OF KEY VALUES COVERED WITHIN SNS PROJECTS

Environmental sustainability	Societal sustainability	Economic sustainability
Energy Efficiency	Accessibility and Availability	Cost savings or reduced costs for individuals and companies
Decreased energy consumption	Trust	Affordable solutions for all
Decreased resources use	Safety of individuals and workers	Increasing future industries impact, market shares, competitive advantage
Reduction of waste	Privacy	Business value and profit
Improved recycling and reuse	Security	Improve productivity
circular lifecycle	Digital Inculsion	Economic resilience
Improved impact awareness	Building Knowledge And Skills	Boost economic growth
Decreased air pollution	Job Opportunities	Open value configurations
Modular and durable equipment	Open Collabroations	Sharing economy models
Longevity	Quality of life	Increased competitiveness
Use of alternative materials	Cultural & Social Connection	Just transition
Improved ecological footprint	Healthier Individuals and Communities	Economic inequality
Reduction of environmental impacts	Well-Being	
	Flexibility	
	Job Opportunities	
	Transparency	
	Resilience	
	Inclusiveness (beyond digital inclusion)	
	Fairness	
	User Experience	

The most commonly engaged Key Value themes are related to **energy efficiency, accessibility, cost savings, affordability and increased competitive advantage or market share**. These are already widespread strategic values for ICT and 5G and relate to current business models, and thus projects and partners are already set up to engage them. Overall, the pillars of Environmental and Societal Sustainability are represented relatively equally across the projects examined. Sustainable 6G is more prominent than 6G for sustainability, likely because it can be more readily quantified and measured technologically.

4.3.1.1 Environmental Sustainability in the projects

The large majority of KVIs in the environmental pillar focus on energy efficiency and consumption. While often related to the reduction of greenhouse gas emissions, of pollution (both air and water), of operational and consumer costs, waste generated, and of materials used, the scale and scope of impact were often not identified, together with the measures for these aspects. In context, what assumptions about how 6G is deployed and used are behind linking reduced energy use over a testbed equate to reduced pollution or increased air quality? What else needs to be in place in the bigger system for these causal assumptions to hold?

A more limited set of projects address recycling, reusability, waste and reductions in materials used. Other aspects of environmental sustainability are covered by only a small number of projects and with minimal dimensions. This aligns with the industry strategy in this area, which puts the challenge to address different aspects of energy and its relationship to greenhouse gas reduction as a primary goal. However, both policy and industry strategy include circular economy and decreased waste as key to reducing footprints, making their more limited presence in KVIs surprising. Moreover, sustainability policy, and the EU-US Beyond 5G/6G Roadmap also prioritises mitigating biodiversity loss and other forms of environmental harms, such as toxic pollution.

4.3.1.2 Societal Sustainability in the projects

Societal values are more broadly represented across the projects. There is strong awareness as to variety of ways 6G can benefit society. Many interpretations of objectives under the societal sustainability KVs highlight output issues around costs to deploy, technical features (like availability and latency), system features, or user satisfaction in a trial. These are elements that can be covered readily within projects, due to the skillsets of partners, the existence (or not) of use cases, and access to stakeholders in trials. Again, the focus within projects aligns with the most commonly named elements across industry strategy that relate to no person or place left behind.

Notably, in many cases, the “who” of society is left unsaid. For example, trust is often measured via technical and security features (e.g. zero-trust mechanisms, platform resilience, etc.); accessibility is most often treated via the availability of networks, low-cost services, or ease of use; and knowledge and skills are measures by number of trainings offered. Yet, people at the centre, supporting solidarity, access to essential services, fostering participation, increasing empowerment, improving quality of life, and reducing poverty are all key to the Pillar of Social Rights and Digital Rights that are considered intertwined with the Green Deal. To deal with these involves considering specifics about the people involved. For instance, trust, as related to social sustainability is linked more closely to solidarity, ability to work together, trust in society, or trust with institutions (especially ones deploying such tools than trust in technology

[110]. Further consensus is needed as to what key elements of social sustainability should be covered and to what end goals, and the role of 6G in upholding these values.

Thus, an analysis of the projects leaves questions as to what and how societal sustainability could be addressed. Much is currently dependent upon how the use cases are chosen; currently, these are mostly technology driven, rather than value and impact driven, as elaborated in the impact section. This removes the people from the frame of success, making it difficult to know what to prioritise, for who, and why one project might do it the same or differently than another. This raises a question about the current structure of the projects: within this structure is it possible to address issues like equality, inclusivity, and well-being? At what intervention points of technological design is this best addressed? What kind of access to the necessary data exists and what skills exist on the projects to formulate scientifically credible value questions? These remain priority questions for 6G4Society and require full engagement from the SNS project ecosystem.

4.3.1.3 Economic Sustainability in the projects

The least diversely defined category is economic sustainability. It is currently driven by priority themes around cost savings, affordability and market share. In some cases, accessibility was also considered economic with related metrics that focused on cost. Again, industry strategy is driven by economic growth and innovation, where cost is a key element. However, policy also suggests focusing on activities that support the growth of other businesses in ways that build vibrant, sustainable and circular economies, with responsible supply chains, consumption and production. These elements are not missing from 6G strategy, but clarity on what they mean and what their end goal is would benefit any indicator development. For example, does economic competitiveness and well-being focus on 6G companies, the (local, regional, national, international) economies they enter, or both? What characteristics make up economic wellbeing? How does labour relate to economic sustainability: a digitally connected workforce, a digitally savvy workforce, improved job opportunities that are accessible or equal access?

TABLE 4:SAMPLING OF KVS AND KVIS RELATED TO ENERGY EFFICIENCY, INCLUSIVITY, AND COST SAVINGS IN USE BY SNS PROJECTS TO DEMONSTRATE THE SPREAD

	Key Value	Key Value Indicator
Energy Efficiency	Network capabilities are energy-efficient	Reduction of the energy footprint of telecommunication solutions
	Reduction in Energy Consumption	Energy efficiency degradation due to activity
	Improve energy efficiency at architectural levels	Energy improvements arising by the use of the new AI, and energy-efficient sharing of multi-source and multi-purpose ML models among domains.
	Energy efficiency improvements	The ability to adapt symbol modulation to channel conditions will result in enhanced spectral efficiency and minimized retransmission.
	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 signaling
	Energy Efficiency	Reduce energy consumption of networks by edge computing, reducing data through the system
	Energy Efficiency	Number of implemented analytics for energy backpressure.

	Key Value	Key Value Indicator
Cost Savings	Economically sustainable solution for Industry	High Benefit vs Cost ratio - for Industry to manufacture and proliferate/commercialise the solution
	Provide economically sustainable solution to stakeholders	Affordable service/Cost of service for service customers.
	Resource Savings	Quantity of resources saved (money, time, material) predicted through the use of the tools
	OPEX reductions	DCI compression will increase network capacity and help the network serve more users in the same bandwidth. Operating margins will thus grow.
	Economic Growth	Vertical solution cost efficiency
	Reduced costs for stakeholders	Enabler: XR technologies that allow remote experts to guide and assist in maintenance process.
	Higher quality education at lower cost	Enabler: Low latency and high reliability communications

	Key Value	Key Value Indicator
Inclusion	Digital Inclusion	Digital literacy
	Digital Inclusion	The ability of a system to provide equal access to digital technologies and services, regardless of income, gender, end-user equipment or other factors
	Digital Inclusion	Flexible and adjustable
	Digital Inclusion	Non-discriminatory, e.g., consider IT literacy and culture of all types of end-users
	Digital Inclusion	Availability in terms of both coverage and capacity
	Digital Inclusion	Increased footprint of gaming services
	Reduce digital divide	Input will be sought from key stakeholder groups as part of the design process and focus group surveys will be conducted to check whether 6G services be more accessible in terms of cost, location types, device types, and persons with disabilities.
	Gender equality	Ratio (from survey) of project outputs deemed relevant and useful for men and women.
	Representation in use-cases	Use-cases that reflect the diversity of local communities they should benefit; reflect urban and rural opportunities
	Equal Opportunity	Unemployment Rate (total, male, female, age groups, other groups)
	Inclusiveness	Coverage of solutions
	Inclusiveness	Access of people to the vertical solutions

This incongruity suggests that enhanced multidisciplinary teams are needed to bring together the knowledge to reach into other elements of the Key Value definitions. HEXA-X-II has provided a strong starting list of definitions in D1.1 building on existing ICT literature from different foundations, standards associations, policy institutions, and libraries [8]. **Bringing together the working definitions within the projects and enriching and validating these definitions by different expert and stakeholders' groups would ensure that the approaches taken will reach the sustainability impacts, not just the ICT impacts, being sought.**

4.3.2 How are these translated to Indicators?

High-level principles do not automatically translate into practice. While many, though not all, work within a general high-level methodology, projects have taken different approaches to defining the KVIs. The effect is that **KVI granularity varies a great deal: what is a key value for one, is an indicator for another, or a measure of an indicator for another**.

Some projects draw on Global SDGs as a starting place to map development indicators onto 6G. Many start from the list of undefined values in the 5GPPP. Others look to what was done already in other projects in order to emulate their categories. Some projects do more in-depth research as to 6G strategy and sustainability policy to build their starting place. Others assess impact areas to consider what a vertical might prioritise as impacts. Some projects struggle with where to focus due to a lack of use cases or stakeholders. Projects without use cases often work from abstract policy values as a starting place for their KVI analysis. This is where the strategic values of the 6G industry are important drivers, shaping what values are selected.

A classification system is needed not only for values, but for connecting value to target to indicator to align the projects. What some define as a Key Values, others define as the KVI itself, and yet others as an objective or aim within a Key Value. **Differences currently have it that some projects:**

- Select the KVIs that align with performance goals.
- Engage a non-measurement approach, aligning KVIs with “enabler” technologies to explore what could be possible were a technology to be applied in a specific way.
- Some who define enablers go a step further and identifying a KPI related to an enabler, shifting back to addressing a technological component they think will support that outcome.
- Define KVIs at KPI metrics from the start.
- Frame KVIs as a larger goal (e.g. societal goal)
- Frame KVIs as a use case goal
- Classify their values based on user goal or perspective,
- Further elaborate KVIs prior to defining a measurement for it, including details such as relevance, aim, scope, scale, and stakeholders, following many best practices for sustainability indicators
- Provide direct links to KPIs, following more traditional technology metrics practices
- Break their values down via the three sub-categories of sustainability
- Use the sub-categories as KVIs in and of themselves
- Link KVIs to objectives within those principles
- Use the principles as the KVIs.

Examples of the variety of pathways are overlayed in the Figure 9, demonstrating the diversity of starting points, considerations in the KVI across the projects, the steps between value and indicators, and the key formats the indicators and evidence for them take.

This variety is partly due to different frames of reference and starting points for the KVI analysis. They are also due to the TRLs levels within the projects, access to stakeholders, and what stream the projects belong to (e.g. D vs B). Some go through a range of steps to get from value principle to indicator and measure. Some start with the SDGs and move to greater specificity considering their available technology. Some work up from the use case goal. Some consider impact by vertical. Projects without use cases more often combine policy and strategy directly with technology implementation. Some KVIs look at specific periods, e.g. during operation, between lap and trial, user evaluation after test session, etc. Most, however, leave the scale and scope to be determined by the metric/measure that will evidence the KVI, e.g. reduced wait time, digital literacy, ozone depletion, home energy savings.

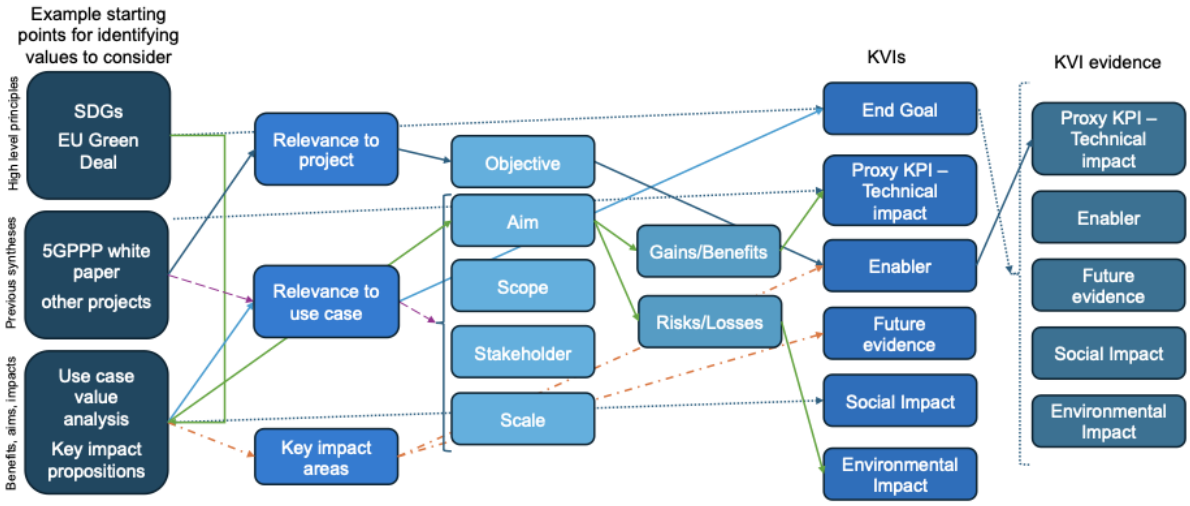

FIGURE 9: DEMONSTRATING THE COMPLEXITY OF THE VARIETY, EXAMPLE PATHWAYS FROM STARTING POINTS FROM WHICH TO IDENTIFY KEY VALUES TO KVI AND ASSESSMENT MEASURES.

4.3.2.1 Translating principles into actionable impacts

The variations in approaches to indicators, and approaches to assessing societal and sustainable impact in the first place, "demonstrate that there is no single dominant starting point to assessing how normative values become actionable leading to impacts" [33]. Even when policy is already translated into indicators (such as the SDG indicators), they are often meant for a different scale of activity than that of 6G innovation, and thus not always directly measurable or directly applicable as defined.

As a result, when translating indicators to measures, many become more traditional KPIs, pointing to technological performance or user evaluations (e.g. the range of output data available within projects as they are currently arranged). A few KVIs seek to look beyond the user, like improved health outcomes, job opportunities, diverse workforces, reduced energy bills. However, because these are outcomes, not outputs, the data for these are less accessible to the projects. A survey of a user's trust or opinion of a tool does not always correlate with societal solidarity, increased digital inclusivity, or real societal impact. **This suggests the need to better address the primary goal of KVIs as currently defined, as impacts and outcomes, and develop project assessment and evidence formats and partner relations that will support accessing non-technical evidence and longer-term observation**s. Despite discussions in many KVI formulations, and within policy and industry strategy, of circular economies, KVIs that support assessment along lifecycles and value chains need development.

How KVIs are different from KPIs

While developed for socially responsible business finance, Souakri and Forterre [109] present a valuable differentiation between KVIs and KPIs. A key distinction they draw is that KVIs are often intangible and less visible than KPI. KVIs focus strongly on broad stakeholders, purpose, and strategic priorities over the longer term. KPIs, while more narrowly focused stakeholders can be involved, are more about aligning operational results with expectations over a limited time. Their table, presented below, has been slightly modified to represent projects instead of companies.

TABLE 5: DESCRIPTIVE EXAMPLE OF THE DIFFERENCES BETWEEN KVIS AND KPIS, MODIFIED FROM [109]

	KPI	KVI
Field of application	The project's operational activities: measures how a project operates to deliver value to stakeholders	The project's strategic assets: measures how a project creates and delivers value to its stakeholders
Approach	Descriptive: answers "how" is the project effectively generating value?	Reflexive: answer "why and for what" purpose does the project want to create value, for who, what mission does it fulfil and to create what type of value?
For who	Stakeholders restricted to the most important (at the very least, only investors or key customers)	Broader stakeholders (publics affected by technology being developed, suppliers of materials or energy, environment affected, business communities, etc.)
Logic	Evaluation focused on performance and financial results and return on investment	Assessment based on the satisfaction of stakeholders' and policy expectations and related tangible and/or intangible benefits
Metric	Tangible (visible), operational	Tangible (visible) and intangible
Final Materialisation	Financial capital, technological performance	Tangible and intangible (e.g. social or environmental) capital with a strong emblematic component
Goal	Optimising and orchestrating resource allocation	Engaging all of a project's capabilities (resources & skills) towards growth potential benefiting all broader stakeholders
Vision	Downstream/Past: relates to achieving alignment with strategic objectives through activities and targets for operation. Relates to what was completed in a project	Upstream/Future: refers to the alignment strategic priorities with impact on stakeholders. Relates to present but also what could emerge over time.

Object of assessment	Extrinsic value: effectiveness of the targets for operation in terms of operational results of the targeted and concrete actions undertaken	Intrinsic value: transformation of all types of capital into tangible and intangible wealth. Emblematic dimensions
Time Scale	Over a limited period (exploiting the current value creation model)	Medium to long term (develop and realise value creation potential)
Examples	Distance travelled for work; Softness of care tires	CO2 emissions/carbon footprint

4.3.2.2 Keeping impact and outcomes in view

Some KVIs look at outcomes, outside of project outputs. These show a rich variety in the projects, often tied to the use case goals and include elements like reduced injuries in the workplace, improved community safety, increased operational efficiency, job opportunities, or improved health outcomes. **A focus on outcomes is crucial to addressing sustainability, keeping the end in focus, rather than just the 6G means to that end.** While outputs are often easier to define and monitor, they do not necessarily indicate progress towards a larger goal and could just be measures of what would happen despite an intervention. Real impact and change are outcomes. But outcomes often take time, do not happen in the scope of a research project, and are not as readily translated to isolatable metrics [111]. Outcomes also require engaging an ecosystem directly (e.g. working with stakeholders and experts from other disciplines to articulate what is at stake for who).

Support is needed to shift from value as outputs to value as outcomes, at different scales and scopes, and to validate the link between indicator and outcome. Often, ways of measuring these indicators are still being worked out by the projects. Some projects are addressing this by identifying enablers rather than metrics. Some are then defining KPIs for those enablers, seeking to push technological development in a specific value-enabling direction. Others are yet unknown.

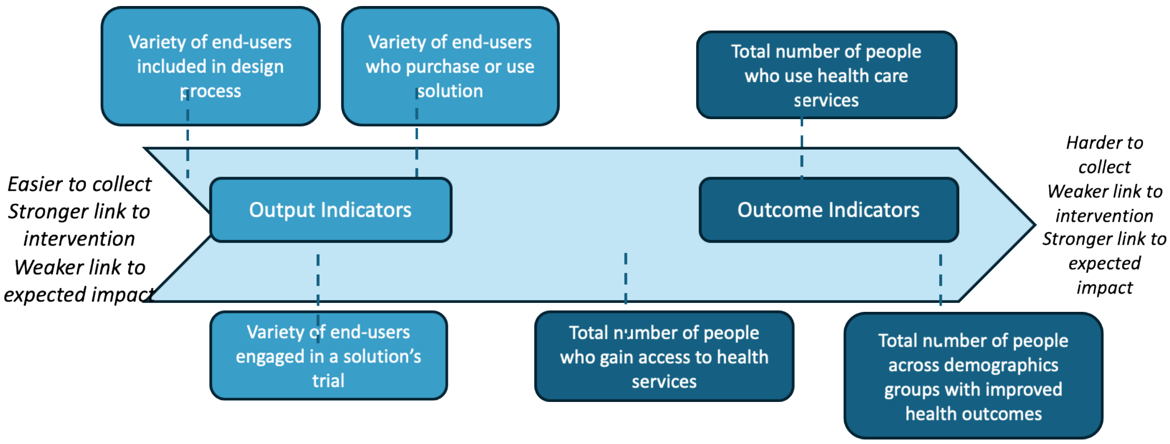

FIGURE 10: DIFFERENCES IN KVIS BETWEEN OUTPUT AND OUTCOME. ADAPTED FROM [111]

Outcome indicators require data and evidence outside what is often regularly gathered in projects. **To really assess if under-reached groups are better able to participate in society, data is needed about those groups in relevant areas and their activities, over**

time and space not just if a 6G network will be built near them. However, this data is often not yet gathered nationally, let alone in research projects [41].

Included in these definitions need to be what makes an adequate number and type of indicators, how well-founded is determined, and what is considered a reasonable cost for obtaining the evidence [112].

However, projects need to be very clear about what they are doing with KVIs:

- Articulate why they are measuring (what is the objective of the work with KVIs)?
- Agree on what the measurements mean (are you measuring technical or societal trust)?
- What correlation or causation assumptions are you making?

And they need to decide if KVIs are a way to:

- Prove a target is met in the short term, like a KPI?
- Show projects are making choices that have the potential to enable sustainability in the long term?
- Demonstrate sustainability activities to the funders?
- Enforce considerations of sustainability in projects, not just performance?
- Provide transparency for public accountability?
- Support industry to self-monitor?
- Provide evidence for governments to assess policy implementation?

4.3.2.3 Some Important lessons about working with indicators from other areas

Clear criteria and definitions are needed to avoid bias. This lesson has been learned in other areas of development, including medical and auto safety. For example, early medical standards for heart attack symptoms – kinds of indicators – were designed around men's symptoms. For this reason, women, who often have different or less common symptoms as their primary ones, were regularly missed and had worse health outcomes as a result of these standards being used. Even today, the result of these emphases on specific indicators has led to differences that still exist in expectation and experience leading women's symptoms to be missed both by themselves and by their physicians [113].

Focus on strategy, not reporting [114]. This was a key early downfall of a certification scheme of building indicators used to provide sustainability certificates. This certification would provide access to tax benefits or grants. It also did not require context to be considered (a building could be green even if the location was brown). If it takes increased pollution to get to it, the net might remain the same. These benefits to business ended up driving why people engaged (to save money) not to benefit the environment. This was exacerbated by the fact that those using the indicators would gain benefit but would receive no harm were they to not. This shift in goals (from sustainable outcome to gaining tax breaks) became evident after on average LEED certified buildings performed worse on sustainability elements than other similar buildings. [115].

Avoid framing value challenges in terms of design flaws. This has shown to ensure values remain described as "fundamentally technical, shielded from [stakeholder (or democratic)] intervention." [116]

Smaller scales remain elusive when working with indicators. Sustainability, in particular, remains elusive to accounting techniques at smaller scales, despite the success at global scales. At issue are which issues to prioritise, via what criteria, and how many indicators should be used for the unique contexts smaller scales encompass [117].

4.4 A NOTE ABOUT TRADE-OFF LOGIC

How can societal and environmental value co-exist with market and performance incentives, and not just be a trade-off that always loses? Our actions and choices are the result of a **hierarchy of values** (that can change). This comprises a number of **pivot values treated as non-negotiable priorities**, around which others would be traded off. Trade-offs arise for a variety of reasons, from incompatible features to competing value frames. Creating a framework supporting the ability to balance **conflicts** between values is therefore paramount.

Current 6G strategy priorities, policy applications, and business models relate to a frame where sustainability "weights" a different value than features relating to competitiveness advantages, including performance, cost efficiency, or increasing market share. Profitability and economic growth are often considered on one end of a scale and environmental or societal well-being on the other, as alternative or opposite elements. This can be seen in 6G-IA's Position Paper, where sustainability is separated from other strategic goals, highlighting it as a different kind of value, leading to statements like: "the goal is to find the ***required trade-off*** and balance between performance and sustainability goals." [32]. There is a fundamental assumption behind such statements: that sustainability and competitiveness are in conflict, where sustainability puts a barrier on profit or markets. It also assumes that resources from people and planet are endless and thus not part of normal value equations.

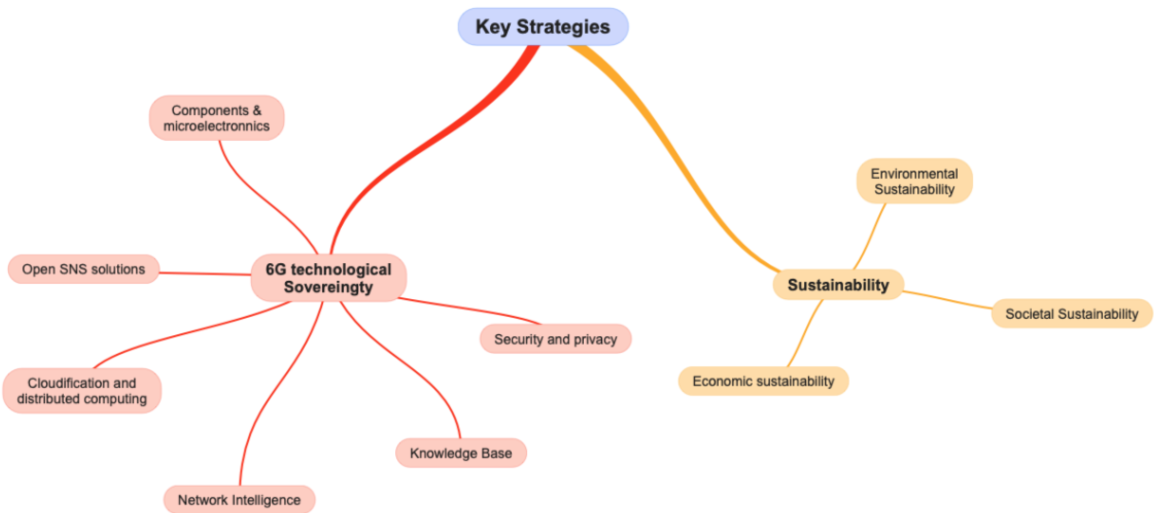

FIGURE 11: 6G-IA KEY STRATEGIES FROM 2023 POSITION PAPER, PUTTING SUSTAINABILITY SEPARATE FROM ALL OTHER STRATEGIC GOALS, SETTING IT UP AS A DIFFERENT KIND OF VALUE.

This setting, although dominant, does not necessarily need to be this way. Responsible Research and Innovation (RRI) highlights the need to **balance feasibility with desirability**. This implies the responsibility to demonstrate that technology stands neutrally between these two ends, or, at least, that any trade-offs between them are ethically accountable. **This involves integrating sustainability values within the business model and the value proposition of the brand or product**. Security and privacy are already understood to be undeniable needs: they are desirability driven values regardless of feasibility. If a solution costs more to be secure, then the expense will be considered appropriate. A solution that is faster or cheaper would not be put on the market at the trade-off of security or privacy. In fact, there is no market without these features. The same logic needs to apply to sustainability, acknowledging there is no world or people to make a market from without sustainability.

Security and privacy are already understood to be undeniable needs: they are desirability driven values regardless of feasibility. If a solution costs more to be secure, then the expense will be considered appropriate. A solution that is faster or cheaper would not be put on the market at the trade-off of security or privacy. In fact, there is no market without these features. The same logic needs to apply to sustainability, acknowledging there is no world or people to make a market from without sustainability.

Currently, there is widespread acknowledgement that the conception and incorporation of sustainability needs to shift. Sustainability policy requires decoupling growth from resource use, which suggests the need for new models for valuation behind strategic drivers. Hints of this do appear in a number of 6G strategic documents. For example, “The drivers for 6G network development are not only the typical and expected performance improvements (e.g., throughput, latency, reliability, coverage, spectrum efficiency) but the societal, business, and policy goals that 6G can address” [66]. Strategies and business models need to take a less limited view of what makes competitiveness to build more holistic, long term, less antagonistic frameworks. In a business model based on values or desirability, values would be an automatic component of competitivity. Potentially this also needs to link to different incentive models, where incentives are centred around preserving people and resources. Without this, KVIs will always be a second elements of design, reactive instead of proactive.

That said, there is also understanding that this shifts the global competitiveness of 6G, where other countries might not have the same values and working through different business models. This is a challenge that cannot be wholly addressed at the level of design but needs policy guidance.

4.5 WORKING TOWARDS A KEY SUSTAINABILITY INDICATORS (KSIS) FRAMEWORK

Key Sustainability indicators (KSIs) are a subset of KVIs that focus on the three branches of sustainability while taking into account their interdependencies. They work through KVIs to monitor progress but in ways that keep in view the holistic and complex ecosystem necessary to address sustainability. **KSIs, even if they also are assessing technical performance, should act as a toolset for** [40]**:**

- monitoring progress towards the future impacts related to sustainability;
- supporting decision-making in design and implementation;
- defining strategy and policy;

- focusing on those most vulnerable to negative impacts or most likely to be left behind from the positive impacts;
- supporting awareness, education, and acceptance.

In doing so, they address sustainability on the same plane as impacts: as a problem of complex outcomes rather than one of performance outputs.

Sustainability indicators have been in use since at least the early 1990s, and have a broad foothold on research and innovation across a range of domains, from buildings to finance, with a variety of indicator frameworks already in existence. Early mentions of sustainability indicators describe a need to increase awareness of a sustainability issue, to provide data about the current state of affairs for decision-making, to measure progress towards established goals, and to provide a tool that encourages stakeholder involvement [118]. As a tool for accountability, they echo a business's, organisation's, or institution's values and culture. They should also support the ability to see how 6G's piece of the puzzle fits within the bigger picture.

ISO 21929-1:2011 defines an indicator for sustainability as "quantitative, qualitative or descriptive measure representative of one or more impact categories". **KSIs can be individual but can and should also consider the interrelationship between them**, highlighting how, as ISO/TR 37121:2017 states, "the well-being of societies and communities relies daily on a web of institutions, infrastructure and information". Such a need to consider the interrelationships for 6G is acknowledged by NextG Alliance, which aims to establish a new interdisciplinary collaboration between technologists, policy makers, social scientists, and economists to further develop these concepts [59]. **If done holistically, they support balancing longer-term impacts with shorter-term performance** [48]. The IWA 42:2022 *Net Zero Guidelines* also state that monitoring **needs to look not just at GHG reductions but at a given strategy's wider impacts, particularly on equity and empowerment, as well as considerations of how the strategy being monitored relates to a fair and just transition, protecting communities and economies as well as environments**.

4.5.1 Building a KSI Framework

Sustainability is an outcomes-based concept. KSIs need to be based upon concrete and evidence-based approaches to assessing outcomes over space and time. This involves looking at the results of current KVI iterations within the projects, to assess what is practicable within the scope of current SNS projects' structure, as well as looking at other outcome-based indicators to identify what could be possible based on the experiences of outside yet similar efforts.

> It would be premature at this stage to propose a consolidated or consensus-based list of KVIs that could form a basis for KSIs. This is due to the disparities, disconnects, and different foci within current KVIs. This is further exacerbated by existing KVI gaps in key green and social policy areas, which need to be resolved.

Building on what was learned already from working with KVIs, 6G4Society has produced key features and guiding questions necessary for a framework to support the coordination and effectiveness of these activities towards sustainability goals across the SNS ecosystem. This basis for a framework should also support users to focus on values important for societal sustainability, as a bridge between assessing impact and working towards producing acceptance.

Over the course of 6G4Society's activities, we aim to elaborate, enrich, and refined this basis into key guidance, working examples, and practical steps projects should take. By the end of the project, the aim is to understand how KSIs matter and can be implemented across different SNS program Streams, taking into account different TRLs, different level of stakeholder (e.g. user and beyond) engagement, and different verticals.

Key driving questions that need to be answered before any KSIs can be selected and prioritised are ([117], [119]):

- What dimensions of sustainability should be addressed for 6G? for the specific vertical within?
- How should they be correlated with stakeholder interests, policy, and business goals?
- What criteria are used to prioritise values and select indicators?
- What is needed so the indicators are actually used and assessed?
- What methodology should be used for the final evaluation and interpretation of the indicators?
- When do we need to work with external stakeholders (e.g. those not in SNS projects) to address the above?

Critically, this means KSIs should be designed and selected in order to be a way of working with KVIs that focus on unique features that support sustainability. Tactically, KSI should:

- Provide ways of monitoring the route to sustainable outcomes and the impact of those outcomes on people, the planet, and prosperity.
- Look at interrelationships and impacts of indicators on each other
- Explore ways of proactively engaging sustainability as a core feature, not an externality or trade-off
- Support deliberation and debate around pathways towards sustainability
- Support building sustainability codes of conduct that go beyond designer activities
- Accurately convey the real and full sustainability story a product, service, or system is part of.

Within projects, good use of such indicators are activities that [49] [120]:

- impact <u>all</u> three goals of sustainability,
- show that the selected indicators make a complete set towards an impact,
- show awareness of how one indicator affects others, and
- justify the indicators as appropriate
- are able to acknowledge and address objectives that change over the time [49] [120].

Establishing KSIs requires concerted strategic efforts. To develop the indicators for the SDGs, they required an interdisciplinary group of experts to assess the principles of the SDGs, break them down into agree upon objectives and goals, and only then did they begin to define indicators. The final selection of key indicators was chosen after a long process trying to identify what feature of a given goal would offer the best indication of if that principle's objectives were likely to be met. In many cases, that meant encouraging new forms of data collection and the inclusion of new skills. The UN also acknowledged that while ideally they are, often the direct comparability of metrics is not always possible and that each country and region needs to refine these to be appropriate to their context.

4.5.2 Key Features Needed to build a KSI framework

Building a KSI framework requires specific decisions, policies, and strategies that identify, prioritize, and address key sustainability elements. It also requires clearly articulated objectives and outcomes for sustainable impact. But it can also be defined as actions needed to support social solidarity or trust in governments. While the technical aspect is necessary and directly implementable, the latter is rather perceived by society as the outcome of a trustworthy system. Considering the impacts of 5G described in the previous chapter (e.g. social connectivity, isolation, and trust in government and industry actions) objectives within trustworthiness need to address these more social elements as well as the technical. Similarly, is the principle of “leaving no one behind” to be addressed abstractly as a target of 6G availability, or of usability of a network application, or of the ability to of a person or community to benefit from a service provided over 6G?

This requires answering a few key questions (Figure 12 below) that need to be agreed upon by the SNS community before KSIs will be accepted at either the project or strategic level. Without this layered agreement, any work within the projects will likely remain in the projects, traded-off for other strategic goals (e.g. performance and profit).

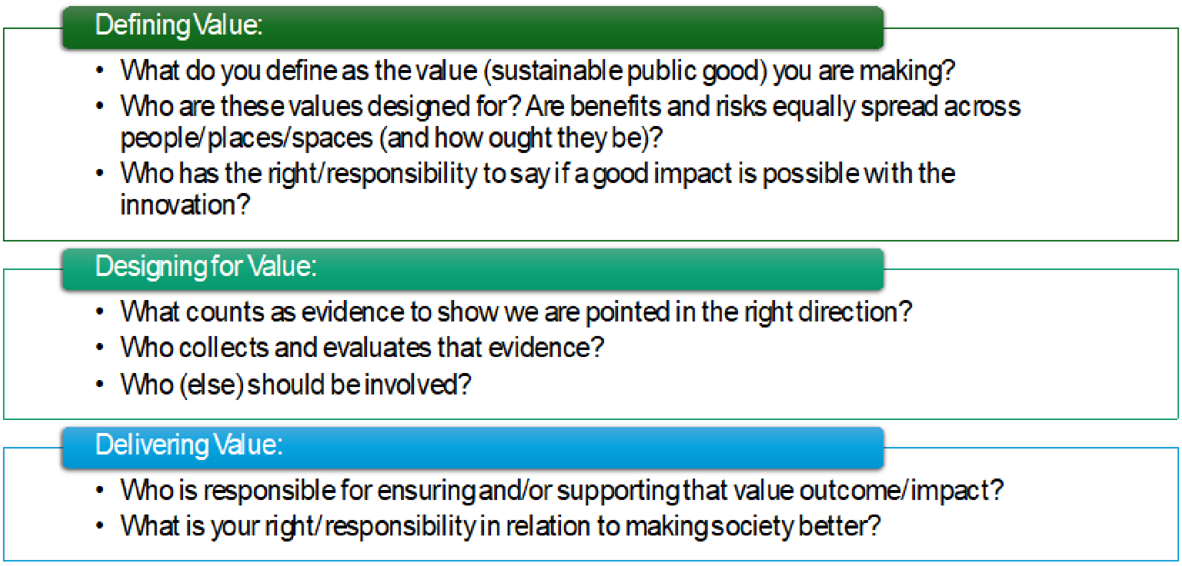

FIGURE 12: VALUE – DEFINING, DESIGNING FOR, DELIVERING

To support the establishment of a framework, ten steps have been defined and are further elaborated below.

1. Build consensus on the aim and ends of KSIs, in order to create a set of prioritisation criteria
2. Build a stakeholder-relevant Key Value Frame to work within
3. Consider the goal of the indicator

4. Define the criteria of a good indicator, including what data or evidence are best suited for the outcome
5. Validate indicators to outcomes in a way that supports a stakeholder accepting this work as likely to make a difference
6. Explore different intervention points in the innovation process
7. Engage cross-pillar, interdependent indicators, and compound indicators to ensure accuracy
8. Defining KSIs themselves
9. Build a searchable, living database of potential indicators relevant to 6G
10. Make sure KSIs work in a way that speaks to decision-makers and stakeholders

Answering these questions requires engagement with diverse communities with different opinions, priorities, values, and visions. This means that the stakeholders involved, including researchers, can bring biases and conflicts that need to be elicited and resolved in a way that support decision-making. Thus, along with applying the strategy outlined below, two other elements need to be addressed.

First, a bias mitigation strategy needs to be developed for identifying or minimizing potential biases in data collection, stakeholder involvement, or analysis process, as consensus is built towards what values are prioritised and what KSIs and data should be engaged. This can include selection bias, confirmation bias, response bias, and cultural bias. These methods need to be appropriately applied at different points of value intervention (e.g., Steps 2, 4 and 6).

Second is the need to address conflict between those involved in the process, which will inevitably arise as different priorities, personal, and business values meet in this work. Processes such as multi-criteria decision analysis, Delphi techniques, or analytical hierarchy process, can help. These are formal decision-making tools used to evaluate multiple criteria in situations where trade-offs, conflict resolution, consensus building, or prioritisation are necessary. They can also complement problem definition and vision building techniques that elicit the challenges seen and assumed objectives needed to clarify the common goals. In addition, a set of prioritisation criteria needs to be developed once the goals and objectives of a KSI are agreed upon that can guide the decision and consensus process (e.g., Step 1).

4.5.2.1 Step 1: Build consensus on the aim and ends of KSIs

As a whole, sustainability indicators can support (ISO 21929-1:2011):

- design and decision-making process(es) during the planning phase
- development and application of assessment methods and certification systems
- indicating performance
- monitoring or evaluating the achievement of objectives over time
- accepting responsibility for impacts on the environment and society
- representing activities and results in the context of responsibility towards the economy, environment and society.

SNS community need to decide which of these are their end goals, as each of these requires different types of indicators and evidence and thus suggests different kinds of KSIs needed. This is important considering the diversity of KVIs and indicator types already in play. For example, performance features would look more at elements like current KPIs. Accepting responsibility for impacts could require indicators that are more enablers, putting in place specific evidence-based ingredients that support the future achievement of impact but in and of themselves are not traditional quantitative measurements. If looking at evaluating achievements over time, this could involve engaging directly with stakeholders to work with them to assess change. They speak to different audiences and suggest different forms of transparency and accountability.

4.5.2.2 Step 2: Build a stakeholder relevant Key Value Frame to work within

> *"Indicators arise from values (we measure what we care about), and they create values (we care about what we measure)" (Meadows, 1998).*

The value frame that drives the selection of indicators is as important as the indicators themselves [121]. This is not only because this frame defines the priority areas (the "Key" of KSI), but it also defines the balances in trade-offs, and the scope of what is at stake, and it can serve as a basis for developing interrelated or composite indicators. It is needed in order to support interrogation, deliberation, and accountability towards the decisions made in addressing an indicator, particularly in relation to the other elements of 6G development.

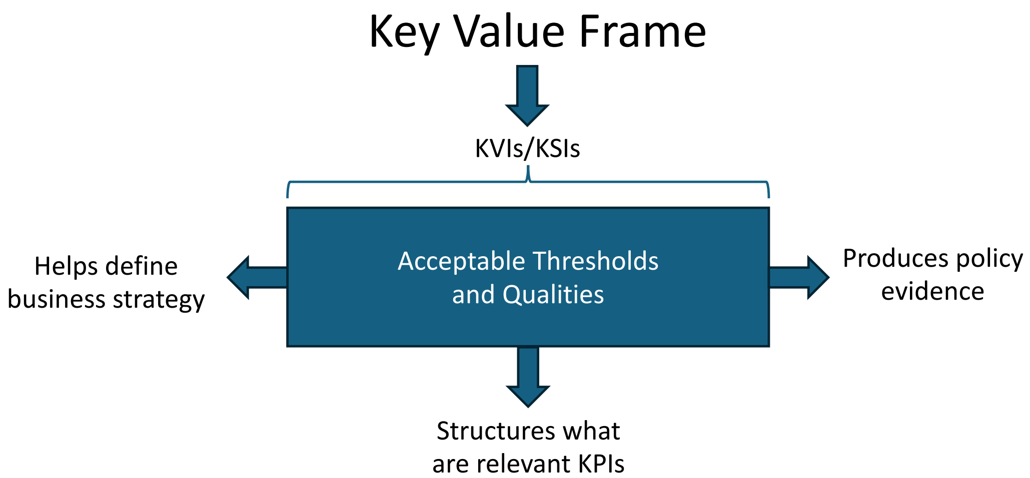

FIGURE 13: THE IMPACT OF A VALUE FRAME.

A clear and agreed-upon key value-frame will support those working with KSIs to reflect upon, discuss, and prioritise the intended objective before any indicator is engaged. This requires an analysis of the systems in which 6G are embedded to determine what elements have the most significant contributions towards sustainability, building on what is in the previous chapter. It involves identifying the potential societal impact use cases (not just added-value potentials of technology-driven use cases) where 6G could contribute. It also calls for an assessment of what kind of use and decision-making, and by who, and thus potential for change - in the world - outside of a given technological design the indicator would support.

Key questions to ask to support the value frame:

- What impacts, and to who, does this value frame consider?
- How do you know these impacts matter?
- How does this leave no one behind?
- Can it help projects decide between a small impact for many people or a large impact on a vulnerable few? How does this empower people to act and participate?
- How can it help support the articulation and agreement of shared responsibility?

For this, a multidirectional technique can be valuable, bridging top-down literature, policy and global perspectives to identify potential indicators with bottom-up, real-world, local circumstances to assess their relevance and ability to demonstrate impact [117]. This requires multidisciplinary activities, because different segments of the ecosystem prioritise different values and indicators, e.g. academics focus more on ecological indicators while government sector focuses on economic [122]. These activities should include:

- Define sustainable values in details. Then articulate and further define the objectives within for 6G. Include both high-level as well as contextual, local definitions.
- Develop consensus on:
  - which values/objectives are priority, bridging political, public, and industry values;
  - which are not priorities but should still be addressed in specific contexts (e.g. they matter to a segment of the population, specific geographic regions of engagement, or a vertical);
  - which can be revisited at a later iteration of this analysis.
- Articulate how these priorities change by vertical or use case.
- Develop a schedule for which this consensus should be iteratively revised to address how values change over time, place, and goal.

Key elements of a sustainable value definition are: source, goal of the value, places covered, people impacted, context of relevancy, time scale. It also important to be transparent about who/what was included/consulted in making this definition (e.g. policy, experts in other areas).

These activities entail bringing together experts in these issues. This, in turn, requires concerted effort to build consensus and address conflicts, as stated in the introduction. For example, techniques like multi-criteria decision analysis and the analytical hierarchy process provide a structured way to evaluate and prioritize indicators based on competing values and criteria. Using these method, stakeholders' inputs can be quantified and weighted, to allow for clear comparisons and prioritisation between different societal values in ways that do not just rely on majority ranking. The Delphi technique is a process for working with a large panel of experts to survey perspectives and build towards consensus. Methods like these can balance stakeholder values, ensuring that indicators reflect local needs and societal goals while maintaining relevance to 6G innovation.

The results of this activity can enhance, refine, and more directly focus the value taxonomies articulated in the policy analysis above. The end output should be a clear taxonomy of Key

(Sustainability) Values for 6G, with objectives, expected outcomes, and impacts, defined. This should be clearly tied to articulating what is at stake for who/what.

4.5.2.3 Step 3: Consider the end-goal of the indicator

Different kinds of indicators could be needed depending on the end goal of an indicator and the scale of activity. The aims of KSIs could be to design technology differently, to encourage different uses, to govern the application and evaluation of technology, to support future policy directions, or to provide evidence of change. As already discussed in the analysis of current KVIs, and further discussed in step 4, there are different styles of indicators emerging for these various goals. Existing sustainability indicators for other domains also similarly include diverse indicator styles to express the range of desired outcomes and impacts. Aims of KSIs could also assess technology, user, community, nation, ecosystem, each requiring a different style, sometimes quantitative, sometimes qualitative, indicators. **Thus, consensus on the different acceptable goals and formats for indicators is needed. In addition, for each of these end goals, guidelines need to be created that support their coherent selection across various 6G activities**. In order to produce these guidelines, clarity is needed as to how to use these indicators to represent or point to trends in environmental or human conditions. This requires further analysis of existing research, particularly into how other existing indicator schemes were validated.

Guidance should address:

- How to demonstrate and validate that an indicator shows progress?
- How to define the geographical domain or temporal scope of measurement/assessment?
- How to determine what data should be provided as part of the measurement/assessment?
- How to consider what data we currently have access to as part of this process, without overly limiting the indicators selected?
- What criteria should be used to determine if impact data that is provided is complete?
- How to consider how the indicators' results will be used (e.g. for design, policy, public accountability) in defining its form?
- How to modify indicators based on the phase in design you are (e.g. conceptualisation, design, diffusion, use; low vs high TRL)?

4.5.2.4 Step 4: Define the criteria of a good indicator, including what data or evidence are best suited for the outcome

A range of different possible measures or assessment forms exist, not just KPIs. Many of these are better situated to capture elements of the value impact being sought. Once the value frames are in place it is important to assess what features of a situation best represent that impact and select the evidence most directly tied to it. This can include, but is not limited to:

- Quantitative metric, like a KPI or quantitative survey result
- Boolean: Y/N (e.g. SDG indicator 5.1.1 whether or not legal frameworks are in place to promote, enforce and monitor equality and non-discrimination as concerns sex).

- Proportional relations (e.g. SDG indicator 6.3.2 Proportion of bodies of water with good ambient water quality).
- Descriptive: e.g. describing a situation or relationship
- Qualitative: e.g. the results of a stakeholder forum or workshop
- Flow (e.g. SDG 7.a.1 International financial flows to developing countries in support of clean energy research and development and renewable energy production, including hybrid systems).
- Enablers,providing the building blocks for a potential, yet uncertain, outcome.

Important questions to consider when deciding on an assessment or measure:

- Is it measuring output (of the immediate activities) or outcome (from the results of the intervention)?
- Who is the indicator for? (e.g. who will use it)?
- How does it relate to the decisions that need to be made with it?
- In what context will it be applied?
- What is the scale and scope of impact being addressed?

While some assessments can take place at the scale of a tool, much requires data and perspectives from the world within which a tool is embedded. This requires new forms of data and expertise not traditionally engaged in SNS projects, or R&D projects in general. This could involve exploring new data sources outside technology performance and user surveys. For example, while water use for the production of a given 6G network could offer insight into resource use and pollution, this data is currently not collected in a way that could be translated to such an indicator. What data to use?

In order to determine what data or evidence to gather and use, the following three actions are suggested [123]:

a. Once ideal indicators are defined, identify what data can realistically be collected;
b. When data or evidence does not already exist alternatives shall be researched; then, evidence-based decision-making shall be used to determine an alternative rationale for linking measure to indicators, and eventually to outcome.
c. When data is needed, develop a strategy for getting such data. This could involve new funding, engaging partnerships with new organisations, or lobbying policy-makers to create new institutional structures.

4.5.2.5 Step 5: Validate indicators to outcomes in a way that supports a stakeholder accepting this work as likely to make a difference

Collaborative deliberation is essential to assess whether an indicator is appropriate for a given situation. The metric must not only be accepted by stakeholders but also effectively reflect the relevant characteristics at different scales or scopes. Important questions emerge from how KSIs are selected and applied that, if left unanswered, could affect acceptability:

- Who validates the link in impact being argued by a KSI?

- How is the validation process independent from those driving the innovation?
- How might validation look different for projects with different structures and formats, such as Stream D, B, or lighthouse?

The indicators need not only to be scientifically credible and verifiable, bu also to be understandable to the public. They need to be backed up with enough scientific (qualitative or quantitative) research to support data collection, which requires engagement with an appropriate and credible scientific community, be it traditional peer-reviewed literature or citizen-science activities [124]. Further research and governance are needed on how to make judgements that work for the projects and to ensure evidence provided towards an indicator of a claimed value impact will have the potential to encourage the necessary changes to reach a sustainable outcome.

4.5.2.6 Step 6: Explore different intervention points in the innovation process

The variations in how value becomes embedded into technology opens up new opportunities as to where, in the innovation process, KSIs could be assessed. These should be further explored to determine their potential. Does having a gender-balanced conception and design team lead to more societally impactful outputs? Instead of relying on designer narratives, does developing policy targets that guide selections of target audiences improve inclusivity? What about KSIs that affect early decisions about target audiences of a 6G innovation? Or KSIs that inform the narrative about the good life or support infrastructural change around an innovation that would improve the sustainability of that innovation? Could KSIs at these intervention points in activity support more sustainable outcomes?

4.5.2.7 Step 7: Engage cross-pillar, interdependent indicators, and compound indicators to ensure accuracy

Some elements of sustainability are more accurately described when two or three-dimensional [121]. **KSIs, then, can be considered KVIs that work together to articulate and assess the impact across categories and on each other.** Considering synergy between indicators is crucial and better represents sustainability as a system. Individually the KVI used within these could be unexceptional, but in combination they represent a pathway to change and transition. Or vice versa, individually they seem to make a significant impact, whereas combined their impact appears more limited. Thus, once objectives and indicators styles are defined, KSI development should explore what elements within those should be considered in tangent.

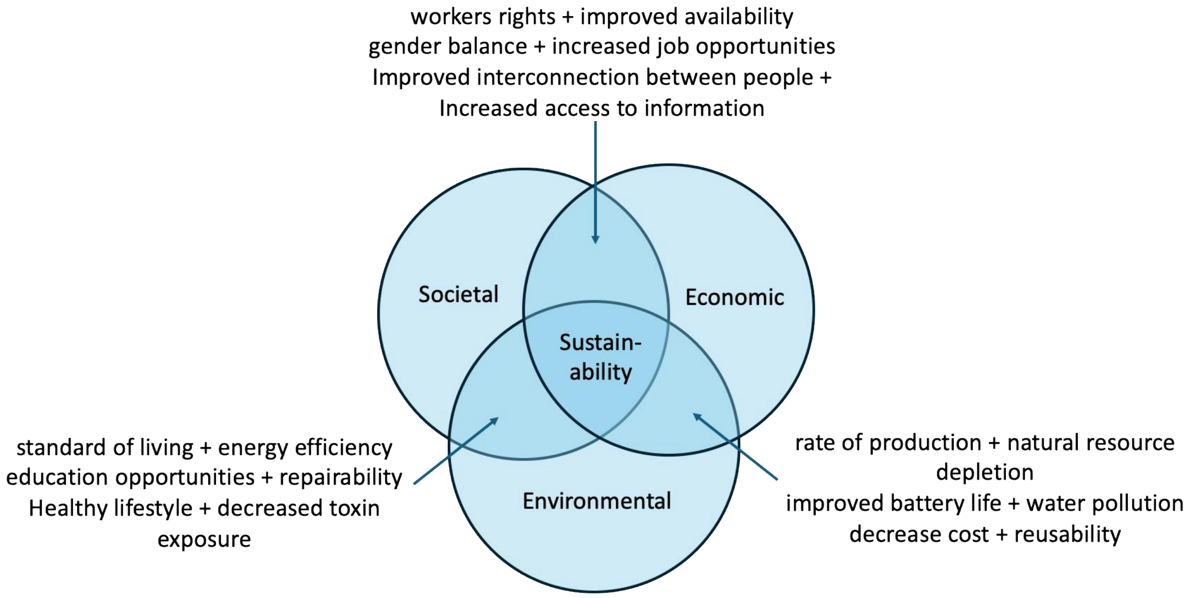

FIGURE 14: EXAMPLES OF INTERDEPENDENT 2-DIMENSIONAL INDICATORS

This can be said for different formulations of energy benefits, whereby creating a situation that reduces car use (e.g. avoid pollution, a harm) does not necessarily create the benefit of cleaner air because it does not support/address the interconnections needed to ensure that benefit (e.g. are people above to have access to what they need if they do not have a car? Are there alternatives that are less polluting? Will economies continue to thrive if people change mobilities? Moving activity to the cloud or edge computing can reduce energy for a network application, but does it also reduce the energy needs across the overall system required to use of that app. A well-defined KSI should be able to make visible that while a design or use option might be cheaper at face value, there could be hidden costs to society, such as emissions or e-waste, that raise the overall cost (and support such elements to be explicitly counted within costs).

In addition, compounding indicators that look at different scales of activity or with different types of data availability over time will strengthen the results [117]. This could be, for example, Pairing Energy Efficiency KPIs with environmental pollution measures, or combining device efficiency with network efficiency with reduced regional system load. It could be trial participant gender balance combined with a survey of people outside of the trials across genders about imagined value and overall change in gender accessibility over 2 years. It could be weekly records of people engaged in online training classes with yearly records of completion and 3-yearly records of ongoing employment.

This work is multi-disciplinary by nature. Neither a technologist nor a social scientist alone could address such an approach. However, doing it can support a better understanding of the impacts, over time and space, of trade-offs being considered.

4.5.2.8 Step 8: Defining KSIs themselves

Once all this background framework is established that can allow indicators to be clearly linked to sustainability targets, the next step is to define the KSIs themselves. These should be couched within the taxonomy defined values (categories of action), objectives within (sub-categories), and indicator goals (what the output is and how that is linked to an outcome).

These need to be understandable, clear, unambiguous, conceptually sound, and representative of consensus [124]. This list is built from the existing KVI work, practices in recent sustainability indicator literature, as well as methods suggested by organisations such as the UN and the EPA.

	Key Value and Objectives
Pillar	societal, environmental, and/or economic
Value Theme	e.g. inclusion
Sub-theme	e.g. what about inclusion is the focus?
Dimensions considered	1, 2, or 3
Objective	improved ability to participate in community

	Name, Target and Goal
Indicator Name	self-explanatory name
Brief Description	what does it look at and point to?
Target	if there is one, what is the target? how/from what was the target defined?

	Definitions
Impact Kind	output, outcome, other?
Who makes decisions with it?	Who can make decisions using it? what kind of decisions?
Who/what is affected	the specific people, elements of the environment, and parts of the economy. improved jobs for who? reduced pollution in what, where?
Scale and Scope	scale, scope, and type of activity or system being considered. For example, energy use can be one dimensional and narrow scale (a products use of energy), two dimensional and narrow scale (how much energy is used by a person towards a goal) or two dimensional and wide scale (how much energy use over an infrastructure when used in a community).
Significance of impact	How much difference will be made towards the value

	Data and Source
Measure	kind of evidence
Unit of Measure	e.g. percentage
Source	Where does the evidence come from?
Place of gathering	at what location is it gathered (e.g. local village, testbed, lab, etc.)

Status of gathering methodology	e.g. is it well established and accepted? is it experimental?

	Rationale
Rationale for linking indicator to value	how do you know this indicator points in the direction of a value outcome?
Relevance	what purpose; why this value and objective in relation to policy, 6g goals, and if relevant use-case goals?
Linkages to other indicators	is this compound or interdependent with other KSI?

	Relation to Innovation Process
Intervention Point	when in the 6G innovation process is this indicator most effective (e.g. at conception, in use?)
Responsibility	Who (e.g. what kind of partner, actor) is responsible for monitoring

	Limitations
Limitations of the indicator	what can it not tell us? When should it not be used?

	References
Linkages to standards	Is this informed by any standards?
References	Sources of information used

4.5.2.9 Step 9: Build a searchable, living database of potential indicators relevant to 6G

The following step would be a review of existing indicators outside SNS to provide an overview of current practices, priorities, and evidence-based indicators already accepted by other communities. Within SNS JU Activities, KVIs have already been partially collected within 6G4Society activities, though not all projects are yet included. This project-based index should become a shared resource and an experimental space for standardising indicators across different problem sets. Outside of SNS JU Activities, many lists exist of existing indicators that should be drawn upon, particularly as guidance for further defining the areas in which there are gaps or mismatches between policy objectives and current practice and for inspiration as to what forms such indicators could take. Many of these also provide correlates, describing interdependencies across indicators (e.g. wealth and clean water). For example, ISO/TR 37121:2017 is gathering existing guidelines and approaches on sustainable development and resilience in cities into a living inventory with the objective “to establish a set of indicators that can be used with any resilience framework to help cities with their resilience planning and will be built upon the guidelines and approaches contained in this document." In addition, other resources are available, which the community should assess for relevancy, and to create an index as a resource.

This database should be paired with guidance as to: a) how to enter new information; and b) how to extract indicators that are relevant for specific projects, use cases, or solutions. In addition, support within the database as to how identifying compounds and multi-dimensional indicators would need to be produced. Multidisciplinary consensus should be drawn across and beyond the 6G ecosystem regarding the logic of organisation and compilation. This is important to ensure that the definitions used within the frame of 6G align with, or are at least understandable by, the various audiences for which the indicators will be used.

4.5.2.10 Step 10: Make sure KSIs work in a way that speaks to decision-makers and stakeholders

Sustainability is not just an endeavour for designers or developers; instead, it involves strategic decision-makers as those who set priorities and define how values matter to 6G. KSIs need to be able to inform, and be informed by, these actors, too. Therefore, if the indicators become an instrument for policy evidence, their meaning shall be aligned with, and meaningful to, that area of policy. If the indicators will become part of marketing, they need to align with the public's understanding of the values and objectives.

Further work on this involves bringing together different people to the table with a strong focus on the interdisciplinary elements of the conversation that support the articulation and assessment of an indicator. But this work also requires bringing to the conversation people who have insight into how impact matters to the world, and who have the ability to ensure that impact becomes a priority for industry as well as policy. For example, a technology developer can implement sustainable elements in their particular research and innovation activity, but are not the people who can achieve business model change that would see the sustainability elements carried through as a priority (over or alongside performance and profit) towards a final product. Similarly, they alone cannot articulate how an impact will likely emerge or what needs to be in place around a technology to support the realisation of that impact. This requires KSIs being developed in ways that bring together decision-makers, technologists, socio-economists and environmental scientists to understand how the elements interplay between design, impact, and business decisions.

5 UNDERSTANDING ACCEPTANCE THROUGH CONTROVERSIES ON THE PUBLIC SPHERE

5.1 6G: THE QUEST FOR ACCEPTANCE

6G technology is still at a conceptual and exploratory stage; however, spotlights have been turned on, as of the earliest steps, towards the issue of social acceptance. Reflections or requests about the need to further explore and understand the dynamics and variables influencing social acceptance have found room and evidence in the framework of industrial and institutional orientation documents, including the R&I work programmes that orient industrial research in this sense [1].

Such attention comes as a direct consequence of what happened at the societal level on 5G. Indeed, the fifth generation of mobile communication networks (5G) was conceived to make a revolutionary change in the information and communication world, i.e. providing a unique and ubiquitous wireless platform to enable communication and data sharing among both human beings and technological devices with unparalleled performances. Despite these promises, and regardless of the technical challenges encountered during its development, 5G technology stands out for the reactions it has triggered, distinguishing itself by unprecedented organised opposition from diverse groups including citizen activists, associations, scientists, medical professionals, and elements of the political class. The social responses to this technology have been characterised by opposition, rejection, and even bans, in some instances. This unexpected backlash has highlighted the critical importance of considering social factors alongside technological advancements in the development and deployment of new communication technologies.

In this section the focus will be on the relationship between emerging or new technologies, and society, introducing the issue of social acceptance of technology from the very specific perspective of the social reaction to 5G. This is meant as a starting point to understand and explore different dimensions and scales of social acceptance in the specific context of 6G technology. After analysing the controversies and the public debate surrounding 5G, the focus will shift to social acceptance. The study will explore different dimensions of the relationship between society, and technology innovation as they relate to the acceptance and acceptability of technology. The research will be based on a methodological framework, the Social Acceptance Technology (SAT), specifically tailored to 6G. This approach aims to provide a comprehensive understanding of the potential social impacts and dimensions relevant to the next generation of mobile communication technology. The framework is presented and offered as a recommended tool for future social acceptance assessments, providing a structured (but flexible) method for incorporating the social dimensions and proactively working towards social acceptability and acceptance of emerging 6G technologies.

5.2 UNDERSTANDING CONTROVERSIES IN SCIENCE AND TECHNOLOGY

Co-funded by the European Union

Public opposition towards opportunities or orientations of science and technologies has concerned nuclear power, genetically modified organisms, genomics, cloning, embryo research, and nanotechnology. What became progressively clear is that the acceptance of technological innovation is not only determined by the technical features of an artefact or a product, or by its capacity to perform and solve a problem. Moreover, as public debates play a crucial role in shaping the trajectory of new technologies, the governance of innovation becomes intertwined with broader democratic processes and even nation-building projects, influencing how citizens evaluate and accept new scientific developments.

> The interaction between technology and societal factors discussed in the main text is well-illustrated in the literature. Bauer and Gaskell's [125] study on biotechnology controversies provides concrete examples of how public perception shaped the development and regulation of GMOs across Europe. They found that media coverage and public opinion significantly influenced policy decisions, demonstrating the power of public debate in technology trajectories. Jasanafoff's [126] comparative analysis of biotechnology governance in the US, UK and Germany further exemplifies how cultural and political contexts affect technology acceptance. For instance, she shows how different national approaches to regulating stem cell research reflect distinct understandings of human dignity and the role of science in society.

One way to access the complex relationship between society and technology is through analysing possible **controversies** surrounding technological innovations. It is important to understand that the study of controversies is not intended to discredit the value of technology. On the contrary, **recognising that public attitudes vary significantly across different fields of science and technology, the complexity of society's responses calls for the investigation of the social dimensions playing a role in the acceptance or rejection of specific technological innovations** [127].

Controversies in this context refer to debates and disagreements surrounding scientific or technological developments [128] their implications, and societal impacts.

> After WWII, the belief in technological progress started progressively to be questioned by the citizenry. Silent Spring, Rachel Carson's ground-breaking 1962 book, exemplified this shift, and marked a milestone for the emergent environmental movement. The book exposed the detrimental effects of pesticides and called attention to the need to consider the broader social and ecological implications of technological development. The idea of unfettered technological progress was challenged, since, on many fronts.

They typically arise from conflicting perceptions or awareness of potential unintended consequences, impacts, or hazards associated with new inventions or innovations. For instance, the debate around genetically modified organisms (GMOs) illustrates how a technological advancement can spark widespread controversy, involving concerns about food safety, environmental impact, and corporate control of agriculture. While public debate and conflict around science and technology is not a new phenomenon, the frequency and intensity of these controversies seem to have increased in recent decades, reflecting the growing societal impact of rapid technological change [129].

> The study of controversies in Science and Technology is a key approach within Science and Technology Studies (STS). For a comprehensive introduction to this field and its methodologies [128]. The increasing prevalence and intensity of public debates surrounding technological innovations have been noted by scholars for decades. Conrad [129] provides an early examination of this trend, focusing on the nuclear and recombinant DNA debates. More recently, Callon [130] has expanded on this concept, exploring how the multiplication of controversies in our increasingly technologised world necessitates new forms of democratic engagement with science and technology.

As part of public discourse, controversies are valuable for understanding social acceptance for at least two main reasons:

1. They happen in public, staged in and often by the media [131] which makes it possible to follow and study them.
2. They usually involve multiple stakeholders with varying perspectives, interests and values, offering precious insights into the dynamics between the stakeholders and the technology in question, revealing underlying assumptions, power relations and political struggles embedded in the scientific and technological realms.

This perspective aligns with Responsible Research and Innovation principles, acknowledging the reciprocal relationship between technology and society and providing a privileged standpoint to observe the complex interactions of technology and society.

In the context of the 6G4Society project, this specific approach was shaped by discussions instigated by the European Commission regarding the challenges faced by 5G implementation. These reflections on why 5G failed to meet certain expectations led us to recognise the potential value of identifying and analysing controversies as a crucial step in developing our Social Acceptance of Technology framework. While an exhaustive analysis was not conducted, a preliminary exploration of debates surrounding 5G highlighted key social variables and mechanisms that influence public acceptance or rejection of emerging technologies. These include aspects such as trust in institutions, risk perception, and effectiveness of communication strategies. This initial identification of controversies demonstrates how such an approach can provide valuable context for applying a social acceptance framework. It lays the groundwork for a more comprehensive understanding of societal concerns, potentially leading to a more robust and socially attuned acceptance model for future technologies, particularly 6G.

Here is a summary of relevant societal dimensions on which controversies can shed light on:

- The public's engagement with complex technologies: the diverse claims, objections, and arguments raised by various stakeholders, including protest groups, reveal the multiple ways in which technologies are understood, perceived, and contested in society, highlighting areas of uncertainty and different interpretations.
- Issues of public apprehension or concern (e.g., doubts, uncertainties, fears): often stem from public perception or awareness of potential or realised unintended impacts, consequences, or hazards associated with new inventions or innovations.
- Tensions, dissent, friction, resistance, misunderstandings (incl. dissent within the scientific community), misapprehension, informative asymmetry.
- The characterisation of the diverse publics involved and the relationships among multiple stakeholders (e.g. policy-makers, advocacy groups, industry players, developers). This analysis should encompass their claims, perspectives, varying interests and concerns, as well as the distribution of decisional and political power among these groups.

These allow in turn to draw considerations on a number of strategic elements connected to social acceptance:

- Social and moral **values** more important for society, and/or social values or priorities impacted by technology:
- Future scenarios generating positive **impact** on society

- Considerations about **governance** and space for more inclusive and participatory decision-making processes
- **Communication** issues.

The capacity to properly read through these controversies is therefore essential to identify the different forces and interests behind them, and to distinguish between conflicts that arise from misinformation or public manipulation, and those that must be reconciled a legitimate diversity of perspectives within the democratic arena, or the scientific community.

This awareness can inform decision-making processes that shape the direction of research, technological development, and innovation. Additionally, it is essential for fine-tuning appropriate communication strategies with various stakeholders.

5.3 THE PUBLIC DEBATE SURROUNDING 5G

The rollout of 5G communications technology worldwide has ignited significant debates involving industry, government, researchers, and the public. In the EU, this technology has been met with a complex array of public responses, ranging from enthusiasm for its potential economic and social benefits, to deep concerns about its possible health, environmental, and political implications.

This section aims to provide a comprehensive overview of public perception and stakeholder interactions surrounding 5G technology across Europe. The analysis highlights the key issues and topics central to episodes of dissent, conflict, and misunderstanding. To achieve this, desk research was conducted, drawing from a variety of secondary sources including academic literature, media reports, and policy documents. This approach offers an informed perspective on the principal areas of controversy, synthesising existing information to identify patterns and themes in the discourse surrounding 5G technology, that are reflected in 6G discussions.

The analysis focuses on the broader European context, with detailed examinations of France, Switzerland, and Italy (see appendix C – Examples of 5G controversies in the EU). While not exhaustive due to the task scope and timeline, this approach offers representative insights into common themes, patterns, and divergences in the 5G debate across different national contexts. Switzerland and Italy were chosen due to their direct involvement through project partners and their experience with significant 5G rollout delays, which generated substantial public and policy debates. France was selected for its focused analyses of 5G-related controversies [132], providing valuable insights into how technological debates can become matters of public concern. These nations collectively demonstrate how controversies can shape public perception and regulatory decisions regarding 5G implementation. Their experiences illustrate the utility of mapping of controversies in understanding the socio-political environments where Social Acceptance frameworks may be subsequently applied, highlighting the importance of addressing controversies as a foundational step in assessing social acceptance.

The main aspects this analysis searched for are:

- Different voices and interests (stakeholders) contributing to the 5G narrative. The claims of the different stakeholders.
- Governance level at which the discussion initiated

- Controversies and democratic discourse - legitimate dissent and power dynamics
- Public perception
- Impact of other fears (e.g., Covid-19)
- Communication dynamics, including the role of expert – non-expert dialogue, and of dominant cultures or interests.
- Polarisation of perspectives

5.3.1 Public response to 5G

Public discourse surrounding mobile network technologies has a history, predating 5G by decades. The groundwork for the 5G debate had been laid years prior, driven by advancements in technology and the establishment of multilateral standardisation agreements. In the year 2000, as the world was primarily focused on the ongoing transition from 2G to 3G mobile networks, 5G technology was still a distant concept. However, the seeds of public concern regarding the potential health and environmental impacts of wireless technologies have already been shown. Opposition and protests against mobile network technologies have persisted from 3G to 5G. For a detailed analysis of these conflicts in Germany [133]. Public concerns about the health, environmental, privacy and economic impacts of mobile communication technologies are not a new phenomenon. They date back at least to the early 2000s, when various citizens' groups, activists and associations raised questions about potential health risks from electromagnetic field (EMF) radiation, negative effects on property values, visual blight from antennas and lack of public consultation on infrastructure deployment.

> An example of such citizen's group is A.I.E (Associazione Italiana Elettrosensibili), an Italian association for electrosensitive individuals established in 2005. Registered as a social promotion with the Veneto Region, A.I.E. raises awareness about potential health risks associated with electromagnetic fields (EMF). The association's board comprises a President, Vice President, and three Council Members, serving three-year terms. A.I.E holds monthly meetings, often via conference calls or web meetings, and organizes local events and discussions with the public to address concerns about EMF exposure and the impacts of wireless technologies on health and well-being.

Notably, a group of scientists called for a moratorium on 5G deployment in 2017, well before the Covid-19 pandemic and the subsequent wave of conspiracy theories which also hooked into 5G.

> The "5G Appeal" [134]is a petition signed by scientists and doctors recommending a moratorium on the deployment of fifth-generation (5G) wireless technology. They express concerns that 5G will significantly increase exposure to radiofrequency electromagnetic fields (RF-EMF), which they claim may pose potential health risks to humans and the environment. The appeal calls for thorough, independent research into these potential hazards before the technology is widely implemented.

Widespread public and political discussion about 5G intensified in early 2019[2], corresponding with the initial commercial rollouts of 5G networks in several countries [135]. As 5G networks have been deployed globally, the controversies surrounding this technology have evolved, encompassing a broader range of societal concerns and intersecting with wider narratives and

[2] This sort of delayed reaction does not come as a novelty. For example, also nuclear energy was not a controversial issue before it reached a commercial stage in the late sixties [129].

conflicts. The Covid-19 pandemic in 2020 significantly impacted these debates across Europe, exacerbating fears and fuelling misinformation [136]. This period marked a critical point where the debate around 5G gained unprecedented attention, often intertwining with conspiracy theories and broader social anxieties[3].

The opposition and lack of support for 5G technology became particularly evident at the local level, where the presence of antennas frequently disturbed residents and elicited various forms of backlash. Acts of vandalism and arson targeting 5G infrastructure were seen in many places around the world. The telecom industry lobby group GSMA registered more than 221 attacks across 18 countries globally, with the UK seeing the highest numbers of instances. Of the 27 countries, 10 experienced arson attacks on telecom infrastructure, catching many off guard and unprepared. The UK alone reported over 87 incidents of arson and vandalism, with more than 70 occurring in the first half of 2020. France followed with 50 attacks, while the Netherlands experienced 30, including 16 5G masts set on fire leading to significant delays in the technology's deployment. Other European countries also saw incidents: Ireland reported 3 arson attacks, while Belgium, Italy, Cyprus, and Sweden each reported at least one such incident [137].

The reasons behind these attacks and protests are complex and diverse, requiring careful investigation to avoid oversimplification. It's crucial to differentiate between violent acts, such as arson attacks, and other forms of protest or opposition, including peaceful demonstrations, legal challenges, or municipal bans. While some incidents coincided with the spread of conspiracy theories linking 5G to Covid-19 during the pandemic, it's crucial to note that opposition to 5G predates these theories and stems from various concerns.

> Conflating opposition to 5G and cell towers with conspiracy theories obscures legitimate concerns raised by experts in various fields. For example, the BabySafe Project, led by Dr. Hugh Taylor, Chair of the Department of Obstetrics, Gynecology and Reproductive Sciences at Yale University School of Medicine, highlights potential risks of RF radiation exposure during pregnancy and advocates for precautionary measures to protect fetal development. For more information [138].

As Gerli [139] points out, "little has been said on the factors and actors shaping the debate on 5G within local communities". This gap in understanding highlights the need for more comprehensive research by social scientists and investigative journalists. Motivations may range from concerns raised by some doctors and scientists, as evidenced by the 2017 EU 5G Appeal, to environmental and health worries unrelated to conspiracy theories. The pandemic context likely exacerbated existing anxieties, but it's important not to conflate all opposition with misinformation. Understanding the full spectrum of concerns and motivations, from legitimate scientific questions to local community issues, requires more nuanced research and open dialogue. This approach is essential to distinguish between various forms of opposition and to address the real issues that might be overshadowed by more sensational narratives.

5.3.2 Debate terms

The debate around 5G, including the main and recurrent concerns and debated aspects expressed by the protestors, has revolved around the following topics. It is important to notice

---

[3] Ahmed [233] conducted a social network analysis of Twitter data to understand the spread of 5G-Covid-19 conspiracy theories. Their research revealed how misinformation rapidly gained visibility on social media during the pandemic, even as most users did not genuinely believe the conspiracy.

how the different topics relate to different types of stakeholders (citizens, industry, policymakers), and to different levels and fields of expertise (non-experts; experts or scientist in the tech field; experts or scientist in other fields).

Health and safety. The launch of 5G has reignited and amplified the long-standing debates around the potential **health** risks associated with radiofrequency (RF) electromagnetic field (EMF) radiation from 5G networks. Despite reassurances from regulatory bodies and industry stakeholders, the deployment of 5G's higher frequencies and denser network infrastructure has fuelled public fears and speculations about the technology's impact on human health, particularly in the absence of conclusive long-term studies. In particular, critics argued that current safety guidelines may not be adequate to protect public health, and they called for more research into the long-term effects of EMF exposure. Other types of concerns in matters of health (e.g. in connection with Covid) spread within the context of conspiracy theories.

> Conflating opposition to 5G and cell towers with conspiracy theories obscures legitimate concerns raised by experts in various fields. For example, the BabySafe Project [138], led by Dr. Hugh Taylor, Chair of the Department of Obstetrics, Gynecology and Reproductive Sciences at Yale University School of Medicine, highlights potential risks of RF radiation exposure during pregnancy and advocates for precautionary measures to protect fetal development.

Environment. The perceived **environmental impact and footprint** [140] of 5G networks have resonated with the growing environmental consciousness and sustainability movements. Environmental impacts include fears about the increased energy consumption required by 5G infrastructure and its potential contribution to climate change, besides the effects of such footprint on biodiversity. Additionally, there were concerns about the visual blight of new antennas in the landscape.

Beyond these immediate infrastructural concerns, the environmental impact of 5G extends to broader lifecycle considerations. The European Parliament's study [141] has identified significant research gaps in understanding the effects of new frequency ranges on wildlife, particularly regarding invertebrates and plants. Furthermore, the acceleration of device turnover associated with 5G adoption raises serious concerns about electronic waste management. The Global E-waste Monitor 2024 [142] reports that e-waste is rising five times faster than documented recycling rates, with only 22.3% being properly collected and recycled in 2022. This challenge is particularly relevant as 5G deployment may accelerate the obsolescence of existing devices and network equipment. All these aspects suggest that the environmental impact of 5G involves complex trade-offs.

Privacy and Surveillance [143]**.** The issue of **privacy** and **surveillance** has also emerged as a significant point of contention. The vast data collection capabilities enabled by 5G's enhanced and ubiquitous connectivity, tapping into broader societal debates around digital rights and civil liberties, have raised fears about the potential for increased government and corporate surveillance, potential data breaches, and the erosion of personal privacy.

Global attitudes towards these privacy concerns vary significantly, as revealed by a 2020 POLITICO/Qualcomm survey [144]. In the United States, 60 percent of respondents expressed fears that 5G could increase their vulnerability to hacking and data breaches. However, the willingness to sacrifice privacy for the benefits of 5G technology differs markedly across regions. While only 21 percent of U.S. consumers were willing to accept reduced privacy standards in exchange for 5G speeds, 64 percent of respondents in China and India, and 61 percent in Brazil, were more amenable to this trade-off. These disparities reflect varying cultural attitudes and regulatory environments, suggesting that approaches to privacy in the 5G era may diverge significantly across different countries and regions.

Digital Divide. The digital divide refers to the gap between individuals and communities that have access to modern information and communication technologies (and related opportunities) and those that do not. This divide can exist due to various factors, including socioeconomic status, geographic location, age, and education, and acts as a reinforcing factor for inequalities. By enabling faster and more reliable internet connectivity, and enhancing economic opportunities and educational access, 5G technology is seen as a critical tool for closing the digital divide. The narratives surrounding 5G in matters of digital divide, however, have also intersected with concerns over the concentration of power and control in the hands of a few dominant technology companies. Critics have raised regarding the potential for these companies to dictate the terms of access and affordability, potentially exacerbating the digital divide along economic and geographic lines.

Perceived underperformance and sense of unfulfilled promises have emerged as central themes in public discourse surrounding 5G. According to the SK Telecom 6G White Paper, the arrival of 5G initially sparked widespread enthusiasm, with promises of revolutionary advancements such as 20Gbps peak data rates and transformative applications like self-driving cars, Urban Air Mobility (UAM), telesurgery, immersive virtual reality (XR), holograms, and digital twins. However, many of these services have not materialised as anticipated due to a combination of technical and practical factors. For instance, while successful experiments with autonomous cars and telesurgery have demonstrated the feasibility of 5G as an enabler, further development is needed to ensure robustness, resilience, and trustworthiness in real-life scenarios. This coupled with slower deployment and coverage due to supply chain disruptions (such as delays caused by the COVID-19 pandemic) and regulatory gaps (e.g., accountability for autonomous vehicles), has led to a more evolutionary transition from 4G/LTE than a revolutionary leap. The disparity between initial expectations and the reality of 5G's rollout has nurtured perceptions of underperformance and unmet promises, contributing to public disillusionment and scepticism. This sentiment is reflected in Europe, where issues such as a delayed 5G deployment and low uptake, particularly compared to regions like Asia and North America, have raised concerns about the continent's ability to stay competitive in the global digital landscape.

> The perceived gap between the promises and reality of 5G has been echoed by both industry reports and public sentiment. SK Telecom's 6G White Paper highlights the high expectations set for 5G, which included applications like autonomous cars and telesurgery, but many of these technologies have yet to reach their full potential due to technical and regulatory challenges. In Europe, a slow 5G uptake and deployment delays, exacerbated by supply chain disruptions and regulatory hurdles, have been identified as significant factors hindering progress. The European Telecommunications Network Operators' Association (ETNO) has noted that Europe is lagging behind other regions like Asia and North America in key technological developments such as 5G standalone networks and edge cloud [145] [146] [147].

Contrasts within the industrial world. The deployment of 5G has also sparked discussions within different industry sectors, particularly aviation and telecommunications, and among their respective regulatory bodies. For instance, the aviation industry raised concerns about the potential interference between 5G signals and aircraft navigation systems, specifically radio altimeters, which are critical for safe landings in low-visibility conditions. Similarly, the meteorological community has expressed concerns that certain frequencies used by 5G networks might interfere with weather forecasting systems, particularly those that rely on satellite data to monitor atmospheric conditions like water vapour. Both of these debates highlight the broader challenge of balancing technological advancement with safety in critical sectors, requiring ongoing dialogue between stakeholders to address these potential risks.

These industry-specific concerns have led to concrete actions and ongoing research. In the U.S., the Federal Aviation Administration has worked with telecom companies to create buffer zones around airports and has overseen the upgrading of aircraft equipment. In Europe, while similar concerns exist, the European Union Aviation Safety Agency (EASA) reported in January 2024 that no major incidents of interference have been recorded. The debate in meteorology continues, with ongoing studies to quantify the potential impact on weather forecasting accuracy.

Geopolitical tensions surrounding critical infrastructure. The Deployment of 5G technology has also become entangled in broader geopolitical tensions and concerns over technological sovereignty. A central issue has been the involvement of Chinese telecommunications companies, particularly Huawei, in the development and rollout of 5G networks around the world. The United States, under the Trump administration, took a hard-line stance against Huawei, citing national security concerns and allegations of potential espionage and intellectual property theft. Several European countries imposed restrictions or outright bans on certain vendors. This controversy merits deeper analysis as it exemplifies broader discussions about technological sovereignty – a core principle in the EU's strategy for developing its autonomous technological future. While this analysis focuses on other aspects of the 5G controversy, the geopolitical dimension represents a crucial layer that reveals how technological infrastructures become sites of political and economic contestation.

The controversy continues to evolve. As reported by the Financial Times (June 2023), the EU has been considering a mandatory ban on companies deemed security risks in 5G networks, with only a third of EU member states having implemented restrictions on high-risk vendors despite Brussels' recommendations. This ongoing debate highlights the persistent tension between technological development, national security, and economic interests in the European context [148].

Amplifying factor: disinformation and misinformation. The debate surrounding 5G has also been exacerbated by the proliferation of disinformation and **conspiracy** theories, particularly in the context of the COVID-19 pandemic. Such theories linked the spreading of Covid19 to the radio waves sent by 5G technology, which supposedly enabled small changes to people's bodies that would make them more susceptible to the virus. Platforms like Facebook, Twitter, and YouTube, which reward sensational content with increased visibility, allowed the rapid spread of disinformation, reaching millions of people and fuelling public fears. The discontent originated from such theories flew into the various acts of vandalism and violence against 5G infrastructure, presented above in this section.

Internet celebrities such as Sacha Stone, a British New Age influencer, played a significant role in spreading disinformation about 5G. He produced a documentary titled "5G Apocalypse: The Extinction Event," which promoted the idea that 5G networks are a military weapon disguised as a telephone system. This documentary featured on YouTube garnered over a million views, before being taken down by the company. Stone further exploited these fears by marketing the 5G Bioshield, a USB stick professedly designed to protect users from the harmful effects of 5G radiation, which was later deemed a fraudulent scam.

5.4 CONTROVERSIES AS A GOVERNANCE ISSUE

This section examines how 5G controversies have evolved into fundamental governance challenges, revealing deeper tensions in the relationship between technological innovation and democratic processes. By analysing the interplay between conspiracy theories and legitimate dissent, national objectives and local autonomy, and communication strategies and public trust, we identify critical patterns in how technological controversies manifest as governance issues. The analysis reveals that these controversies extend beyond mere technical or implementation challenges, representing broader societal debates about technological governance, democratic participation, and the balance between innovation and precaution. Drawing from experiences across European countries, particularly France, Switzerland, and Italy, this section demonstrates how the 5G debate has become a catalyst for reconsidering traditional approaches to technological governance and highlights the need for more inclusive, transparent, and responsive decision-making frameworks.

5.4.1 Conspiracy versus Legitimate Dissent

Concerning the protests and attacks described above, some governments and media tended to present and explain them as directly and exclusively triggered by the spread of conspiracy theory contents and disinformation campaigns, and exacerbated by the pandemic. However, this explanation risks oversimplifying a more complex situation. Interpreting the discontent as a direct product of conspiracy thinking risks lumping together the doubts and concerns raised by citizens, activists, associations, politicians, and mayors with unfounded fears, thereby muddying the waters of legitimate scientific discourse and healthy public policy debates. Such an interpretation, in particular, risks **overshadowing valid concerns and genuine doubts**, failing to adequately **acknowledge the nuanced reasons** and diverse voices within the democratic arena. It also makes it harder for legitimate questions and issues—such as those raised in earlier network-related innovations (e.g. the use of mobile phones)—to receive proper attention and be addressed thoughtfully, based on evidence. The consequence of this approach is even greater polarisation and radicalisation of opinions, increasing public mistrust and negatively impacting the debate as a whole [149].

Indeed, concerns about the health and environmental impacts of wireless technologies are not new. Entirely dismissing them as the result of irrational forces supported by disinformation may not be the most appropriate or useful approach to understanding and addressing the situation, since it tends to turn away from a neutral understanding of the real concerns underlying these facts. What happened with 5G in terms of public debate, is not that different - as a social phenomenon - from the historical cases of nuclear power plants, chemical industries, and other sectors that profoundly impact people's lives, where social debates revolved around people's struggles for **transparency and accountability from governments and industries.**

The controversies surrounding 5G deployment underscore the need for a more inclusive and democratic approach to technological governance, aligning with the principles of Responsible Research and Innovation (RRI) [12]. RRI emphasizes the importance of anticipating and assessing potential implications and societal expectations regarding research and innovation, fostering the design of inclusive and sustainable research and innovation [150].

In this context, the divergence of positions on 5G can be viewed as a legitimate debate across different interests and expertise fields within the democratic space, each putting forward a different system of values and priorities. A balanced approach to 5G governance would acknowledge concerns about disinformation while recognizing the range of legitimate issues raised by various stakeholders. This perspective frames dissent and protests as positive, necessary forces in society, aimed at balancing the pace of technological progress and market-driven approaches, with the precautionary principle of protecting public health and the environment [151].

The debate around 5G reflects broader societal anxieties, conflicts, and aspirations, extending beyond the technology itself to encompass issues of public health, environmental sustainability, privacy, technological sovereignty, and socio-economic implications of rapid technological change. Effective governance in this context requires meaningful engagement with diverse stakeholders, including citizens, scientists, policymakers, and industry representatives [152]. This multi-stakeholder approach, central to RRI, can help in developing more robust, socially acceptable, and ethically sound technological solutions.

Understanding the complexity of these stakeholder dynamics, including the historical context of resistance to previous generations of mobile infrastructure, can inform efforts to develop more inclusive approaches to technological governance. Rather than dismissing public objections, an RRI-informed approach would integrate these perspectives into the innovation process, aiming to bring people closer and overcome polarization [153]. This approach not only enhances the democratic legitimacy of technological development but also potentially improves the quality and social robustness of the innovations themselves [154].

Appendix B – Health and safety debate around 5G presents a summary of the ongoing debate regarding the potential health impacts of 5G technology.

5.4.2 Local versus National

One of the most striking features of the 5G controversy across these cases is the tension between national objectives and local autonomy. In France, Switzerland, and Italy, we see a clear pattern of national governments pushing for the rapid deployment of 5G infrastructure as part of broader strategies for economic competitiveness, digital transformation, and technological innovation. However, this top-down approach has been met with significant resistance from local authorities, activists, and concerned citizens who fear that their voices and interests are being marginalised in the rush to embrace 5G.

The Italian case is particularly illustrative of this dynamic, with numerous municipalities implementing bans or restrictions on 5G installation in response to perceived health and environmental risks. Despite the national government's efforts to reassert its authority through measures like the *Simplification Decree* [155], local opposition has persisted, leading to delays in the rollout of 5G in underserved areas. At the time of writing this deliverable, May 2024, numerous municipalities in Italy continue to object to the installation of 5G antennas, urging caution and calling for more scientific evidence to reassure citizens about potential health effects. Similarly, in France and Switzerland, we see a patchwork of local initiatives and petitions seeking to halt or slow down 5G deployment, often justified based on the precautionary principle and the need for more extensive public consultation and scientific assessment of potential risks.

Across these examples, a common, key role has been played by grassroots movements and civil society organisations, in shaping public opinion and mobilising opposition to 5G. In Italy, the Stop 5G Alliance has been instrumental in lobbying local authorities and amplifying concerns about the technology's potential impacts. In France, environmental and health advocacy groups have been at the forefront of calls for a moratorium on 5G deployment, while in Switzerland, citizen-led initiatives have forced the issue onto the political agenda and raised the prospect of a national referendum on the technology's future.

Despite these common patterns, there are also important points of divergence across the case studies that reflect specific political, cultural, and institutional contexts of each country. In Switzerland, for example, the tradition of direct democracy and the ability of citizens to force referendums on issues of concern has given the anti-5G movement a powerful tool for shaping the national debate. In France, the centralised nature of the state and the technocratic orientation of policymaking have arguably made it more difficult for local concerns to gain traction, although recent events suggest that this may be changing.

5.4.3 Communication and acceptance considerations

Managing expectations. In retrospect, it seems there is reason to question whether the transformative potential of 5G may have been overestimated, perhaps driven by optimistic projections that centred primarily on the technology itself. This vision may have overlooked the varying readiness levels across the broader infrastructure and ecosystem, including regulatory frameworks and market preparedness.

The disconnection between the vision presented to the public, and the reality of the rollout experience, stresses on the one hand the importance of ensuring a more holistic view on future technology development and innovation, and on the other hand, the importance of managing expectations through clear communication.

Lack of transparency, mistrust, and risk communication. Public opposition to 5G might be interpreted as a call for greater reassurance and clarity. The mistrust in prevailing narratives about 5G stems largely from a perceived lack of transparency and a general scepticism towards official sources, particularly regarding the potential risks associated with deploying this new technology. Effective risk communication is important in this context, but it requires a delicate balance. Simply denying risks tends to exacerbate mistrust; instead, a more balanced approach that acknowledges both risks and opportunities, and carefully weighs them, is necessary. However, effective risk communication goes beyond mere information dissemination. It necessitates genuine public engagement, which involves moving away from policy orientations that solely reflect the vision of dominant stakeholders. This shift requires a willingness to cede some decision-making power to alternative visions and diverse stakeholders, truly incorporating their perspectives into the policy-making process. Such an approach not only addresses transparency concerns but also helps build trust and fosters a more inclusive dialogue about the future of technology in society [156].

The 5G case highlights the significant **role and dimension of infrastructure** in shaping public (social) acceptance of technological innovation. When innovations involve extensive infrastructure deployment and impact public interest services such as healthcare, transportation, or utilities, a unique aspect of public (social) acceptance emerges. Unlike consumer technologies that individuals can choose to adopt or ignore, infrastructure-based innovations like 5G and 6G necessitate a degree of collective acceptance or at least acquiescence. This stems from their fundamental alteration of the shared physical and digital environment, affecting entire communities regardless of individual preferences. As a result, gaining public endorsement for these infrastructural innovations becomes a central concern, extending beyond individual consumer choice to issues of public policy, urban planning, and societal consensus [157] [158]. The dynamic highlights the value of a more inclusive and participatory approach to infrastructure-based innovations, where public engagements are not just beneficial but integral to successful implementation and widespread acceptance.

5.4.4 Governance considerations and conclusions

Ultimately, the 5G controversy in Europe raises fundamental questions about the governance of emerging technologies and the need for more inclusive, transparent, and responsive decision-making processes. As the varying responses to 5G deployment across France, Italy and Switzerland have shown, introducing new mobile network technologies is not merely a matter of technical innovation but also a complex social and political issue.

The opposition and public concerns about technology voiced by mayors, elected representatives, political leaders, environmental activists, and concerned citizens, often reflect different deeper values and priorities, which may lead to visions of the future that are different than those proposed by industry.

Such instances push to emerge and call for their share in the democratic space, demonstrating the need for a more transparent, diversified, inclusive, and flexible approach to technology governance, able to critically question the dominant direction of research and technological development, and welcome different nuances of technological progress and future priorities, towards societal well-being and sustainability.

As the national realities demonstrate, the top-down, industry-driven approach to 5G deployment has generated significant backlash and resistance from local communities who feel that their concerns and aspirations are being ignored in the name of economic and technological progress.

To address these challenges, policymakers and industry leaders will need to develop new models of innovation governance that prioritise public engagement, scientific assessment, and local participation in the design and implementation of emerging technologies. This may require a fundamental rethinking of the balance between national and local authority, and a greater willingness to engage with the legitimate concerns and aspirations of citizens and communities.

By synthesising the insights and takeaways from these case studies, researchers, policymakers, and industry analysts can contribute to developing a more nuanced and effective framework for understanding and managing the complex social, political, and technological dimensions of the 5G rollout. This framework should be grounded in recognising the importance of local context and the need for flexibility and adaptability in the face of rapidly evolving technologies and public attitudes.

The success of 5G and other emerging technologies, such as 6G, will depend on our ability to navigate the tensions and trade-offs between innovation and precaution, efficiency and democracy, and national priorities and local autonomy. By learning from the experiences of France, Switzerland, Italy, and other countries grappling with these challenges, we can chart a path forward that harnesses the transformative potential of these technologies while ensuring that they serve the needs and aspirations of all members of society.

6 6G AND SOCIAL ACCEPTANCE

Social acceptance is increasingly recognised as vital for the sustainability of innovation. Indeed, the attempt to align scientific and technical advancements with societal values and needs is not new at the European policy level for research and innovation. It stems back to the ELSA (Ethical, Legal and Social Aspects) framework, introduced in the 4th European Research Framework Programme (1994), and later strengthened through RRI framework, introduced by the EC research agenda in 2010.

More in particular, social acceptance research and assessments have the primary aim of ensuring that innovations are developed and implemented with public trust and engagement, addressing ethical, cultural, and social concerns, fostering inclusive decision-making, transparent communication, and collaboration between researchers, industry, and the public. For this reason, attention to social acceptance during the shaping process of emerging technologies is also increasingly recognised as conducive to guaranteeing sustainable technological progress. By prioritising social acceptance, policymakers can enhance the legitimacy and impact of research outcomes. Lately, the EU is promoting and encouraging the inclusion of social acceptance studies and assessments in various R&I projects (e.g., 5G Solutions [159], BRIGHT [160], IRIS [161], and COMFORTage [162]).

This section explores the social acceptance of technology in the context of 6G, examining the concept's current uses in contemporary research and defining its scope for 6G applications. A **framework for investigating 6G social acceptance** is proposed, acknowledging the complexity of 6G innovation scenarios while offering feasible methodologies for assessment. The framework distinguishes between acceptability and acceptance, incorporating various theoretical approaches to create a scalable and modular structure adaptable to different stages of the technology life cycle. Social acceptance is conceptualised, some relevant theoretical and methodological approaches are surveyed, and a comprehensive framework tailored to 6G is presented. Throughout this discussion, the general implications of 6G for social acceptance are analysed across various dimensions.

With the aim of identifying why society needs 6G solutions and considering the acceptability of a new 6G technological wave, the adopted approach seeks to provide a point of departure for understanding and evaluating the societal reception and possible adoption of 6G innovation and 6G technologies as they evolve.

6.1 SOCIAL ACCEPTANCE CONCEPTUALISATION

The concept of social acceptance of a technology refers to the degree to which a technology is embraced or rejected by society and depends on considerations at the individual and social level. These encompass broader societal attitudes, values, norms, and the impact of technology on individual users as well as on social structures and relationships.

Over the past decade, the concepts of **'acceptance'** and **'acceptability'** have become increasingly significant across various disciplines and at multiple levels of research focused on technology implementation strategies. Studies on acceptance and acceptability drew from a broader range of theories and frameworks, also according to different research contexts and needs. However, the diverse interpretations of these terms have led to a degree of ambiguity.

This lack of consensus is not merely an academic concern. It can sometimes diminish these concepts' practical value in the development of new technologies, affecting both real-world applications and academic research. Recent research efforts [163]; [164] propose to bring some legibility and clarification to this heterogeneous conceptual landscape.

An examination of the diverse interpretations of these concepts also reveals the intricate complexity characterising the interplay between power structures, social norms, and individual agency in shaping our technological landscape. Formulating a holistic approach to technology acceptance and acceptability is complicated by the multifaceted nature of human-technology interactions. Understanding this interplay is important in transitioning from the theoretical discussion of Social Acceptance of Technology to its practical applications in cutting-edge projects on 6G technology. By acknowledging these complexities, researchers and practitioners can better navigate the nuanced dynamics influencing the development, implementation, and societal integration of new technologies.

The objective of the following discussion is to establish the foundations for a framework that critically examines how acceptance and acceptability operate at different levels - from systemic perspectives to social groups or user-centred analyses - across various stages of the technology innovation development process. This framework aims to inform more responsible and socially conscious technological innovation. As part of the effort to discuss the importance of evaluating the societal and environmental implications of technological advancements, it's necessary to examine the concepts of "acceptance" and "acceptability" and how they have gained prominence in shaping technology implementation strategies.

6.1.1 Origin of the social acceptance concept and applications

The concept of social acceptance was originally used in social psychology [165] [166], primarily focusing on interpersonal dynamics such as peer acceptance and the integration of new individuals into social groups and communities. However, its application has significantly evolved as it crossed into other disciplines and research areas.

In particular, social acceptance has been an expanding topic of research since the 1990s. The term's scope progressively broadened, encompassing not only human-to-human relations but also the environmental and behavioural changes that arise from adopting new technologies and practices. Indeed, the concept of acceptance found fertile ground in technical fields and practical applications across various areas of study, including energy, fuels, environmental studies, management, human-computer interaction, and healthcare, applied mainly to the relationship between humans and novel "entities" - including technological devices, resource provision systems, and new practices.

Now social acceptance research spans many areas of social production, involving multidisciplinary communities of knowledge and practice. Across different fields acceptance is approached differently. These variations concern the understanding and definition of the concept of acceptance itself, the underlying rationale for acceptance research, and its practical application in various contexts, influencing the methodologies employed for application, the nature of findings, and the overall research scope and objectives.

6.1.2 A Tripartite View on acceptance: distinct disciplinary contributions

The following section, drawing from the recent work of Moesker [164], presents a brief review of the contribution of different disciplines to the development of the concept of acceptance, each offering distinct yet complementary perspectives on the dynamics of social acceptance.

Moesker [164] provides a comprehensive overview of how acceptance and acceptability have been conceptualised across these fields, highlighting the diverse interpretations that have emerged to meet each discipline's unique demands and research needs. Their work reveals that while these varied perspectives are all valuable, the lack of consistent definitions has led to miscommunications and difficulties in comparing research findings across studies.

The primary contributions to social acceptance research come from the research fields of applied **innovation sciences** and **social studies**. Additionally, the **ethics of technology** emerges as another significant domain which offers a distinct perspective on technology acceptance.

6.1.2.1 Innovation studies

Innovation studies encompass a broad spectrum of research fields, including innovation, economics, and market studies. Drawing from marketing strategies and diffusion theory, this field focused on the role of acceptance in facilitating a successful technology adoption process, studying how individuals and organisations adopt and adapt to new technologies and innovative practices. This field often conceptualises acceptance in terms of measurable user adoption of technology, while acceptability is seen as the anticipated willingness or positive attitude toward adoption. However, Moesker [164] notes that these terms are often used interchangeably in practice, contributing to conceptual ambiguity. Within this field, two major focus areas have emerged, closely interrelated: the **diffusion of innovation theory (DOI)** and **technology acceptance models**.

- The **Diffusion of Innovation** (DOI) theory, proposed by **Rogers** [167] in **1962**, explores how and why new technologies spread within a social system. DOI highlights four key elements: the characteristics of the innovation, the communication channels through which information about the technology is shared, the timing or rate of technology adoption, and the social system or network of users and cultural context that influences adoption. This theory provides a broader perspective on how innovations are **communicated** and **adopted** across entire social systems, distinguishing itself from the more individual-focused technology acceptance models. Furthermore, unlike the aforementioned methodologies, DOI focuses less on modelling user adoption and more on understanding the phenomenon at a larger societal level.

Drawing inspiration from the DOI, a number of acceptance models have been developed, focusing on capturing and measuring a number of human or context-related factors and variables influencing technology adoption. In particular:

- Technology acceptance models aim to understand and predict how users come to accept and use new technologies. Several key models have been developed, each building upon its predecessors and adding new insights.
- The Theory of Reasoned Action (TRA), introduced by Fishbein and Ajzen in 1975, laid the groundwork by focusing on an individual's intention to adopt a behaviour, considering both attitude and subjective norm as key factors.

- Building on TRA, Davis [168] introduced the Technology Acceptance Model (TAM) in 1989, applying it especially to work contexts. TAM emphasises perceived usefulness and perceived ease of use as primary factors influencing technology adoption. As research in this field progressed, the Unified Theory of Acceptance and Use of Technology (UTAUT) [169] emerged as an evolution of TAM. UTAUT broadened the scope by incorporating additional factors such as performance expectancy, effort expectancy, social influence, and facilitating conditions.
- Recognising the importance of organisational context, Tornatzky and Fleischer [170] developed the Technology, Organisation and Environment (TOE) framework in 1990. This framework shifted focus to organisational and environmental factors, considering technological characteristics, organisational factors, and environmental factors in the adoption process.

  More recently, researchers have developed models tailored to specific technologies and contexts. The integrated Sustainable Energy Technology Adoption Model (i-SETA) [171] is one such example, focusing on renewable energy adoption. This model considers personal values, trust, interest, and social influence, while also proposing a tripartite conception of acceptance formed by public support, individual willingness to use, and readiness to pay.

6.1.2.2 Social studies

In social studies, research on the concept of social acceptance emerged at the intersection of new technology diffusion, innovation, and social scientific inquiry into energy and policy. The field of energy and fuels has been a significant arena for the development of acceptance research (Taebi, [172]; Gaede et al., [173]) with a broader view on the social context.

In this field, acceptance research initially focused on public opposition issues, and developed as a response to critiques of traditional risk assessment methods, such as probabilistic risk assessments for nuclear reactor meltdowns, which were seen as neglecting social aspects of risk and public acceptance [172]. The concept has been applied in particular to understand public attitudes towards new energy technologies, fuels, renewable energy projects, energy policy changes as well as community response to infrastructures, becoming instrumental in understanding and facilitating societal transitions in energy use and technological advancement.

Recent approaches, termed the “third social acceptance wave” critically assess energy technologies, and question whether overcoming public opposition should always be the goal. This shift reflects a growing recognition of the complex, multi-level nature of technology implementation in society, and wider acceptance processes. Progressively, the approach evolved to a more nuanced, process-oriented perspective. Over the decades, researchers have focused on combining socio-political, contextual, and individual (e.g. psychological) dimensions to create more nuanced understandings of acceptance. Wüstenhagen et al. [174] introduced a seminal framework based on three: socio-political, community, and market acceptance. This framework was later refined by Upham et al. [175], who proposed a cross-disciplinary approach analysing acceptance at macro, meso, and micro levels, considering various actor groups. Studies in this field have explored diverse aspects, including perceptions of risk, attitude formation towards technology, trust in governance and other key stakeholders, as exemplified by Hujits et al.’s [176] work on carbon dioxide storage acceptance. This evolving body of research has significantly contributed towards the understanding of how different actors and different dimensions of acceptance come into play regarding technology innovations with broader expected impacts affecting multiple sectors of society and various aspects of daily life such as 6G.

6.1.2.3 Ethics of technology

The ethics of technology researchers have contributed by emphasising the moral dimensions of acceptance and acceptability. They distinguish between acceptance as an empirical state of affairs and acceptability as a normative judgement of how technology ought to be. This field has highlighted the importance of considering moral values, such as justice and sustainability, in technology development and implementation.

6.1.3 Acceptance and Acceptability

In social acceptance scholarship, acceptance and acceptability are sometimes treated as separate entities, sometimes interchangeably. Differentiating between "acceptance" and "acceptability" is not merely a theoretical exercise, but a crucial methodological step that helps clarify the kind of analysis needed to generate meaningful knowledge. Although the distinction has at first been overlooked in the literature, some works have focused on that from the point of view of the ethics of technology [172] and more recently regarding different fields of inquiry [164]. In investigating 6G social acceptance, clarifying and correctly applying the concepts of acceptance and acceptability is important, to better focus the analysis and choose the adequate research methods.

While social **acceptance** “refers to the fact that a new technology is accepted - or merely tolerated - by a community” [172], **acceptability** is normative and refers to a way of reflecting on a new technology, “by taking into account the moral issues that emerge from its introduction” [172]. Both these concepts have a social dimension, since moral judgments also are “social” and to be correctly predicted may need empirical input. The main conceptual distinction is that **social acceptance**, as a fact, is about how things are, and **social acceptability** is about how things could and should be. This distinction has strong methodological implications, in the way we deal with the exploration of future features, especially if we consider that in in technology acceptance research the level of how things are and how things should be are not always clearly demarcated and sometimes end up overlapping.

Therefore, ex-post acceptance should not be confused with ex-ante acceptability. While a correlation often exists between acceptance and acceptability, they are neither necessary nor sufficient conditions for each other. A technology might be widely adopted by a society (acceptance) yet deemed ethically problematic (low acceptability). As highlighted by Cowell [164] people do accept all sorts of unwanted outcomes, once the technology has been implemented. Conversely, a technology might be deemed ethically sound (high acceptability) but not being accepted (low acceptance) for other reasons. Therefore, **acceptability does not guarantee acceptance**.

While these concepts do not exist on a continuum, it is important to be aware that technology innovations acceptance is often addressed simultaneously with a future oriented outlook, e.g. using anticipatory analysis, and with the will of learning from the state of things, through

Co-funded by the European Union

empirical observations of existing technologies or their predecessors, drawing lessons from past and present experiences. For methodological purposes, it is important to understand and better clarify the coexistence of these perspectives by using the image spectrum.

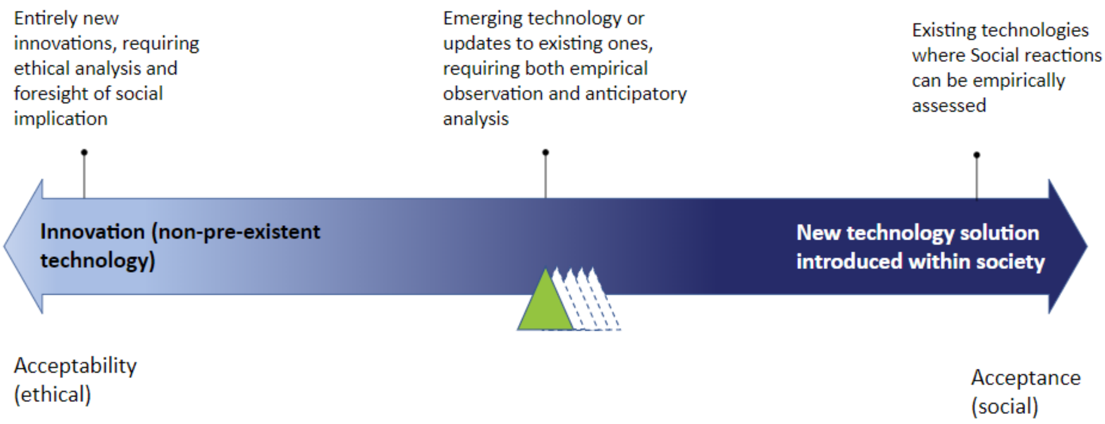

FIGURE 15: METHODOLOGICAL SPECTRUM ON SOCIAL ACCEPTABILITY OR ACCEPTANCE OF TECHNOLOGY

On the spectrum in Figure 15, empirical analysis of the social reactions to existing technologies is at one end, while the ethical normative analysis of entirely new innovations is placed on the other. At one end of this spectrum are innovative technological solutions already introduced in society, where empirical assessment of social acceptance is possible and advisable. At the opposite end, are innovations where no pre-existing solution exists (e.g. emerging technologies), necessitating an acceptability-oriented ethical analysis to address emerging concerns, therefore only foresight of social implications and expectations is feasible.

> ! Technology Acceptance and Technology Acceptability can be viewed as two extremities of this spectrum not because of conceptual continuity, but for their different "degree of reality": acceptability is a projection – as such it can be inferred, predicted – while acceptance is a fact – and as such can be assessed.

Besides these considerations on the evolution, definition and multi-dimensional nature of the concept of acceptance, an additional level of analysis shall be considered: the **specific characteristics of the technological context**. Indeed, the specificities of each technological landscape may express a relevance in influencing technology acceptance, and being able to identify and manage them helps fostering innovation that aligns with broader societal values and expectations.

6.2 SOCIAL ACCEPTANCE SCOPE FOR 6G

Discussions on 6G social acceptance must carefully consider the nature of this technological innovation. 6G encompasses both connectivity infrastructure and services, with implications across all sectors of the economy, from agriculture and industrial production to healthcare, education, and beyond. It promises unprecedented advancements, including microsecond latency, terabyte-per-second data rates, and integration with artificial intelligence for optimised computing and resource allocation.

Drawing on learnings from initial research, it is evident that 6G represents not just an infrastructure innovation but a catalyst for further societal digitalisation. Consequently, the social implications of 6G cannot be fully understood by merely examining the interaction between individual users and specific technologies, as most Technology Acceptance Models (TAMs) allow. **To comprehend 6G's impact, social acceptance research must adopt a socio-technical systems perspective**. This approach examines the interplay between social and technical elements within society, recognising that technological systems like 6G do not operate in isolation but are embedded within complex social structures. It emphasises the interdependence of people, technology, and processes, and how they influence each other over time. Shifting the focus from user acceptance to social acceptance broadens the perspective, allowing for a more comprehensive understanding of these dynamics across systemic, societal, and individual levels.

However, the concept of 6G technology is challenging to depict concisely due to its multifaceted nature, different layers, wide-ranging effects, and diverse applications. This complexity leads to an epistemological asymmetry where discussions often focus more on describing what 6G is rather than what it does, potentially skewing perceptions and complicating acceptance studies.

6.2.1 Complexity and Multi-dimensional Approach

6G is indeed a complex technology that will have far-reaching impacts across multiple levels of society. This complexity necessitates a holistic and multi-dimensional perspective to understanding and fostering its social acceptance. The objective of this section is to set up the basis for a comprehensive framework tailored to the specificities of the 6G technological context, and able to address the multifaceted, complex challenges inherent in 6G implementation, comprising 6G's technical features, societal ramifications, and ethical dimensions.

A first framework providing a solid foundation for addressing this multidimensional nature of acceptance is proposed by Wüstenhagen et al. [174]. Their model identifies three distinct but interrelated dimensions: **socio-political acceptance, community acceptance, and market acceptance.** Each of these dimensions involves different stakeholders, operates at different scales, and is influenced by distinct factors. Therefore, as Wolsink [177] argues, these dimensions should not be viewed in isolation or in a hierarchical manner; instead, they form part of a complex, multi-level process where acceptance at one level can influence and be influenced by acceptance at other levels. For example, positive market acceptance could drive more favourable socio-political acceptance, while community resistance to infrastructure deployment could hinder market adoption.

- **Socio-political** acceptance encompasses the broader societal and policy-level acceptance of 6G technology and its associated policies. This dimension involves key stakeholders such as policymakers, industry leaders, and the general public. In practice: socio-political acceptance might be shaped by national economic strategies and global technological competition.
- **Community** acceptance focuses on the responses of local stakeholders to specific 6G infrastructure projects, such as the installation of small cells or edge computing facilities. In practice: community acceptance could be more influenced by local concerns about electromagnetic fields or the aesthetic impacts of infrastructure.
- **Market** acceptance considers the adoption of 6G technologies by consumers, investors, and firms. In practice: market acceptance might depend on factors such as perceived

usefulness, ease of use, and cost-benefit considerations for individual users and businesses.

Another perspective on the multi-dimensional aspects of acceptance is provided by Moesker et al. [164]. With their concept of "**Funnel of acceptance and acceptability**" Moesker et al. propose a multi-tiered and nuanced model to interpret and analyse the concepts acceptance and acceptability, approaching them differently across different levels of observation: **systemic, social and individual level.** The specificity of each level is explained below.

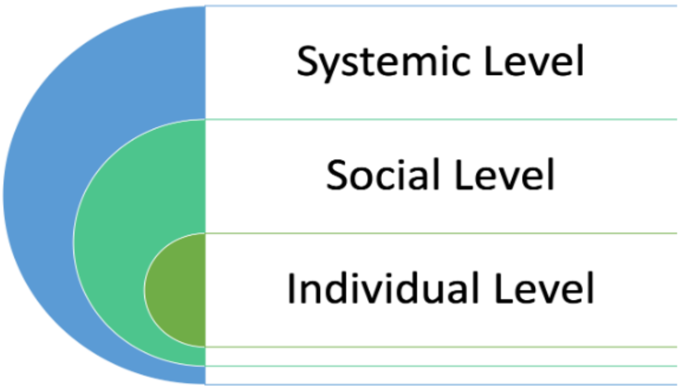

FIGURE 16: THREE DIFFERENT LEVELS OF SOCIAL ACCEPTANCE OF TECHNOLOGY

- **Acceptance at the systemic level (Macro):**
  - Provides a general perspective on technology desirability within a socio-technical system
  - Considers interactions between state institutions, markets, and societal groups
  - Includes ethical, legal, political, and market aspects
  - Focuses on the overall process of technology implementation in society
  - More productive for a horizontal outlook (e.g., 6G impacts across all sectors of the economy)
- **Acceptance at the social level (Meso):**
  - Focuses on groups and communities affected by technology implementation
  - Revolves around ethical and social impacts of technology
  - Acceptance often refers to a generally positive attitude towards technology
  - Acceptability encompasses social and ethical desirability aspects
  - Useful for investigating acceptance in specific verticals or in technology innovations enabled by the specific technology.
- **Acceptance at the individual level (Micro):**
  - Considers acceptance and acceptability as indicators of individual tool adoption
  - Acceptance is characterised by actual, measurable use of technology

- Acceptability indicates willingness and readiness to adopt technology
- Applicable for specific verticals or technology-enabled innovations

As we move from the systemic to the individual level, the scale and object of acceptance become more specific and less aggregated. Also, the relation between acceptance and acceptability varies across the different levels of observation, from broad societal implications to specific user experiences or perceptions. At the systemic level, acceptance might relate to the desired outcomes of 6G implementation on a national or global scale, while acceptability concerns the process of introducing 6G, including policy and regulatory considerations. At the societal level, acceptance could involve the measurable adoption of 6G-based solutions in various sectors, with acceptability addressing the ethical and social desirability of these applications. Finally, at the individual level, acceptance refers to the actual usage of 6G-enabled devices and services, while acceptability reflects personal willingness to adopt these new technologies in daily life. This produces implications at the methodological level.

Building upon and concluding the analysis of the previous paragraphs, additional key points from recent academic discussions on social acceptance can be mentioned and taken into account for a comprehensive analysis:

➲ **From user acceptance to the social quality of technology acceptance**

In the context of disruptive technological innovations with broad societal impact, focusing solely on user acceptance may prove insufficient. Indeed, it has progressively been recognised that the adoption of ICT innovations relies not just on end-users, but on acceptance from a wide array of stakeholders and social groups [178]. This evidence allowed the acknowledgment of a “social” quality of technology acceptance. Therefore, when aiming for technology acceptance and integration into society, the perspectives and needs of diverse users and social actors become essential.

➲ **Dynamic Process of Social Acceptance**

Recent positions informed by social studies view social acceptance not as a binary outcome (acceptance/rejection) but as a dynamic process involving multiple levels, objectives, and needs [177].

➲ **Interaction among technologies**

The multi-dimensional nature of 6G acceptance is further complicated by the technology’s potential to enable and interact with other emerging technologies such as artificial intelligence, the Internet of Things, and extended reality. This creates a complex web of interdependencies that must be considered in any comprehensive acceptance framework.

➲ **Industrial Policy Context**

Some “technology-specific” characteristics of the European 6G industrial policy (highlighted in Rossi, 2024) [179] are particularly relevant and could influence social acceptance research. European policy measures for 5G/6G technologies embody a novel approach to EU industrial policy, departing from the traditional dichotomy between vertical and horizontal interventions. The policy is neither clearly directed across all sectors of the economy (horizontal) nor focused on a single specific sector (vertical). This marks a shift from conventional supply-side orientations, placing greater importance on demand-side.

6.2.2 A definition of Social Acceptance of Technology in the 6G context

Given this complexity, no single existing model can fully capture all aspects of 6G acceptance. Rather than selecting a single definition or conceptualisation specific to one research field or social acceptance model, it is preferable to construct an integrated framework that allows for analysis of social acceptance across various levels and dimensions, combining insights from various frameworks and adapting them to the specific context of 6G technology. This approach should be flexible enough to adapt to various contexts and research needs within the 6G landscape, and in particular:

- account for the dynamic interplay between different dimensions of acceptance;
- account for the evolving nature of the technology and its societal impacts;
- be specifically tailored to the unique nature of 6G innovation;
- be flexible and scalable to be applicable both at a horizontal level (across multiple sectors) and at a vertical level (within a specific sector or domain of application).
- be flexible and scalable to be applicable at different scales of implementation, spanning from innovation at the systemic level to community level (social group dynamics, specific organisational context) or user acceptance at the individual level (individual perceptions).

Accordingly, the complexity described above could be reflected in a broad definition of Social Acceptance of Technology, where acceptance is:

3. A dynamic, relational process
4. It is context-specific
5. It is deeply influenced by technological capabilities, existing socio-cultural values, political and regulatory aspects, historical factors.

This definition encompasses the process by which a technology innovation is embraced or rejected by society, extending beyond individual user acceptance. It includes broader societal attitudes, values, and norms, as well as the impact of technology on social structures and relationships.

6.3 SOCIAL ACCEPTANCE OF TECHNOLOGY (SAT) FRAMEWORK

In light of the considerations drawn until now, we propose **a comprehensive model to explore and evaluate technology acceptance within Research and Development (R&D) and Research and Innovation (R&I) contexts**: the **Social Acceptance of Technology (SAT)** framework, a multi-level approach to acceptance and acceptability, able to comprehensively assess the complex dynamics proper of the 6G context. This model:

- has been developed, tested and disseminated in the scientific community [180] [181] [182] [183] by partner CyberEthics Lab. in the context of several EU R&D projects[4]

---

[4] They are listed above in the current document section

- builds upon and enhances the methodology originally developed in 5G-SOLUTIONS [184] [185].
- looks at the interactional dimension of technology and society by adopting a **Socio-Technical System perspective**. According to this perspective, technological artefacts are to be considered as integral components of broader socio-technical networks, focusing on the dynamic interplay between social and technical elements and the reciprocal influence between technology and society. This approach examines the mutual implications of socio-cultural factors and technological innovation, exploring the intricate relationships among people, technology applications, and design processes.

The SAT process will encompass the following stages, detailed in the subsequent subsections:

- **Stage 1 - Preliminary contextualisation**: section 6.3.1 will outline the preliminary, general steps needed to help clarify the overall approach and set the initial framework for the assessment.
- **Stage 2 - Methods selection**: section 6.3.2 will illustrate the methods that can be selected to carry out the SAT.
- **Stage 3 - Stakeholders identification**: section 6.3.3 will describe stakeholder perspectives useful for a shared evaluation.
- **Stage 4 - Adoption of the four dimensions**: the SAT conceptualises the acceptance and acceptability of disruptive technologies through four distinct dimensions of society-technology interaction, each encapsulating a crucial aspect of the socio-technical relationship: User Experience; Values; Social Disruptiveness; and Trust. As explained in section 6.3.5, the whole framework is modular and scalable. These dimensions will be detailed in section 6.3.3.

6.3.1 Stage 1: Preliminary contextualisation of acceptance

At first, the research team must understand whether the assessment is more inclined towards acceptability or acceptance and why. In other words, where it is positioned on the continuum in Figure 15.

The following questions can help with this decision:

What is to be accepted?

The answer can vary depending on the specific context. But generally, it could be:

- An absolute innovation: a completely new technology or concept without direct predecessors.
- An existent technology with significant upgrades: such as the transition from 4G to 5G in telecommunications.
- A new application of existing technology: using established tech in novel ways or sectors.

In many cases, especially when dealing with technologies such as 5G/6G, we often encounter a mix of incremental advancements and novel innovations (like digital twins). This dual nature provides an opportunity to evaluate social acceptance through two complementary approaches. First, we can observe and analyse societal responses to existing implementations (for instance, the controversies surrounding 5G). Second, we can supplement this empirical data with a forward-looking ethical assessment to gauge the potential acceptability of emerging features or applications.

This approach allows for a comprehensive examination of social acceptance, combining real-world reactions with anticipatory ethical considerations. It acknowledges both the evolutionary aspects of these technologies and their potentially disruptive innovations, providing a nuanced framework for understanding how society may receive and integrate these advancements.

After defining what is to be accepted, it is recommended to ask:

Who should accept?

This question aims at eliciting who needs to accept the technology, who are the **publics** involved. The answer can include:

- End-users or final consumers
- Industry professionals and businesses
- Policymakers and regulators
- Professional categories
- Local communities affected by the technology's implementation
- Broader society, including those not directly using the technology but impacted by its effects
- Other social groups

Are there controversies surrounding this technology?

When examining a technology innovation, if there are previous versions or related innovations within the same field or vertical, possible public controversies should be mapped. This mapping serves several critical functions:

- Primary function: identifying whether a particular technology innovation is contentious within society, and pinpointing the specific nature of these controversies:
    - Clarify the specific aspects of the technology that are subject to acceptance or rejection.
    - Identify key stakeholders and affected groups who play a role in the acceptance process.
    - Uncover nuances in public perception and expert opinions that may influence acceptance.
- Thematic analysis: through mapping controversies, we can feed the thematic analysis linked to the "bubbles", particularly the one dealing with values, social disruptiveness, and trust.
- Refinement of Analysis: the mapping process helps me refine the answers to two fundamental questions: (1) What is to be accepted? (2) Who should accept?

6.3.1.1 The level of perception

After addressing these questions, it is important to consider potential variations in the perception and awareness of an innovation among different stakeholders. As Rogers (2003, p.12) aptly notes, “An innovation is an idea, practice, or object that is perceived as new by an individual or other unit of adoption.” This perception of novelty can significantly influence the applicability of both social and ethical approaches across various stakeholder categories.

The diversity in stakeholder perspectives may affect:

- The relevance and effectiveness of social acceptance studies.
- The scope and depth of ethical analyses required.
- The communication strategies needed to engage with different groups.

Understanding these variations is crucial for:

- Tailoring research methodologies.
- Developing more inclusive innovation processes.
- Anticipating potential barriers to acceptance or adoption.

> Clarifying “who should accept” and “what is to be accepted”, and identifying the publics involved in controversies are important steps. However, these do not substitute for comprehensive stakeholder identification (see below paragraph on stakeholder identification). The results of these questions help map relevant publics from which to select representatives and identify social actors to engage as research participants. These findings should be compared, systematised, and integrated with considerations from stakeholder identification. This process ensures incremental reasoning and understanding from different perspectives, ultimately leading to the identification and engagement of all relevant stakeholders for assessing social acceptance.

6.3.2 Stage 2: Assessment methods selection

SAT assessment can be conducted using various methods at different stages of the development lifecycle. In the early stages, **desk research** plays a crucial role in contextualising the four dimensions of technology-society interactions within the specific domains affected by applications. This research also aids in answering the previously outlined questions and mapping controversies.

Additionally, collecting **expert judgements** is vital. This process should ensure adequate representation of diverse expertise, involving specialists who understand the specific context and challenge of the domain. Such experts may include technical professionals, Science and Technology Studies (STS) specialists, and experts from the domain of application.

6.3.2.1 Assessing not-yet-existing technologies

For existing technologies, it is possible to assess and measure perceptions through empirical experiments and compare them to users' needs and expectations. However, when dealing with enabling technologies or innovations that do not yet exist (including infrastructure innovations), the most relevant approach is to collect perceptions based on narratives (storytelling) or existing information. This can be done, for example, by analysing expectations in terms of perceived benefits and concerns or perceived risks.

For an assessment of not existing technologies, a step-by-step guide is provided:

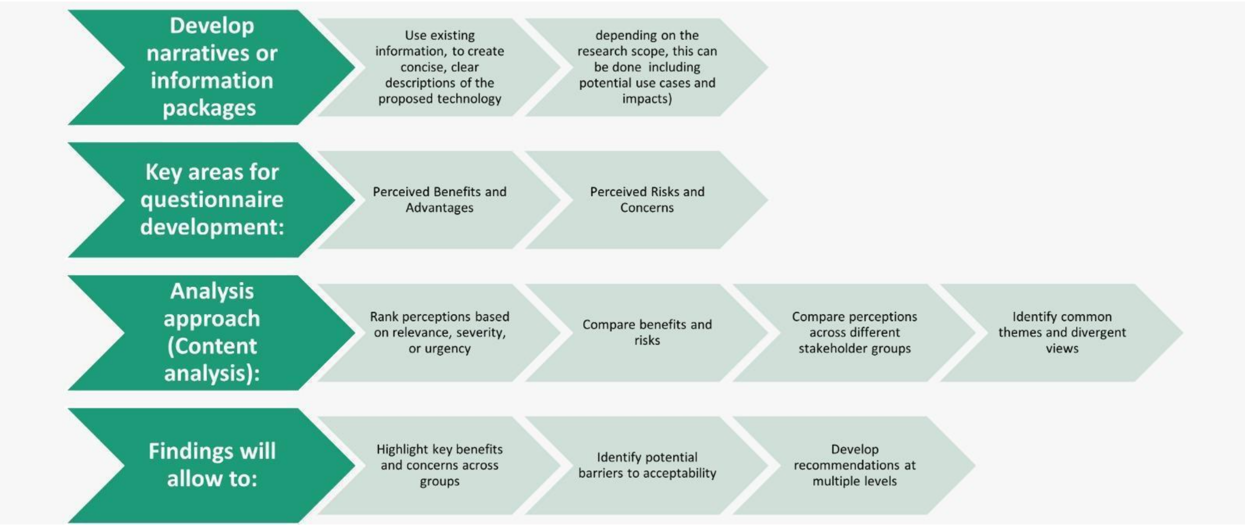

FIGURE 17: METHODOLOGICAL STEPS TO ASSESS NOT EXISTING TECHNOLOGIES

6.3.3 Stage 3: Stakeholders identification

SAT assessment can be carried out following different methods at different stages of the development lifecycle. In the early stages, **desk research** helps contextualise the four dimensions of technology-society interactions within specific application domains. However, gathering **expert judgements**, ensuring representation across various areas of expertise and perspectives, and identifying and involving specialists familiar with the unique context and challenges of each domain (such as technical experts, STS specialists, and domain-specific professionals) is essential.

6.3.3.1 Socio-Technical System perspective to identify stakeholders

6G is a disruptive innovation, both in terms of the evolution of mobile connectivity and the innovations it can enable in different sectors (verticals). The identification of key stakeholders for the assessment process should be based on the specific socio-technical system involved (e.g., agriculture, healthcare system, smart transport, education).

The societal response to new or existing technological innovation encompasses a wide range of attitudes and behaviours. These reactions, which can include supporting, embracing, resisting or rejecting the technology, emerge from the complex interplay between society and technology at different levels. Due to this multifaceted nature, the social acceptance of technology is inherently collective, reflecting the collective sentiment and responses of social collectives rather than individual preferences alone.

One of the key outcomes of social acceptance assessments is the examination of stakeholder perspectives, which enables researchers to draw conclusions about a shared evaluation. This collective assessment, whether favourable or unfavourable, is dynamic and may vary across different geographical scales—from local to regional to national. Nevertheless, this evaluation can be converted into specifications for subsequent phases of the development process. It serves as an effective method for collecting feedback, ultimately contributing to the creation of responsible and socially acceptable innovations.

6.3.3.2 Not only social, but also ethical

While our society is investing heavily in the promised benefits of 6G, as with any disruptive innovation, there are also concerns about the risk of harm, damage and loss to individuals, social groups and the environment. Some of the innovations that 6G will enable are recognised - even at the regulatory level - as posing high risks. The European Union's AI Act, for example, classifies several categories of AI applications as high risk because of their potential impact on the health and well-being of individuals, as well as their wider implications for society.

This proposes an ethical stance, intimately connected to social acceptability, which guides and enriches the SAT's methodology for identifying research stakeholders.

In this framework, instead of selecting stakeholders based solely on their capacity to assist or harm project goals, engagement should be driven by stakeholders' fundamental rights, interests, concerns, and the potential impact a particular project might have on them.

This approach prioritises the inclusion of diverse voices and varied perspectives and takes into account the requirements and apprehensions of all impacted parties, regardless of their power or influence over the success of the project. Embracing this normative viewpoint ensures that a project not only achieves its technical objectives but also aligns with values, expectation, and well-being of the wider community.

This approach, based on the salience model [186], is enriched by the incorporation of **ethics and sustainability considerations**. As suggested by Miller [187], beyond the salience model's attributes of

- Power
- Legitimacy
- Urgency

Stakeholders are identified using the additional attribute of “harm”. This approach allows explicit **passive stakeholders**[5], something **from a social acceptance / acceptability perspective**. Passive stakeholders, who may be impacted by the technology but lack direct influence on its development, are thus included in the assessment, broadening the scope of acceptance considerations.

Integrating both social and ethical considerations, the enhanced stakeholder identification framework represents a significant evolution in technology acceptance models. Expanding beyond traditional attributes to include the concept of “harm” ensures a more comprehensive and inclusive approach to 6G development. The method not only addresses potential risks and concerns but also aligns technological progress with societal values and ethical standards. As 6G continues to evolve, the framework could play an important role in fostering responsible innovation, building public trust, and ensuring that the benefits of this transformative technology are equitably distributed across society. Ultimately, the approach sets a new

[5] The inclusion of passive stakeholders in this approach bridges the gap between acceptance and acceptability. While acceptance concerns observable phenomena, acceptability addresses ethical and normative considerations. By considering passive stakeholders, we ensure that both the current reality (acceptance) and future potential (acceptability) of 6G technology are addressed, even for those who may not have a direct voice in its development.

standard for how we conceptualise and implement emerging technologies, prioritising human welfare and societal well-being alongside technological advancement.

6.3.4 Adoption of the SAT four dimensions

The SAT framework comprises four dimensions, represented as "bubbles", that describe and analyse the interaction of technology and society from different thematic angles, all relevant to both acceptance and acceptability of technology.

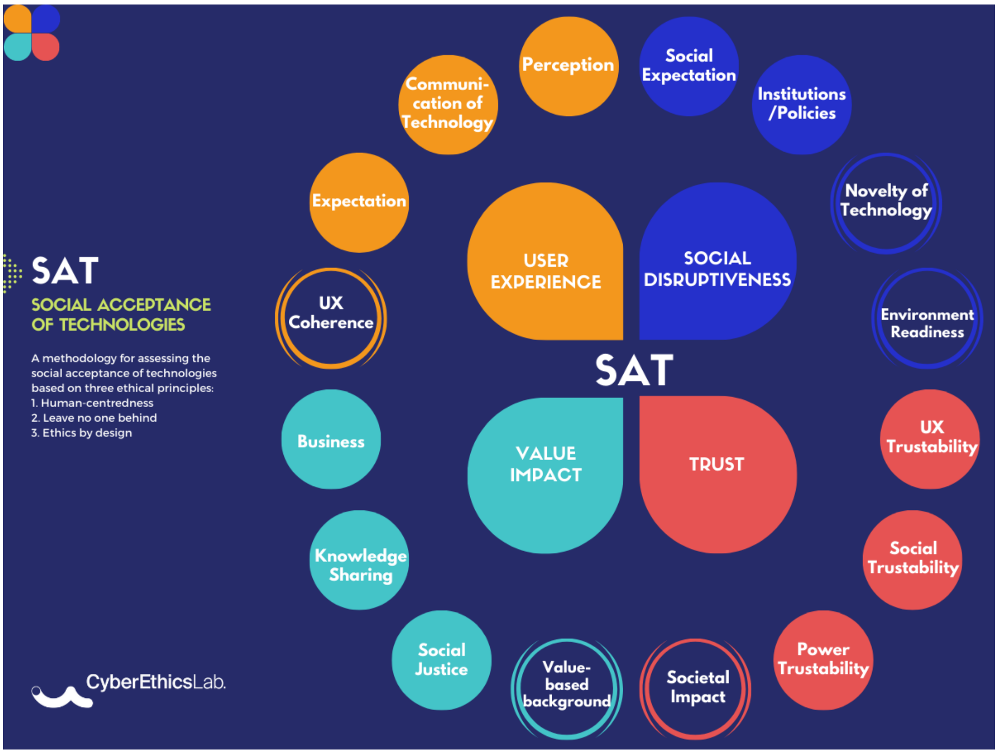

FIGURE 18: THE SOCIAL ACCEPTANCE OF TECHNOLOGIES (SAT)

Some bubbles are better suited to focus on individual aspects, such as the **User Experience** (UX), which considers users' interactions with technology and draws from Human-Computer Interaction (HCI) knowledge. Others, like the **Value Impact** and **Trust** bubbles, allow for both individual-oriented perspectives and more collective analyses. The **Social Disruptiveness** bubble takes a broader view, examining technology's potential consequences on wide-ranging social aspects, including social relations, institutions, epistemic paradigms, foundational concepts, values, and the very nature of human cognition and experience [188] [189].

The following subsections describe the SAT bubbles in detail.

6.3.4.1 Social Disruptiveness

The potential of 6G to fundamentally change communication, work, and social life requires careful consideration of its wider implications. The introduction of 6G technology is predicted to significantly alter social relations and power dynamics, thereby potentially affecting society at multiple levels. For instance, 6G's ability to provide ubiquitous connectivity and integrate advanced technologies like AI and IoT could lead to major shifts in economic models, social interactions, and governance structures. These changes might include the creation of new digital divides, transformations in job markets, and increased surveillance capabilities, all of which could have profound implications on privacy, security, and societal norms.

Evaluating the potential social disruptiveness of 6G is crucial, as any substantial alteration in societal dynamics could impact the overall acceptance of this technology. By understanding and addressing these disruptions, policymakers and stakeholders can better navigate the challenges and opportunities presented by 6G, ensuring its integration into society is as smooth and beneficial as possible.

Social disruptiveness is understood here according to the conceptualisation of Schuelke-Leech [190] as change which affects a broad range of societal norms and operation, including relationships, organisational structures, institutions, public policies and the physical environment [190]. This definition is enriched with other elements highlighted by Brey et al. [188] who argues that the kind of change brought about by emerging technologies is able to affect not only social relations and institutions but also epistemic paradigms, foundational concepts, values, moral norms and the very nature of human cognition and experience [189].

The analysis of the complex concept of social disruptiveness is needed in order to capture the role of technology in society and the relations between technology and society at multiple levels, as well as to open the analysis to technology's potential to catalyse significant change. Moreover, since technology and society mutually interact and influence each other, we can speak about techno-social disruption, referring to the complex and dynamic process by which technological innovations both drive and are influenced by social changes.

As evidenced by other concepts above, **the social disruptiveness of technology is inherently context-specific**. This means the following:

- It is not intrinsic to technology itself, but it emerges from the intricate interplay between a technology and its specific social context.
- This context-dependency means that disruption can manifest differently across various industries, business sectors, and social groups.

While analysing the social disruptiveness of 6G, it will be possible to focus on its potential to disrupt rather than its actual historical impact; although some of the changes brought about by 6G are foreseeable on the basis of the impacts of earlier generations of connectivity innovation, here the focus is on those changes caused by 6G that have not yet left concrete historical traces. At this point it is also important to note that social disruptiveness is not a binary concept but exists on a spectrum.

To assess this potential, **a multifaceted and multilevel approach is necessary**, one that mobilises interdisciplinarity beyond the technical fields, while promoting a common field of enquiry among the fields (such as Science and Technology Studies, Human-Computer Interaction, Design Science Research, Ethics of Technology) which are more inclined to socio-empirical and ethical reflection on issues of justice, equality, and the foundational nature of human experience and social structures, in relation with technology innovation.

Social disruptiveness is the first dimension of the proposed framework. To understand its complexity, we need to address several key questions.

1. What technology is?

To develop a clear understanding of technology, it is crucial to:

- Examine its core functionalities, primary purpose, the problem it aims to solve, and the capabilities it intends to provide. Try to grasp the basic scientific or engineering principles underlying the technology, even if only at a high level.
- Identify how the new technology differs from or improves upon existing solutions in the same domain.
- Consider the infrastructure or ecosystem the technology requires to function effectively. Explore various applications of the technology across different sectors or use cases.
- Determine where the technology is in its development cycle: its conceptual, in early testing, or near market-ready? Investigate who is developing the technology, who might use it, and who might be affected by its implementation.
- Consider scalability and accessibility: assess how easily the technology could be scaled up and how accessible it might be to different user groups. Evaluate potential limitations, and consider how the technology might interact with or depend on other technologies or systems.

2. How does it interact with social developments or social change?

The first step in understanding technology's role is to recognize that it is not developed in isolation, but is shaped by social, cultural, and economic factors. Technology is both a product of society and a force that shapes society. To grasp this dynamic, it's crucial to consider the debate between technological determinism (the idea that technology drives social change) and the social shaping of technology (the concept that social factors influence technological development). Sociotechnical systems theory offers a comprehensive perspective, viewing technology as part of larger systems that encompass not only the technology itself but also the people, organisations, and institutions that create, use, and regulate it. The fundamental aspects to be considered can be addressed as follows:

- Ask what sociotechnical system is implicated by the technology under consideration. This inquiry leads to questions about the people and organisations involved, as well as the institutions that create, use, and regulate the technology.
- Consider how technology mediates human experiences and relationships with the world, altering perceptions, actions, and interactions. In the case of 6G, the answer to this question highly depends on the sectors of application. To accurately address this, a specific vertical with its use cases should be considered.
- Account for the cultural and historical context, as the meaning and impact of technology can vary across different cultures and historical periods.
- Recognise the possibility of unintended consequences: technologies often have unforeseen effects on society and beyond their intended purposes. In the case of socially disruptive technologies, we must accept that not all changes are foreseeable. This reality emphasises the importance of:
  - Examining how technology can reinforce or challenge existing power structures in society.
  - Reflecting on the ethical dimensions of technological development and use, including issues of privacy, autonomy, and social justice.

By considering these aspects, a more nuanced and comprehensive understanding of technology's role in society can be developed. This approach facilitates the understanding of technological affordances - how the design and characteristics of technologies enable or constrain certain social practices and behaviours. Additionally, these reflections provide a suitable framework for public policy-making at different levels (global, regional, national) and in various fields (industrial, economic, regulatory, social policy).

Posing these questions will also lead to answers for the third question, which is:

3. **How can technological changes affect critical societal functions?**

This question prioritises critical elements resulting from point 2 analysis.

In terms of **technology assessment** aimed at predicting or analysing **social acceptance**, it is key to consider dimensions of social disruptiveness. These dimensions encompass several factors of social disruptiveness: the depth and range of impacts, the valence of these impacts, their ethical salience, the extent of uncertainty surrounding them, the pace of change they introduce, and the reversibility of their effects. These aspects are briefly defined below, drawing from Hopster's work:

- **Depth of Impact**: it refers to how deeply technology may affect core beliefs, values, social norms, and human capacities. It challenges fundamental categories of thought and basic human practices, potentially altering our self-understanding and worldview.
- **Range of Impacts:** it describes the scope of domains affected by the technology. The more ubiquitous the impacts across different sectors and areas of life and society, the more disruptive the technology is considered to be.
- **Valence of Impacts:** it relates to how technological innovation may affect key determinants of societal, natural, and human life quality. The intensity of emotional and affective disturbances caused by the disruption can be a measure of its disruptiveness.
- **Ethical Salience of Impacts:** while all disruptive technologies likely raise some ethical issues, this category considers how pronounced or significant these ethical challenges are. When technologies touch upon the very essence of politics, social life, human experience, and human nature, as 6G is expected to do, ethical reflection becomes imperative.
- **Levels of Uncertainty:** it encompasses the unpredictability of how new technologies interact with socio-historical trends and other emerging technologies. It includes predictive uncertainty, conceptual ambiguity, moral confusion, and disagreement. The greater the difficulty in anticipating outcomes, the more disruptive the technology may be perceived.

A demonstration of such analysis is displayed in the table below. The scheme outlines how 6G technology and its applications can be evaluated across the aspects pertaining to the dimension of social disruptiveness, highlighting its potentially profound and wide-ranging impacts on society, and setting the ground for subsequent research steps.

TABLE 6: SOCIAL DISRUPTIVENESS ASPECTS AND THEIR SPECIFIC ELEMENTS TO BE ASSESSED

Social Disruptiveness Aspects	Specific Elements to be assessed

Depth of impact	Fundamental changes in communication infrastructure
	Potential transformation of the Internet architecture
	Profound effects on data processing and storage paradigms
Range of impacts	Telecommunications
	Healthcare (advanced telemedicine) and biomedical research
	Education and skill development (immersive learning experiences)
	Transportation (autonomous vehicles, smart cities) and logistics
	Entertainment and media (holographic media, advanced AR/VR)
	Manufacturing (advanced IoT, smart factories)
	Energy management (smart grids) and environmental monitoring
	Agriculture (precision farming) and food production
	Finance (advanced fintech solutions) and economic systems
	National security and governance
Valence of impacts	Positive: Enhanced connectivity, new economic opportunities, advancements in various fields
	Negative: Potential for increased inequality, privacy concerns, digital divide issues, technological dependence
	Intense reactions likely due to fundamental changes in daily life, social interaction, human technology relationships and work patterns
Ethical salience of impacts	Privacy and data protection challenges in hyper-connected world
	Autonomy and free will in a highly automated
	AI-driven environment
	Equity concerns regarding access to 6G technology potentially exacerbating digital divides (across geographic spaces and social groups)
	Potential for increased surveillance capabilities
	Environmental impacts of infrastructure development
	Workforce disruption and job displacement anxieties
	Controversies about 5G
Levels of uncertainty	Unpredictable interactions with other emerging technologies (AI, quantum computing, nanotechnology)

	Unclear long-term societal adaptations to high-speed ubiquitous connectivity
	Potential for unforeseen applications and use cases
	Uncertainty about long-term environmental and health effects related to increased electromagnetic exposure
	Conceptual ambiguity around the nature of reality in highly immersive digital environments
	Moral confusion and disagreement about the appropriate use and regulation of 6G technologies
	Unpredictable shifts in social norms, practices, and institutions
	Potential for unexpected geopolitical impacts and power dynamics
	Controversies about 5G

From the methodological point of view, **these aspects can be addressed by building scenarios**. Through scenarios, we can better anticipate and address the ethical challenges and uncertainties of 6G deployment, exploring the potential positive or negative impact, and learning from and building on the controversies and lessons of 5G implementation. A methodological requirement for such activity is to engage diverse expertise. This means not only including representatives from industry, R&D teams, planners, and the SSH field, but also incorporating specific competencies and institutional roles. Expert figures with more analytically oriented practices must be engaged alongside design-oriented experts, as well as those with operational research and decision-making profiles.

However, given the low Technology Readiness Level (TRL) of 6G, **conducting a reliable acceptance study on 6G's potential social disruption is currently impractical, unless a social impact exploration of previous generations, such as 4G and 5G, is used as a foundational step towards this goal**. By examining the relationships between the societal impact discussion (section 3) and controversies and concerns (section 5) presented in the previous sections, we can begin to explore potential social implications. **Error! Reference source not found.** reports the impact of social disruptiveness on some specific social domains.

Although these outcomes are uncertain and may lead to unforeseen societal challenges and opportunities, the cases described in the Annex illustrate the potential far-reaching consequences of 6G on various aspects of social life. By examining how 6G reshapes societal relationships, economic infrastructures, privacy norms, and cultural standards, stakeholders can proactively shape its integration into society, ensuring it aligns with societal values and supports sustainable development. In summary, understanding the potential positive and negative impacts of techno-social disruption ensures that technology serves the needs of all people and contributes to a sustainable future, allowing us to mitigate potential negative impacts and maximise the benefits.

6.3.4.2 Value Impact

The value impact bubble aims at evaluating the broader effects and benefits that an innovation can bring to users, stakeholders, and society. This includes understanding how the innovation aligns with social values, with particular attention to value tensions or conflicts. By assessing the value impact, stakeholders can determine the social sustainability and societal relevance of the new technology or product. Relevant questions to explore this dimension include:

- What values are embedded or promoted by this project/technology?
- What values should be embedded to make this technology acceptable (ethics)?
- Are these values aligned with societal norms, intended users' values, intended buyers' values, and wider societal values?
- Are there tensions or conflicts with the values of some groups, communities, or categories?

While we refer to the specific section on values for a more in-depth contextualisation of the concept, we recall that although the **notion of 'value'** is increasingly used, there no universally accepted definition. In general, values are associated with what is good and desirable, often providing people with an orientation for behaviour [191]. Some key points to consider:

- Some authors define values as "lasting convictions or matters that people feel should be strived for in general and not just for themselves to be able to lead a good life or realise a good society" [192].
- Values pertain to individuals and are shared among social groups, but are not homogeneously spread across societies.

The idea that values may be embodied in technical systems is now common across various fields. Building on this understanding, a more action-oriented perspective has emerged, advocating for the deliberate incorporation of values into the design process [193]. This approach encourages technologists and engineers to consciously consider values as essential criteria when evaluating the quality and effectiveness of their creations.

To perform a value impact assessment, the following steps should be pursued:

- Elicit "intended" values, norms, and requirements of a given project:
  - List the high-level values the project wants to uphold
  - For each value, try to elicit "norms" - what should be done to realise the values
  - List the requirements that accomplish the norm
- Elicit values important for other actors (users and stakeholders):
  - Elicit norms and requirements
- Assess whether the project is working toward these values, and how.

When demonstrating or storytelling about a technology for assessment purposes, it is vital to be able to **formulate use cases and user stories** that clearly demonstrate the values or the impact of technology on values. In case of controversies surrounding a technology, the demonstration must be transparent and non-manipulative. Alternatively, **co-designing** the use case with stakeholders can be an effective approach.

6.3.4.3 User Experience (UX)

The UX dimension of the SAT assessment is represented as the first bubble in Figure 18. This cluster focuses more on the individual interaction of a person – in his / her role as a user – and a technology innovation. It draws on UX, usability and user acceptance research. The UX assessment typically focuses on users' emotions and expectations when interacting with a technology. This evaluation provides insights into the innovation's overall usefulness, usability, appeal, and likability. The results reveal how satisfied individuals are when interacting with the technology as users and, in some cases, their propensity to adopt it.

A UX assessment can be conducted through different approaches, for example:

- Reactions to a narrative (e.g., a demonstration made through storytelling or the presentation of the technology and its use cases)
- Experience in using a demo or prototype (via actual usage sessions with the technology)

Generally, a positive UX is considered to be positively correlated with acceptability and technology adoption. The choice of assessment method depends on several factors:

- Scope of analysis: Whether the focus is on acceptance or acceptability
- Development stage: Whether it's a testable technology, proof of concept, or demonstration
- Level of assessment: Individual, social, or systemic

For instance, when assessing a demonstrable solution, prototype, or testable technology, researchers might apply a specialised UX questionnaire or a TAM survey. These tools help gauge user perceptions and predict potential adoption rates.

This approach provides valuable insights for technology development, communication strategies, and policy frameworks. Stakeholders' expectations and concerns shed light on what is important to people and may help identify differences across categories of stakeholders. This is relevant for analysing values across and within different social groups.

For an enabling technology acceptability study, such as the one this project concerns, questions can be developed to address areas such as Perceived Benefits and Advantages, as well as Perceived Risks and Concerns.

To facilitate the analysis of the results, perceptions can be ranked by research interlocutors based on relevance, severity or urgency. Depending on the level of benefits and risks, conclusions will be useful not only to improve the user experience, but also the communication about the technology. Also, conclusions can provide inputs on policy or regulatory needs, allowing to draw policy recommendations at multiple levels, including organisational, national, and EU-wide frameworks.

Finally, it is worth highlighting the potential outcome of such an approach. Indeed, beyond the narrower focus on user experience, the potential results of such an assessment are relevant in terms of:

1. Improving the technology design
2. Improve communication about the technology

3. Providing input to the value impact bubble[6]
4. Providing input to policy or regulatory needs
5. Provide policy recommendations at different levels (organisational, national, EU-wide).

However, at the current stage of development, **it might be difficult to analyse 6G from the UX** point of view for several factors:

- 6G has a low TRL. Since the technology does not concretely exist yet, it is challenging to accurately depict or explain it to individuals who have no prior experience with it.
- 6G is an ICT connectivity infrastructure. As such, it could not, in itself, be directly experienced by users.
- Experience could be assessed at the level of particular technologies and applications in specific sectors, but they do not exist yet.

In this context, a step-by-step guide illustrated in section 6.3.2.1 might be applied.

6.3.4.4 Trust

The fourth dimension of social acceptance is trust. Trust, influencing not only interpersonal and institutional relationships but also technology adoption. Since, it plays an important role in determining how individuals and societies interact with new technological innovations, trust, affects adoption rates, public opinion, and overall acceptance. Therefore, by exploring trust in its various forms and contexts, we can better comprehend its impact on the social acceptance of technology.

Trust is not a monolithic concept, but is multifaceted, context-dependent, and it encompasses multiple dimensions:

- **Interpersonal trust** refers to the confidence individuals have in one another, to act reliably and truthfully. This form of trust is fundamental in daily interactions and relationships, providing a foundation for cooperation and mutual support.
- **Group trust** extends this concept to collective entities, where trust is placed in organisations, communities, or social groups. Trust in groups influences technology adoption within communities, as people are more likely to embrace new technologies endorsed by trusted leaders or influential groups.
- **Institutional Trust** refers to the confidence individuals have in societal institutions, such as government bodies, regulatory agencies, scientific institutions, and corporations. This form of trust has a privileged place in the context of technological innovation, particularly for emerging technologies like 6G. When people trust the institutions responsible for developing, regulating, and implementing new technologies, they are more likely to accept and adopt these innovations. High levels of institutional trust can facilitate smoother rollouts of new technologies, as the public believes that these institutions are acting in their best interests and have the necessary expertise to manage potential risks.

[6] By applying content analysis, it is possible to identify what is important to different groups and obtain data to analyse values across and within various social groups

Several studies have examined the role of trust in social acceptance of various technologies. Bronfman et al. [194] found that for controversial electricity generation sources, perceived benefits were the primary factor influencing acceptability, with trust in regulatory agencies playing a secondary role. Li et al. [195] showed that trust in government significantly affected public acceptance of hazardous chemical factories in China. Siegrist [196] demonstrated that trust in institutions using gene technology had a positive impact on perceived benefits and a negative influence on perceived risks, indirectly affecting technology acceptance. Hujits et al [176] highlighted the importance of trust in professional actors for public acceptance of carbon dioxide storage, especially when public knowledge is limited. Terwel et. al [197]found that trust in stakeholders significantly affects public acceptance of carbon capture and storage technology, with environmental NGOs generally being trusted more than industrial stakeholders due to perceived motives.

In the context of 5G technology, Akbari et al [198] developed an integrated model incorporating trust into the Technology Acceptance Model (TAM). Their study found that trust mediates the relationships between perceived ease of use, perceived usefulness, and the intention to use 5G, emphasising the importance of designing trustworthy and supportive services. Liang and Campbell [199] further highlighted the role of social climate in shaping 5G acceptance, noting that while perceived technological features explained favourable attitudes, privacy concerns led to negative attitudes. Their study also revealed cultural differences, with 5G viewed as an instrument for national elevation in China, while health concerns were more prevalent in the United States. These studies collectively indicate the complex role of trust in shaping public acceptance of new communication technologies, interacting with factors such as perceived risks, benefits, and cultural context.

- **Generalised trust**, also known as **social trust**, refers to the overall levels of trust individuals have in society at large, including strangers in unfamiliar situations. This form of trust is particularly relevant in the adoption of widespread technological systems like 6G, which require cooperation and interconnectedness on a societal scale. Some research suggests that societies with higher levels of generalised trust tend to be more open to innovation and potentially more willing to engage with new technologies.

This perspective is supported by several studies exploring the relationship between trust and societal development. Delhey & Newton [200] investigate the links between generalised trust and various societal factors across nations, providing evidence for the connection between trust and societal development. Fukuyama's [201] that high-trust societies are more likely to innovate and prosper economically. Building on these ideas, Zak & Knack [202] demonstrate a strong correlation between levels of trust in a society and economic growth, which is often associated with technological innovation and adoption. While these studies don't directly address 6G technology, they offer valuable insights into how generalised trust might influence a society's openness to new technological systems.

Building on these different forms of trust, it's important to note that in the context of technology acceptance, trust is highly context-dependent, varying across different situations and relationships. Factors such as reliability, truth, ability, vulnerability, and shared norms all influence trust levels. Therefore, a nuanced understanding of these contextual influences and of how trust operates in different settings is essential for developing strategies to enhance trust and facilitate technology acceptance. A more elaborate view on factors influencing trust will be provided below.

6.3.4.4.1 Relations with other social acceptance dimensions

As described hereafter, trust is a dimension of acceptance that can be influenced by the results of the other dimensions (UX, Social Disruptiveness and Value Impact), as well as by controversies.

User Experience and Social Disruptiveness. Trust intersects with User Experience (UX) and Social Disruptiveness through the notion of socio-technical uncertainty. Uncertainty extends beyond user-perceived uncertainty, which primarily concerns the technology's

Co-funded by the European Union

immediate effects on the individual. Instead, socio-technical uncertainty encompasses the broader, indirect impacts that a technology is perceived to have on an individual's life and social context. As technologies reshape the social systems surrounding individuals, they inevitably alter people's relationships with the external world. Importantly, this form of uncertainty stems not from the technology itself, but from the complex interactions between the technology and the social system. When stakeholders perceive that a technology negatively affects their surrounding environment, it erodes trust in that technology, highlighting the intricate relationship between trust and the broader socio-technical landscape.

Value Impact. The dimension of trust is also intrinsically linked to the analysis of values, particularly in how technology is perceived to align with social values. When a technology is seen as congruent with societal expectations, ethical standards, and cultural values, it is more likely to be trusted. Conversely, technologies that appear to conflict with or undermine established social norms may face scepticism and reduced trust. The degree to which a technology aligns or misaligns with societal norms plays a significant role in shaping public perception, influencing acceptance rates, and determining how successfully the technology integrates into society.

For emerging technologies like 6G, demonstrating how they potentially support or enhance societal values - such as privacy, equality, or sustainability - could significantly improve trust. However, this relationship is not guaranteed and depends on various elements including effective communication and the actual performance of the technology. Therefore, considering and addressing societal values and norms in the development and deployment of new technologies is crucial for building and maintaining public trust, though it does not ensure it.

Controversies. From a methodological standpoint, exploring the dynamics of trust can be effectively approached by surveying controversies surrounding previous and current technologies. The approach, grounded in Science and Technology studies (STS), provides valuable insights into how trust operates in different settings.

Controversies play an important role in promoting public trust in technologies. They often reveal areas where trust is lacking or challenged, illuminating cultural factors and perceived risks that influence public perception. For instance, controversies surrounding 5G deployment have highlighted concerns about health and environmental impacts, showcasing how cultural beliefs and risk perceptions affect trust. These controversies provide valuable insights into how trust might be impacted for future technologies like 6G. By studying these debates, a deeper understanding of the specific cultural, social, and political contexts that affect trust in technology are gained. Essentially, controversies serve as a window into public perception and trust issues, offering real-world examples of how trust operates in different settings. This knowledge is particularly important for emerging technologies, allowing for proactive trust-building measures during early stages of development and implementation.

This approach holds particular promise for technologies still at low Technology Readiness Levels (TRLs), where proactive trust-building can significantly impact future adoption and implementation. For emerging technologies like 6G, studying past controversies may help anticipate potential trust issues and develop strategies to address them early in the development process. Consequently, this method not only deepens our understanding of trust dynamics but also offers practical insights that could facilitate the acceptance and successful integration of future technologies into society.

6.3.4.4.2 Factors Influencing Trust

As introduced above, various factors interact to shape trust in different contexts, including reliability, ability, vulnerability, and shared norms.

- **Reliability** refers to the consistency and dependability of an entity or technology.
- **Truth** relates to honesty and transparency in communication and actions.
- **Ability** denotes the perceived competence of an entity to perform actions effectively.
- **Vulnerability** represents an individual's willingness to expose themselves to potential risks or harm when trusting an entity.
- Lastly, **shared norms** are the common values and beliefs that underpin trust relationships.

More in particular:

- Reliability and ability are paramount for building trust in the realm of technology. Trust is influenced by users' perception of technology's reliability and ability, as they must be confident that the technology will function as expected to fulfil their needs.
- Trust is influenced by the perceived vulnerability of users in adopting new technologies. For instance, the adoption of a new mobile payment system might depend on users' trust in its reliability in processing transactions accurately and securely.
- Honesty is essential for fostering trust, as users must comprehend the technology's capabilities, limitations, and potential risks.
- Shared norms and values also play a role, as technologies that align with societal values and cultural norms are more likely to be accepted.
- Also, cultural factors, previous experiences with similar technologies, and the perceived benefits and risks associated with adoption play a role in shaping trust.

The concept of trust may be further nuanced when elaborated in its relation to acceptance. Indeed, the distinction between the **normative dimension of ethical acceptability** and the **empirical perspective on acceptance** (see Figure 15) may rebound on the conceptual distinction between trust and trustworthiness. Indeed, the normative approach focuses on establishing ethical standards for "trustworthy" technology, while the empirical perspective examines how trust manifests in real-world technology adoption. This distinction shapes how researchers approach the concept of trust in technology studies.

- Studies centred on acceptability or proactive approaches to developing acceptable technology typically establish normative requirements for "trustworthy" technology. These requirements can be evaluated through technology assessments or social acceptance studies of enabling technologies in specific verticals. For instance, researchers might assess the trustworthiness of a new 6G application in healthcare by examining its reliability, data protection measures, and transparency in algorithmic decision-making.
- Empirical studies, on the other hand, operationalise trust through measurable indicators. By defining specific metrics for these indicators, researchers can collect data and analyse the role of trust in technology acceptance at various levels (e.g. individual users,

stakeholders’ categories, social groups) and in specific contexts or technologies. Such detailed metrics enable a comprehensive grasp of how trust shapes the adoption and use of new technologies in real-world scenarios. In Figure 19 some indicators that could measure trustworthiness in technology assessments are displayed.

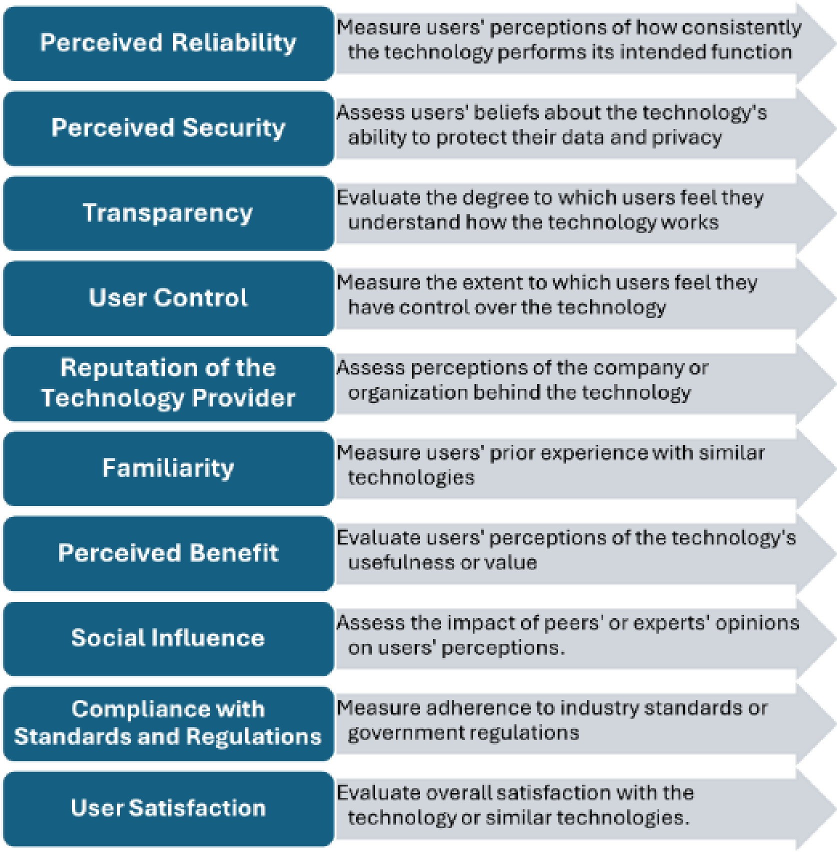

FIGURE 19: SOME TRUST INDICATORS FOR TECHNOLOGY ASSESSMENT

Conversely, determining whether individuals or social groups trust or perceive a technological innovation as trustworthy is an empirical question. The same can be said of research questions regarding how trust is influenced by a certain type of communication. A demonstration of such an empirical approach is provided in Appendix D – A common example of mistrust and distrust.

Whether the approach of the study is normative or empirical, it is first necessary to identify the type of trust in question. This involves defining the subject of the trust (the trustor) and the object of the trust (the trustee).

The object of trust must be well defined. Is it a specific technology? A group? An institution? Or perhaps a combination of these? Sometimes researchers are interested in trust towards a “thing” (technological artefact) when in fact the innovation is apt to mediate a *relationship* between two social actors (e.g. the bank and a customer) or groups (workers and employers in the case of platform work).

In technology risk research, it is widely acknowledged that the perceived acceptability of technological risks is significantly influenced by public trust in institutions’ ability to effectively regulate these risks ([203]; [204]).

6.3.4.4.3 Trust and 6G

In the context of 6G, the object of trust might shift depending on the stage of development and implementation. It could range from trust in the underlying scientific principles, to trust in the companies developing the technology, to trust in the regulatory bodies overseeing its deployment. Mapping these diverse objects of trust reveals the multifaceted nature of 6G acceptance, shedding light on how different stakeholders' perceptions may evolve throughout the technology's development and deployment phases. Institutional trustworthiness and trust in technology providers often serve as proxies for overall trust in technology. This insight emerges not just from trust-specific studies on 5G, but from a broader analysis of research examining the 5G rollout process, its challenges, and public responses. By studying the conflicts between citizens, local authorities, telecom companies, and national governments during 5G implementation, we can extrapolate valuable lessons for 6G. They offer an empirical window into real-world dynamics affecting technology adoption, revealing areas for building and maintaining trust. This approach allows us to identify potential pain points and trust-related challenges that may arise during 6G development and deployment, informed by the concrete experiences of 5G rollout across various communities and contexts.

In the context of 6G, understanding potential trust issues can benefit from examining the rollout experiences of previous technologies, particularly 5G. While not exclusively focused on trust, social science studies of 5G have revealed the complex dynamics between citizens, local authorities, telecom companies, and national governments pursuing digitalisation plans. These studies, which explore acceptance issues, deployment challenges, and public opposition, offer valuable insights for anticipating and addressing trust-related concerns in 6G development.

For instance, analysing challenges that emerged during 5G rollout can highlight areas where trust might be challenged or eroded. This approach allows us to extrapolate lessons from real-world experiences to inform proactive trust-building strategies for 6G. By examining the interplay between the various stakeholders and their concerns, we can identify potential objects of trust (or distrust) relevant to 6G implementation.

Appendix D – A common example of mistrust and distrust, a petition against 5G antennas, authored by a community in Italy, is presented as an example of such conflicts. Qualitative content analysis of this petition reveals topics of distrust and local perceptions related to tensions around values such as local quality of life, residents' health, landscape aesthetics, and local property values.

6.3.5 SAT modularity and scalability for 6G social acceptance

The analytical "bubbles" that compose the SAT framework to 6G ensure its modularity, making the methodology adaptable. Depending on the context and the focus of the analysis, only one or two bubbles may be applied while still providing meaningful insights into social acceptance by capturing its relational techno-social nature.

This flexibility is enhanced by the elicitation of different possible levels of analysis (Figure 16). This adds scalability: SAT can focus on a specific technology, allowing analysis of its Value Impact, User Experience, Social Disruptiveness and Trust, by privileging individual aspects of acceptance or acceptability. This makes this methodology suitable for applying to a wide range of technology innovations.

As shown here, such scalability is particularly useful because 6G presents a series of peculiarities both *per se*, as an innovation, and in the way its development and implementation are governed at the policy and industry level.

For these reasons the Social Disruptiveness dimension (section 6.3.4.1) is a key analytical lens, to understand the impact of its implementation at systemic and social level, on social relations and institutions, such as the economy, as well as power dynamics and societal values. If these are profoundly altered, the investigation of social acceptance of 6G at a systemic level, shows how it will shape many levels of our future society which may be irreversibly affected.

The SAT framework's modular nature allows it balance forward-looking acceptability assessment with insights from historical experience. While 6G research naturally focuses on future acceptability to inform design and policy decisions, the framework's flexibility enables integration of valuable lessons from previous generations of connectivity innovation, particularly 5G implementation. Our empirical analysis of 5G public reception and controversies enriches mainly both the Value Impact and Trust dimensions, demonstrating how past experiences can strengthen future acceptance strategies.

The Value Impact dimension focuses on whether 6G embeds shared societal values. The results of this question can improve design from an early stage, avoiding or trying to avoid a type of design that does not reflect people's values or exacerbates some value tensions, which would have important consequences for the acceptance of 6G.

6.3.6 Conclusions on SAT capabilities

The SAT framework's ability to operate at multiple levels of analysis while integrating historical lessons with future considerations makes it particularly valuable for assessing complex technological innovations like 6G. Rather than treating social acceptance as a single-dimensional challenge, the framework enables a nuanced understanding of how different actors - from systemic disruptions to individual experiences – interact and influence overall acceptance.

The framework's particular strength lies in its ability to bridge multiple analytical needs: it can assess both present acceptance and future acceptability; it can operate at different scales from systemic to individual levels; and it can integrate historical lessons with forward-looking considerations. This versatility is especially crucial for 6G technology, where the complexity and far-reaching implications of the innovation demand assessment tools that can capture both immediate impacts and longer-term societal transformations.

Looking ahead, the SAT framework offers a foundation for more responsible and inclusive technology development. By enabling early identification of potential societal impacts and value tensions, facilitating meaningful stakeholder engagement, and providing structured ways to assess trust and user experience, it supports decision-making that better aligns technological innovation with societal needs and values. This approach is particularly vital for 6G, where success will depend not just on technical excellence but on achieving genuine social acceptance through careful attention to societal implications, value alignment, and trust-building from the earliest stages of development.

7 KEY FINDINGS AND CONCLUSIONS

As part of the 6G4Society project, this deliverable serves not only as a knowledge base, but also as an actionable framework for future phases of the project and the broader SNS JU community. It focuses on deepening the understanding of the relationship between 6G and society, and on how 6G development can effectively integrate societal values and sustainability goals into technological development, by analysing three main interrelated concepts: societal impact, values, and social acceptance. Consistently, the work has produced three main contributions aimed at equipping stakeholders with essential tools for embedding societal values and sustainability into the 6G innovation process:

- A comprehensive analysis of societal impacts and controversies,
- A guideline for Key Values and Key Sustainability Indicators (KVIs and KSIs),
- The Social Acceptance of Technology (SAT) framework.

The tools and recommendations presented support a development approach where innovation and sustainability are not in conflict, contributing to a technological future that serves and reflects European values and aspirations. Here after the main findings and prospective reflections considered critical for a responsible 6G-based innovation are illustrated.

Understanding broader societal implications. Far from being just an incremental advance in telecommunications, 6G represents a paradigmatic shift in the information and communication landscape and in how technology interfaces with society. All modifications in the information, communication and media landscape produce effects at all levels of life, shaping and orienting social development, activating or dismissing practices, and defining our symbolic universe and value system. Therefore, the transformative potential of 6G will extend far beyond direct technological effects. It will fundamentally transform human experience across dimensions of space, time, body-technology interaction, and social relationships. Assessing 6G's potential influence requires to move beyond performance metrics or the immediate scope of applications, questioning instead how fundamental aspects of human experience and social organisation may be affected, such as cultural dynamics, individual autonomy or social inclusion.

Relativising the path of innovation. Reflections on broader societal implications are tied to a critical examination of the mechanisms and assumptions shaping actions and decisions in the research and innovation sector. These assumptions - often taken for granted and acting beneath the threshold of awareness - affect the vision of the future, the criteria for setting priorities and objectives, problem-solving approaches, and implementation paths. As noted by Science and Technology Studies (STS), these assumptions typically reflect the interests, goals, and future visions of specific societal segments, particularly those directing technology development. This raises questions about the extent to which the perspectives of other stakeholders or societal groups - guided by varied value systems and priorities - are represented in these visions and expectations. Secondly, technological paths that may appear inevitable can be questioned, as they are products of specific cultural and historical contexts. This opens the possibility of considering alternative visions of the future, with technological priorities, use-case prioritisation, and approaches to problem-solving shaped around different value systems.

Exploring the influence of a new media paradigm. Immersive communication introduces a new model in media. For the first time the physical dimension of devices is surpassed, towards a vision of invisible, hidden, silent, and seamlessly integrated technology. Similarly, for the first time in the history of human communication, the full dimension of the body enters a model of distant communication. The relationship between human, media and the environment will be subverted, transforming human experience across space, body, and reality perception, extending human sensory and cognitive abilities, and reshaping how we generate and interpret meaning. Although "naturalised" and immanent, mediation will continue to be present and exert a specific influence, participating in the process of meaning creation. Current research lacks a comprehensive approach linking the 6G technology landscape, media theories, and the immersive communication environment. Understanding these intersections is essential for anticipating the societal and cultural impacts of immersive media, properly interpreting future social dynamics, and guiding technology development for positive social change.

Building a nuanced and contextual guidance to integrate sustainability. There is widespread consensus at both EU and global levels on the core values driving actions toward a more sustainable society, and on the need to address economic, environmental, and social dimensions cohesively and holistically. Despite strong high-level commitments to engage sustainability, a clear gap exists between commitments and the way values are prioritised and integrated in the innovation processes. Business interests and technological capabilities are still often prioritised, sidelining a truly holistic view of sustainability. One reason for this can be identified in the lack of a thorough and practical understanding of how value drivers, including sustainability, can actually be reflected across all phases of technology development - e.g., setting technology requirements, selecting and developing use cases, or designing business models. A nuanced, contextual approach is essential to truly and differently embed sustainability at each stage, while accounting for the specificities of different policy contexts.

Supporting holistic sustainability at a deeper cultural level. Sustainability still tends to be framed as a trade-off, positioning itself in tension or in opposition to competitiveness, performance and profit goals. A real holistic approach to sustainability, instead, would consider it as a core component of competitiveness and long-term success, fully integrated with business related goals. This gap stems from the persistence of a dominant and consolidated cultural and value framework that is still tuned towards different priorities. For sustainability to be genuinely and holistically embedded, it shall become culturally recognized as a fundamental asset for technological and competitive success within both policy and business - similar to how privacy and security have become intrinsic design principles. With sustainability fully repositioned as foundational, it would directly participate in shaping relevant Key Performance Indicators (KPIs), defining use cases, targeting audiences, and setting the overall business and innovation goals. A serious reflection on the deeper cultural value systems underpinning sustainability decisions is needed both at the policy and business level, to reshape the foundational values and priorities that the criteria for competitiveness and product appeal from a business perspective.

Controversies are not the simple result of disinformation. Controversies surrounding technologies like 5G are not the mere result of misinformation; they reveal deeper insights into the relationship between technological innovation and social acceptance. Public concerns about 5G, particularly on health effects, are often dismissed as conspiracy theories. However, controversies in science and technology should not be viewed simply as a result of ignorance or misunderstanding. Firstly, this dismissal can increase polarisation, erode trust, and complicate communication among stakeholders, making it challenging to foster informed public debate. Secondly, and most importantly, controversies may reflect legitimate dissent within the scientific community and between competing expert knowledge; also, they may highlight the diverse aspirations, priorities, concerns, visions for the future, and value systems existing across different local contexts and social groups. Given that there is no single solution or universal vision for a desirable future, these dynamics underscore the need to articulate the legitimacy of differing priorities and values, revealing fundamental conflicts between values and acceptable trade-offs as perceived by different groups. In the context of 6G, addressing health-related controversies is essential, as they are a major source of opposition to 5G rollout. prioritising health and environmental concerns as core values would help guide technological research and innovation toward solutions that respect diverse perspectives on social acceptance and resistance.

A framework to explore social acceptance. The Social Acceptance of Technology (SAT) framework provides a systematic approach for exploring, evaluating and promoting acceptance, particularly emphasising the inclusion of passive stakeholders who may be significantly impacted but lack direct influence over development. By addressing four key dimensions – Social Disruptiveness, Value Impact, User Experience, and Trust – the framework moves beyond traditional adoption metrics, addressing broader societal implications. Its modular and scalable nature enables assessment at multiple levels, from systemic changes to individual interactions. This approach directly addresses the governance challenges observed in 5G deployment, by providing structured mechanisms for identifying and addressing potential societal impacts and engaging public resistance as a component of the societal dynamic. For 6G development, the framework supports implementation through three concrete pathways: (1) continuous stakeholder engagement that considers potential harm alongside traditional metrics of influence; (2) systematic monitoring of acceptance factors throughout the technology development lifecycle; and (3) evidence-based governance that balances innovation goals and advancements with societal needs and well-being.

These findings highlight two main strategic priorities, relevant for research and innovation management and policy:

- Technological governance mechanisms must recognize the legitimacy of diverse aspirations and priorities within society and address the unique needs of different governance levels (EU, national, local), while upholding clear common thresholds for human rights and environmental protection. This approach should be based on a culture of transparent risk communication and foster inclusive dialogue from the earliest stages of technology development, to better address the complexities of acceptance and sustainability. The public discourse shall be recognised as legitimate in its different nuances, acknowledging questions from various scientific fields and areas of expertise. This balanced approach is crucial to enhance public understanding of the potential risks and benefits associated with technology and to support informed decision-making. Additionally, this governance model should recognize that each design decision shapes a potential future society. Rather than viewing technology as a fixed and predetermined trajectory, its role in society should be redefined and centred on the opportunity to consciously select and prioritise specific human principles and visions for the future.

- Sustainability considerations shall move beyond the context of evaluation tools, to become foundational design criterion, relevant for acceptability and competitiveness, such as privacy or security. Success criteria should fundamentally valorise societal well-being, social and environmental sustainability, and inclusive innovation as core measures of technological advancement, overcoming the paradigm where these elements are approached in a trade-off or conflicting modality.

REFERENCES

[1] The 5G Infrastructure Association, *European Vision for the 6G Network Ecosystem,* 2021.

[2] Smart Networks and Services Joint Undertaking, *SNS R&I Work Programme 2021-2022.*

[3] OECD, Applying Evaluation Criteria Thoughtfully, OECD, 2021.

[4] Hexa-X-II, *Deliverable D1.2 6G Use Cases and Requirements,* 2023.

[5] P. Ahokangas and A. Aagaard, Eds., The Changing World of Mobile Communications: 5G, 6G and the Future of Digital Services, Cham: Springer International Publishing, 2024.

[6] Hexa-X, *About Hexa-X: Motivation.*

[7] HEXA-X, *Hexa-X: Vision.*

[8] Hexa-X-II, *D1.1 Environmental, social and economic drivers and goals for 6G,* 2023.

[9] J. Millard, Impact of digital transformation on public governance - New forms of policy-making and the provision of innovative, people-centric and inclusive public services, Luxembourg: Manzoni, M. and Schade, S. (Editors), Publications Office of the European Union, 2023.

[10] L. Royakkers, J. Timmer, L. Kool and R. Van Est, "Societal and ethical issues of digitization," *Ethics and Information Technology,* vol. 20, p. 127–142, June 2018.

[11] European Commission: DGRI, “Options for strengthening responsible research and innovation – Report of the Expert Group on the State of Art in Europe on Responsible Research and Innovation,” 2013. [Online]. Available: https://data.europa.eu/doi/10.2777/46253. [Accessed October 2024].

[12] R. Von Schomber, “A vision of responsible innovation,” in *Responsible Innovation: Managing the Responsible Emergence of Science and Innovation in Society*, London, John Wiley & Sons, Ltd, 2013.

[13] P. A. E. Brey, “Ethics of Emerging Technologies,” in *Methods for the Ethics of Technology*, S. O. Hansson, Ed., Rowman and Littlefield International, 2017.

[14] H. A. Becker, "Social impact assessment," *European Journal of Operational Research,* vol. 128, p. 311–321, January 2001.

[15] M. McLuhan, Understanding media, New York: Mentor, 1964.

[16] I. Hutchby, “Technologies, Texts and Affordances,” *Sociology,* vol. 35, no. 2, pp. 441-456, 2001.

[17] P. Starr, The Creation of the Media: Political Origins of Modern Communications, Basic Books, 2004.

[18] J. Van Dijk, The network society, Sage Publications, 2020.

[19] L. Floridi, Ed., The Onlife Manifesto, Cham: Springer International Publishing, 2015.

[20] S. De Luca, “The path to 6G. Briefing,” 2024.

[21] Q. Li, Immersive Communication, Routledge, 2020.

[22] P. Levinson, The Soft Edge: A Natural History and Future of the Information Revolution, Routledge, 1998.

[23] Brubacker, Hyperconnectivity and its discontents, Polity Press, 2023.

[24] B. Schwartz, The Paradox of Choice: Why More Is Less, Harper Perennial, 2005.

[25] E. Scharrer, “Media Exposure and Sensitivity to Violence in News Reports: Evidence of Desensitization?,” *Journalism & Mass Communication Quarterly,* vol. 85, pp. 291-310, 2008.

[26] A. Quito, “The Next Design Trend is One That Eliminates All Choices.,” 2015. [Online]. Available: https://qz.com/429929/the-next-design-trend-is-one-that-eliminates-all-choices. [Accessed October 2024].

[27] HEXA-X-II, “D1.3 "Environmental and social view on 6G",” 2024. [Online]. Available: https://hexa-x-ii.eu/wp-content/uploads/2024/03/Hexa-X-II_D1.3_v1.00_GA_approved.pdf. [Accessed October 2024].

[28] HEXA-X, “Deliverable D1.2 “Expanded 6G vision, use cases and societal values””.

[29] T. S. Project, “Energy and climate: What virtual worlds for a sustainable real world?,” 2024. [Online]. Available: https://theshiftproject.org/wp-content/uploads/2024/05/The-Shift-Project-Quels-mondes-virtuels-pour-quel-monde-reel-Annexes-2024_ENG.pdf. [Accessed October 2024].

[30] P. Timmers, “The Technological Construction of Sovereignty,” in *Perspectives on Digital Humanism* , Springer, 2022, pp. 213-218.

[31] E. Prem, "Principles of digital humanism: A critical post-humanist view," *Journal of Responsible Technology,* vol. 17, p. 100075, March 2024.

[32] A. Kaloxylos, W. Mohr, C. Anton Haro, D. Bourse, N. Ciulli, R. De Peppe, E. Dotaro, D. Filipovic, A. Garcia, C. Lerquin, H. Lønsethagen, T. Norp, A. Osseiran, V. Quintuna Rodriguez, M. Schubert, E. Schulz, K. Trichias, G. Wikström and C. Willcock, “Key Strategies for 6G Smart Networks and Services,” *6G-IA Position Paper,* 2023.

[33] G. Wikström, N. Bledow, M. Matinmikko-Blue, H. Breuer, C. Costa, G. Darzanos, A. Gavras, T. Hossfeld, I. Mesogiti, K. Petersen, P. Porambage, R. Stoica and S. Wunderer, "Key value indicators: A framework for values-driven next-generation ICT solutions," *Telecommunications Policy,* vol. 48, July 2024.

[34] ISO, *Sustainable cities and communities — Vocabulary.*

[35] M. Matinmikko-Blue and A. Arslan, "Sustainability Transition and 6G Mobile Communications," in *The Changing World of Mobile Communications: 5G, 6G and the Future of Digital Services*, P. Ahokangas and A. Aagaard, Eds., Cham, Springer International Publishing, 2024, p. 93–109.

[36] United Nations Development Programme (UNDP), *What are the Sustainable Development Goals?,* 2024.

[37] United Nations Development Programme (UNDP), “United Nations Development Programme Strategic Plan 2022–2025,” 2021.

[38] M. Matinmikko-Blue, S. Yrjölä, P. Ahokangas, K. Ojutkangas and E. Rossi, "6G and the UN SDGs: Where is the Connection?," *Wireless Personal Communications,* vol. 121, p. 1339–1360, November 2021.

[39] United Nations, *Transforming our world: the 2030 Agenda for Sustainable Development. Resolution adopted by the General Assembly,* 2015.

[40] United Nations Development Programme (UNDP), “Guidance Note. Data for Implementation and Monitoring of the 2030 Agenda for Sustainable Development.,” 2017.

[41] UNDESA, “Guidance in Preparing a National Sustainable Development Strategy: Managing Sustainable Development in the New Millenium. Background Paper No. 13,” 2002.

[42] UNDESA, *Indicators of Sustainable Development: Guidelines and Methodologies, 3rd Edition,* 2007.

[43] European Commission, *The European Green Deal. COMMUNICATION FROM THE COMMISSION TO THE EUROPEAN PARLIAMENT, THE EUROPEAN COUNCIL, THE COUNCIL, THE EUROPEAN ECONOMIC AND SOCIAL COMMITTEE AND THE COMMITTEE OF THE REGIONS.,* Document 52019DC0640. COM/2019/640 final, 2019.

[44] European Commission, *Delivering the European Green Deal.*

[45] European Commission, “How to master Europe’s digital infrastructure needs?,” 2024.

[46] OECD, *How to measure distance to SDG targets anywhere,* SDD WORKING PAPER No.105, 2020.

[47] Ministerio de Economia, *CHARTER OF DIGITAL RIGHTS.,* 2021.

[48] Welsh Government, *Wellbeing of Wales: national indicators,* 2022.

[49] Welsh Government, *Shared Purpose: Shared Future Statutory guidance on the Well-being of Future Generations (Wales) Act 2015,* 2024.

[50] German Federal Government, *General Administrative Regulation for the Procurement of Climate-Friendly Services (Allgemeine Verwaltungsvorschrift zur Beschaffung klimafreundlicher Leistungen, AVV Klima). Vom 19,* BAnz AT 22.10.2021 B1, 2021.

[51] French Government, *Law No. 2020-105 of February 10, 2020, relating to the fight against waste and the circular economy..*

[52] UK Government, *Social Value Act,* 2013.

[53] Institut fédéral pour le Développement durable, *En 2050 Une vision stratégique fédérale à long terme pour un développement durable,* Belgium, 2016.

[54] R. Blog, “Normativa ESG: come è regolamentata la sostenibilità aziendale,” 2024. [Online]. Available: https://www.rajapack.it/blog-it/normativa-esg-regolamentata-la-sostenibilita-aziendale#: :text=Il%20Decreto%20Legislativo%20254%2F2016%20rappresenta%20un%20vero%20punto%20di,ambientali%2C%20sociali%20e%20di%20governance..

[55] 6GSNS SMART NETWORKS AND SERVICES JOINT UNDERTAKING, *SNS JU Annual Activity Report 2023.*

[56] G. Wikström, A. Schuler Scott, I. Mesogiti, R.-A. Stoica, G. Georgiev, S. Barmpounakis, A. Gavras, P. Demestichas, M.-H. Hamon, H.-S. Hallingby and D. Lund, “What societal values will 6G address?,” May 2022.

[57] NGMN Alliance, “Green Future Networks: Metering in Virtualised RAN Infrastructure,” 2024.

[58] AIOTI WG Digital for Green, “IoT and Edge Computing Carbon Footprint Measurement Methodology,” 2022.

[59] Next G Alliance, “Evolution of Sustainability Indicators for Next-Generation Radio Network Technologies.,” 2023.

[60] ITU, *Adaptation to climate change through sustainable and resilient digital technologies,* Q12/5.

[61] ITU, *Low-cost sustainable ICT solutions for climate change adaptation in rural areas and communities.*

[62] ITU, *Sustainable and Resilient Digital Technologies for Adaptation to Climate Change.*

[63] ETNO, *ETNO POSITION PAPER ON 6G,* 2024.

[64] P. Jain, *IMT-2030 Use Case Workshop: A Catalyst for 6G Planning,* P25 Workshop Article, 2024.

[65] ITU, *Building circular and sustainable cities and communities.*

[66] ATIS and S. N. S. 6G, *EU-US Beyond 5G/6G Roadmap,* 2023.

[67] ITU, *Biodiversity Adaptation to Climate Change.*

[68] TTC2, “6G outlook. Annex 4,” 2023.

[69] ETNO, *Empowering Consumers in the Green Transition,* ETNO POSITION PAPER, 2022.

[70] Next G Alliance, “Beyond Speed: Promoting Social and Economic Opportunities through 6G and Beyond,” 2023.

[71] R. Mansell and J.-C. Plantin, “Imagining 5G Networks: Infrastructure and Public Accountability,” vol. 16, p. 19, 2022.

[72] K. Mason and S. Wagg, “White Paper: The Importance of Social Engagement in Putting 5G Connectivity Infrastructures in Place,” 2022.

[73] V. Butot and L. Van Zoonen, "Contesting Infrastructural Futures: 5G Opposition as a Technological Drama," *Science, Technology, & Human Values,* vol. 49, p. 1017–1044, September 2024.

[74] World Economic Forum, “The Impact of 5G: Creating New Value across Industries and Society,” 2020.

[75] U. Soler, "Social perception of 5G technology," *Rocznik Instytutu Europy Środkowo-Wschodniej,* vol. 20, p. 103–120, December 2022.

[76] U. Pesch, "Identifying interventions for responsible innovation: The sociotechnical value map," in *Teaching design for values: concepts, tools et practices*, R. Rocco, A. Thomas and M. Novas-Ferradás, Eds., Delft, The: TU Delft OPEN Publishing, 2022.

[77] M. Maiese, “Causes of Disputes and Conflicts,” in *Beyond Intractability*, G. Burgess and H. Burgess, Eds., 2003.

[78] L. Halman, T. Reeskens, I. Sieben and M. van Zundert, *Atlas of European Values: Change and Continuity in Turbulent Times,* Open Press Tilburg University, 2022.

[79] I. Van De Poel, T. De Wildt and D. Van Kooten Pássaro, "COVID-19 and Changing Values," in *Values for a Post-Pandemic Future*, vol. 40, M. J. Dennis, G. Ishmaev, S. Umbrello and J. Van Den Hoven, Eds., Cham, Springer International Publishing, 2022, p. 23–58.

[80] W. Leal Filho, V. Levesque, S. Sivapalan, A. L. Salvia, B. Fritzen, R. Deckert, V. Kozlova, T. J. LeVasseur, K. Emblen-Perry, U. M. Azeiteiro, A. Paço, B. Borsari and C. Shiel, "Social values and sustainable development: community experiences," *Environmental Sciences Europe,* vol. 34, p. 67, December 2022.

[81] S. H. Schwartz, “Values: cultural and individual,” in *Fundamental Questions in Cross-Cultural Psychology*, F. J. R. van de Vijver, A. Chasiotis and S. M. E. Breugelmans, Eds., Cambridge University Press, 2011, p. 463–493.

[82] A. Lindgreen, C. A. Di Benedetto, A. H. Clarke, M. R. Evald, N. Bjørn-Andersen and D. M. Lambert, "How to define, identify, and measure societal value," *Industrial Marketing Management,* vol. 97, p. A1–A13, August 2021.

[83] OECD, *Value added by activity. Indicator,* 2022.

[84] A. Hayes, *Value-Added Product: What It Means in Industry and Marketing.*

[85] City of Haarlem, “Haarlem’s approach to Social Return on Investment: Making Socially Responsible Public Procurement Work: 71 Good Practice Cases,” 2020.

[86] M. Porter, G. Serafeim and M. Karmer, “Where ESG Fails,” [Online]. Available: https://www.institutionalinvestor.com/article/2bswdin8nvg922puxdzwg/opinion/where-esg-fails.

[87] OECD, Integrating Responsible Business Conduct in Public Procurement, OECD, 2020.

[88] OECD, “OECD Due Diligence Guidance for Responsible Business Conduct,” 2018.

[89] M. Porter and M. Karmer, “Strategy and Society, The Link between Competitive Advantage and Corporate Social Responsibility,” *Harvard Business Review,* 2006.

[90] M. Porter and M. Karmer, “Creating Shared Value: How to reinvent capitalism—and unleash a wave of innovation and growth,” *Harvard Business Review,* vol. January/February, 2011.

[91] J. Tscherrig and C. J. Parreira, “Embracing a Beyond Growth Approach for Sustainable Futures,” 2023. [Online]. Available: https://sdg.iisd.org/commentary/guest-articles/embracing-a-beyond-growth-approach-for-sustainable-futures/.

[92] L. Winner, “Do artifacts have politics?,” *Daedalus,* vol. 109, p. 121–136, 1980.

[93] B. Latour, “Where are the missing masses? The sociology of a few mundane artifacts,” in *Shaping Technology/Building Society: Studies in Sociotechnical Change*, Cambridge, MA, MIT Press, 1992, pp. 225-258.

[94] P.-P. Verbeek, "Materializing Morality: Design Ethics and Technological Mediation," *Science, Technology, & Human Values,* vol. 31, p. 361–380, May 2006.

[95] Gottfried, Kurt, March 4, Anniversary Edition: Scientists, Students, and Society, MIT Press, 2019.

[96] K. Crawford, Atlas of AI: power, politics, and the planetary costs of artificial intelligence, New Haven London: Yale University Press, 2021.

[97] X. Ferrer, T. V. Nuenen, J. M. Such, M. Cote and N. Criado, “Bias and Discrimination in AI: A Cross-Disciplinary Perspective,” *IEEE Technology and Society Magazine,* vol. 40, p. 72–80, June 2021.

[98] M. Heikkila, “Dutch scandal serves as a warning for Europe over risks of using algorithms. Politico.,” March 2022.

[99] T. Moreau, R. Sinatra and V. Sekara, "Failing Our Youngest: On the Biases, Pitfalls, and Risks in a Decision Support Algorithm Used for Child Protection," in *The 2024 ACM Conference on Fairness, Accountability, and Transparency*, Rio de Janeiro Brazil, 2024.

[100] L. Slapakova, A. Fraser, M. Hughes, M. C. Aquilino and K. Thue, "How can emerging technologies shape culture? Insights from a deep-dive into the future information environment," 2024.

[101] J. Kania, M. Kramer and P. Senge, *The Water of Systems Change,* 2018.

[102] K. Konrad, H. Van Lente, C. Groves and C. Selin, “Performing and Governing the Future in Science and Technology,” in *The handbook of science and technology studies*, Fourth edition ed., Cambridge, Massachusetts: The MIT Press, 2017, p. 465–493.

[103] M. Boenink and O. Kudina, "Values in responsible research and innovation: from entities to practices," *Journal of Responsible Innovation,* vol. 7, p. 450–470, September 2020.

[104] S. Umbrello and I. Van De Poel, "Mapping value sensitive design onto AI for social good principles," *AI and Ethics,* vol. 1, p. 283–296, August 2021.

[105] High-Level Expert Group on Artificial Intelligence (AI HLEG), "Assessment List for Trustworthy Artificial Intelligence (ALTAI) for self-assessment".

[106] OECD, "Framework for Anticipatory Governance of Emerging Technologies," 2024.

[107] P. A. E. Brey, "Anticipatory Ethics for Emerging Technologies," *NanoEthics,* vol. 6, p. 1–13, April 2012.

[108] European Commission, *Directive (EU) 2022/2464 of the European Parliament and of the Council of 14 December 2022 amending Regulation (EU) No 537/2014, Directive 2004/109/EC, Directive 2006/43/EC and Directive 2013/34/EU, as regards corporate sustainability reporting (Text with EEA relevance),* PE/35/2022/REV/1.

[109] A. Souakri and D. Forterre, *Navigating business resilience in turbulent times: Integrating extra-financial value for strategic success,* ESCP Impact Paper No. 2024-62-EN, 2024.

[110] P. Barron, L. Cord, J. A. Cuesta, S. A. Espinoza, G. M. Larson and M. J. V. Woolcock, Social sustainability in development: meeting the challenges of the 21st century, Washington, DC: World Bank Group, 2023.

[111] T. Sheppard, “Defining social impact indicators, setting targets and refining your social model,” [Online]. Available: https://www.unltd.org.uk/learn/defining-social-impact-indicators-setting-targets-and-refining-your-social/.

[112] S. Kuşakcı, M. Yilmaz, A. S. Kusakci, S. Samba and F. Nantembelele, “Towards sustainable cities: A sustainability assessment study for metropolitan cities in Turkey via a hybridized IT2F-AHP and COPRAS approach.,” *Sustainable Cities and Society,* vol. 78, no. 4, 2021.

[113] European Society of Cardiology, “Heart attack diagnosis missed in women more often than in men,” 2021. [Online]. Available: https://www.escardio.org/The-ESC/Press-Office/Press-

releases/Heart-attack-diagnosis-missed-in-women-more-often-than-in-men. [Accessed 10 2024].

[114] M. R. Kramer and M. W. & Pfitzer, “The Essential Link Between ESG Targets & Financial Performance,” *Harvard Business Review,* no. September-October, 2022.

[115] R. Orr, *The problems with LEED. Lean Urbanism Brief,* 2014.

[116] D. Greene, A. L. Hoffmann and L. & Stark, “Better, Nicer, Clearer, Fairer: A Critical Assessment of the Movement for Ethical Artificial Intelligence and Machine Learning,” *Proceedings of the 52nd Hawaii International Conference on System Sciences,* pp. 2122-2131, 2019.

[117] M. R. Guarini, F. Sica, F. Tajani, E. Sabatelli and D. Anelli, "A Strategic Multidirectional Approach for Picking Indicator Systems of Sustainability in Urban Areas," *Urban Science,* vol. 8, p. 107, August 2024.

[118] D. Michalina, P. Mederly, H. Diefenbacher and B. Held, "Sustainable Urban Development: A Review of Urban Sustainability Indicator Frameworks," *Sustainability,* vol. 13, p. 9348, August 2021.

[119] R. Rebolledo-Leiva, L. Vásquez-Ibarra, G. Feijoo, M. T. Moreira and S. González-García, "Determining key indicators for the assessment of sustainable development in Spanish cities under a multi-criteria approach," *Cleaner Production Letters,* vol. 5, p. 100046, December 2023.

[120] Welsh Government, *Well-being of future generations act: the essentials,* 2024.

[121] EPA, *Database of Sustainability Indicators and Indices (DOSII),* 2014.

[122] P. Pakzad, P. Osmond and L. Corkery, "Developing Key Sustainability Indicators for Assessing Green Infrastructure Performance," *Procedia Engineering,* vol. 180, p. 146–156, 2017.

[123] J. Fiskel, T. Eason and H. Frederickson, *A Framework for Sustainability Indicators at EPA. EPA/600/R/12/687,* United States Environmental Protection Agency, 2012.

[124] UNEP, “Embedding the Environment in Sustainable Development Goals. UNEP Post-2015 Discussion Paper 1,” July 2013. [Online]. Available: https://sustainabledevelopment.un.org/content/documents/972embedding-environments-in-SDGs-v2.pdf. [Accessed October 2024].

[125] M. W. Bauer and G. Gaskell, Biotechnology: The making of a Global Controversy, Cambridge University Press., 2002.

[126] S. Jasanoff, Designs on Nature: Science and Democracy in Europe and the United States, Princeton University Press, 2005.

[127] S. Kim and S. & Kim, “The role of value in the social acceptance of science-technology,” *International Review of Public Administration,* vol. 20, no. 3, pp. 305-322, 2015.

[128] S. Sismondo, An introduction to science and technology studies, John Wiley & Sons., 2011.

[129] J. Conrad, “Scientific expertise in technological controversies: The nuclear and the recombinant DNA debates,” *International Political Science Review,* vol. 3, no. 3, pp. 315-322, 1982.

[130] M. Callon, P. Lascoumes and Y. Barthe, Acting in an uncertain world: An essay on technical democracy, MIT Press , 2011.

Co-funded by the European Union

[131] T. Venturini and A. K. & Munk, Controversy mapping: A field guide, John Wiley & Sons, 2021.

[132] N. Sabouring, “The 5G controversy in France,” 2021. [Online]. Available: https://storymaps.arcgis.com/stories/7a3bd9d0d268401ab5517626eaa617ee. [Accessed October 2024].

[133] J. Dittel, “Past and present (landscape) conflicts about the cellular network expansion in Germany,” in *Landscape conflicts*, Wiesbaden, Springer Fachmediem Wiesbaden, 2024, pp. 403-427.

[134] “5G Appeal,” 2018. [Online]. Available: https://www.5gappeal.eu. [Accessed October 2024].

[135] GSMA, “5G Global Launches and Statistics,” 2024. [Online]. Available: https://www.gsma.com/solutions-and-impact/technologies/networks/5g-network-technologies-and-solutions/5g-innovation. [Accessed October 2024].

[136] J. Langguth, P. Filkuková, S. Brenner, D. T. Schroeder and K. Pogorelov, “COVID-19 and 5G conspiracy theories: long term observation of a digital wildfire.,” *International journal of data science and analytics,* vol. 15, no. 3, pp. 329-346, 2023.

[137] W. Cerulus, “How anti-5G anger sparked a wave of arson attacks,” 20 April 2020. [Online]. Available: https://www.politico.eu/article/coronavirus-5g-arson-attacks-online-theories/ . [Accessed October 2024].

[138] “The BabySafe Project,” 2024. [Online]. Available: https://www.babysafeproject.org/. [Accessed October 2024].

[139] P. Gerli, “Municipal 5G bans during the Covid-19 pandemic: the case of Italy,” *Digital Policy, Regulation and Governance,* vol. 23, no. 6, pp. 553-573, 2021.

[140] S. Abiteboul and P. Lagrange, “Will 5G improve or worsen our digital carbon footprint?,” Polytechnique Insights, 2022. [Online]. Available: https://www.polytechnique-insights.com/en/braincamps/digital75g-6g/will-5g-improve-or-worsen-our-digital-carbon-footprint/. [Accessed October 2024].

[141] E. P. T. Tank, “Environmental Impacts of 5G,” 2021. [Online]. Available: https://www.europarl.europa.eu/thinktank/en/document/EPRS_STU(2021)690021. [Accessed October 2024].

[142] V. Forti and e. al., “The Global E-waste Monitor 2024 – Electronic Waste Rising Five times faster than documented E-waste recycling,” 2024. [Online]. Available: https://ewastemonitor.info/the-global-e-waste-monitor-2024/. [Accessed October 2024].

[143] C. Occhipinti, L. Briguglio, A. Carnevale, R. Santilli, E. Tangari and A. Iannone, Privacy and security aspects of 5G technology. In Privacy and security aspects of 5G technology., Scientific Foresight Unit (STOA) EPRS European Parliamentary Research Service, 2022.

[144] “POLITICO/Qualcomm Survey. Consumers Divided Globally on Whether to trade 5G speeds for privacy,” 2020. [Online]. Available: https://www.politico.com/news/2020/02/14/5g-wireless-speeds-privacy-poll-115058. [Accessed October 2024].

[145] S. Telecom, “6G White Paper: 5G Lessons learned, 6G key requirements, 6G network evolution, and 6G Spectrum,” 2023. [Online]. Available: https//ee.cdnartwhere.eu/wp-content/uploads/2023/08/SKT6G-White-PaperEng-v1,0-web.pdf . [Accessed October 2024].

Co-funded by the European Union

[146] T. E. Times, “How 5G Disappointed ‘Pretty Much Everybody,” February 2023. [Online]. Available: https://telecom.economictiemes.indiatimes.com/news/how-5g-disappointed-pretty-much-everybody/98321122 . [Accessed October 2024].

[147] ETNO, “State of Digital Communications 2024 Report,” 2024. [Online]. Available: htpps://etno.eu/news/all-news/8-news/788-state-of-digital-communications-2024-etno.html. [Accessed October 2024].

[148] J. Espinoza, “EU considers mandatory ban on using Huawei to build 5G,” 2023. [Online]. Available: https://www.ft.com/content/a6900b0f-08d5-433d-bfb0-f57b6041e381. [Accessed October 2024].

[149] K. K. Bar-On, E. Dimant, L. Y. and D. G. Rand, “Unraveling polarization: insights into individual and collective dynamics,” *PNAS Nexus,* vol. 3, no. 10, p. 426, 2024.

[150] E. Commission, “Rome Declaration on Responsible Research and Innovation in Europe.,” 2014. [Online]. Available: https://ec.europa.eu/research/swafs/pdf/rome_declaration_RRI-final_21_November.pdf. [Accessed October 2024].

[151] J. Stilgoe, R. Owen and P. Macnaghten, “Developing a framework for responsible innovation,” *Research Policy,* vol. 42, no. 9, pp. 1568-1580, 2013.

[152] A. Genus and A. Stirling, “Collingridge and the dilemma of control: Towards responsible and accountable innovation,” *Research Policy,* vol. 47, no. 1, pp. 61-69 , 2018.

[153] J. Chilvers and M. Kearnes, Remaking participation: Science, environment and emergent publics, Routledge, 2016.

[154] R. Owen, P. Macnaghten and J. Stilgoe, “Responsible research and innovation: From science in society to science for society, with society,” *Science and Public Policy,* vol. 39, no. 6, pp. 751-760, 2012.

[155] “Decreto-Legge 16 luglio 2020, n.76: Misure urgenti per la semplificazione e l’innovazione digitale,” 16 July 2020. [Online]. Available: https://www.gazzettaufficiale.it/eli/gu/2020/07/16/178/so/24/sg/pdf.

[156] J. Stilgoe, S. J. Lock and J. Wilsdon, “Why should we promote public engagement with science?,” *Public Understanding of Science,* vol. 23, no. 1, pp. 4-15, 2014.

[157] E. Van der Vleuten, “Infrastructures and societal change. A view from the large technical systems field,” *Technology Analysis & Strategic Management,* vol. 16, no. 3, pp. 395-414, 2004.

[158] J. Planko, J. Cramer, M. P. Hekkert and M. M. Chapping, “Combining the technological innovation systems framework with the entrepreneurs’ perspective on innovation,” *Technology Analysis & Strategic Management,* vol. 29, no. 6, pp. 614-625, 2017.

[159] “The 5G-Solutions Project,” [Online]. Available: https://5gsolutionsproject.eu/.

[160] “The BRIGHT Project,” [Online]. Available: https://www.brightproject.eu/.

[161] “The IRIS Project,” [Online]. Available: https://www.iris-h2020.eu.

[162] “The COMFORTage Project,” [Online]. Available: https://comfortage.eu/.

Co-funded by the European Union

[163] M. Koelle and e. al., “Your smart glasses' camera bothers me!: exploring opt-in and opt-out gestures for privacy mediation,” *NordiCHI '18: Proceedings of the 10th Nordic Conference on Human-Computer Interaction,* pp. 473-481, 2018.

[164] K. Moesker, U. Pesch and N. & Doorn, “Making sense of acceptance and acceptability: Mapping concept use in energy technologies research,” *Energy Research & Social Science,* vol. 115, no. 103654, 2024.

[165] M. E. Bonney, “Personality traits of socially successful and socially unsuccessful children,” *Journal of Educational Psychology,* vol. 34, no. 8, p. 449–472, 1943.

[166] R. G. Kuhlen and B. J. Lee, “Personality characteristics and social acceptability in adolescence,” *Journal of Educational Psychology,* vol. 34, no. 6, p. 321–340, 1943.

[167] E. M. Rogers, Diffusion of innovations, New York: Free Press, 2003.

[168] F. D. Davis, “Technology acceptance model: TAM.,” in *Information Seeking Behavior and Technology Adoption*, 1989, pp. 205-219.

[169] V. Venkatesh, M. G. Morris, G. B. Davis and F. D. Davis, “User Acceptance of Information Technology: Toward a Unified View,” *MIS Quarterly,* vol. 27, no. 3, p. 425–478, 2003.

[170] L. G. Tornatzky and M. Fleisher, The processes of technological innovation, Lexington Books, 1990.

[171] M. Bonaiuto, O. Mosca, A. Milani, S. Ariccio, F. Dessi and F. Fornara, “Beliefs about technological and contextual features drive biofuels’ social acceptance,” *Renewable and Sustainable Energy Reviews,* vol. 189, no. 113867, 2024.

[172] B. Taebi, “Bridging the Gap between Social Acceptance and Ethical Acceptability,” *Risk Analysis,* vol. 37, no. 10, p. 1817–1827, 2017.

[173] J. Gaede and I. H. Rowlands, “Visualizing social acceptance research: A bibliometric review of the social acceptance literature for energy technology and fuels,” *Energy Research & Social Science,* vol. 40, p. 142–158, 2018.

[174] R. Wüstenhagen, M. Wolsink and M. J. Bürer, “Social acceptance of renewable energy innovation: An introduction to the concept,” *Energy Policy,* vol. 35, no. 5, p. 2683–2691, 2007.

[175] e. a. Paul Upham, “Towards a cross-paradigmatic framework of the social acceptance of energy systems.,” *Energy Research & Social Science ,* vol. 8, pp. 100-112, 2015.

[176] N. M. A. Huijts, C. J. H. Midden and A. L. Meijnders, “Social acceptance of carbon dioxide storage,” *Energy Policy,* vol. 35, no. 5, p. 2780–2789, 2007.

[177] M. Wolsink, “Social acceptance revisited: gaps, questionable trends, and an auspicious perspective,” *Energy Research & Social Science,* vol. 46, p. 287–295, 2018.

[178] G. a. G. C. Tabourdeau, “From User Acceptance to Social Acceptance,” in *Proceedings of the Nineteenth Annual Pre-ICIS Workshop on HCI Research in MIS*, 2020.

[179] M. A. Rossi, “EU technology-specific industrial policy. The case of 5G and 6G,” *Telecommunications Policy,* vol. 48, no. 2, 2024.

[180] A. Carnevale and C. T. E. B. L. Occhipinti, “L’origine e i limiti del dibattito politico sul 5G,” *Euractiv,* 2020.

[181] E. O. C. B. L. Tangari, “Close-The-Loop Model: Social Acceptance of Technology for Sustainability,” *The Climate Action: Mathematics, Informatics and Socio-Economics Accelerating the Sustainability,* no. 121, pp. 26-27, April 2020.

[182] L. Briguglio, P. Nesse, A. Di Giglio, C. Occhipinti, P. Durkin and I. Markopoulos, “Business Value and Social Acceptance for the Validation of 5G Technology,” *IEEE International Mediterranean Conference on Communications and Networking (MeditCom),* pp. 132-137, 2021.

[183] C. Occhipinti, L. Briguglio, A. Carnevale, R. Santilli, E. Tangari and A. Iannone, Privacy and security aspects of 5G technology, Scientific Foresight Unit (STOA) EPRS European Parliamentary Research Service, 2021.

[184] 5G-SOLUTIONS project, “D1.1B "Definition and analysis of use cases/scenarios and corresponding KPIs based on LLs (v2.0)",” 2022.

[185] 5G-SOLUTIONS project, “D8.1A (5G-SOLUTIONS, D8.1A: Market assessment & technology monitoring (v1.0),” 2020.

[186] R. K. Mitchell and e. al, “Toward a theory of stakeholder identification and salience: Defining the principle of who and what really counts,” *Academy of management review,* vol. 22, no. 4, pp. 853-886, 1997.

[187] G. J. Miller, “Stakeholder roles in artificial intelligence projects,” *Project Leadership and Society,* vol. 3, 2022.

[188] P. Brey, S. Roeser, W. IJsselsteijn and e. al, “Ethics of Socially Disruptive Technologies,” *Project proposal for Netherlands Organisation of Scientific Research,* 2019.

[189] J. Hopster, “What are socially disruptive technologies?,” *Technology in Society,* vol. 67, no. 101750, 2021.

[190] B. Schuelke-Leech, “A model for understanding the orders of magnitude of disruptive technologies,” *Technol. Forecast. Soc. Change,* vol. 129, p. 261–274, 2018.

[191] I. Van de Poel, “Embedding values in artificial intelligence (AI) systems.,” *Minds and machines,* vol. 30, no. 3, pp. 385-409., 2020.

[192] L. Royakkers and I. Van de Poel, “Ethics, Technology, and Engineering: an introduction,” 2011.

[193] T. Flanagan, “Scripting a Collaborative Narrative: An Approach for Spanning Boundaries,” *Design Management Review,* vol. 19, no. 3, 2008.

[194] N. C. e. a. Bronfman, “Understanding social acceptance of electricity generation sources.,” *Energy policy,* vol. 46, pp. 246-252, 2012.

[195] W. e. a. Li, “Research on the impact factors of public acceptance towards NIMBY facilities in China-A case study on hazardous chemicals factory.,” *Habitat International,* pp. 11-19, 2019.

[196] M. Siegrist, “The influence of trust and perceptions of risks and benefits on the acceptance of gene technology,” *Risk analysis,* vol. 20, no. 2, pp. 195-204., 2000.

[197] B. W. e. a. Terwel, “Going beyond the properties of CO2 capture and storage (CCS) technology: How trust in stakeholders affects public acceptance of CCS,” *International Journal of Greenhouse Gas Control,* vol. 5, no. 2, pp. 181-188, 2011.

[198] A. e. al., “Acceptance of 5 G technology: Mediation role of Trust and Concentration.,” *Journal of Engineering and Technology Management,* vol. 57, 2020.

[199] F. a. S. W. C. Liang, “Explaining the technological acceptance of 5G: Quantitative and qualitative insights from China and the United States.,” *International Communication Gazette,* vol. 86, no. 6, pp. 655-671, 2024.

[200] J. a. K. N. Delhey, “Predicting cross-national levels of social trust: global pattern or Nordic exceptionalism?,” *European sociological review,* vol. 21, no. 4, pp. 311-327, 2005.

[201] F. Fukuyama, Trust: The social virtues and the creation of prosperity., Simon and Schuster, 1996.

[202] P. J. &. K. S. Zak, “Trust and Growth.,” *The Economic Journal,,* vol. 111, p. 295–321., 2001.

[203] W. R. Freudenburg, “Perceived Risk, Real Risk: Social Science and the Art of Probabilistic Risk Assessment,” *Science,* vol. 242, no. 4875, pp. 44-49, 1988.

[204] W. Poortinga and N. Pidgeon, “Trust in Risk Regulation: Cause or Consequence of the Acceptability of GM Food?,” *Risk Analysis,* vol. 25, no. 1, pp. 199-209, 2005.

[205] GSMA, “Safety of 5G Networks,” - - 2020. [Online]. Available: https://www.gsma.com/solutions-and-impact/connectivity-for-good/public-policy/regulatory-environment/emf-and-health/safety-of-5g-networks/. [Accessed 11 September 2024].

[206] UNESCO COMEST, “The Precautionary Principle,” 2005. [Online]. Available: https://unesdoc.unesco.org/ark:/48223/pf0000139578.

[207] P. Assembly, “The Potential dangers of electromagnetic fields and their effect on the environment.,” 27 May 2011. [Online]. Available: https://assembly.coe.int/nw/xml/XRef/Xref-XML2HTML-en.asp?fileid=17994. [Accessed 12 June 2024].

[208] M. W. News, “IARC will soon reassess RF Cancer Risk – Or maybe not.,” 21 March 2024. [Online]. Available: https://www.microwavenews.com/news-center/iarc-2nd-rf-monograph-meeting. [Accessed 4 June 2024].

[209] I. Europe, “Eric Van Rongen, of the International Commission on Non-Ionising Radiation Protection: “We need more studies on 5G, but it is not ICNIRP’s task to decide that.,” 2 April 2020. [Online]. Available: https://www.investigate-europe.eu/posts/eric-van-rongen-of-the-international-commission-on-non-ionising-radiation-protection-we-need-more-studies-on-5g-but-it-is-not-icnirps-task-to-decide-that. [Accessed 3 June 2024].

[210] I. a. P. P. Eliassen, “Real 5G issues overshadowed by COVID-19 conspiracy theories.,” 12 June 2020. [Online]. Available: https://www.investigate-europe.eu/posts/5g-covid-conspiracy.

[211] E. a. K. L. Braun, ““Macron ‘Amish’ comments fuel grassroots 5G skepticism,” 23 September 2020. [Online]. Available: https://www.politico.eu/article/emmanuel-macrons-amish-comments-5g-detractors/. [Accessed 11 June 2024].

[212] O. Mollaret, “Lyon: Grégory Doucet signe une tribune pour un moratoire sur la 5G.,” 13 September 2020. [Online]. Available: https://www.lyoncapitale.fr/actualite/lyon-gregory-doucet-signe-une-tribune-pour-une-moratoire-sur-la-5g. [Accessed 11 June 2024].

[213] O. Mollaret, “Lyon: une journée de mobilisation contre la 5G le 19 septembre,” 13 Septembre 2020. [Online]. Available: https://www.lyoncapitale.fr/actualite/lyon-une-journee-de-mobilisation-contre-la-5g-le-19-septembre. [Accessed 11 June 2024].

[214] R. JDD, “EXCLUSIF. Lyon, Bordeaux, Marseille : les maires de 11 grandes villes demandent un moratoire sur la 5G,” 12 September 2020. [Online]. Available: https://www.lejdd.fr/Societe/5g-une-soixantaine-de-maires-et-de-deputes-demandent-un-moratoire-au-moins-jusqua-lete-2021-3991401.

[215] M. Damgé, “Une ville ou une région peuvent-elles interdire la 5G ?,” 15 September 2020. [Online]. Available: https://www.lemonde.fr/les-decodeurs/article/2020/09/15/une-ville-ou-une-region-peuvent-elles-interdire-la-5g_6052267_4355770.html. [Accessed 18 June 2024].

[216] Ilpost.it, “I comuni italiani temono ancora il 5G,” 4 June 2020. [Online]. Available: https://www.ilpost.it/2024/06/04/comuni-opposizione-rete-5g/. [Accessed 4 June 2024].

[217] L. Zorloni, “C'è stato un boom di Comuni no-5G durante l'emergenza coronavirus,” 5 May 2020. [Online]. Available: https://www.wired.it/internet/tlc/2020/05/26/5g-comuni-no-coronavirus/. [Accessed 11 June 2024].

[218] G. Falcomatà, “Ord. Sind. N.75/2020 – Sospensione precauz. della sperimentazione e/o attivazione della tecnologia 5G sul territorio del Comune di Reggio Calabria,” 6 July 2020. [Online]. Available: https://www.reggiocal.it/Notizie/Details/1289#:~:text=Descrizione%20Il%20Sindaco%20Giuseppe%20Falcomat%C3%A0%2C%20con%20ordinanza%20sindacale,5G%20sull%27intero%20territorio%20del%20Comune%20di%20Reggio%20Calabria%3B. [Accessed 11 June 2024].

[219] P. d. Repubblica, “Ulteriori disposizioni in materia di politiche di coesione,” 7 May 2024. [Online]. Available: https://www.gazzettaufficiale.it/eli/id/2024/05/07/24G00077/sg. [Accessed 18 June 2024].

[220] A. L. V. s. antennes, “Les cantons Neuchâtel, Jura, Genève Demandent un Moratoire sur la 5G Millimétrique,” 11 May 2021. [Online]. Available: https://levaudsansantennes.ch/2021/05/18/les-cantons-neuchatel-jura-geneve-demandent-un-moratoire-sur-la-5g-millimetrique/. [Accessed 18 June 2024].

[221] Jura, “Le Parlement jurassien rétablit un moratoire sur le déploiement de la 5G,” 31 October 2019. [Online]. Available: https://www.rts.ch/info/regions/jura/10828789-le-parlement-jurassien-retablit-un-moratoire-sur-le-deploiement-de-la-5g.html. [Accessed 18 June 2024].

[222] Swissinfo.ch, “5G: from popular anger to people’s initiatives,” 6 December 2019. [Online]. Available: https://www.swissinfo.ch/eng/democracy/direct-democracy_5g-from-popular-anger-to-people-s-initiatives/45415836. [Accessed 19 June 2024].

[223] RTS.ch, “Un rapport fédéral affirme que la 5G n'est pas nocive pour la santé,” 28 July 2022. [Online]. Available: https://www.rts.ch/info/suisse/13272441-un-rapport-federal-affirme-que-la-5g-nest-pas-nocive-pour-la-sante.html.

[224] Swissinfo.ch, “Initiative aims to overcome Swiss public’s 5G technology misconceptions,” 10 July 2020. [Online]. Available: https://www.swissinfo.ch/eng/politics/initiative-aims-to-overcome-swiss-public-s-5g-technology-misconceptions/45894726. [Accessed 20 June 2024].

[225] S. Baudino, “Siderno, la città calabrese che lotta contro le antenne 5G,” 3 July 2024. [Online]. Available: https://www.lindipendente.online/2024/07/03/siderno-la-citta-calabrese-che-lotta-contro-le-antenne-5g/. [Accessed 11 July 2024].

[226] K. Shepherd, D. Hubbard, N. Fenton, K. Claxton, E. Luedeling and J. De Leeuw, "Policy: Development goals should enable decision-making," *Nature,* vol. 523, p. 152–154, July 2015.

[227] R. Nicels, “Roger Nichols: 6G is about Impacts, not data rates.’ Interviewed by Michael Koziol,” *IEEE Spectrum,* 2022.

[228] E. Murphy, P. P. Walsh and A. Banerjee, *Framework for Achieving the Environmental Sustainable Development Goals,* EPA Research, Report No. 397, 2021.

[229] B. Mittelstadt, "Principles Alone Cannot Guarantee Ethical AI," *Nature Machine Intelligence,* 2019.

[230] D. Meadows, "Indicators and Information Systems for Sustainable Development," in *The Earthscan Reader in Sustainable Cities*, 1 ed., London, Routledge, 2021, p. 364–393.

[231] L. Mattei, “The semiconductor supply chain: searching for a balance in the global asset,” *ITSS Verona Magazine,* vol. 3, 2024.

[232] M. Matinmikko-Blue, S. Aalto, M. I. Asghar, H. Berndt, Y. Chen, S. Dixit, R. Jurva, P. Karppinen, M. Kekkonen, M. Kinnula, P. Kostakos, J. Lindberg, E. Mutafungwa, K. Ojutkangas, E. Rossi, S. Yrjola, A. Oorni, P. Ahokangas, M.-Z. Asghar, F. Chen, N. Iivari, M. Katz, A. Kinnula, J. Noll, H. Oinas-Kukkonen, I. Oppermann, E. Peltonen, H. Saarela, H. Saarnisaari, A. Suorsa, G. Wikstrom and V. Ziegler, *White Paper on 6G Drivers and the UN SDGs,* arXiv, 2020.

[233] W. Ahmed, J. Vidal-Alaball, J. Downing and F. L. Seguí, “COVID-19 and the 5G conspiracy theory: social network analysis of Twitter data,” *Journal of medical internet research,* vol. 22, no. 5, 2020.

APPENDIX A – A GLIMPSE ON SPECIFIC APPLICATION SCENARIOS

6G's enhanced connectivity is expected to deeply change existing communication technologies and networks. Integration with other cutting-edge technologies such as artificial intelligence, Internet of Things (IoT), and edge computing, holds the potential of disrupt existing industries by enabling new business models, altering production processes, and changing the way services are delivered across sectors. Changes will concern both the level of existing technological infrastructure, and vertical sectors like healthcare, manufacturing, transportation, and entertainment. Applications such as telemedicine, precision agriculture, autonomous vehicles, renewable energy and smart cities stand to benefit greatly from 6G technology. In particular, healthcare and education stand to be profoundly transformed.

Health-care and Well-being: in the realm of healthcare and well-being, increased connectivity has already enabled significant advancements in telemedicine and mental health support. The enhanced connectivity of current technologies has facilitated high-quality consultations and remote monitoring. With the advent of 6G, we can expect these capabilities to expand further, since advanced telemedicine and distance learning enabled by 6G could redefine how societies approach, manage, and experience these essential services. Continuous and real-time health monitoring through IoT devices, more immersive virtual and augmented reality consultations, as well as remote medical procedures could dramatically improve healthcare access and outcomes. In the realm of mental health support, real-time AI-driven interventions and virtual therapy sessions open the way for the possibility of reaching more people in need of mental healthcare. However, notwithstanding technological feasibility, the debate is open about the potential and pitfalls of mental health remote support, through counselling or apps.

Digital and Online Learning: education and learning have been similarly transformed. Online learning platforms have democratised access to education, allowing individuals to learn from anywhere at any time. The transition from 4G to 5G improved the quality and accessibility of these platforms, and 6G promises to make online education even more interactive and effective. We can anticipate real-time feedback, virtual labs, and AI-driven personalised learning paths that will further transform the educational landscape.

Entertainment and media consumption: streaming services and online gaming have become integral parts of modern entertainment, with high-speed, low-latency capabilities improving the quality of these experiences. As we move towards 6G, we can anticipate ultra-high-definition streaming, real-time interactivity, and cloud gaming becoming seamless, providing richer and more immersive experiences. Enhanced connectivity has also given rise to new forms of content creation and distribution, allowing for real-time collaboration and high-quality production. Platforms like YouTube and TikTok have flourished, allowing individuals to become creators and reach global audiences. Looking towards 6G, we can expect creators to push boundaries further, with real-time feedback, virtual sets, and advanced production tools becoming more accessible.

Industrial and business sector: smart networks are expected to contribute to the creation of new ecosystems, value chains, markets, and transformational services, built on novel conceptions and business models emerging from 6G capabilities. Manufacturing is expected to benefit from improved human-machine interaction (HMI) across services and industries, and from a more harmonised relation between human intelligence and advanced, cognitive computing. This will result in full digital automation of the process, which in turn will further support the production of highly sophisticated products, systems, and personalised services and tailorisation (including mass customisation), while guaranteeing process efficiency. Besides this, the availability in real-time of data and their analysis, is expected to promote a shift from product creation to service delivery (product servitisation).

APPENDIX B – HEALTH AND SAFETY DEBATE AROUND 5G

The following is a summary of the ongoing debate regarding the potential health impacts of 5G technology. It focuses especially on reporting the positions held by members of the scientific community who have expressed concerns about possible health effects. The aim is to provide an overview of the current scientific discourse surrounding this controversial topic.

Introduction: Public Concerns

The rollout of 5G technology has reignited long-standing debates about the potential health risks posed by radiofrequency electromagnetic fields (RF-EMF). Industry groups, such as the **GSMA**, argue that the radio signals used in mobile networks, including 5G, are safe and in compliance with international guidelines like those set by the **International Commission on Non-Ionizing Radiation Protection** (**ICNIRP**). GSMA reassures the public that no credible evidence links 5G to adverse health effects. However, their communication strategy, including RF-EMF's carcinogenic classification to that of pickled vegetables [205], potentially understates the complexity of ongoing scientific investigations into RF exposure and health risks.

Chronological Context: Key Milestones

May 31, 2011 – WHO/IARC Classification: The International Agency for Research on Cancer (IARC) classified RF-EMF as "possibly carcinogenic to humans" (Group 2B), largely based on studies linking wireless phone use to an increased risk of gliomas, a type of brain cancer.

September 13, **2017 – The 5G Appeal**: Over 230 scientists and doctors signed the 5G Appeal [134], calling for a moratorium on 5G deployment until independent research can fully assess potential health hazards. By **July 2024**, this number had risen to 438 signatories. The appeal argues that 5G's higher frequencies and widespread antenna deployment could increase public exposure to RF-EMF, exacerbating risks such as cancer, genetic damage, neurological disorders, and harm to reproductive health.

April 2019 – **Calls for Reevaluation**: An IARC advisory committee recommended that RF-EMF exposure be re-evaluated as "high priority", based on new findings from the **National Toxicology Program** (NTP) and **Ramazzini Institute** animal studies, which demonstrated higher rates of tumours in rats exposed to cell phone radiation. The reassessment is slated for 2024, with the potential to upgrade RF's carcinogenic status.

December 2022 – IARC Decision on RF Re-Evaluation: IARC Director Elisabete Weiderpass suggested that the reassessment of RF-EMF could take place in early 2024. This decision came after mounting calls for a re-evaluation due to the growing body of scientific evidence regarding the risks associated with RF exposure.

Scientific Evidence and Legitimate Concerns

Lower frequencies (450-6000 MHz): The Scientific Technology Options Assessment (**STOA**) Report (2021), authored by **Dr. Fiorella Belpoggi**, reviewed evidence related to RF-EMF exposure in this frequency range. It found limited evidence of carcinogenicity in humans but sufficient evidence of reproductive and developmental hazards, particularly in animal studies. The report also flagged the need for more comprehensive research on these effects in humans.

Higher frequencies (24-100 GHz): Very few studies have been conducted on millimetre waves (used in 5G), leaving a significant gap in our understanding of their potential health impacts. The 5G Appeal emphasizes the importance of studying non-thermal effects of these higher frequencies. Scientists warn that the proliferation of small cell antennas required for 5G could significantly increase public exposure.

Precautionary Principle and Resolution 1815: The 5G Appeal stresses that the Precautionary Principle [206] (2005), which recommends precaution in cases of scientific uncertainty, and **Council of Europe Resolution 1815** [207], which advises reducing exposure to RF-EMF, should be applied to 5G technology. The current safety guidelines, they argue, prioritize industry interests over public health, necessitating stricter regulations to protect vulnerable populations.

GSMA's language vs. Scientific Concerns

GSMA's Position: GSMA emphasises that 5G complies with international safety standards and cites the updated ICNIRP guidelines (2020), which cover the frequencies used by 5G. They claim there is no credible evidence linking RF radiation from 5G to health risks as long as exposure stays within established limits. GSMA dismisses claims that 5G is harmful, often comparing RF-EMF exposure to other low-risk activities like eating pickled vegetables, thus downplaying legitimate scientific concerns.

GSMA's Approach: GSMA's language fails to adequately address the concerns raised by scientists, particularly those involved in the 5G Appeal. Their comparison of RF-EMF to trivial risks, such as processed foods, trivialises serious concerns about long-term exposure to RF-EMF. Moreover, GSMA does not address the growing body of evidence from animal studies and epidemiological research that suggests RF-EMF may have harmful biological effects, even at exposure levels below current guidelines.

Legitimate Scientific Debate

The **5G Appeal** stresses that a significant number of scientists, including those unaffiliated with industry, have expressed serious concerns about the health impacts of RF-EMF, particularly with 5G. They point to peer-reviewed studies showing biological effects, such as increased cancer risk, cellular stress, genetic damage, and reproductive harm, occurring at exposure levels well below ICNIRP guidelines. These scientists argue for a precautionary approach until more conclusive data is available.

Sceptical Scientists (ICNIRP and IARC Affiliates): On the other hand, many scientists remain sceptical of any strong link between RF-EMF and carcinogenicity. For example, **Joachim Schüz**, head of IARC's environment section, has publicly expressed scepticism about RF-EMF leading to cancer, citing inconsistencies in epidemiological studies like **Interphone** and **Hardell** studies [208]**.** Schüz, along with **Eric van Rongen** from ICNIRP, has emphasized that the evidence is insufficient to revise exposure limits or justify any classification upgrade. Schüz's opinion, shared by other scientists, highlights that while the **NTP** and **Ramazzini** studies show cancer links in animals, these results are not yet conclusive to animals.

ICNIRP's Position: Eric van Rongen, the vice chair of ICNIRP, and his colleagues have consistently argued that while more research is needed, the existing data not conclusively show that RF-EMF from 5G is harmful to human health. ICNIRP maintains that the current guidelines, focused on preventing tissue heating, provide adequate protection against known health risks, and they question the quality and reproducibility of studies that claim otherwise [209].

Investigate Europe (team of investigative journalists) reports [210] supports the view that the scientific community is divided. It notes that legitimate questions about 5G's health effects are often overshadowed by baseless conspiracy theories, such as those linking 5G to COVID-19. This polarisation has made it difficult to have a clear, informed public debate. The real scientific disagreements around RF-EMF and 5G remain unresolved, particularly due to the lack of studies on millimetre waves.

Recent Developments (Evolving Stance of IARC)

In March 2024, a new group of IARC advisors met in Lyon to set the agency's research priorities for 2025-2029. Despite earlier indications that IARC would reassess RF's carcinogenic risk in 2024, the timeline remains uncertain. **Elisabete Weiderpass**, IARC's director, has provided varying updates on the status of this reassessment, with potential delays attributed to ongoing studies requiring further validation. The scientific community continues to debate issue, with interpretations ranging from calls for precautionary measures to demands for more conclusive evidence before implementing regulatory changes.

This overview highlights the legitimate scientific concerns surrounding 5G technology, juxtaposing them with industry assurances provided by organisations like GSMA. While GSMA emphasises regulatory compliance and existing safety standards, their communications often do not fully acknowledge the ongoing scientific debate. The scientific community itself is divided: some experts advocate for a precautionary approach based on animal studies and epidemiological data, while others, including prominent figures from IARC and ICNIRP, maintain that current evidence is insufficient to warrant heightened concern. This complex landscape stresses the need for a more nuanced public discourse that addresses both the established safety standards set by bodies like ICNIRP and the valid health concerns raised by independent scientists. Such a balanced approach is crucial for fostering informed decision-making and public understanding of the potential risks and benefits associated with 5G technology. Addressing these health controversies is particularly important as they represent one of the primary concerns driving opposition to the 5G rollout, making a thorough understanding of this debate essential for any comprehensive analysis of social acceptance and resistance to 5G technology.

APPENDIX C – EXAMPLES OF 5G CONTROVERSIES IN THE EU

France

The rollout of 5G technology in France illustrates key tensions between national technological ambitions and local autonomy. The controversy gained significant public attention when President Emmanuel Macron dismissed 5G critics as favouring an “Amish model” and wanting France to “return to the oil lamp” [211]. This dismissive stance toward opposition became emblematic of broader governance challenges in implementing new technologies [212].

Main points of Controversy: The resistance centred on three key issues: health concerns, environmental impacts, and notably, the perceived lack of democratic debate. In September 2020, protesters gathered in Lyon [213], with their messaging directly challenging Macron’s characterization of opposition. The controversy expanded beyond traditional environmental concerns when approximately sixty elected representatives[7], including prominent figures like Jean-Luc Mélenchon and François Ruffin, published an opinion piece calling for a delay in 5G rollout [214]. Their concerns focused on:

- Ecological Impact (resource exploitation and e-waste)
- Health implications from electromagnetic exposure.
- Need for democratic consultation

Grenoble provides a compelling example of the dynamics at play. As a recognized hub for technological innovation, the city exemplifies the tension between technological advancement and environmental priorities. Under Green Party governance since 2014, the municipality has actively opposed 5G deployment while maintaining its status as a tech centre. The case reflects the efforts of local authorities to navigate competing priorities within the framework of national policy, seeking to harmonize innovation with sustainable governance.

Governance implications: The implementation revealed significant institutional tensions. Despite opposition from mayors in cities like Lyon and Grenoble, telecom operators proceeded with network expansion, installing over 2,300 antennas in the Auvergne-Rhône-Alps region by early 2021. This limited the legal authority of municipalities, as confirmed by a 2011 Conseil d’État ruling that restricted local governments’ ability to opposed rollout [215]. The varied response across French cities – from Lille’s moratorium to Marseille’s embrace of the technology – demonstrates the challenge of balancing national technological priorities with local concerns. More significantly, it reveals how technological implementation becomes a battlefield for broader questions about democratic participation and governance levels in technological decision-making.

Italy

The Italian experience with 5G deployment brings to the fore a particularly acute tension between national objectives and municipal autonomy. While the national government pursued aggressive deployment targets as part of its digital transformation strategy, a significant

[7] The call for a moratorium on 5G by prominent mayors and elected officials, including those from Lyon and Villeurbanne, illustrates how parts of the political class took steps to reflect citizen concerns about the rollout, specifically regarding its health and environmental impacts, and the need for public debate.

grassroots movement emerged at the local level, leading to widespread municipal resistance [216].

Main points of Controversy: The opposition in Italy crystallized around several issues that gained momentum during 2020-2021:

- Health and environmental concerns, often framed through the precautionary principle
- Questions of local autonomy in technological decision-making
- Democratic participation in infrastructure planning, approximately 4.5 million Italians were living in municipalities that had implemented measures against 5G, demonstrating the scale of local resistance [217].

Municipal Bans and Legal Challenges: The tension between governance levels came to a head through a series of legal confrontations. By April 2021, around 60 municipalities had implemented 5G bans. A notable example is Reggio Calabria, where Mayor Giuseppe Falcomatà justified the ban by invoking the precautionary principle [218]. These local initiatives were subsequently challenged through two main channels:

1. Court cases initiated by telecommunication companies, which generally ruled in favor of operators.
2. The national government's Decree, specifically designed to limit municipal authority over 5G deployment [219].

Governance Implications: The Italian case reveals several critical aspects of technological governance:

- The limits of local authorities in national infrastructure projects
- The role of legal frameworks in resolving multi-level governance conflicts
- The challenge of balancing technological progress with local democratic processes

Recent developments under the Draghi and Meloni governments demonstrate the persistent nature of these challenges. Despite national-level interventions aimed at accelerating deployment, local resistance continues to significantly impact 5G rollout in underserved areas. This ongoing tension suggests that purely top-down approaches to technological implementation may be insufficient for achieving both technical and social objectives.

Switzerland

Switzerland offers a distinctive case in 5G implementation, where strong democratic traditions and decentralized governance structures significantly shaped the technology's rollout. Despite being an early adopter with Swisscom claiming over 90% population coverage by early 2020, the deployment faced unique challenges within Switzerland's direct democracy system [220] [221].

Main points of Controversy: While sharing common concerns with other European countries regarding health and environmental impacts, Switzerland's response was characterized by:

1. Formal democratic initiatives targeting 5G implementation [222]:

- Proposals to make telecom companies liable for potential damages
- Initiatives to increase local control over antenna placement
- Calls for more sustainable network planning

2. Regional variations in implementation: Several cantons, including Geneva, Vaud, and Jura, enacted moratoriums on new 5G antennas, creating a patchwork of regulations across the country.

Geneva's Response: Geneva's experience particularly illustrates the complexity of 5G governance in the Swiss context. The canton's moratorium represented a direct challenge to federal deployment plans. Analysis of antenna placement revealed concentration patterns that raised questions about service equity, demonstrating how technical decisions intersect with social considerations.

Governance Implications: Switzerland's experience brings to the fore several distinctive aspects of technological governance:

1. The Role of Scientific Assessment: The July 2022 federal study on health impacts attempted to address public concerns through scientific evidence [223]. However, debates about methodology and interpretation demonstrated the challenges of using technical assessments to resolve societal concerns.
2. Adaptive Industry Response: The launch of the "CHANGE5G" platform in July 2020 represented a shift toward proactive stakeholder engagement, acknowledging the need for public dialogue beyond technical considerations [224].
3. Evolution of Technology and Regulation: The ongoing adjustment of both technical specifications and regulatory frameworks shows how governance systems can adapt to public concerns while maintaining development goals.

The Swiss case demonstrates how established democratic mechanisms can shape technological implementation, suggesting that effective governance requires flexibility in both technical and social dimensions.

The examination of France, Italy, and Switzerland's experiences with 5G deployment reveals distinct yet interconnected patterns in how technological controversies manifest across different national contexts. While France exemplifies the tension between national technological ambitions and local environmental priorities, Italy shows how municipal authorities can become powerful actors in technological resistance, challenging national implementation strategies. Switzerland, meanwhile, demonstrates how established democratic mechanisms can shape technological implementation. Together, these cases illustrate how infrastructure-based innovations necessarily engage with existing socio-political structures, leading to varying forms of resistance and adaptation.

The analysis is not exhaustive, and significant work remains to be done in documenting and understanding the full scope of 5G implementation controversies across Europe and beyond. A comprehensive project examining the rollout of 5G from the perspective of public concerns and oppositions is urgently needed. Such research would not only provide valuable insights for future technological deployments but would also help illuminate the complex dynamics of the public sphere in technological decision-making. By bridging controversies to the forefront of analysis, rather than treating them as obstacles to be overcome, enables a better understand the diverse stakeholders involved and their roles in shaping technological governance. The ongoing rollout of 5G presents a unique opportunity to study and document how societies engage with and shape technological implementation. The mapping of controversies might be an important first step if one wants to move towards the development of a Social Acceptance of Technology framework.

APPENDIX D – A COMMON EXAMPLE OF MISTRUST AND DISTRUST

"In the heart of our community of Siderno, near via Carrera, an **attack** on the **health** and **safety** of our citizens is about to be perpetrated". This is what some residents of Siderno wrote at the end of May (**2024**) [225] in a letter, opposing to the construction of the 5G facility. "A 5G antenna, approximately 30 metres high, is about to be installed close to homes where many families with children live. This despicable project imposed from above without any respect for the **popular will**, represents a grave threat that we cannot tolerate." According to signatories, the installation of the antenna would not only represent "**a danger to health**" but would also deface the urban landscape, "**degrading the quality of life**" in the neighbourhood and **lowering the value** of real estate properties for those who live there. "We, residents of the municipality of Siderno, ask for the immediate suspension of the 5G antenna installation project - it continues to read in the letter. We demand an independent and rigorous assessment of the health risks associated with this technology, with particular attention to the vulnerability of children and the elderly who live in the area."

On June 4th, the municipal administration and the representatives of the *No al 5G Sotto Casa* committee met at City Hall with representatives of Vodafone and Inwit, respectively the manager and the company responsible for the antenna, to whom the citizens' demands and the administration's willingness to relocate the facility were expressed. While waiting for a response from Vodafone and Inwit, the Committee has launched a petition against the installation of the antenna, requesting "an intervention by the Environment Councilor in concert with Arpacal (Regional Agency for Environmental Protection of Calabria), for a control of the electromagnetic field levels generated by repeaters or antennas mentioned above, as such measurements falls within the verifiability of the electromagnetic radiation emitted by the same sources near the residents' homes." The proposal was welcomed by the mayor, who last Wednesday invited the municipal offices to fulfil the request.

The Siderno case exemplifies the controversies surrounding 5G implementation. Driven primarily by health and safety concerns, the residents' response illuminates key aspects of trust and distrust in technology rollout. Their emotionally charged language ("attack", "despicable project") is an example of a deep-seated mistrust and perceived threat. Institutional trust and procedural fairness emerge as central issues, with residents feeling the project was "imposed from above" without regard for their will. This perceived lack of transparency and democratic process in decision-making has fostered distrust towards authorities and companies involved. Multiple objects of distrust become apparent: the technology itself, the implementing organisations, and the decision-making process all face scrutiny. Beyond health concerns, the community's opposition extends to environmental impact, quality of life, and property values. Such multipronged resistance highlights the complex interplay of factors influencing technology acceptance and trust, encompassing both individual and collective interests.

Local government's response to these concerns, evidenced by stakeholder meetings and mayor's actions, indicates an attempt at rebuilding trust through dialogue and responsiveness. Yet, uncertainty persists as the community pushes for further assessment and potential antenna relocation. Their call for "independent and rigorous assessment" of health risks demonstrate a desire for evidence-based decision-making, emphasising the role of scientific expertise in trust-building processes.