

Article

Sustainability as a Challenge and Driver for Novel Ecosystemic 6G Business Scenarios

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Abstract: Climate change, the deterioration of the environment and exceeding Earth's carrying capacity are major threats in operating environment which require new actions in industrialized and digitalized society. In parallel with the global deployment of 5th generation (5G) mobile communication networks, the telecommunication community has already started to envision 6G networks that target the year 2030. This paper discusses the unprecedented opportunities in the future 6G ecosystem specifically from the business perspective and applies a futures-oriented scenario planning method utilized in two strategy workshops in 2020. The paper portrays four scenario themes and a total of 16 alternative future scenarios for the business of 6G. Through the identification of key trends, their interactions, and related uncertainties, the scenario development process generates alternative futures where 6G business strategies are then developed and assessed through the business model perspective. Scenarios were created under four themes: user experience, business, sustainability, and geopolitics and they are discussed in terms of economical, societal, and environmental perspectives. The findings of the paper highlight the achievement of a preferred sustainable future that calls for attention to the privacy and security aspects considering business and regulatory needs: public/governmental, corporate, community, and human perspectives and aims of governance; ecosystem configuration related to users, decentralized business models, and platforms; user empowerment; and the role of service location-specificity. The findings indicate that it is vital to bring together relevant stakeholders to solve sustainability problems within the ecosystem and pay special attention to open ecosystem-focused value configuration and decentralized poly-nodal power configuration, while responding to the diversified demands of various users across the different verticals.

Keywords: anticipatory action learning; ecosystems; business models; mobile communications; platforms; scenario planning; sustainability; 6G

1. Introduction

Business models of the digital time have been transforming existing industries with unprecedented speed, and the telecommunications industry follows a similar path. The wireless network technology evolution and revolution will transform multiple sectors through services provided at speeds of hundreds of gigabits per second, support of a wide range of novel applications connecting billions of devices and objects, and versatility by virtualization, enabling innovative business models [1,2]. The very first 5th generation (5G) mobile communication networks of release 15 of the 3GPP under deployment have focused on enhanced mobile broadband use cases. The standard release 16 introduced capabilities for industrial ultra-reliable low latency communication use cases in June 2020, and release 17 planned for December 2021 has its focus on high numbers of Internet of Things (IoT) devices,

also known as massive machine-type communication. The current 5G market is dominated by incumbent mobile network operators (MNOs), who provide service to the masses with the help of high infrastructure investments and spectrum licenses granted by the regulators with exclusivity nationwide. At the same time, the delivery of services is changing from MNO centrality to more dynamicity [3]. This stems from the 5G architectural developments where software-defined networking, network function virtualization and network slicing, and cloudification dominate. Additionally, related business developments are taking place such as emerging new local 5G micro operator service business models and vertically structured service and application ecosystems [4].

To make sense of 6G business using alternative futures research, it is important to depict the future 6G systems targeting deployment in the 2030s in a holistic manner covering the interaction between technology and society. The convergence between nanotechnology, biotechnology, information technology, and cognitive science has increased lately. 6G technologies [5] will be at the heart of this convergence and fundamentally contribute to society. In turn, new models for business engagement, identification of opportunities, and development of strategies for both small enterprises and large conglomerates are expected to emerge [2]. The application of big data, artificial intelligence (AI), and cloud computing at the edge of the network with ubiquitous near-real-time wireless connectivity in 6G will change many aspects of our personal and working lives, and the structure of the economy in the 2030s. The inclusion of information technology and communication techniques into the physical industries will positively contribute to productivity growth, especially when digital twins are integrated into the physical world.

The future of 6G will be influenced by increasing societal requirements including inclusivity, sustainability, resilience, and transparency which add up to a complicated societal mix [5,6]. This calls transdisciplinary interaction and human-centered design of technologies from the quintuple of political, economic, social, technological, and environmental perspectives [7]. We are witnessing the emergence of new consumers known as “experientials” who see the user experience as being central in the interaction with technologies [8]. The business perspective specifically needs to consider sustainability [9,10] in a way that combines the economic (e.g., profit, business stability, financial resilience, viability), societal (e.g., individuals’, communities’, regulative values), and environmental (e.g., renewables, low emissions, low waste, biodiversity, pollution prevention) perspectives.

While the basic broadband connectivity service continues to turn into a commodity, the telecommunication industry is seeking ways to expand its connectivity provider role towards the digital transformation [2]. Value chains are increasingly built around access to data and data ownership. Limiting the access to data has become an efficient means of control and restricting opportunity for empowerment. The future 6G system will need to transform how data is collected, shared, analyzed, and acted upon, which creates strong drivers for the future value creation and introduces novel stakeholder roles in the ecosystem. At the same time, the development may also result in severe privacy and ethical concerns about the location and use of data. The impact of artificial intelligence will not be limited to what things look like but will be more profound in the context, meaning, and function, creating an Internet of skills, Internet of senses, and digital twins, while ensuring that trust, security, and privacy are considered [5]. Already the 5G network itself has been considered as a connectivity platform [2] and it can be extended towards a data platform, connecting intelligence and services together. From the engineering research perspective, where product and manufacturing platforms, and more recently service modularity [11], play a key role, the platforms focus on components and interfaces with the goal of economies of scale. From the economics research perspective, connecting the demand and supply sides to enable sustainable growth and create new markets is crucial [12]. Both perspectives see the important role of platforms in creating an ecosystem around them, highlighting the tight coupling between platforms and ecosystems [13]. For example, the authors in [14] have recently discussed the role of platform with its data and algorithms in the transition from current network-for-connectivity business models to a network-of-services model.

The current 5G business research has focused on MNO business models and sees the role of 5G mainly from the technical perspective at the industry level [15]. Some studies have looked into platform or ecosystemic business models [1–4]. Collaborative business models were introduced in [16] where new roles were identified, including system integrator, neutral host, and broker [17–19]. Web-based service models where operators expose network functionalities were analyzed in [20] and cloud-based business models in [21]. The role of local 5G network services appeared in [22] and the related local 5G micro-operator concept was introduced in [23]. These business models can be seen to be built around two basic MNO business models, including the connectivity service provider and its differentiation [22,24]. To date, there is very little work on 6G business models. 6G vision papers considering future communication needs, enabling technologies, the role of AI, and emerging use cases and applications have recently appeared [5,25–27]. Furthermore, discussion has recently expanded to 6G indicators of value and performance [28], the role of regulation and spectrum sharing [29], the antecedents of multi-sided transactional platforms [30], antecedents of the 6G ecosystem [31], and the exploratory scenarios of 6G business [32].

Building on the above discussion, this paper aims at (a) developing future scenarios for sustainable 6G business strategies and (b) analyzing the scenarios from a sustainable business model perspective. In this, two choices need to be considered. First, rather than focusing on a single focal firm that is common in traditional business model research, this research considers business models as a perspective towards ecosystemic activity. Second, as this research concerns the future, the focus is on exploring alternative futures scenarios in the timeframe 2030–2035. To this aim, this research uses an anticipatory action learning method [33–35] and adopts the scenario planning process [36,37] and business modelling perspective [38,39]. The data for this study are based on a set of virtual future-oriented white paper expert group workshops organized by the 6G Flagship [32] and a set of virtual strategy workshops organized by Faculty of Information Technology and Electrical Engineering at the University of Oulu, Finland, in 2020.

The paper is structured as follows: Section 2 describes the research methods and theory frameworks adopted; Section 3 presents results via identified key trends, uncertainties, and developed scenarios; Section 4 discusses their implications for strategic options and business models; and Section 5 draws conclusions and suggests future research topics.

2. Materials and Methods

In this section we describe the research methods and theoretical background for our scenario planning and analysis.

2.1. Scenario Planning Process

This research applies the anticipatory action learning process [33–35] in which professionals representing different stakeholders relevant to the topic of study come together to generate scenarios. Exploratory scenarios represent a foresight method that provides a means to depict, make sense of, and assess alternative future events, trends, and choices in a holistic manner. The scenarios were generated in a series of facilitated workshops during January–June 2020. Special attention was paid in the workshops to the coherence, variation, and validity of the generated scenarios [40,41]. In practice, the scenario work process comprised teleconference sessions and individual homework carried out in steps [36,37] as depicted in Figure 1.

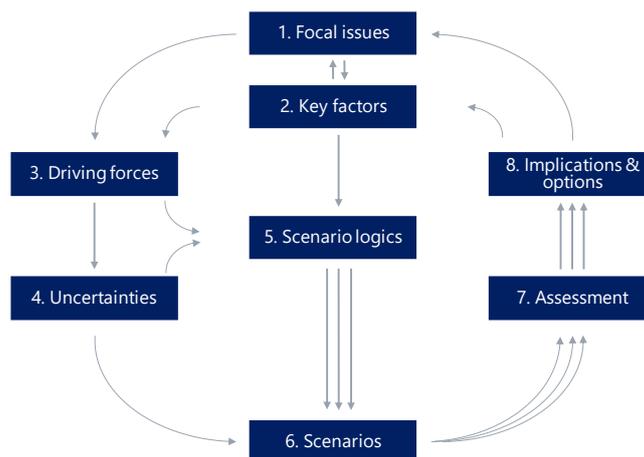


Figure 1. The scenario planning process.

- Defining the focus and relevant time frame: 6G business in 2030–2035, and the global change drivers and focus domains of information technology and electrical engineering research towards the year 2030
- Identification of key factors and driving forces behind the scenarios
- Assessment of the forces in the previous step and choosing the key trends and uncertainties. The assessment was based on the anticipated impact (from small to great) and predictability of consequences (from known to unknown)
- Establishment of the scenario logic based on two orthogonal (unrelated) dimensions that represent significant uncertainties within the selected scenario focus and timeframe
- Creation of the scenario contents for each scenario by building on the identified trends and uncertainties
- Assessment and evaluation of the generated scenarios for their internal consistency, depth and richness of detail, plausibility, and stakeholder behavior [42]
- Utilization of Causal Layered Analysis [34], Futures Triangle [43], and the four perspectives of the Integral Theory [40] to ensure the quality of the scenarios.

For providing high-quality scenarios, the participant composition in the workshops was aimed at ensuring wide variation in participants' backgrounds. Representatives of research, standardization and development, academia, the telecoms industry, government, and verticals were present in all workshops. The generated scenarios were also backcasted [44] to technology-themed 6G White Papers [45] in order to analyze their consistency with key strategic technology options and frames identified in earlier research. Building on desirable futures, backcasting entails working backwards to identify policies and programs that could connect them with the present. Foresight scenarios are by definition futures-focused. This means that the reliability and validity of the scenarios cannot be controlled. However, the quality of scenarios can be evaluated by how probable, plausible, and preferable they appear to be.

2.2. Business Model Perspective

With focus on value creation and capture processes, the business model has become a central analytical device for making boundary-spanning analysis in business research [46]. Traditionally, many business model researchers subscribe to an activity perspective [47] and assume a focal firm. For example, Onetti et al. [47] define the business model "as the way a company structures its own activities in determining the focus, locus and modus of its business." More recent views, e.g., Amit & Zott [48], do not necessarily require a focal firm: "a business model depicts the design of transaction content, structure, and governance so as to create value through the exploitation of business opportunities."

Business models have increasingly been seen as ecosystemic as they connect firms to three strategic choices and related activities within ecosystems: (1) business opportunities that are to be explored and exploited; (2) the value to be (co-)created and (co-)captured; and (3) competitive advantages that are to be explored and exploited [49–51]. Firms' motivation for ecosystemic interaction may be seen to stem from exploring and exploiting opportunities and advantages [52], whereas value co-creation and co-capture—i.e., value creation, delivery, sharing, and capture—are considered the key elements of a functioning business model [53]. In addition, prerequisites for successful business models and growth include three expected strategic consequences: business models need to be (1) scalable [54]; (2) replicable [55]; and (3) sustainable [56]. Although scalability refers to a firm's internal growth potential and flexibility, replicability indicates its external flexibility to adapt. Sustainability, in turn, stems from the feasibility, viability, and environmental or societal impact of a business model. In this, the boundary-spanning feature of the business model concept becomes evident. Business model for sustainability is discussed by Schaltegger, Hansen, & Lüdeke-Freund [56] and it "helps describing, analyzing, managing, and communicating (i) a company's sustainable value proposition to its customers, and all other stakeholders, (ii) how it creates and delivers this value, (iii) and how it captures economic value while maintaining or regenerating natural, social, and economic capital beyond its organizational boundaries." Regarding sustainability, the business model concept is becoming increasingly important as it potentially evokes new forms of governance such as cooperatives, public private partnerships, or social businesses, and helps in transcending the existing rather narrow business models that are made for profit and are profit-maximizing [56].

This research applies the integrated business model configurations and value configurations framework [57] approach to the generated scenarios. Traditionally, business model conceptualizations and value-related discussions have built on Porter's [58] value chain theory and around a supply perspective that sees the business model as a means to capture value from customers [39]. In this view, the producer with the system of activities and respective resources is the sole creator of the value, i.e., the focal firm [59]. In contrast, a demand-focused view emphasizes customer interaction mechanisms to enable value co-creation, highlighting the creation and delivery of value for target customers by using existing resources and processes to promote stable interaction [60].

Additionally, this research further subscribes to service-dominant logic and service ecosystem thinking to analyze the developed scenarios and their potential for transforming the wireless industry from its traditional supply-focused thinking to more ecosystem-focused approaches. Vargo and Lusch [61] see service ecosystems as self-adjusting systems of resource-integrating actors that are connected by shared institutional arrangements and mutual value creation through service exchange. Value co-creation and resource integration are thus seen as systemic and institutional by nature. In case all actors and stakeholders of the ecosystem bring their resources to the common pool—meaning that they continue collaboration within the ecosystem—they all need to benefit from it. The value perspective for ecosystem-focused business models is about value co-creation and co-capture aimed at maximizing the overall ecosystem value and the possible network effects [57]. The ecosystem can be seen to comprise four aspects: (1) the key stakeholders and complementors; (2) governance of networks within it; (3) a modular design of core and periphery; (4) open interfaces and a pool of innovative capabilities and resources [62].

2.3. The Quintuple Helix Model

To accommodate ecosystem thinking, the trends and uncertainties identified in scenario workshops, discussed also in [6,32,63], were categorized utilizing the quintuple helix model [7]. The quintuple helix model is a framework for interdisciplinary and ecosystemic analysis of social ecology and advances in sustainability. The concept aims to explore synergies between ecology and innovation and community, democracy, and business. Here, democracy discusses broadly autonomy and empowerment of the people and basic human rights with attributes like pluralism, heterogeneity, and diversity. The model consists of five segments (helices): policy, education, business, environment, and culture, each

having its own principles. Knowledge is considered as an asset that flows between the segments and transforms into competence and new inventions in the economic system [64]. Furthermore, empowering experiential producers and users in knowledge creation contributes to the democratizing innovation [65] processes in economy, society, and democracy [7].

The assets of the education segment are related to human competencies stemming from the propagation of knowledge and research. The business segment embraces elements of the economic structure and capital of a society, such as governmental organizations, firms, legal and financial actors. Its assets include intellectual properties, manufacturing infrastructure and processes, materials, and capital. The natural assets stem from materials and substances that occur naturally and can be used for economic gain. They include minerals, forests, fertile land, air, water, flora, and fauna. The social culture helix combines media and civil society and discusses related assets like social capital and information. The political and legal segment embodies the accrual of assets and power within their systems and by stakeholders, concretizing in laws and regulations [7].

3. Results

Next, we present the results from our scenario planning for 6G via presenting identified key trends, uncertainties, and developed scenarios.

3.1. Identified Forces

As point of the departure, the workshop participants explored a total of 153 forces in the context of future wireless communications and 6G [32]. Recent works on global trends [63,66–83] were employed as additional secondary data. The forces with the highest impact and the lowest uncertainty were acknowledged as trends, while the high impact, high uncertainty forces were labelled as uncertainties. The assessment results of the forces [32] are summarized in Figure 2 using the segments of quintuple helix concept.

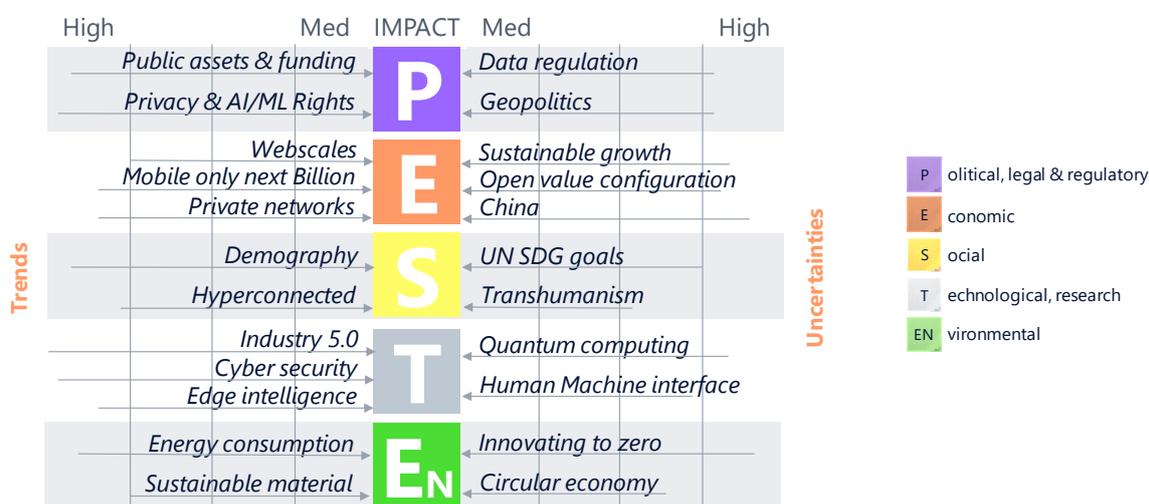


Figure 2. Key trends and uncertainties.

The assessment of forces reveals key trends illustrated on the left side of Figure 2 and important uncertainties on the right side. Next, these prime forces are shortly introduced.

Communal assets and public funding in a 6G context relate particularly to network infrastructure and radio spectrum. Telecommunication network funding and support for deployment programs have conventionally been engaged with rural area coverage and other underserved areas and have now been extended to public–private partnership (PPP) covering several segments of smart communities, such as logistics, transportation, health, public safety, and utilities. Novel PPP funding models emphasize sustainable development and the use of wireless telecommunication infrastructure as a general-purpose

digital platform. Radio spectrum policy, regulation, and management will increase in complexity due to a fast-growing number of frequency bands and a variety of spectrum access concepts such as shared spectrum and local licensing. Localized spectrum licensing will enable distinct network deployments and lower the entry barrier for a variety of new stakeholders. More dynamic spectrum access management will be needed to cope with the rapid introduction of new technologies and the altering needs of users. Shared spectrum concepts will increase the overall efficiency in accommodating novel 6G networks with present deployments. As a valuable asset from financial and innovation perspectives, spectrum regulation plays an important role in technological policymaking looking for an advantage [29].

Mobility-as-a-Service (MaaS) is integrating various transport services into a single mobility service accessible on demand [84]. This comprehensive transport service is intended to provide full mobility services without the need to own and use an own car. The passenger receives a diverse menu of mobility services, such as public transport, ride sharing, taxi or car rental/lease/sharing, or a combination thereof that they need as a door-to-door service and on the basis of a single payment channel instead of multiple ticketing and payment operations. Transport services are intended to work seamlessly together for the passenger and offer value through use of a single application to provide access to mobility and solve the inconvenient parts of individual journeys, as well as the entire system of mobility services. Through the digitalization of services and open data, it is possible that real-time information on the progress of the journey would also be available during the trip. Different MaaS operators bring together transport-related services and brainstorm and develop the MaaS concept together with public administration and entrepreneurs.

The privacy trend is closely related to other identified trends such as economy of data and sharing platforms, virtual assistants, connected intelligent communities, human-enhancement technologies, and digital replicas of living or non-living physical entities. There are substantial differences in the data and artificial intelligence (AI) privacy policies globally. In Europe, GDPR evolution will further strengthen “My data,” the role of which is expected to grow, while for example, the US with several dominant data platform internet companies do not have an unified set of data privacy laws. In China, the law of cybersecurity applies both to the internet webscale firms as well as to telecommunication operators and broadcasting companies as authorities’ requirements on visibility of data indicating any forbidden event. Moreover, as an emerging field, AI rights as a trend has opposing foresights. AI based on proper training data can suggest answers to systemic problems with high complexity and that contribute to economic productivity, sustainability, common prosperity, and human empowerment. In the dystopic forecast, AI will end up working against human rights and for non-democratic movements.

Internet webscale companies exploit collected user data utilizing their cloud-native platform ecosystem with AI to compete with telecommunication operators on the ownership of customer relationships driven increasingly by the user-perceived experience value than connection utility. Furthermore, internet companies operating over-the-top (OTT) increasingly offer basic voice and messaging telecommunication applications in a carrier-neutral way and compete in the rapidly growing cloud infrastructure and service business.

Trends related to urbanization build on the 85 percent of gross domestic product globally created in urban areas today, and future mega-cities will be the powerhouses of the global economy. Predictions for the world in 2030 estimate 5 billion urban inhabitants, residing in 3 percent of the globe, but consuming 80 percent of energy and producing 75 percent of carbon dioxide. Hasty urbanization in the developing world is applying growing pressure on public utilities, environment, and health. Demographic forecasts divide the 9 billion people in 2030 into two groups. Sub-Saharan Africa and South Asia will face explosion, while the growth of inhabitants in Europe, Russia, and China will stall. Cities will be increasingly autonomous with distinct identities and social and economic values. 6G will bring mobility and internet to the next billion, enabled by affordable ubiquitous connections. Rural and urban areas will be served with applications and digital services using native languages,

at an unprecedented scale and with growing impact on achieving the United Nations' Sustainable Development Goals (UN SDGs) and driving sustainable economic growth [6].

In the 6G era, private networks can be deployed irrespective of mobile operator driven by variety of local operators. For example, private networks for industrial segments call for high mission-critical performance in terms of coverage, capacity, latency, reliability, security and privacy, and operational management. The next generation network will connect and integrate not only a variety of devices but data and algorithms across wide range of services for industries, utilities, and communities. Private community networks for privacy in personal space may emerge and only rarely connect with the public internet.

The hyper-connected globe trend forecasts that 90 percent of the global population will be able to read, have access to the internet, and be mobile. 6G will empower urban and rural living with rights to transparent information citizenry, present at the intersection of geopolitics and nationalism. Thus, 6G connectivity-enabled growth in content, context, and commerce intelligence will require aware regulation balancing security, privacy, and sustainable business. The 6G users will be progressively sophisticated in both producing and consuming—"prosuming"—content and application, while being rooted in their local environment from human-machine interfacing (HMI) to local economies.

Industry 5.0 (I5.0) will leverage HMI across applications, services, and processes. With on-line data, AI, and a digital twin of the manufacturing process, industries transform towards the servitization of products. Novel digital automation platforms will reduce complexity friction and have a positive impact on scalability, replicability, and sustainability. I5.0 facilitates the long tail of mass customization, localization, and closer users' interaction, deploying the highest standards of safety and environmental protection.

Cybersecurity and trust will be ubiquitous requirements in the hyper-connected world. Even a momentary loss, subversion, or corruption of technology can result in catastrophic harm to society, our lives, and businesses, e.g., related to medical devices, robotic safety, public safety, critical infrastructures. There is urgency for novel innovations to safeguard society and to make critical infrastructure resilient to unexpected emergencies.

Local edge cloud architecture introducing virtualized communication, computing, storage, and analytics resources at the intelligent edge of architecturally disaggregated 6G system will enable real-time hyper-local access to applications and services such as augmented and mixed reality. The prosumers will act as a node of the intelligent network, locally rooted in the physical world while connected to the hyperreal intelligence networks contributing to crowdsourced shared information processing that can address collective missions such as the ones currently underway to collect and analyze data related to the COVID-19 pandemic.

Innovating to zero and circular economy megatrends stems from sustainable materials and zero-waste and zero-emission product design employing social service innovations. Worldwide carbon emissions of the ICT segment are estimated to grow at a six percent annual compound growth rate. On the other hand, the net positive impact is projected to be accomplished by introduction of a general-purpose 6G platform instead of an enabling technology that enables increased efficiencies, productivity, and environmental performance across other domains. A variety of intelligent devices, in addition to monitoring and gathering information, will harvest energy from the environment and everyday human activity.

Data regulation and net neutrality require of internet service providers to treat all traffic equally. On the other hand, network evolution towards 6G is transforming networks to fully service-driven platforms where connectivity is tailored to specific tenant, use case, and application leveraging virtualized resources between mobile operators and cloud providers. Legislation causes uncertainties on converging edge cloud technologies and services, particularly related to cybersecurity [85].

The geopolitics trend consists of several contradicting trends in globalization, nationalism, poly-nodal networking, and sustainability. In particular, there is a tension between centralized power and the empowerment trend stemming from transparency, inclusion, and democracy. The poly-nodal

world trend re-configures the current multi-polarized world into a network where power will be configured in the interaction of technology, economy, and society. Societal systems will face increasing pressure in volatile, uncertain, complex, ambiguity (VUCA) environments in political, economic, and sustainability systems. Balancing requires agile decision making that strong leaders will bring, and the confirmation of commitments and values of democracy to influence things in communities from the grassroots level. Increasing diversification and polarization will emerge around various tribes and communities, stemming, e.g., from different values, opinions, ages, locations, or lifestyles. On one hand, this can weaken togetherness and fragment future prospects leading to a skepticism, extremist attitudes, and a rise in populism. On the other hand, awareness among people, communities and enterprises on the sustainability crisis may be echoed in a rising number of people and societies changing their habits, and enterprises investing in sustainable growth. The open and frugal innovation paradigms and open value creation utilizing crowdsourcing and open-source may reinvent society's empowerment.

Questions of future resource orchestration and configuration power will emerge arising from the techno-geopolitics in telecommunication and information technologies, and accumulation of data transferred, stored, and analyzed in the networks. Questions on technology choices, data ownership and access, and decisions on the policies will also emerge. The 6G era will increasingly deploy novel sharing economy and circular economy business models that employ existing resources efficiently and sustainably. Ecosystemic platforms will not only facilitate integration and collaboration on resources but create value through identifying, matching, and bridging needs and resources. Furthermore, decentralized platform deployments will not necessitate a focal firm but depict governance to share co-created value.

A common uncertainty theme in all segments was the influence of China. In the China superpower trend, China is seen to exploit foreign resources and technologies. On the other hand, it is threatened by an ageing population, pollution, and political instability that turns China inwards to maintain peace and prosperity and brings its economic triumph to a standstill. Megacity pollution in China drives green tech forward which leads to neglecting some aspects of climate change and sustainability.

The UN SDGs [81,82] and the deployment of 6G are both scheduled till 2030. The seventeen distinct UN SDGs are targeted to frame problems and opportunities of a desirable future covering broad topics such as industry, innovation, and infrastructure; climate actions; ending poverty; building gender equality; developing smart cities; decent work and economic growth; and partnerships for the goals [6]. 6G technology can provide positive impact to UN SDGs directly and through transforming societies, improving productivity, and creating economic growth.

Transhumanism reflects technology-driven evolution of physical, biological, and digital worlds setting societal focus on sustainability, the nature of humanity, values, creativity, and self/social fulfillment and empowerment [86]. The trend includes human-machine interfacing with the emergence of sentient tools and a human-orchestrated evolution from biological, neurological, and physical perspectives.

Quantum computing will disrupt several segments such as science, finance, medical, materials and digital manufacturing in sorting, finding, simulating, and optimizing. Thus, alternative computing approaches will co-exist for long with an increasing level of parallelism.

The circular economy trend with related novel economic business model shifts is based on sharing, lending, and recycling resources instead of owning them aiming to reduce waste. 6G will offer technologies for monitoring and making the circular economy more transparent. Furthermore, combined with the I5.0, it will be possible to make related process intelligent and steerable, improve efficiency, and trigger innovations on digital services.

3.2. Developed Scenarios for 6G

Grounded on the discovered forces and key uncertainties, scenario logics were selected for the scenario generation, as depicted in Figure 3. The dimensions and the end points were selected orthogonally to characterize the most highly weighted uncertainties and those with low cross-correlation.

The developed four logics and eight dimensions were grouped under four themes, resulting in a total of 16 alternative 6G scenarios, which are discussed next.

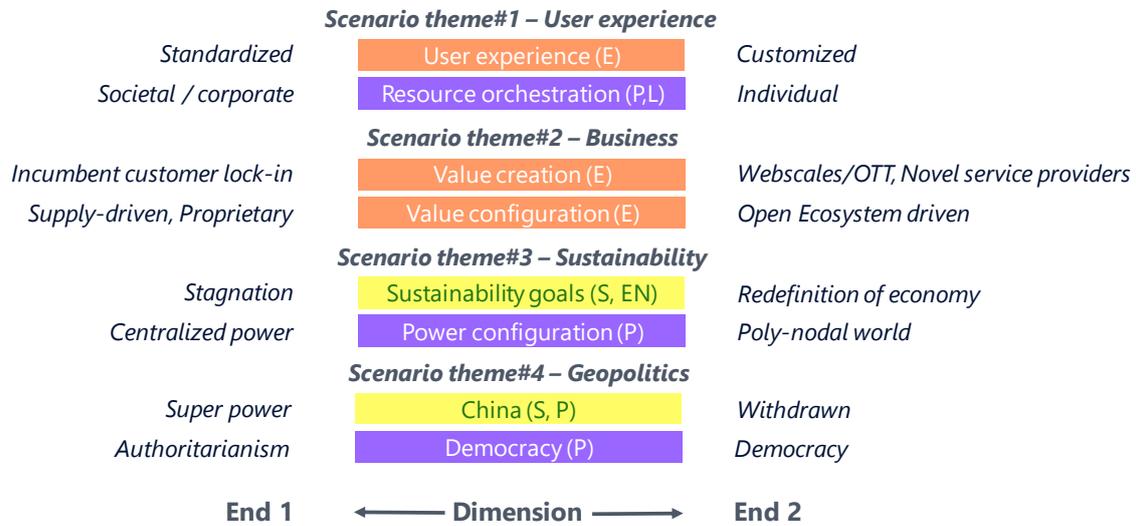


Figure 3. Summary of themes, logics, and dimensions for the scenario development.

3.2.1. User Experience Theme #1

The user experience scenarios build on the resource orchestration and user experience logic, as shown in Figure 4. The polar dimensions are societal/corporate and user-driven resource orchestration, while standardized and customized service experience provisioning are applied as the end points for the user experience logic. The developed four scenarios, depicted in Figure 4, are introduced next.

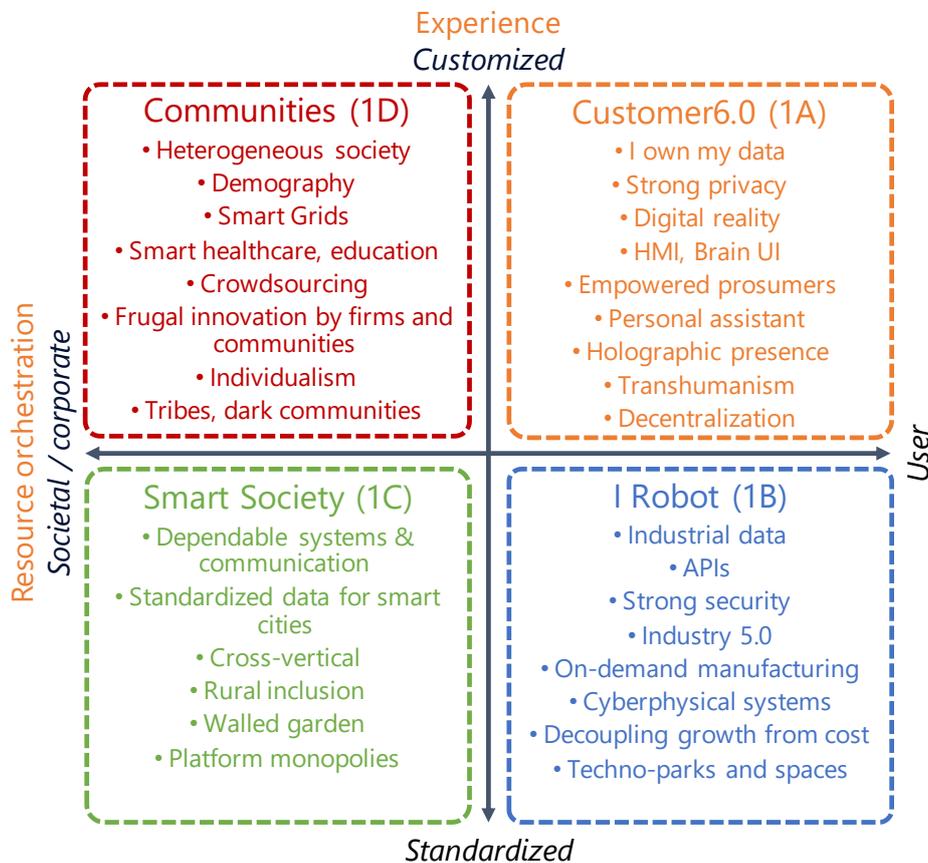


Figure 4. Summary of the user experience scenarios [32].

Customer6.0 Scenario 1A

User experience is customized, and resource orchestration is user-centric in the Customer6.0 scenario. 6G has become a general-purpose platform globally, and connected devices and sensors controlled by AI are a standard part of the environment. Automatized collection of human and environment data, and their analysis, are utilized in intelligent applications and services that make people's lives easier, deliver improved experience, and enable sustainable circular economy models. Opened interfaces, modular architectures, and standardized components have lowered the prices of the systems, making them affordable for the next billion. Energy for the ubiquitous intelligence devices monitoring a person's health, environment, as well as catering to information and entertainment needs, is harvested from everyday human activity. Future media and service consumption are increasingly grounded in local economies and communities.

Hyperconnected and fully automated 6G systems have been deployed, leveraging a public–private partnerships with a view to meeting sustainability goals and the efficient use of digital infrastructure. Decentralized and localized platform initiatives are challenging platform monopolies stemming from the peer-to-peer sharing economy models and a trust economy. The transhumanism trend from biological, behavioral, and human–machine interfacing perspectives reflects the rise of technology-driven evolution. By 2030, societal focus has shifted to sustainability, discussing at length humanity, values, social fulfillment, and self/community empowerment. Cognitive intelligence technologies such as the sentient personal assistant and possibly human-orchestrated evolution in biological, neurological, and physical selection are used. The integrated HMI brain user interface connects people with the biological world. Holopresence extends our spaces via projecting real-time digital twins of people and objects on the spot with a reality-matching presence.

The scenario finds severe challenges related to digital divide and inequality if access to new technologies, knowledge, services, and materials is restricted or controlled. Locally, firms and citizens are creating frugal adaptations to their needs and environment. In this scenario, 6G will be used to transform both urban and rural living towards UN sustainability goals directly and through transforming societies, improving productivity, and creating economic growth. Empowerment will lie in supporting transparency, inclusion, and democracy. People's multiple identities in the social and technological contexts call for a mindful transdisciplinary view of the policies and the regulation of data, media, and telecommunication from sustainability, business, and human empowerment perspectives.

I Robot Scenario 1B

Standardized user experience and user centric resource orchestration are the dimensions for the I Robot scenario. Nano-, bio-, information, and cognitive science technologies are converging and enabling novel products classes, applications, and services. In addition to enabling evolving cyber-physical and IoT systems, and on-demand manufacturing, 6G will widen the scope in industrial setting to biologically based AI. In conjunction with AI systems, biological intelligence will extend to biology-based self-programmable natural and artificial neural networks and micro- and nanobots. The next-generation intelligent industrial systems will be based on the interaction with hybrid bio-industrial automation. The industrial market segment will have a short to medium change horizon calling for agile and scalable local presence. Furthermore, growing requirements on independence, assurance, and resilience, combined with the emphasis on sustainability and circular economy models, have led to an increase of localized demand–supply models. Decentralized agile manufacturing composes a multi-tenant production ecosystem with producers of different scope and scale. Managing the dynamic network of robotized production plants will utilize distributed ledger technologies for the provenance tracking, inter-organizational record keeping, and integration in the supply chain management.

6G extends HMI to robotization across future industries via connecting human intelligence with advances in cognitive computing. With online data, AI, and a digital twin of the manufacturing process, industries transform towards the servitization of products. Novel digital automation platform with open interfaces will reduce complexity friction and have a positive impact on scalability, replicability,

and sustainability. I5.0 facilitates the long tail of mass customization, localization, and closer user interaction. Trustworthy quantum-enhanced I5.0 networking and services deploy the highest standards of safety and environmental protection.

Genetic engineering and synthetic biology allow the creation of programmed and modified organisms for specific purposes across industries, e.g., in food, chemical, pharmaceutical, textile, and construction processes. This will decouple growth from cost and resource usage. The interaction and synchronicity with these novel bio-nano-artificial intelligence technologies call for new dynamic capabilities for employees and society.

Smart Society Scenario 1C

The smart society scenario builds on standardized user experience and society-driven resource orchestration. The global societal concerns on resilience, stability, and sustainability expand across all strata of society and segments from finance to education. A growing number of services and processes are automated, production and operations localized and decentralized, and interaction utilizes augmented and virtual environments. This requires continuous competence development from individuals and firms. Intelligent societies build standardized dependable communication architectures and data platforms, which are employed by walled garden monopolies. Multilocality is the new normal uniting urban life and rural inclusion with isolation from crowds as a new trend. Trusted 6G connectivity enables augmented telepresence work that has resulted in knowledge-based jobs shifting to a sustainable rustic life balancing urban and rural developments and making society more inclusive of the disparate cultures. Data security, privacy and AI rights have opposing foresights depending on vested motivations. AI based on proper training data can suggest answers to systemic problems with high complexity, contributing to economic productivity, sustainability, common prosperity, and human empowerment. On the other hand, AI can end up working against human rights and for non-democratic movements. In this smart city scenario centrally managed and orchestrated sustainability action will take center stage. The aim will be to create a just and egalitarian society through the use of appropriate information regulation and mutual distancing through the creation of safe and creative collaboration spaces that support the interests of likeminded groups and communities. Actions at the level of individuals supported by 6G technologies will provide a morally sustainable world in which every citizen will be a self-aware informed citizen with a dual identity: recognizing allegiance to the nation, as well as living within the constraints of the global pan-dimensional virtually connected world.

Communities Scenario 1D

In the customized experience and corporate-centric-driven Communities scenario, 6G enables humans to participate and directly collaborate and act in society in an unprecedented way. In addition to open access to technologies, the scenario presumes competences and skills needed in applying new applications, services, and new forms of organization and innovation such as sharing economy and crowdsourcing. In the community society, well-being and working life build on social networks and the trust and reciprocity they foster.

Telecommunication network funding and support for deployment programs that have conventionally been engaged with extending rural area coverage and non-served areas have extended to public-private partnership (PPP) covering several segments of smart communities, such as logistics, transportation, health, public safety, and utilities. Novel PPP funding models emphasize sustainable development and the use of wireless telecommunication infrastructure as a general-purpose digital platform. Availability of real-time trusted personal health data will empower personalized and preventive care and medical consultation by healthcare professionals in need. Genome editing will enable the development of new medicines and treatments.

In this corporate-centric scenario, less restrictive regulation on platforms and data can lead to a country acting as resource pools of cheap labors, resources, and human data. Platforms can assist in developing frugal innovations serving the growing population in low-income nations, as well as

powering education with the Internet of skills applications and services. Access to a global pool of virtual courses and degrees and global educational networking will support wide range of international career opportunities.

The nature of physical and virtual communities has fragmentation and there is growing tension between individuals and communities and between communities with morphing values and identity. Leveraging 6G technologies, online communities have moved toward a more accelerated and hyperreal set of interactions. Cyberterrorism has affected every networked system with emergent potential for a global crisis and a shocking impact on the economy. Holistic media experience and interaction have intensified public opinion-shaping activities with a stronger impact than ever on mobilizing people. Enabled “wisdom of crowds” allows for more egalitarian and informed decision making and empowerment. At the same time, the hyperreal experiential hate “wisdom” may be perverted without bounds, resulting in a bleak communal life with crime and terrorism.

3.2.2. Business Theme #2

The scenarios in the business theme build on value configuration and value to capture logic, as shown in Figure 5. The polar points of the value configuration dimension are closed supply-focused and open ecosystem-focused configurations. Value to capture logic is grounded on the incumbent mobile network operator-dominated model and the model extending to novel digital service providers.

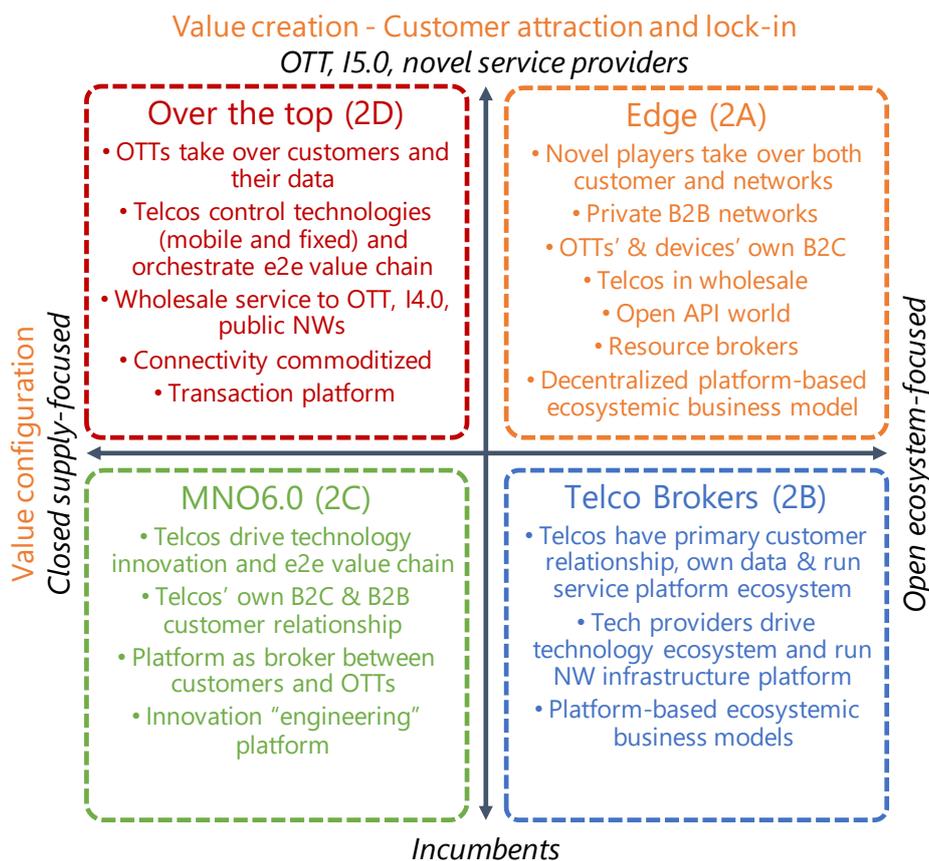


Figure 5. Summary of business scenarios [32].

Edge Scenario 2A

The scenario for novel service providers stems from open value configuration and ecosystem-driven business models. Novel players such as webscales, OTTs, and technology vendors have taken over both customer ownership and networks owning the business-to-consumer (B2C) relationship. Telecommunications operators provide a wholesale connectivity service while local private cloud

networks complement total offering in the business-to-business (B2B) customer segment. Open service-based architecture, modular APIs, virtualized open-source world, and novel resource brokerage have expanded technology and innovation ownership.

Local communities and interest groups will increasingly start to operate the edge, e.g., in expanding services into rural areas, or educational and research organizations deploying their own networks and resources to speed up local innovation. These local sub-network edge resources contribute to sustainable, ecologically efficient, and trustworthy non-invasive deployments. Furthermore, future networks are extending financial, healthcare, and governmental services affordably to masses. Empowered local entities operating semi-autonomous 6G sub-network collaborate with wholesale service providers for wider connectivity and innovating applications and services on the general-purpose decentralized platforms. There will be very specific network areas and zones from an in-body communication personal zone to the wider family or community zone shared strictly between members and offering tailored services. Moreover, dynamic automated local management enables particular zones to be shared based on personal preferences and the changing requirements of the group or community.

The transport service ecosystem requires new kinds of cooperation, integration of services, and traffic planning, utilizing 6G connectivity and services. The aim is to implement the actual services on market terms. In order to achieve the objectives of sustainable mobility, the provision of comprehensive services must also consider the energy efficiency and emissions of mobility. Enabling wireless vehicle-to-everything (V2X) technology access to vast information in the cloud, including real-time traffic, sensor, and high-definition mapping data keeps the entire ecosystem of movers' vehicles, infrastructure, and pedestrians in sync. MaaS wireless access technologies set new requirements on the neighboring environment, e.g., programmable intelligent meta-surfaces on buildings, street furniture, and vehicles, enabling the built environment to augment the 6G system via configurable opportunistic radio wave reflections [87,88].

For the development of successful business models, security, trust, and identity management will be a challenge and opportunity. Airborne networks via satellites, balloons, and unmanned aerial vehicles are needed to achieve ubiquitous connectivity. 6G as a digital value platform delivers extended and augmented virtual reality applications, supporting immersive experiences. Digital value platforms converge multimodal engagement with media and the physicality of lived experience, and are seamlessly accessible through HMI extended to all five senses, including the senses of touch and taste. Individual and collaborative users can seamlessly switch between any form of immersive mobile extended reality, encompassing virtual reality, augmented reality, and mixed reality consisting of both virtual and augmented objects. Application of future immersive digital realities can be found across industries facilitating novel ways of learning, understanding, and memorizing subjects in many sciences such as chemistry, physics, biology, medicine, and astronomy.

Telco Broker Scenario 2B

In this incumbent-driven value creation scenario, value configuration is open and ecosystemic. Traditional mobile network operators have focused on retaining the customer relationship and transformed to capture value from data and services via the service platform ecosystem. Technology vendors manage and orchestrate the network technology ecosystem and offer an efficient infrastructure as a service. End-to-end automatized service-driven network management and dynamic service provisioning are used for efficient, flexible, and scalable extraction of value from connectivity. For the spot markets of virtualized network resources with certain performance attributes, automated service management is the key enabler across the network, with full key performance indicator (KPI) granularity. In particular, virtualized communication, computing, storage, and analytics resources at the intelligent edge of the architecturally disaggregated 6G system have become a new source of value creation enabling real-time hyperlocal access to applications and services such as augmented and mixed reality.

In distinct locations, sub-network and private local network deployments can provide premium connectivity based on service-level agreement. Premium service requires security guarantees and proofs of the verifiability and trustworthiness of the network. The decoupling of technology platforms in the telco broker scenario has lowered the barriers for entry and allows multiple stakeholders to participate in the ecosystem. Moreover, fine-grained modular network architecture and open vertical and horizontal interfaces combined with the service platform marketplace facilitate the long tail of mass customization, localization, and closer user interaction. This will open business to a variety of smaller payers, leading to innovation, and possibly to commoditization.

MNO6.0 Scenario 2C

This scenario is built on closed supply-focused value configurations and value creation by an incumbent mobile network operator. MNOs continue both to drive technology innovation and to control the traditional end-to-end (e2e) value chain. The business opportunity and advantage stems from the wide existing customer base in B2C and B2B segments, both with a growing demand for capacity and data speed. MNO6.0 will leverage a paradigm of AI-based automation and virtualization, creating dynamic instantiation of thousands of slices on demand to gain dynamic scalability, shortened time-to-service, and massive productivity improvement. To make it difficult for new companies to enter the market, MNOs leverage fully their installed infrastructure, Third Generation Partnership Project (3GPP) standardization, and exclusive radio spectrum regulation regime. Furthermore, as a real option, an MNO can challenge competing novel digital service providers to convert into virtual network operators or partner via leasing valuable spectrum assets.

In addition to serving consumers, MNOs will utilize their scale and scope advantages across enterprise and vertical market segments. Virtualized, softwarized, and cloud-native 6G technologies, combined with the use of higher frequency bands and network densification at the edges, decouple costs from growth. Technology innovations leveraging the opening-up of network interfaces, combined with transaction platform connecting customers and OTT players, enable telecom firms to co-develop within their value chain to address the long tail of specialized local and industrial use cases.

Over-the-Top Scenario 2D

The over-the-top scenario builds on value creation by novel service providers and closed ecosystem-driven value configurations. Novel digital service providers have leveraged their access to customer data in winning customers from traditional mobile network operators. MNOs continue to own and manage commoditized connectivity technologies and orchestrate the e2e mobile and fixed value chains. Operators have actively created partnerships with webscales, industrial service providers, and public networks to provide wholesale services utilizing their transaction platforms. Webscale internet companies base their connectivity offering on free and subsidized business models, utilizing revisited net neutrality policies, to reach the next billion.

It is essential for an MNO to retain control of network technology, the related spectrum, and network management and orchestration. Edge cloud has become a new control point and local sharing with webscales and OTTs could follow the potential for internal asset leverage in combination with media content and industrial data. Cloud-native edge applications and services represent the new demand and, combined with a local and instant context analytics and autonomic security capabilities, create a new competitive advantage over centralized cloud services for existing customers and new vertical enterprise segments. Such edge intelligence and information service platform can be extended to a highly local and dynamic marketplace for content, services, resources, and information. Quantum computing and distributed ledger technologies will be taken into use in proving 6G to be a secure and predictable general-purpose digital trust platform used widely in critical infrastructures such as public safety, utilities, fintech, and healthcare.

The 6G system will itself employ digital twin technologies to create an exact digital replica of its physical and virtual assets and processes in order to provide manageable and controllable insight into

the real system and further forecasts predicting future behavior. The supply and demand of resources are identified and matched through novel aggregator and broker roles, including various network infrastructure and service providers, specialized resource brokers, and application providers offering, e.g., security and privacy services. Utilized 6G platforms are extended beyond modular elements and open interfaces toward data and algorithms leveraging cloud-native technology practices and their large open-source inheritance.

3.2.3. Sustainability Theme #3

The sustainability theme recognizes the increased environmental awareness and the UN sustainability goals as important drivers for 6G. The scenario’s logic is grounded in sustainability development and the configuration of power, as depicted in Figure 6.

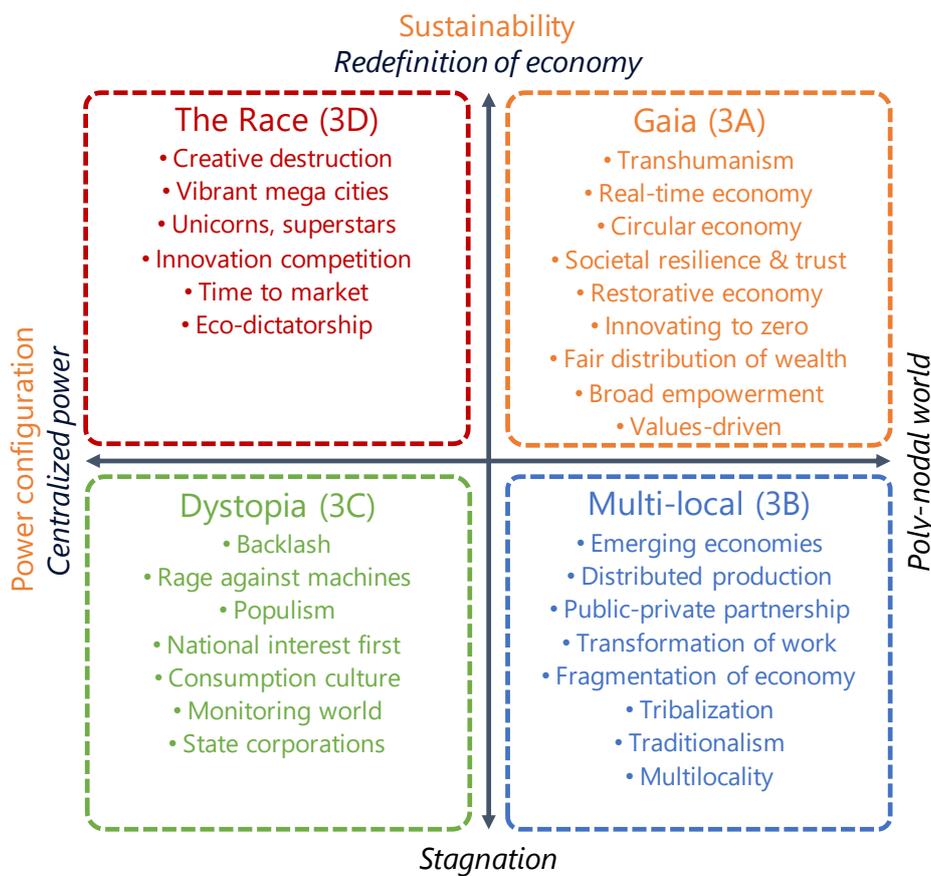


Figure 6. Summary of sustainability scenarios [32].

Gaia Scenario 3A

The Gaia scenario stems from redefined economy and poly-nodal power configuration. Climate change and biodiversity crises have increased green awareness and resulted in empowered actions on the individual and society levels. The emphasis on global politics has moved towards relationships and interaction, replacing the polarized power regime. In the poly-nodal scenario, think tanks, non-profit organizations municipalities, local communities, and increasingly firms are playing a significant role. 6G has enabled online economy, where transactions have been digitalized and automated, impacting productivity across industries. Energy production originating mainly from renewable sources has become increasingly decentralized as people and communities produce and trade energy. Utilizing circular economy and sharing economy business models, production and consumption are managed and orchestrated to minimize waste, while materials and their value flow via sharing, leasing, repair, and reuse. In the innovation to zero context, ultra-low-power 6G communication

leverages innovations in energy harvesting and wireless power to “next billion devices”. Disruptive business model concepts building on platform cooperatives, peer-to-peer and crowdsourcing, and the progress of the human-driven fair data economy have established counterforces to winner-takes-all monopolies. Furthermore, international co-operation in policies and regulation has played a vital role in regulating platform business. From IoT, focus has moved to the Internet of human skills and senses, utilizing enhanced HMI for restorative economy characterized by empowerment, equality, well-being, and sustainability. Achieved societal resilience provides the ability to cope with the future world with uncertainty, turbulence, rapid change, dynamism, disruption, complexity, hyper-competition, high-velocity markets, and flux. Furthermore, resilience can be seen as the dynamic capability of a society to overcome adversities, the ability to learn and adjust, and the ability to craft sets of institutions that foster individual welfare and sustainable societal robustness to future challenges and crises.

Multi-Local Scenario 3B

In the scenario, sustainability development has stagnated in the poly-nodal world. Geopolitics have shifted from a polarized and multipolar towards a poly-nodal networked world with nodes encompassing countries, emerging economies, mega-cities, enterprises, and other non-state actors. Traditionalism can be seen as a response to disorder favoring public–private partnership. Environmental crises and disruptions will turn people increasingly towards polarized communities and tribes formed around values, beliefs, locations, political opinions, consumption choices, or lifestyles for guidance. The economical fragmentation, new models of education and work, transforming organizations and disruptive business models will challenge the traditional employer–employee relationship. Universities and various platforms offer tailored virtually augmented education environments to enterprises and private entrepreneurs. People favor domestic products and can themselves choose where and how goods and products are manufactured. 6G-enabled distributed localized manufacturing is leveraged by enterprises with a network of geographically dispersed manufacturing, as well as prosumers utilizing enhanced 3D printing technologies.

Dystopia Scenario 3C

The scenario logic is characterized by stagnated sustainability development and centralized power configuration. The dystopic scenario stems from a consumption culture exploiting nature as a free resource combined with unequal distribution of wealth. Deteriorated foresight, political polarization, and the dividing effect of social media have led to a rise in populism, which stresses the division between the elites and the masses. Internationalism and global collaboration are not recognized, and the negative aspects are emphasized to protect local turf. Moreover, nationalism and an emphasis on national state corporations have increased as an opposing reaction. Democracy is challenged by practical autocracy and technocracy, grounded on the notion that sees democracy as too slow or ineffective in the current VUCA era. The yearning for simple solutions to complex and systemic problems has made strong leaders popular and presents a challenge to a democracy. Technology is increasingly being used to monitor people and to spread disinformation, and efforts to influence opinions are geared toward instigating confusion and discord. The “rage against machines” digitalization backlash has delayed or put public 6G network deployment on hold.

The Race Scenario 3D

The Race scenario was built on redefined sustainable economy driven by centralized power configuration. The utmost urgency for climate and sustainability actions has led to creative destruction and eco-dictatorship as voluntary movements in the behavior of individuals and communities are considered tardy in reacting to the changing environment. The population becomes even more concentrated in a few distinct growth areas and vibrant megacities, where unicorn superstars dominate technology innovation and the platform ecosystems they form and control. In the creative destruction,

the process of industrial mutation and innovation competition race incessantly revolutionizes the economic structure from within, incessantly destroying the old one while creating a new one.

3.2.4. Geopolitics Theme #4

The Geopolitics scenarios discuss how political power is strengthened or diluted by geographical measures such as borders, alliances, networks, scarce resources, and technologies. In the created scenarios, the vertical axis represents democracy and the horizontal influence of China, as depicted in Figure 7. The polar dimensions of the democracy axis are democracy and authoritarianism, while the ends of the China dimension are superpower and withdrawal.

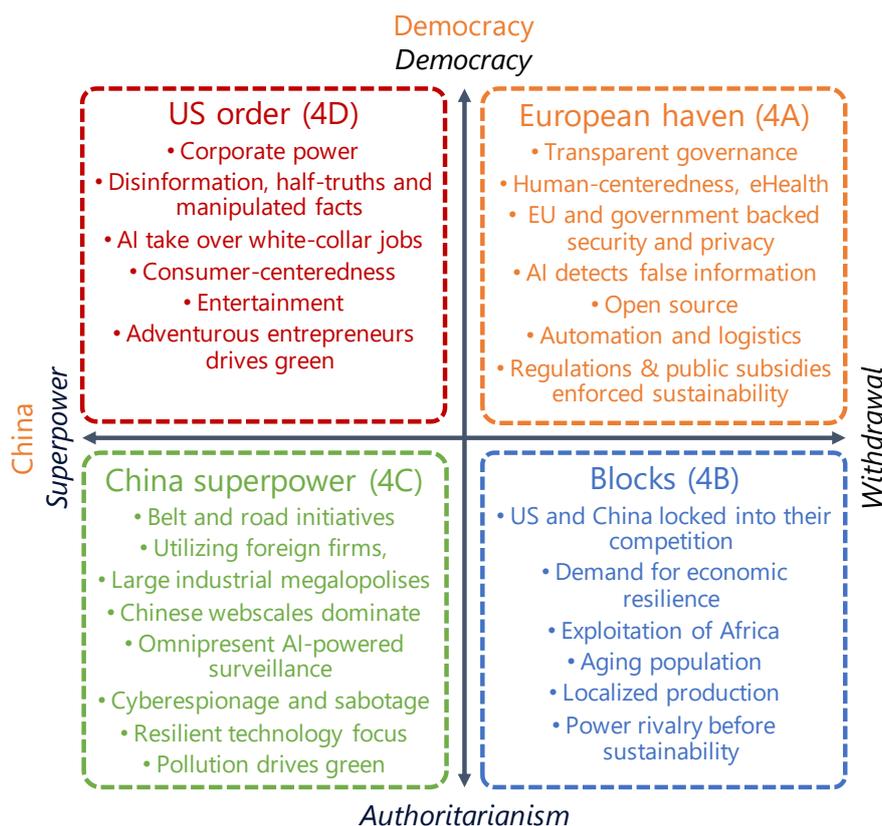


Figure 7. Summary of the geopolitical scenarios.

European Haven Scenario 4A in the World of Blocks Scenario 4B

The slowing globalization and the demands for economic resilience have led to the formation of three distinct blocks: Europe, North America, and East Asia. The blocks are largely self-contained economies which trade with neighboring areas, but not very much with the other blocks. How each block approaches various issues reflects its cultural traits. The United States, a horizontal society, is clearly about the individual and a person’s own choices and focuses heavily on the consumer. China could be best described as a three-dimensional actor, meaning that the state is involved in everything. Europe, on the other hand, is generally vertical, with organizations taking responsibility in planning and development.

Throughout the decade, China has been moving some of its manufacturing base abroad, including Africa. Largely self-reliant in innovation and product development, the country is now facing the way of Japan—the ageing population threatens to bring its economic triumph to a standstill. Financial woes start to set in as the economic growth, albeit still higher than in the Western countries, cannot keep up with public spending. The United States is mired with its internal problems, and its debt-laden

economy is a subject of constant predictions of imminent and disastrous collapse. Western Europe, on the other hand, is also struggling to keep up its welfare systems.

By 2030, EU is still known for many positive things, but its main competitive edge is its reputation for its transparent and uncorrupted government. Competition in the field of technologies now mainly takes place between the US, EU, and the joint efforts of Japan and Korea. China still creates significant numbers of innovations, but the totalitarian society seems not to be able to grant the space needed for truly unique thinking. The situation in China is further exacerbated by worsening corruption made possible by the failed introduction of AI-powered governance—an initiative that remains mostly a pet project of some elite members but with few real-life implications. Europe has emerged as a haven of both individual's rights in the online world, as well as a hub for open-source. The EU has managed to create regulation that has enabled the open-source producer to certify their work as reliable. The Union has also banned some foreign tech giants from its markets because of data protection and espionage issues. Europe has become the main driver towards a more human-centered society in both technological and governmental questions. Whereas the US is all about the consumer needs and sellable products, Europe, in addition to the consumer focus, seeks to ensure that the products are ethical, that is, sustainable, and responsibly and fairly produced. Through its research efforts, the EU has been contributing towards a more open society, as, paradoxically, it has made communications more secure; as people feel that their secrets are not divulged without their consent, they feel comfortable to be more open about those things they are ready to share. The Western governments, as well, taught by the pandemic, have been in the process of adopting this principle of openness.

The US and China, locked into their competition, have somewhat eschewed the notion of sustainability to ensure primacy, although lip service to the environment is regularly paid in public speeches. Europe is also virtually the only place where the issues related to AI ethics are taken seriously, while the two other blocks are competing for supremacy in that field without any concerns.

The ageing population in Europe, together with the memory of the pandemic and need for cost cuts, has made telecare a permanent fixture of the healthcare systems. Moreover, work and entertainment are increasingly taking place on online platforms, not necessarily anymore in offices, theatres, or cinemas. However, this is also creating problems with loneliness and isolation. Thanks to the introduction of 6G, each block has created its own system of watching the movements of its citizens to, at least officially, be prepared for future pandemics. The European car industry has become a central advancing power of technologies. Autonomous vehicles have entered the streets, both in the public and private transport markets. Because of the automotive industry's role, industrial data have become especially valuable in the EU, in contrast to customer data in the US. Transportation and mobility are experiencing a change from multiple perspectives in the ecosystem. Novel mobility solutions utilizing 6G and IoT technologies serving new dynamic mobility patterns are characterized by scalability, replicability, and sustainability. MaaS concepts are taking advantage of the sharing economy concept, while at the same time providing solutions that help to reduce congestion and constraints in transport capacity, with lower emissions and lower cost. To date, a great variety of business models have emerged, stemming from cross-industry ecosystems having stakeholders from different industries collaborating and competing in "co-opetition." Additionally, Europe is more concentrated on business-to-business products, whereas the United States is driven by the business-to-customer focus. Automation has taken leaps in Europe, since industrial work, that has to some extent returned to the continent, is expensive.

Each of the blocks seems to start to diverge in how different technologies are mixed; while Europe focuses on the automation of movement and logistics because of the industrial interests of different member states, China and the US are adopting local production concepts, mainly thanks to their space-faring efforts. The technologies, however, in many cases do not become diffused between the blocks because of protective laws. As the EU has also been the leading champion of sustainability, regulations enforced by it now necessitate that sustainability be one of the critical factors in virtually all development plans and public tenders.

China Superpower Scenario 4C

By 2030, the old regime of post-Second World War order has been buried for good and China is the leading economy and becoming the leading superpower. The Chinese belt and road initiative (BRI) has tied much of Eurasia to China, ousting US influence in many places. Active trade takes place throughout Eurasia, but “slowbalisation” has somewhat affected the commerce between North America and Eurasia. Because of the stress the rise of China has caused, the United States is more and more openly advancing only its own interests. China is actively seeking to buy and utilize foreign companies with interesting technologies. At the same time, it still sends out massive numbers of students to study abroad, to learn the best practices and bring them home. There is an active push towards sustainable and green technologies. However, their primary driver is not climate change, but the polluted megacities of China. The technologies in this field are increasingly geared towards making human life bearable in large industrial megalopolises, which means that some of the vital environmental and climate-related problems are not appropriately addressed.

Europe is sandwiched between China and the USA. Acting more like a field of competition for the two, Europe’s grip on its destiny is more tenuous now than before. Most of the consumer technology innovation is done elsewhere, and the economy of the old continent is sluggish, largely due to the ageing population. In general, the large webscale companies, such as Google, Amazon, Alibaba, and Baidu, dominate the markets. Europe has not been able to create its tech giants, although it tries to regulate what is done on its market area.

Cyberthreats are persistent and demand more funds and best talents are sought after for superpower projects to develop cyber capabilities. This has led to increasing demands of privacy protection in the Western countries. At the same time, the rights of citizens in many countries are curtailed by omnipresent AI-powered surveillance. There is a need for trust and security, especially in the Western markets. Cyberespionage and sabotage take place continually, as do information operations. Individuals, companies, and government organizations are constantly looking for ways to reduce and eliminate vulnerabilities in their systems, which ties up resources and causes delays. Resilient technologies, referring to technologies that are both resilient to external damages, both natural and human-caused, while at the same time promote the resilience of nature, have emerged as an important field. In the West, resilience has partly replaced sustainability as a term in political and research discourse.

US Order Scenario 4D

The impressive economic gains made by China by 2021 were followed by a slower pace, mainly because of its unfavorable age structure. The idea of Chinese dominance spreading over Asia, Europe, and Africa was slowly dropped from conversations as it became clear that it needed to focus on keeping its population both peaceful and reasonably prosperous: China has started to turn inwards. Despite all this, the world is more than ever replete with disinformation, half-truths, and manipulated facts. The reason for this is that those opposed to the US-led order have understood that their only option is to attack the only way they truly can challenge the superpower: by conquering, or at least demoralizing, the minds of those on the other side. The aim is to weaken the national unity of the Western countries, break their mutual relations, and increase tensions among them. The large Western technology companies, followed by many others, have, in conjunction with various universities, implemented policies and measures to combat disinformation. AI-powered tools, together with humans, search and correct false information. At the same time, the governments of Europe and North America have been increasingly engaged in strategic communication operations aimed at both their domestic as well as foreign audiences. Truth has become elusive.

The data security questions were a vital issue of the early 2020s but were resolved to a degree as the largest US corporations, together with the government, implemented blockchain-based encryption to their communications and data storage. The European companies followed suit, but the EU has been hesitant to endorse the use of blockchain because of perceived possibilities of tax evasion and

other harmful activities. Human-centeredness, or consumer-centeredness, has become the current driving force in technologies designed in the Western countries, meaning that more than ever, new consumer needs are actively discovered and also created through psychological, sociological, and cultural research. Some have pointed out that these efforts, combined with the strategic communication operations, could be seen as active engineering of the minds of people. However, the memory of the pandemic has made people more trusting towards communication technology than ever. The slow introduction of autonomous vehicles and co-working between robots and humans has kept manual laborers employed, but AI has started to take over many white-collar jobs formerly held, for example, by lawyers and programmers.

Even though the coronavirus forced many locations to shift their entertainment offerings online, the large concert crowds, full cinemas, and crowded restaurants returned quickly in early 2021. During the decade, the large-scale introduction of virtual reality (VR)/AR applications together with fast 5G networks and edge computing have transformed some entertainment forms completely. For example, gigs of the most popular pop stars are regularly attended by an audience wearing AR glasses that enable computer-generated effects, turning already great shows into absolutely fantastic displays of artistic creativity. Once the acute crisis of the early 2020s pandemic was over, the attention turned again to keeping climate change at bay. Public subsidies and adventurous entrepreneurs have achieved some impressive gains in photovoltaics, wave power, and wood-based materials.

3.2.5. Scenario Summary

Sixteen alternative future scenarios were developed under four scenario themes: user experience, business, sustainability, and geopolitics, as summarized in Figure 8. The scenarios can be seen as sub-sets from user experience towards geopolitics at the widest contextual level. To summarize the discussion of 6G business, the probability, plausibility, and preferability of the scenarios were assessed at the end of the workshop series by the workshop participants. The probability was assessed based on the identified forces impacting the scenario. Secondly, the plausibility was analyzed, based on the coherence of the scenario, by exploring the potential alternative futures that could occur. The final step was to identify the most preferred scenario stemming from the values and choices the team made regarding alternative futures. The teams assessed the scenarios across themes in a largely similar way. The probability and plausibility assessments were found to correlate while preferable scenarios were considered probable or plausible in few cases, even though they were seen as worthwhile and sought after.

The most probable and most plausible scenarios originate from evolutionary supply-driven dimensions toward a multi-local networked world grounded in strong trends and low uncertainty. In the business theme, the most probable and plausible scenarios, OTT (2D) and MNO6.0 (2C), stem from the tension between competition and protective dimensions and market views. On the other hand, the networked multi-local scenario (3B) was seen simultaneously as the most probable and plausible under the sustainability theme. The preferred scenarios, Gaia (3A), Edge (2A), and Customer6.0 (1A), represent all demand-driven transformations toward sustainability, empowerment, and open ecosystems building on democratic geopolitical scenario. Further, these revolutionary scenarios are founded on high-impact driving forces with higher uncertainty compared to scenarios assessed most probable and plausible.

The preferred future is characterized by automatic collection of different kinds of data from humans and environment, and their intelligent analysis utilized for highly sophisticated products and systems that empowers people and communities while making lives easier and more sustainable. The edge resources will be increasingly operated by local communities expanding services to unserved or rural areas, or organizations deploying their own edge resources to accelerate local innovation. 6G will augment distributed platform collectives, crowdsourcing, and sharing economy business models, and accelerate the human-driven fair data economy and the fair distribution of wealth. To recapitulate, we identified the choices for developing the preferred sustainable 6G business future common for all stakeholders in future 6G business, summarized in Figure 9, by adopting the quintuple helix model.

Transformative drivers were found to be climate change, the UN sustainable development goals, and decentralization toward a networked poly-nodal world. External barriers concern high uncertainties related to the platform dominance, policies, and regulation related to AI, HMI and resources, and the future of democracy. Acknowledged internal challenges relate to the novelty of a disruptive business model leveraging sharing and circular economy concepts and ways to cope with the empowered individual and community users' rights.

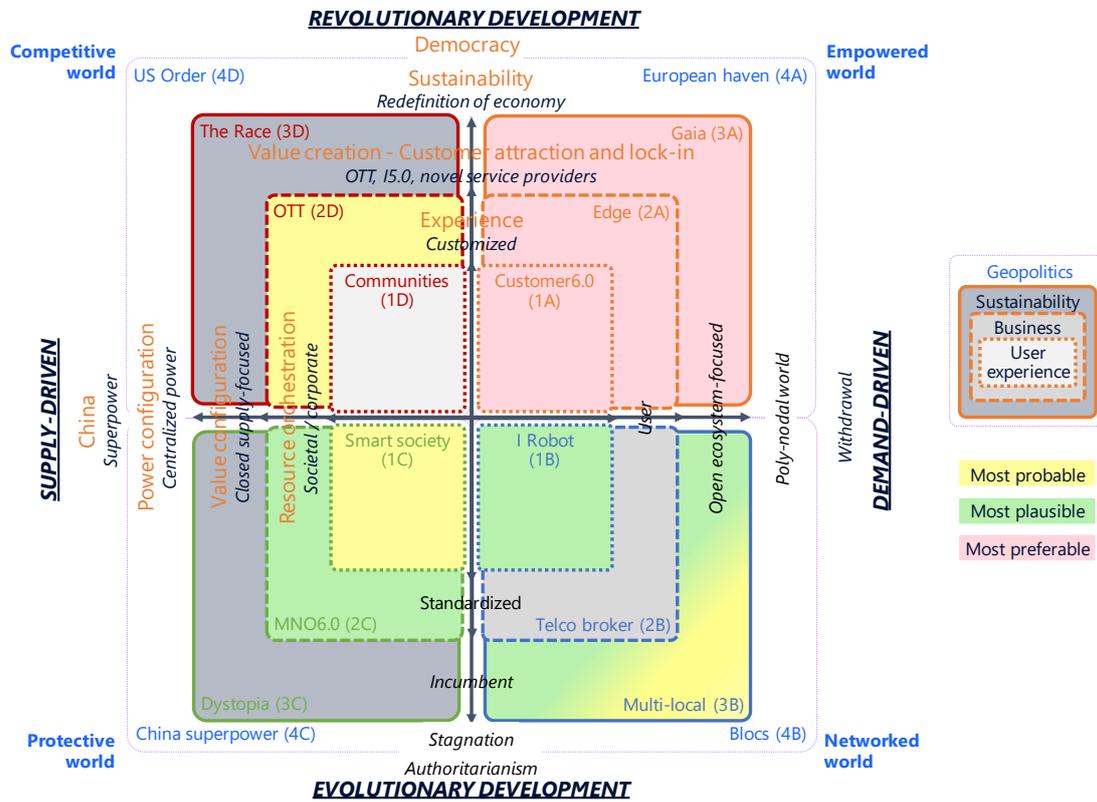


Figure 8. Summary of four scenario themes: user experience, business, sustainability, and geopolitics.

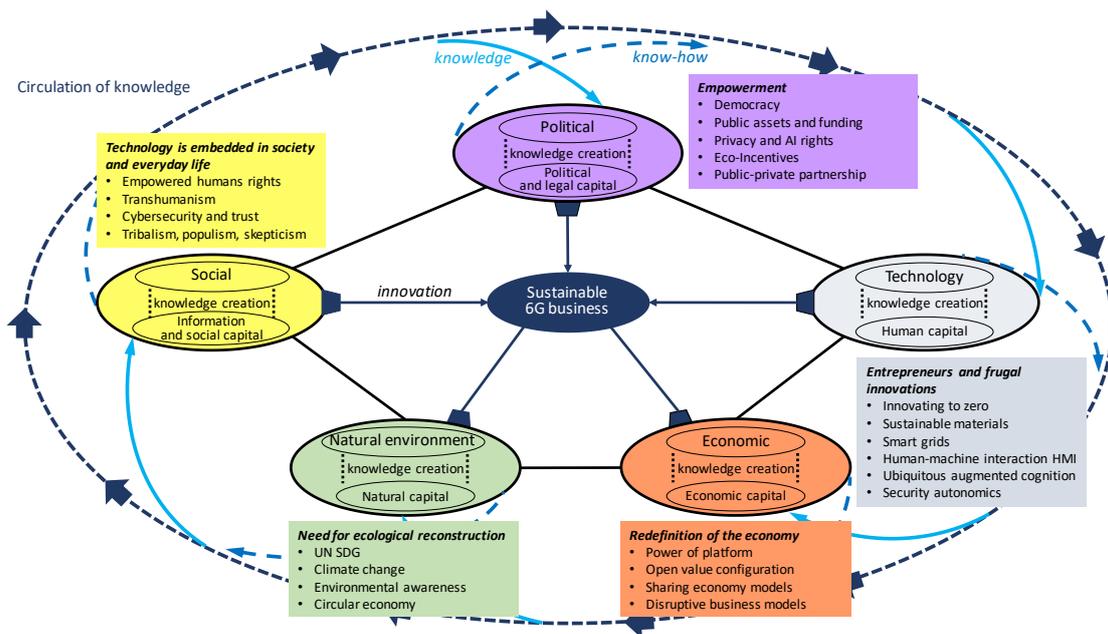


Figure 9. Summary of essential choices for developing the preferred sustainable 6G business futures.

4. Discussion

The scenarios presented in Section 3 open up a multitude of alternative futures for 6G. We will summarize and discuss our findings in two parts, first by looking at what kind of economic, societal, and environmental notions we may draw from the scenarios, and second, how the sustainable 6G businesses might be influenced when applying the business model perspective.

From economic perspective, the key messages of the four sets of scenarios can be summarized as follows:

- The customization of user experience will increase with the help of user-centric resource orchestration models
- Localized—especially for spatial circular economies—demand–supply–consumption models will become prominent at a global level
- Community-driven networks and public–private partnerships (PPP) will bring about new societal models for future service provisioning
- Platform ecosystems will extend from offering search, social media, and e-commerce to providing infrastructures for innovation and transactions
- 6G will have a strong role in various vertical and industrial contexts
- Lowering the market entry barriers will be enabled by the decoupling of technology platforms, making it possible for multiple entities to contribute to 6G innovations
- Smaller payers will be able to provide highly specialized solutions and services due to fine-grained modularity and open-source
- Decentralized platform cooperatives will start to challenge the existing “winner-takes-all” platform monopolies.

From societal perspective, the scenarios indicate the following:

- Hybrid threats and influence will be exercised by various economic, technological, cultural, and military powers
- Different tensions between the competitive, protective, networked, and empowered worldviews will emerge
- The global power configuration may be transformed from a multipolarized to a poly-nodal world where power will be determined in networks of economic, technological, and cultural interaction
- Empowering citizens as knowledge producers and users will contribute to a process of human-centered, democratized innovation, contributing to pluralism and increased diversity
- Privacy regulation will be strongly influenced by the increased platform data economy or sharing economy, emergence of intelligent assistants (AI), connected living in smart cities, transhumanism, and digital twins.

From environmental perspective:

- 6G will enable services that help to steer communities and countries towards reaching the UN SDGs
- 6G will enable monitoring and steering the circular economy, thereby also helping to create better understanding of the big picture of sustainable data economy
- Sharing- and circular economy-based co-creation will enable promoting sustainable interaction also with existing resources and processes
- Companies will be able to develop products and technologies that innovate to zero, for example, zero-waste and zero-emission technologies
- The 6G-enabled immersive digital realities will facilitate novel ways of learning, understanding, and memorizing in several fields of science.

Next, the scenarios will be analyzed utilizing the integrated frameworks of ecosystem-focused business model configuration and open value configuration [57], as depicted in Figure 10. The

Gaia, Edge, Customer6.0, and European Haven scenarios can be seen as transforming businesses toward an open ecosystem. This open ecosystem configuration stems from a collection of forces such as customized user experience, attraction and lock-in by OTTs, I5.0, emergence of novel service providers. It also builds on sustainability, empowerment, and redefined economic values and networked poly-nodal decentralized democratic power configuration. The centralized and community-based OTT, Communities, and Race scenarios utilize mixed value configuration and demand-focused business models, although they maintain a focal point for value capture. The protective MNO6.0, Smart society, and Dystopia scenarios are built on closed supply-focused value and power configurations that are not necessitating democracy, pluralism, or diversity. These incumbent-power-based and stagnated scenarios evolve slowly toward open and demand-focused networked business in the Telco brokers, Multi-local, and I Robot scenarios.

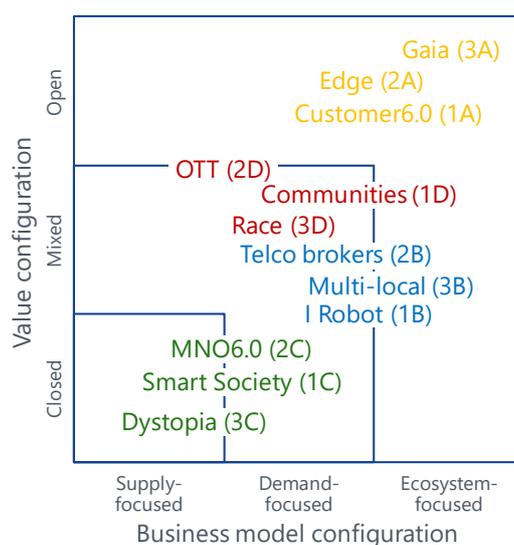


Figure 10. The positioning of the scenarios within the integrated ecosystem-focused business model/open value configuration framework [32]. Adapted from Xu [57].

The user, business, sustainability, and geopolitics level scenario sets can be considered as parallel, because they do not exclude the existence of each other. However, high volatility, uncertainty, complexity, and ambiguity (VUCA) is visible in all scenario themes as a “meta trend” and reflecting the global concerns over the resilience and stability of societies. Additional insight can therefore be gained by cross-examining the scenario set contents, linkages, and tensions at different layers or units of analysis including markets, industries, ecosystems, business models/strategies, products/services, customers/segments, and different types of user. This cross-examination reveals a consistent importance of privacy and security issues across all scenarios from public/governmental, corporate, community, and user(s) perspectives. In summary, five key perspectives and themes were identified as indicators or signposts that provide insight into how or which of the generated scenarios will actually unfold (Figure 10): (1) time-to-market in 6G; (2) complementarities and potential spill-over effects and competitive landscape within the wireless industry, especially the platform wars expected to emerge; (3) appropriability regime (value capture), e.g., bottleneck assets and who profits from innovation and how; (4) antecedents to the sharing economy; and (5) the recognition and deployment of sustainability goals (SDGs) and the redefined economy of the future.

The business model perspective applied, summarized in Figure 11, provides two kinds of practical implications. First, the twelve alternative business scenarios presented in this research can be used as a baseline for conceptualizing novel ecosystemic business models for the emerging 6G business ecosystem. Second, the business model framework will allow various ecosystem stakeholders to create strategic options and indicators for exploring novel 6G opportunities. Our findings are

indicative of a multitude of alternative future business opportunities and models for different 6G ecosystem stakeholders. We propose that a focus on business models as a way of thinking can help in ecosystem stakeholders' business model-related choices regarding future opportunities, value-add and advantages ex-ante. In addition, the expected consequences of business models—scalability, replicability, and sustainability—help to look at the future from an ex-post perspective. With the right business choices, opportunities related to novel and unmet needs, new types of customers, and service provisioning, for example, interfacing humans with machines, can be identified. In particular, the scenarios envision novel opportunities to emerge for serving empowered prosumers' needs related to achieving the sustainable development goals. New value-added is expected from real-time and trustworthy communications, local contextualized data and intelligence, and the commoditization of shared 6G resources. The expected business consequences of scalability may be related to the long tail of services: dataflow architecture, automation, and open collaboration between partners. In turn, replicability may stem from deliberately designed modularity and complementarity within platforms. Finally, sustainability may emerge for empowered users and communities, as well as the utilization of sharing economic mechanisms in markets.

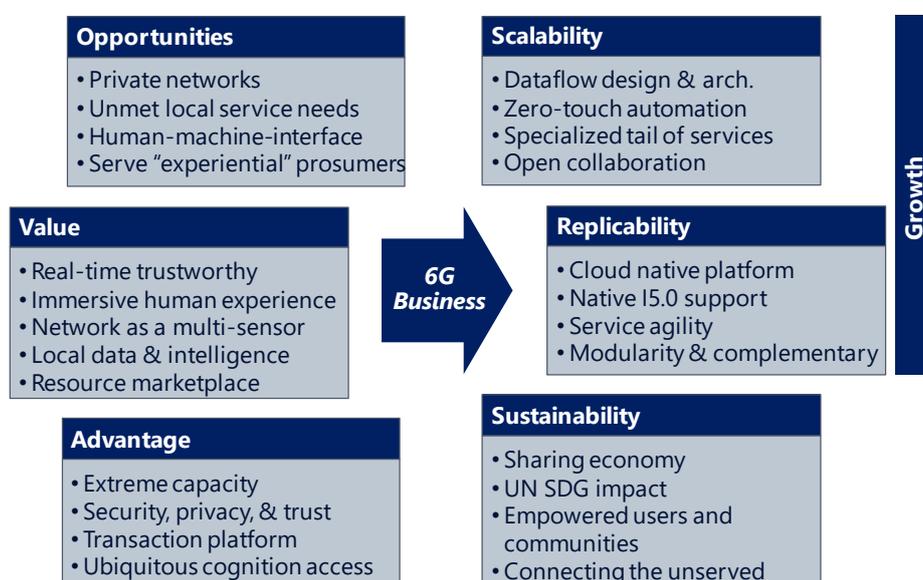


Figure 11. Summary of strategic 6G business model choices, activities, and their consequences [32].

The above discussion directs attention to the dynamics and dynamism of 6G platforms and ecosystems. Extant research acknowledges business models as enablers of ecosystemic interaction and devices for open value configurations [52,57]. However, digital convergence across industries and the future multi-level 6G platforms and ecosystems are contributing to an increasingly complex environment that can open up novel opportunities, as well as problems. However, unanswered questions remain, concerning ecosystemic business models in the context of sustainability. In light of our findings, business ecosystems that aim to bring together stakeholders to solve systemic sustainability problems will require open ecosystem-focused value configuration and a decentralized poly-nodal power configuration for finding the long tail of specialized user requirements that spans industries. Furthermore, a functioning quintuple helix model requires transdisciplinary interaction of all the helices in order to reach sustainable innovations in 6G or coevolution toward the knowledge economy, knowledge society, and knowledge democracy.

5. Conclusions

The emergence of 6G in the 2030s calls for a thorough reconsideration of several types of multilevel ecosystemic interactions. In addition to the platform owners' own business models, it is

crucial to develop feasible business models for platform developers, integrators, managers, public, corporate, and individual users who also need to be able to reach the benefits of 6G. The roles of collaborative standards development, modularity, and the complementarity of technological solutions have become increasingly important in 6G development. This opens up challenges related to the openness, transparency and control, and collaboration vs. competition issues. The use of data and algorithms, such as AI, will play a key role in this to achieve the network effect. Technological complementarities are also required to ensure that the innovations complement each other in the actual commercialization. This is particularly important if the role of 6G is to be seen as a pervasive general-purpose system instead of yet another enabling technology. There will be complex technical dependencies when separate companies commercialize different 6G technologies and solutions (input oligopoly complementarity). Finally, consumer and production complementarities are required to efficiently regulate, standardize, and balance the supply and demand of 6G services.

The 6G era is more than technical, service, and business infrastructures. The role of users is important, and they will need to have access to the services, required devices, and knowledge to use the devices services. It is also important to consider non-users and potential reasons for their exclusion. Users' opportunities to actively participate in the 6G ecosystem increase through a deeper understanding of technologies including design, development, programming, or digital fabrication skills and allows to shape the technologies for personalized needs. This will help to assess the technologies and their role in the user's own life and society, and opens up new questions, such as: Who benefits from technology or service use, and how?; Who experiences value?; What is the real price, and is it worth paying?

This study has focused on the case of 6G, which currently is in its birth phase as a technology and a business ecosystem [89]. The elements of ecosystemic business model scenarios will be different depending on the lifecycle phase. This paper has roots in both engineering and economics research domains, and demonstrates the need for more foresight research for the development of ecosystemic business models in the 6G context and highlights the importance of three nested levels of experience, value creation, and sustainability. More transdisciplinary research is needed, especially in the following themes: How can new 6G ecosystem roles and business models emerge and change in different scenarios for those other than platform owners?; What kind of dynamic capabilities will be needed in 6G to sense and seize opportunities?; How can 6G become a truly general-purpose instead of an enabling technology?; and How could user empowerment be supported so the users can play an active role in this business ecosystem, including designing techniques for experimenting, making, and shaping technologies for their personal needs?

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