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Sustainability Transition and 6G Mobile Communications

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Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs.

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Introduction to Sustainability Transition

Sustainability has become a buzzword in academia as well as policy-making circles these days due to visible influences of climate change on daily life (e.g., Arslan et al., 2021; Barber, 2021; Heikkurinen & Ruuska, 2021) along with the recognition that social sustainability lies at the core of achieving the UN sustainable development goals (Baldwin & King, 2018; Ranjabari et al., 2021). Scholars have started to include sustainability principles in their research in various fields in response to growing sustainability concerns as well as funding agency requirements. Consequently, the number of publications focusing on various aspects of sustainability in different industries, national contexts, and organizational settings has increased. In parallel, firms have also increasingly started to see sustainability not as an additional cost, but also as a business opportunity.

Elkington's (1997) environmental, social, and economic approaches toward sustainability is often referred to as the triple bottom line (TBL). To manage the interdependence, the demands stemming from the three perspectives should not be compromised but balanced. Economic sustainability aims to secure profitability and liquidity; social sustainability aims to contribute to human and social capital; and environmental sustainability favors the consumption of reproducible resources (Khan et al., 2021).

In recent discussions, the term resilience has started to emerge as connected with sustainability, albeit without clarity regarding the difference between the two. The extant literature views resilience and sustainability either as: (1) independent and separate; (2) overlapping or complementary; or (3) a component of the other (Marchese et al., 2018). Resilience refers to the ability of an entity or system to return to a normal condition after disruption—being a measure of a system's ability to absorb continuous and unpredictable change and continue to function (Hosseini et al., 2016; Pregenzer, 2011). Thus, the term value can be found at the hearth of both sustainability and resilience, i.e., to identify, create, convey, deliver, and capture, but also protect and sustain long-term value, whether economic, environmental, or social (Liu et al., 2021).

Sustainability, Innovation, and Disruption

In the context of sustainability, there is an increasing recognition among management scholars that understanding the transition toward environmental and social sustainability is vital despite attractive slogans. If the actual sustainability transition process is not understood and managed well, achieving sustainable development-related goals will be harder (Bai et al., 2009; Geels, 2011; Heikkurinen & Ruuska, 2021; Williams & Robinson, 2020). This sustainability transition is highly linked to economic sustainability, which has limited the actions on environmental and social sustainability. In this context of the sustainability transition, the role of disruptive innovations has emerged as critical in recent years because these disruptive innovations demand socio-technical change at multiple levels (Heikkurinen & Ruuska, 2021; Park et al., 2021); thereby bringing the transition element to the forefront of the debate (e.g., Bai et al., 2009; Brauch et al., 2016; Geels, 2011, 2019; Kivimaa et al., 2021). This sustainability transition approach is different from many traditional sustainability focused studies, which either focus on a micro-context (firm level sustainability initiatives) or macro-level (change toward sustainability in industries and countries), where the process of this transition does not usually get the due attention.

The sustainability transition has primarily been studied in the context of innovation in the energy sector due to its' visible linkages with environmental degradation (e.g., Bogdanov et al., 2021; Brauch et al., 2016; Kivimaa et al., 2021). However, calls have been made by scholars to apply a wider approach to studying sustainability transition in relation to innovations (disruptive innovations) in different industries, national contexts, and organizational settings (e.g., Rohe & Chlebna, 2022; van der Loos et al., 2020, 2022). At the same time, the other critical element of the sustainability transition associated with social sustainability is even less studied, and most research in the larger field of management has focused on organizational responsibilities and policy initiatives leading to social sustainability, so far (e.g., Hutchins & Sutherland, 2008; Amrutha & Geeta, 2020; Ranjbari et al., 2021). A review of the prior literature further reveals that the potential of disruptive innovations in the transition toward social sustainability is rarely studied; a visible gap that our

chapter aims to fill is the potential of 6G mobile telecommunications technology.

6G systems have a high potential to contribute to both environmental and social sustainability while ensuring economic sustainability, and this has been established by several studies published in recent years (e.g., Matinmikko-Blue et al., 2020; Matinmikko-Blue et al., 2021; Ojutkangas et al., 2022). However, as 6G is still a future technology in the vision and framework development phase, we still lack knowledge of how it can potentially contribute to the sustainability transition on environmental, economic, and social levels. Prior work has linked 6G with the UN SDGs (Matinmikko-Blue et al., 2020; Ojutkangas et al., 2022) and the triple bottom line of sustainability (Matinmikko-Blue et al., 2021, 2022) and identified several research topics for further study by the research community including environmental, economic, and social perspectives.

Sustainability considerations of existing mobile communication systems have primarily focused on environmental sustainability aiming at minimizing energy consumption and maximizing resource efficiency including energy efficiency (Zhang et al., 2016). The role of mobile communication is seen as important in the sustainability transition of society at large (Wu et al., 2018), but this development should not occur at the expense of increasing the ICT sector's own sustainability burden. Most recently, sustainability has become an important design criterion for 6G, (ITU-R, 2022; Matinmikko-Blue et al., 2020), while opening the door for defining a new set of requirements on mobile communications stemming from the sustainability transition.

Aims of the Chapter

The current chapter aims to address the sustainability transition and 6G interlinkage conceptually along with substantiating the discussion with some practical examples, using the most prominent approach used in transition studies, i.e., a multi-level perspective (MLP) (Geels, 2002, 2011, 2019, 2020; Rip & Kemp, 1998), which combines ideas from innovation studies, sociology, evolutionary economics, and institutional

theory. The core argument of MLP is that transition is a result of a dynamic process at three different levels including: (1) niches, which are the core premises where the radical innovations are developed; (2) socio-technical regimes, representing institutional drivers toward the change; and (3) the exogenous socio-technical landscape of the larger society. By establishing the link between 6G and the sustainability transition including environmental, economic, and social perspectives using the MLP lens, our chapter offers two critical contributions to the extant 6G, sustainability transition, and innovation management literature streams. Firstly, this chapter highlights the potential of 6G in both environmental and social sustainability conceptually while ensuring economic sustainability as well as practically by referring to examples. Secondly, it is one of the rare studies that focuses on the larger picture in the 6G and sustainability debate by highlighting specific UN SDGs which can be achieved in the sustainability transition and the role of endogenous and exogenous factors using the MLP lens. Hence, the potential practical and policy implications of this chapter are expected to be profound.

The rest of this chapter is organized in the following manner. The next section analyzes the established connection between sustainability and 6G. After that, 6G development in relation to the sustainability transition is analyzed via the MLP approach. Here, the niche aspects are presented, after which the socio-technical regimes and institutional factors linked to the sustainability transition in this context are discussed along with the wider debate on the UN SDGs. The sub-section after that discussion aims to bring the larger society into debate by focusing on exogenous the socio-technical landscape of 6G development and sustainability transition. The last section presents theoretical and policy implications, along with a discussion on the study limitations and future research directions, restructuring possibilities linked to 6G are discussed in relation to the increased complexity of the external environment.

Connecting Sustainability to 6G

6G mobile communication systems are expected to be deployed around the year 2030, which is also the target year for the achievement of the UN SDGs (Matinmikko-Blue et al., 2020). Idealistically, the targets from the UN SDG framework should be reached prior to the emergence of 6G, allowing 6G to enter a world where major sustainability challenges are already solved. This, however, will not be the case and the entire R&D of the next generation of mobile communication systems is driven by sustainability and sustainable development (Latva-aho & Leppänen, 2019; Matinmikko-Blue et al., 2020). No prior generation of mobile communications has taken sustainability as seriously as a core value as 6G has. The development of the 4G system adopted the principle of green communications (Zhang et al., 2016), which meant optimization of resource usage and especially energy efficiency. 5G adopted energy efficiency as one of its key performance indicators (ITU-R, 2017), but no target values were defined. In 6G development, sustainability principles are talked about but concrete actions and design criteria for sustainability in 6G R&D are yet un(der)defined.

The triple bottom line of sustainability (Elkington, 1997) has highlighted the interdependencies between social, environmental, and economic sustainability principles. This also applies to 6G, where the ongoing 6G development aims at solving major social and/or environmental sustainability challenges, while being economically sustainable. The attempts to enable the sustainability transition in other sectors of society through the so-called enablement effect has received considerable attention (Hilty & Aebischer, 2015). The quantification of the enablement effect in terms of the reduction of greenhouse gas emissions (ITU-T, 2022) or energy consumption, for example, has turned out to be a challenge both from methodological and practical perspectives. At the same time, understanding the mobile communication sector's own sustainability impact including lifecycle greenhouse gas emissions (ITU-T, 2018) is a challenging topic as well, and reported data remains low. Both the enablement effect and the mobile communications' own sustainability burden remain equally important in the sustainability transition but require distinct methods and measures.

The original connection between 6G and the UN SDGs was developed in the 6G Flagship's white paper work (Matinmikko-Blue et al., 2020), which stressed a three-fold role for 6G.

- Firstly, 6G will be a provider of services that help steer communities and nations toward the UN SDGs. As an example, global mobile connectivity that will connect the unconnected is a foreseen scenario for 6G requiring cost-efficient and deployable solutions.
- Secondly, 6G will become a powerful measurement tool for data collection at a very local level of granularity to help organizations and nations to report on sustainability-related indicators, which today is a problem. Examples include sensing solutions for collecting environmental data.
- Thirdly, 6G will be a reinforcer of a new technological ecosystem which will be developed according to the high-level requirements set in the UN SDGs.

As an example, translating the requirements stemming from the UN SDG framework in areas such as promoting high-quality education (SDG4), promoting equality (SDG5, SDG10) and digital inclusions (SDG9), to 6G technology development requires introducing new design goals that are both technical and regulatory in nature. The existing indicators in the UN SDG framework address SDG4 (the proportion of schools with access to the Internet for pedagogical purposes; the proportion of schools with access to computers for pedagogical purposes; the proportion of youth/adults with ICT skills, by type of skills), SDG5 (the proportion of individuals who own a mobile telephone, by sex; the percentage of the population covered by a mobile network, broken down by technology) and SDG17 (fixed Internet broadband subscriptions, broken down by speed; the proportion of individuals using the Internet) at a high level. For a sustainability transition where 6G is designed to contribute to the achievement of sustainability targets, contributions to other indicators are also expected as outlined in (Matinmikko-Blue et al., 2020).

A Multi-Level Perspective on the Sustainability Transition in 6G

Using the MLP lens, we analyze sustainability transition in the context of 6G. Our analysis stems from the pioneering work done in the 6G Flagship white paperwork (Latva-aho & Leppänen, 2019; Matinmikko-Blue et al., 2020), followed by several stakeholder interactions at workshops organized in 2021–2022.

Niche Aspects

Niches representing the core premises, where the radical innovations are developed, constitute of two factors in the context of 6G. Firstly, innovations in the context of the sustainability transition in 6G target the enablement effect of using innovative 6G service and solutions to help other sectors of society to act upon their sustainability impact toward environmental and/or social sustainability while maintaining economic sustainability. These innovations reduce GHG emissions and resource consumption including energy consumption through various means. Examples include optimizing processes in an industrial setting, reduction of fuel consumption in a multi-stakeholder port ecosystem with situational awareness, and productivity improvements in agriculture via sensors. Secondly, innovations within the 6G context will take place in 6G solutions and services to improve 6G's environmental and/or social sustainability while ensuring profitability in economic sustainability. Examples of these innovations include architectural designs to optimize the location of computing and communication resources, algorithms to minimize energy consumption in different layers of the network, and cost-efficient network deployment models in challenge areas.

The dual role of ICTs and particularly mobile communications in helping other sectors to achieve sustainability-related targets as well as the mobile communication sector's own sustainability impact are two sides of the complex sustainability transition challenge. Agreed metrics and methods are needed for both sides as presented in (ITU-T, 2022) and (ITU-T, 2018), respectively.

Socio-Technical Regimes and Institutional Factors

Socio-technical regimes and institutional factors in the context of 6G particularly include regulations and standardization, which are discussed in more detail other chapters of this book. The UN SDG framework presented in Agenda 2030 (UN, 2015) is an international treaty that nations have agreed to. At regional level in Europe, the European Commissions' Green Deal positions Europe's targets for member states. Consequently, national level approaches in the EU member countries follow both international and European level rules.

Traditionally, environmental sustainability is the matter of the ministry of environment, while telecommunication communications and services typically belong to the ministry of communications. The introduction of the topics of sustainability of the ICT sector and the enablement effect of the ICT sector in other sectors have resulted in a new setting, where traditional governance boundaries are broken. Consequently, the expertise required for environmental sustainability is not found in traditional telecommunications.

At the European level, the European telecommunications regulators at BEREC have stated that sustainability is a new topic for them (BEREC, 2022). Prior studies on the environmental sustainability of the ICT sector have resulted in conflicting results. One challenge is the lack of data available for unbiased research by the research community. In their current work on sustainability of the ICT sector, much focus is being put on mobile network operators (MNOs) and infrastructure vendors' views.

Governments set sustainability-related requirements in the different sectors of society. Until now, there have not been specific sustainability requirements for prior generations of mobile communication networks. On the one hand, coverage obligations for mobile communication networks introduced early on in Finland and in some other countries can be seen as an early form of a social sustainability requirement. These obligations mandate the MNOs to deploy networks in geographical areas that cover a certain percentage of the population such as 99%. Concrete sustainability requirements for 6G defined by governments are not yet known. International-level discussions have started at the UN-based

agency for ICT, the International Telecommunication Union (ITU), and specific requirements for the radio interface will be defined in the coming years.

The Exogenous Socio-Technical Landscape

The wider society impacting or being impacted by 6G in the sustainability transition particularly involves end users. They have the power to decide on the use of ICT services and solutions. Today, end users do not have information available about the sustainability impact of their ICT choices. In the future, end users will be able to make informed decisions based on sustainability-related information. For example, the environmental footprint of the service usage including energy consumption, greenhouse gas production, and other depletion of natural resources will impact consumer behavior once this information is made available. Today, this is not possible due to the lack of information for consumers and other end users.

More widely, the inclusion of a human perspective in 6G development in the sustainability transition requires the introduction of proper stakeholders in the R&D process at the right stages. Traditionally, mobile communication systems have been defined by the companies involved in the development of the technology and the governments, emphasizing high-level requirements such international roaming, and moving of equipment as well as detailed technical requirements on aspects such as capacity and delays. The research and development of the systems is carried out by the technology vendors in close collaboration with the research domain aiming to respond to the requirements of the customers, who in the mobile communication business are typically MNOs and their end users. Within these requirements, sustainability-related requirements are only emerging, and their format is not clear yet. Additionally, regulators play a key role in setting these requirements. In the deployment and operational phase, the role of the MNOs is critical as they run the infrastructure and act as the interface for the end users. The reduction of energy consumption is already a top requirement by the MNOs to reduce their operational costs and will continue to be so in 6G.

The above discussion also connects to the discussion on system resilience in 6G that covers resilience to cyber-attacks and the utilization of privacy-preserving and trust-creating technologies to achieve trustworthy 6G. Trustworthy 6G comprises topics such as security, privacy, safety, availability, inclusivity, transparency, fairness, accountability, resilience, and compliance with ethical frameworks. In addition, as with artificial intelligence, human agency and oversight based on values should be considered in 6G. These topics correspond with the emerging social sustainability and resilience themes even toward sovereignty and democracy.

Theoretical and Policy Implications

Our study on the sustainability transition in 6G as analyzed via the multi-level perspective offers both theoretical and policy implications. Firstly, a major theoretical implication relates to the specificity of the 6G context in relation to the sustainability transition and the need for theorization. The role of telecommunications services has evolved from offering organization communication tools to multi-level influences across the socioeconomic and technical landscape. The discussion presented in this chapter has shown that 6G can potentially ensure more environmental and social sustainability which can ultimately lead to economic sustainability. This interlinkage has all of the elements of the TBL (triple bottom line) view of sustainability, but at the same time it depicts the criticality of social and environmental sustainability in ensuring economic sustainability. Hence, this aspect should be further explored and theorized in the specific context of telecom sector and 6G as it will enrich the sustainability debate in a novel way. Secondly, the current chapter enriches the understanding of the UN SDGs by linking them with all three levels of MLP concerning the sustainability transition. Hence, we set the bases for future studies to undertake a more in-depth approach to analysis and offer a fine-grained view of these interlinkages in different industrial settings as well as geographical contexts.

On the policy side, regulations are expected to emerge to regulate 6G including the sustainability and resilience perspectives. Traditional requirements for mobile communication systems need to be complemented with a thorough sustainability transition perspective and those discussions have only just started. Today, the future upcoming regulations are unknown, and their derivation requires new skill combinations bringing together telecommunications, environmental, and social and economic sustainability knowhow.

In particular, regulators and policymakers at different levels from the community, national, regional to the international level, will face a new situation with requirements that do not exist today. Yet, national-level approaches should not be too different from each other to allow economic sustainability of the entire mobile communication sector where mobility across borders has been the initial driver. The global success of mobile communications has been based on global harmonization and roaming of devices leading to large markets for the same devices, which has brought prices down and allowed the same equipment to work in a number of countries. If the sustainability requirements are different from country to country, fragmentation of equipment may lead to markets not being served or prices becoming high.

Limitations and Future Research Directions

Our chapter has several limitations similar to any other academic work. Firstly, it is a conceptual piece where empirical analysis has not been undertaken. However, as 6G is a future technology, the possibilities for a specific analysis of its link to the sustainability transition are rather limited. Hence, our chapter builds bases for future studies to be undertaken both as quantitative and qualitative studies analyzing different aspects of the sustainability transition in relation to 6G telecommunications in different industrial and national contexts. Moreover, our chapter discusses all three elements of MLP concerning the sustainability transition without going into too much depth on any of the elements. We recommend future scholars take a more in-depth approach and analyze the specificities of the various niches, socio-technical regimes, and the

exogenous socio-technical landscape of the sustainability transition in different contexts in relation to 6G telecommunications. Additionally, keeping in view the importance of corporate social and environmental innovation (e.g., Golgeci et al., 2022) for the sustainability transition, we recommend future researchers to link these to 6G telecoms as well; thereby enriching the larger debate on the sustainability transition linked to this particular technology. Finally, keeping in view the continuous development of 6G telecoms currently taking place, longitudinal academic studies documenting different phases in relation to the sustainability transition are expected to enrich our understanding both theoretically and practically.

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