Rethinking the Role of ICT for Sustainable Development: From Incremental Improvements Towards Sustainable Societal Transformation

Working Group 9.9: ICT and Sustainable Development

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Abstract. This chapter provides an overview of past, present and future perspectives on the relationship between ICT and sustainable development in research, with a focus on perspectives adopted within WG 9.9. While early research concentrated on the adverse effects of ICT on the environment, including energy usage, hazardous chemicals in production, and electronic waste, the discourse has evolved to emphasize the potential of ICT to promote sustainable development and offer economic, social, and environmental benefits. WG 9.9 emphasizes that ICT can indeed offer sustainability-related benefits, such as dematerialization and optimization. However, technology, including ICT, is currently not geared towards sustainability, and incremental improvements are not sufficient to promote sustainable futures. Instead, a narrow and individualistic focus risks reinforcing an unsustainable status quo. Researchers interested in ICT and sustainable development should take a more critical stance and promote radical societal transformations towards sustainable futures. Among other things, this includes questioning growth, both in terms of technology and the economy, adhering to planetary boundaries, energy and resource limits, and promoting sustainable practices, rather than imposing behavioral changes.

Keywords: ICT · Sustainable Development · WG 9.9 · Planetary Boundaries · Sustainability Transitions · Societal Transformation

Since the first industrial revolution, our largely fossil-based economy has produced much material wealth and development throughout the world. However, as we have realized in the last few decades, this rapid development has brought upon us many negative side effects, not least climate change due to the emissions of carbon dioxide (CO_2) and other greenhouse gases (GHGs) [1]. The rapid pace of climate change is leading to a rise in droughts, floods, and heat waves that are becoming increasingly frequent and unpredictable globally [2]. Researchers claim that we have recently entered a new geological epoch – *the Anthropocene* – where "humanity has become the major force in shaping the future of the Earth system as a whole" [3]. In the Anthropocene, our actions are "challenging the biosphere foundation for a prosperous development of civilizations," and the resilience of the Earth's systems is threatened [3–5].

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The rapid development of technologies has accelerated the impact of human activity on the planet. While it has contributed immensely to the well-being and health of millions of people, problems such as resource scarcity, toxic waste, and climate change would not be such acute global problems without this development. Furthermore, policymakers, researchers, and politicians alike often promote the role of technology to slow down, halt, or even reverse these problems [6]. Not least, information and communication technologies (ICTs) have been claimed to have the potential to facilitate positive change towards sustainability [7]. The relation between sustainable development and technology in general – and ICT in particular – is a complex one.

For a long time, ICT was considered a rather clean and fair technology, at least compared with other technologies used for transportation, resource extraction and electricity production [8]. However, it is now common knowledge that ICT contributes with negative consequences for social and environmental sustainability throughout its value chain [9]. The issue stems from the material nature of ICT, which requires energy and resource intensive production and manufacturing, electricity for usage, and eventual disposal. The current ICT value chain is unsustainable due to its negative impacts, such as CO_2 emissions and toxic waste generation, usage of conflict minerals, unacceptable labor conditions, and e-waste [8, 10]. Many of these problems are well known by the industry and governments, and some of them have been solved or at least alleviated: individual ICT products are getting smaller, and each product now consumes less resources and energy compared with a few decades ago. ICT companies have policies and regulations to follow concerning conflict minerals (known as 3TG: tin, tungsten, tantalum and gold). The amount of electronic waste (e-waste) generated by the west has finally started to decrease. There are also other examples of positive developments towards increased sustainability within the ICT sector that show how directed attention can have successful outcomes. Despite some positive developments, sustainability issues related to ICT overall have grown and continue to grow, particularly with increasing geopolitical instability in Europe and the world following the ongoing invasion of Ukraine.

While there are certainly many problems to solve in regard to how already existing sustainability problems with ICT should be solved, the main focus for research within ICT and sustainable development is how ICT can be used in order to make other parts of society and other industries more sustainable [9]. It is often assumed, for example, that ICT-based systems can be implemented to reduce energy and resource consumption and waste in production processes, improve education in impoverished parts of the world, promote dematerialization of physical goods, reduce the need for carbon intensive travel, and more [11]. While the potential to use ICT for sustainability-related purposes is certainly substantial, ICT is nowadays more often used by companies for other purposes, such as to increase economic profits. Furthermore, the implementation of ICT to solve different sustainability-related problems can result in negative rebound effects, which risk offsetting any positive results [12].

The fact that ICT has a dual character, contributing to environmental and societal problems on one hand and being a solution on the other, makes the relationship between ICT and sustainable development a crucial area of both research and practice. IFIP Working Group (WG) 9.9: ICT and Sustainable Development, which has existed since 2005, aims to contribute to the development of an information society that meets the human needs of the present without compromising the ability of future generations to meet their own needs. The rest of the chapter will provide a brief overview of the history of research in the field of ICT and sustainable development, along with its traditional research methods. Based on this summary and the research conducted by the WG members, potential avenues for future research in ICT and sustainable development will be highlighted.

1 A Brief History of ICT and Sustainable Development Research

While research on issues related to sustainability and related concepts can be traced back to the late 1980s, entire research fields devoted to these subjects were first formed around the mid 2000s. This was the result of what Tomlinson [13] called a "critical juncture" between an intensified environmental discourse, following the *Brundtland Report* in 1987 [14], rapid technological development, and the insight that ICT contributed to a substantial part of the global CO_2 emissions [15].

One of the first fields of research and practice related to ICT and sustainable development that emerged from this critical juncture was *green IT,* where the negative environmental effects of ICT were emphasized. Within green IT, the main objective was to look into how to mitigate negative direct, first-order, effects along the ICT value chain [12]. Resource and water consumption in production processes, electricity consumption in the use phase, and problems related to waste in the disposal phase are examples of such effects.

While early research focused mainly on how the value chain of ICT could become more environmentally sustainable, the researchers soon realized that it was also important to emphasize the "greening potential" of the technology [9, 16]. In 2008, Global e-Sustainability Initiative (GeSI) published their report *SMART 2020 – Enabling the low-carbon economy in the information age* [11]. In this report, the main message was that despite the fact that ICT contributed to many negative sustainability-related effects, ICT could also be *used* to promote sustainability in different ways, for example to boost agricultural yields by 30 percent until 2020 and reduce the emissions of carbon dioxide equivalents (CO_2e) by 20 percent until 2030—all of the while continuing to contribute to economic growth [11]. As to be expected, the report was well received by the ICT industry and also read and cited by academics and policymakers. Critics contended that the report was excessively optimistic and that it would be challenging to fully leverage the potential of ICT for sustainability as rapidly as proposed without the aid of supportive policies and regulations. As we approach 2030 without any substantial decreases in CO_2 emissions due to ICT implementation, it appears these concerns were justified. However, many researchers embraced the discourse that the net sustainability effects of ICT could in fact be positive rather than negative, and researchers started to focus more on how to use ICT in different applications in order to improve the environmental sustainability of other parts of society.

In 2011, Lorenz Hilty and his colleagues concluded that three fields that were focusing on environmental sustainability had emerged, namely *environmental informatics*, *green IT*, and *human-computer interaction* (HCI) [17]. However, sustainable development is not only concerned with the environment, but also with social aspects such as education, health and safety – issues that *ICT for Development* (ICT4D) had focused on for at least a decade by then [18]. A few years after the introduction of green IT, practitioners, policymakers and researchers started to change their vocabulary in order to also take into account aspects related to social sustainability and ICT and incorporated aspects traditionally related to ICT4D. In Sweden, for example, *The Swedish Institute for Standards* (SIS) started working on a standard for green IT in the early 2010s, but it decided to change the name of the standard to *sustainable ICT* for the final release [19]. The shift in focus from green to sustainability broadened the scope of green IT, leading to the emergence of new areas of study such as *sustainable HCI* (SHCI), *ICT for sustainability* (ICT4S), *computing within limits* (LIMITS), and others.

In SHCI, researchers focus on how humans and computers are related in the context of sustainability. According to Blevis, who in his article *Sustainable Interaction Design* laid the foundation for the research field, such research could focus on, for example, how humans acquire, use (or misuse) and dispose of technology in relation to sustainability [20]. Mankoff et al., also an early contributor to the emerging field of research, suggested that such research could either focus on *sustainability through design* or *sustainability in design* [21]. This basically means that we could either focus on how ICT products can be produced, used and disposed of in a more sustainable way, or focus on how ICT products can be used to make other parts of society more sustainable. Similar distinctions emerged also in other related fields, not least in green IT where researchers distinguished between greening of IT and greening by IT. In summary, to make ICT sustainable, it was emphasized that ICT products must be manufactured ethically and sustainably, and also utilized in a manner that minimizes harmful impacts and maximizes positive sustainability outcomes. However, as highlighted by Brynjarsdóttir et al. [22] in a famous article, research within SHCI tended to focus on the latter, and in a quite narrow sense. In their article, they claim that SHCI researchers mainly focus on developing *persuasive technologies*, i.e., products and applications that aim to provoke sustainable behaviors among their users, for example recycling and sustainable forms of [23]. Their main critique was that such a focus risks promoting less unsustainable activities rather than leveraging the full potential of ICT to create entirely new and sustainable practices.

ICT4S is another influential field of research that started as a conference in 2013 and has much in common with SHCI. Research within ICT4S is described as focused around the effects of ICT on sustainability, and in particular the development of more sustainable ICT systems. Anything that would fall within the realm of SHCI would therefore also fit within ICT4S, but the latter encompasses a much wider scope of research. ICT4S, in their annual conference, also emphasize the role not only of research but also that of industrial and governmental actors, and NGOs. While researchers who contribute to SHCI are usually scholars within computing, ICT4S has a somewhat broader audience and accepts social science research in addition to more technical research. According to Hilty and Aebischer [7], ICT4S differentiates itself from other research fields within computing with its "critical perspective that challenges every technological solution by assessing its impact at the societal level." The ICT4S conference is organized by among others Lorenz Hilty, who was previously a member of the WG 9.9. However, some critique has been aimed towards this field of research in recent years, not least from

Mann et al., arguing that much research within ICT4S is focusing on optimizing major unsustainabilities rather than on the transformation to a more sustainable society [24].

To be fair, although much research on ICT and sustainable development is done with good intentions within the above-mentioned fields of research, much of it is built on prevailing assumptions of continued economic growth and technological development, assumptions that do not properly take into consideration planetary boundaries and the inherent contradictions between sustainability and economic growth [9, 24, 25]. Rather than supporting sustainable transitions from, among other things, unsustainable modes of production and consumption, such research risks maintaining a less unsustainable, but not completely sustainable, status quo [9, 26]. Before outlining the more progressive perspectives that guide our work in WG 9.9, I need to briefly address the concerns that research in ICT and sustainable development typically addresses.

2 Conventional Approaches to ICT and Sustainable Development Research

As briefly mentioned in the introduction of this chapter, ICT has traditionally been seen as a rather clean technology with few ethical and sustainability-related implications [8]. Thankfully, this is no longer the prevalent view in research fields that focus on ICT and sustainable development, and it is now widely recognized that there are sustainability-related challenges all along the ICT value chain [27]. Therefore, there is still much potential in focusing on the *sustainability of ICT* (or *greening of ICT*). The most important problems are summarized in Table 1, but there are also other problems related to more specific technologies or hardware.

Most of the above-mentioned aspects have been investigated extensively, not only by scholars within disciplines such as green IT and ICT4D, but also by policymakers and non-governmental organizations (NGOs). The environmental and human rights movements, not least Greenpeace and Amnesty International, have focused on several of these aspects and have been in the forefront of emphasizing problems occurring in the ICT value chain. Amnesty International, in a recent report [30], highlights for example that digital surveillance technologies are being exported from Europe to China where the technology is used to restrict human rights, and the Enough Project have emphasized problems related to the use of conflict minerals in ICT products [31]. Greenpeace Sweden were also very early in criticizing the ICT industry for the use of toxic chemicals in the production of ICT products [32]. These initiatives have had real, positive consequences on ICT-related policy, both in the EU and the US [33], and led to sustainable change within the ICT industry itself [34].

Many of the problems presented in Table 1 are related to some unique properties of ICTs today, such as the rapidly increased demand for ICT products (such as smartphones and laptops), their relatively short useful life, and the complex material composition making them both difficult to produce, repair, refurbish and recycle. Furthermore, the concept of unequal exchange is central to the global nature of the ICT value chain [28, 35], referring to the fact that the benefits of ICT products are mainly enjoyed by the developed part of the world, while most negative side effects such as e-waste and social issues are problems that the developing world have to deal with. As ethics and sustainability are

Table 1. Summary of potential sustainability-related problems along the ICT value chain. Adapted from Fors [9]

Value chain phase	Sustainability-related problems
Extraction of raw materials	Working conditions such as slave labor, child labor, inadequate safety equipment, extended working hours, prohibition of unionization, hazardous waste, usage of harmful chemicals. Emission of GHGs and other air pollutants, reliance on conflict minerals, unequal exchange [28], geopolitical issues associated with REEs and other critical materials, resource depletion, corruption, etc
Transportation and manufacturing	Working conditions (slave labor, child labor, lack of safety equipment, use of hazardous chemicals, long working hours, prohibition of unionization, etc.), hazardous waste, emissions of GHGs, corruption, etc
Use	Electricity use (especially in data centres) and emissions of GHGs, online fraud and harassment, privacy, censorship and corruption, algorithmic bias, accountability and transparency, etc
Disposal	Working conditions related to informal recycling (slave labor, child labor, lack of safety equipment, use of hazardous chemicals, unequal exchange, etc.) [29]. Problems related to recirculation (e.g., repair, reuse, refurbishing and recycling) due to design and policy problems, leading to increased waste and emissions of GHGs, etc

naturally intertwined concepts [36], these aspects are not only emphasized by researchers within WG 9.9, but also discussed in WG 9.6, WG 9.7 and WG 9.10.

The flexibility of ICTs afforded by the complexity of these technologies is also what makes ICT potentially beneficial *for* sustainable development (or *greening by ICT*) [37], as previously mentioned. According to Zapico [38], there are three broad categories of research and practice that aim to make ICT useful for achieving sustainable development (or *greening by ICT*), namely *optimization*, *dematerialization* and the *use of ICT to promote sustainable behaviors and practices*.

Optimization is about increasing the efficiency of a process, for example a production process, to require less energy or resources for the same outcome. ICT is a technology frequently used to increase the performance and the efficiency of different processes, but often in terms of making work, the production of good and everyday life more efficient in terms of time and money [7]. ICTs can be used for optimization by either incrementally improving existing processes (for example, automatic route planning for transportation [39]) or by radically changing the process completely (for example, digital communication through videoconferencing software). Regardless, it is widely believed that an optimized process is more sustainable than an unoptimized one, and that ICT has specific characteristics that make it an appropriate technology for improving resource and energy efficiency [40]. This may hold true in the short term, but it has become a highly debated topic, not least since much research within fields related to ICT and sustainable development have traditionally focused on improving inefficient processes. Hilty et al. [41], for example, show how optimization often leads to an increased output (of products) rather than a decreased input (of energy and/or resources). While not inherently negative *per se*, it demonstrates that higher efficiency does not necessarily equate to greater sustainability. This is usually referred to as the Jevons paradox, which states that when technology improves and increases the efficiency of resource usage, it can lead to an overall increase in resource consumption instead of a reduction. This is due to increased demand created by lower resource prices and improved efficiency. Hilty [40], for instance, demonstrates how the increased energy efficiency of vending machines in Japan made a more widespread installation economically feasible, resulting in a rise in overall energy and material consumption. These kinds of effects are usually referred to as rebound effects and are well documented in research on ICT and sustainable development (see, for example, [42]).

Dematerialization is the second category of research and practices that is often discussed in relation to sustainability within ICT and sustainable development. Dematerialization refers to the activity of replacing energy and resource intensive products with digital options through the use of ICT. This can reduce the need for costly and unsustainable production of goods and therefore reduce waste and pollution. Dematerialization is seen as a key aspect of decoupling economic growth from resource and energy consumption because, in theory, digital products can be endlessly replicated without using additional resources. Previously, dematerialization was considered to be the most important contribution of ICT to lower the emissions of CO_2 from other industries [11] Music, movies, newspapers and video games are examples of digital products that have been dematerialized [43], but it is difficult to say whether this has led to a decrease of energy and resource consumption, as demonstrated by Santarius et al. [44]. As demonstrated during the Covid-19 pandemic in 2020 and 2021, digital services such as virtual meetings, webinars, and online conferences can to a certain extent substitute physical travel. This is sometimes termed “presence dematerialization” [45]. According to Quéré et al. [46], CO_2 emissions have increased steadily by approximately one percent per year during the past century; yet during the pandemic, there was a significant decrease in emissions partly due to decreased travel opportunities. During these years, presence dematerialization helped many people to work from home and attend international conferences and meeting without the need for physical travelling. Still, the drastic decrease during the pandemic was but “a bleep” according to the International Monetary Fund (IMF) [47], and after the pandemic ended emissions started to yet again increase drastically.

Furthermore, there are rebound effects related to other forms of dematerialization that we need to take into consideration. Not only has dematerialization allowed for new ways of consuming media such as music, movies, video games and television series, but it has also had a big impact on our consumption practices in general. The energy demand of the internet is growing quickly, and it is estimated that by 2030 it will account for around 21 percent of the global electricity demand. According to Widdicks et al. [48], around 50 percent of the total data traffic is used by streaming services, and the demand is quickly increasing due to changed watching behaviors and practices. The consumption practices have changed dramatically since streaming has become the new normal. Multi-watching, or media multitasking, is one such new phenomena, and means that people watch multiple streams simultaneously on several different devices. Suski et al. show that high-quality video streaming on, for example, a smart TV is up to ten times as CO_2 intense as streaming on a smartphone, emphasizing the potential of promoting sustainable streaming behaviors [49]. In the Greenpeace report *Click Green 2017* [50], it is emphasized that the power consumption of data centers is not only growing, but many ICT firms still rely on non-renewable energy sources to power their data centers, contributing to climate change. Another phenomenon related to dematerialization is the emergence of cryptocurrencies, which are extremely electricity-demanding to maintain. It is estimated that Bitcoin alone consumes as much electricity as the Netherlands [51], and much hardware (especially graphics processing units, GPUs) are devoted solely to cryptocurrency "mining," which in itself is problematic [52]. As energy prices are increasing as a result of the ongoing war in Ukraine, and the value of Bitcoin and other cryptocurrencies are decreasing, new and more efficient ways of maintaining these currencies are being developed which may help to resolve issues with energy and resource consumption [53].

In summary, dematerialization has traditionally been one main focus within research on ICT and sustainable development. While we have yet to see product dematerialization contributing to the decoupling of economic growth and CO_2 emissions, we can see many beneficial effects from presence dematerialization due to the Covid-19 pandemic. The conflict in Ukraine and the associated surge in energy prices highlight the need to prioritize energy efficiency through ICT in research. However, it is crucial to recognize that while energy optimization can offer both short-term and long-term energy savings, a sole focus on optimization may limit opportunities for more substantial, transformative change [9, 24].

The third and last category of conventional approaches to ICT and sustainable development, according to Zapico [38], is research promoting sustainable behaviors and practices, or as Verbeek [54] puts it, "behavior-influencing technologies," for sustainability. Behavior-influencing technologies are hardware and software with the purpose of influencing personal behaviors or social practices. Such technologies have always existed; in fact, it is difficult to imagine a technology without properties that aim to influence one or several behaviors. Take, for example, Latour's example [55] of a hotel keychain, which is produced to be as clunky and hard to bring with you as possible, because the hotel management wants you to leave the key in the lobby when you leave the hotel. In this example, the keychain is used to persuade hotel guests into a particular behavior, and many behavior-influencing technologies are often also persuasive technologies. For research on ICT in particular, Fogg's [56, 57] work on computers as persuasive technologies became central in the mid 2000s. In the early 2010s, researchers started to apply this research in order to evoke what the designers saw as sustainable behaviors, for example recycling or reducing food waste. There are many different theories of how to best promote such sustainable behaviors. *Eco-feedback* can provide real-time feedback on for example your use of electricity which gives you a hint to how this can be decreased. *Sustainable gamification* aims to make sustainable behavior more fun and enjoyable by awarding such behaviors with points and badges within an app or a video game [23].

There are also other related concepts, such as nudging, that researchers often within the field of SCHI use to promote these kinds of solutions.

Despite the popularity of behavior-influencing technologies, however, the idea of making people become more sustainable through persuasion and similar techniques has been criticized, not least by Brynjarsdóttir et al. [22]. First of all, we need to realize that all technological products, regardless of purpose, have an influence on us as soon as we enter into a relationship with them. As Verbeek [54] puts it, "as soon as a technology is being used, it helps to establish a relation between users and their environment, and the result of that will mediate human actions and perceptions." However, when it comes to behavior-influencing technologies for sustainability, this purpose is clear and explicit: this product is going to make you act more in line with what we think is sustainable. Brynjarsdóttir et al. [22] argue that sustainability is being pushed onto the users in a top-down fashion by such technologies, and that it is not up to the designers of these technologies to decide what is sustainable or not. Furthermore, the perception of sustainability in these applications is often limited to just resource efficiency, making it unlikely for individual actions to drive the significant societal changes required. Many fun and interesting applications are being developed based on these assumptions that might very well contribute to more sustainable individual behaviors. Still, such initiatives make sustainability seen as a complex problem to solve for individual consumers [26], rather than a process which requires more transformational, societal change [24, 58, 59]. However, ICT has the potential to support the adoption of sustainable practices that replace current unsustainable ones and facilitate sustainable transitions, not least in the realm of consumption [60]. Examples of such practices include sharing [61], repairing [62], and second-hand shopping [63]. These practices, driven by ICT, advance innovative forms of resource- and energy-efficient and socially responsible consumption that greatly diverge from conventional practices [64, 65].

3 New and Promising Perspectives on ICT and Sustainable Development Research

In the previous section, I presented conventional perspectives on ICT and sustainable development in research and practice. While we understand that ICT is now an unavoidable part of our professional and private lives, and that there are ways in which ICT can guide our societies towards more sustainable trajectories, there are many assumptions and understandings within ICT and sustainable development research that need to be problematized [9]. This can be worked on within existing fields, such as ICT4S [24], or through the creation of new organizations, such as LIMITS. In the remainder of this chapter, I will present some streams of thought and fields of research that guide the research and the discussions within WG 9.9.

Within LIMITS, another important critique of conventional ICT and sustainable development research and practice is presented, which is related to what a sustainable future might entail. In conventional discourses on sustainability, i.e., sustainable development, Nardi et al. [66] argue, it is assumed that future sustainable societies will resemble current societies, but with reduced waste and emissions. This implies that rapid technological development, economic growth and consumption can and must continue indefinitely. There is no need for radical transformation of our societies, or new understandings of what we can expect out of sustainable futures. However, as these researchers and WG 9.9 recognize, there are certain ecological, material, and energy limitations that must be considered [3]. The primary questions that arise then center on how to utilize ICT to sustain or enhance the well-being of individuals within these non-negotiable limits. Constrained by such limits, researchers follow three key principles: question growth, consider models of scarcity, and reduce energy and material consumption [66]. Hjorth Warlenius [67] distinguishes two primary categories of economic theories that question economic growth: the trans-Atlantic school, which includes steady-state economics [68] and doughnut economics [25], and the Mediterranean school, which includes de-growth [69]. These two schools of thought have their similarities and they are both influential in research on ICT for sustainable development that promote transformative system change over incremental progress towards a less unsustainable status quo [9, 24]. Hjorth Warlenius explains that the principal distinction between the two schools is that the trans-Atlantic school generally posits that a smaller economy can be realized within the framework of capitalism, whereas the Mediterranean school adopts a more radical stance, asserting that de-growth can only be achieved through a different economic system [67]. The previous chair of WG 9.9, Maja van Der Velden, however, shows that while doughnut economics presents a more holistic approach to research than the sustainable development discourse, it remains firmly rooted within the discourse of the Anthropocene [70]. Santarius et al. [44] also argues that ICT alone cannot reduce the environmental impacts of a growing economy, and that research on ICT and sustainable development should rather focus on how to make use of ICT to foster sustainable post-growth or de-growth. Concerning how research should consider models of scarcity and reduce energy and material consumption, Bergmark and Zachrisson stress the need for establishing a new approach to Life Cycle Assessment based on planetary boundaries [71].

Within ICT4S, Mann et al. [24] argue that research on ICT and sustainable development is oftentimes "ill positioned with regard to the complexity of transforming society in such a way that people and environmental ecologies can coexist in a sustainable system." In line with my discussion above, they argue that such research often focuses on a small subset of sustainability-related parameters (for example, resource efficiency) and ignores the large system in which this is an issue. Therefore, research within fields interested in ICT and sustainable development should rather focus on transformational change towards sustainable futures (see [9]). In order to shift the needle and focus on such change, they developed a "sustainability-based transformational mindset" useful in research on ICT and sustainable development (Table 2).

In *Against Nature*, Kreps [26] writes about ICT and its relation to nature, by drawing on process philosophy. He argues that technological development in general, and ICT development in particular, is currently not geared towards sustainability but rather towards maintaining an unsustainable status quo where we as humans are individualized and alienated from each other and from nature. This is partly because research on ICT (and sustainable development) tends to be grounded in a positivist research paradigm, based on reductionist assumptions about humans as rational and independent, technology as instrumental or deterministic, and sustainability as optimization of resources.

Table 2. The sustainability-based transformation mindset, adapted from [24, 72].

Mindset	Explanation
1. Socioecological restoration over economic justification	Economic development or reasoning is not dismissed, but seen as a means to achieve social, cultural and environmental benefits
2. Transformative system change over small steps to keep business as usual	Transformational systems change means to move beyond the assumption that sustainability can be achieved through (many) marginal lifestyle changes
3. Holistic perspectives over narrow focus	Broader perspective that encompasses considerations of time, space, boundaries, methods, and more [24]
4. Equity and diversity over homogeneity	Diverse systems are resilient systems [24]
5. Respectful, collaborative responsibility over selfish othering	Research should focus on supporting collective action rather than to focus on the role of the individual
6. Action in the face of fear over paralysis or willful ignorance	Complex, "wicked" problems related to sustainability require long-term solutions, and ICT4S can contribute with such solutions
7. Values change over behavior modification	Persuasive technologies have been extensively researched within SHCI and ICT4S for decades now; however, the effectiveness of such applications to contribute to radically transform our society towards sustainable futures is unclear. Rather, we need to work with embedding sustainability as a core cultural value in social systems
8. Empowering engagement over imposed solutions	Empowering individuals and groups and fostering their involvement increases the likelihood of success for any actions taken, compared to solutions imposed by external experts [24]
9. Living positive futures over bleak predictions	To strive for sustainable futures, it is crucial to understand the gravity of the situation and the necessary steps to shift from unsustainable paths. However, it is even more essential to concentrate on potential solutions that enable us to exist within planetary boundaries and other restrictions
10. Humility and desire to learn over fixed knowledge sets	Sustainability is not a "complex problem to solve" [59]. We cannot hope to achieve complete knowledge about the problem or the solutions, but we need to keep up the desire to learn, and to keep challenging conventional underlying assumptions and understandings (see [9])

In short, Kreps [26] argues, "the underlying philosophy and much of [the outcome of computing] runs counter to the health of the environment: it is *against nature*." Kreps introduces the concept of systemic individualization, which implies a perspective to ICT and sustainable development (based on the assumptions presented above) where individual "consumers" can contribute to sustainability through rational, sustainable choices. Such perspectives on ICT and sustainable development research are criticized throughout this chapter. One main conclusion of the book is the argument that we need to resume the philosophical scrutiny of ICT and challenge the underlying positivist philosophy that affects much contemporary computing research. David Kreps was previously chair of TC 9 and a member of WG 9.9 at the time of writing this chapter.

In a similar manner, Fors [9] concerns himself with how ICT should be understood, designed and mobilized for sustainability purposes. The main argument is that ICT for sustainable development research is based on assumptions and understanding that need to be problematized and reformulated. In this thesis, Fors presents and problematizes three abstractions of ICT and sustainable development research and practice, namely the technological, the social, and the sustainable. He argues that research exaggerates the "purely technological" aspects of ICT and sustainable development in terms of their potential for sustainability and therefore often falls into deterministic and essentialist conceptions of technology. He furthermore argues that much research disregards non-technical aspects of ICT (especially research on optimization and dematerialization) but also that research that focuses on *the social* aspects – for example research on persuasive technologies – often reduces human behavior to that of the rational and individualist *homo oeconomicus* (cf. [26]). Such research rarely leads to meaningful transformations towards sustainability, but rather to individualist conceptions of it. The final abstraction, the sustainable, in such research is often imbued with a pro-growth, technology-optimistic, western-centric and neoliberal ideology [73] that many would argue is inherently incompatible with sustainability [74]. By problematizing sustainable ICT, Fors opens up to a radical rethinking of the theoretical and philosophical underpinnings of the subject. His conclusion is that sustainable ICT research should aim to influence collective action and futurescaping (cf. 5, 8 and 9 in Table 2) through the mobilization of politically charged discourses about our co-existence in futures of scarcity and environmental strain (cf. [66]), and practices that aim to change how we related to and dwell in them. Per Fors is the chair of WG 9.9 by the time of writing this chapter.

Although the researchers interested in the activities of WG 9.9 hold similar assumptions about the connection between ICT and sustainable development, they vary in the specific empirical topics they investigate in the field. However, some interests are shared among several of these researchers, including interest in the role of digital economies (such as the sharing economy and the second-hand economy) for sustainable development [61, 75, 76], the role of ICT in education for sustainable development (ESD) [77, 78], resource scarcity [28, 79], e-waste [62, 80, 81], sustainable design and design for sustainability [82, 83], and more.

To sum up, studies regarding the relationship between ICT and sustainable development within WG 9.9 are frequently impacted by one or more of the perspectives outlined in this section of the chapter. These perspectives are often critical and acknowledge among other things ecological, material, and energy boundaries. Furthermore, this research challenge assumptions concerning economic and technological expansion, referring to both quantity ("technomass") and the trajectories of development [35]. Finally, although recognizing that every individual has a responsibility to incorporate sustainable behaviors into their personal lives, research on ICT and sustainable development influenced by the theoretical perspectives outlined in this section puts more emphasis on the role of ICT for societal transformations and transitions towards sustainable futures.

4 Concluding Discussion

In recent decades, there has been a significant increase in research that examines the relationship between ICT and sustainability-related factors within our society. Initially, research primarily concentrated on the adverse effects of ICT on the environment, specifically in terms of electricity usage, the hazardous chemicals employed in production, and electronic waste. This perspective was prevalent in the early stages of green IT. However, as researchers and practitioners recognized that ICT has the potential to promote sustainable development and offer economic, social, and environmental advantages, the discourse swiftly changed. Instead, ICT was presented not mainly as an obstacle for sustainable development, but as a silver bullet for many sustainability-related problems, such as CO_2 emissions, energy use, waste, poverty, unemployment, and more. The main focus areas for research adhering to this positive discourse are optimization, dematerialization and the role of ICT to promote sustainable behaviors and practices. Nonetheless, while acknowledging the potential of such research and practice, WG 9.9 adheres to more critical perspectives that acknowledge the failure of conventional perspectives to promote sustainability in these ways. WG 9.9 argues that concentrating solely on narrow and individual dimensions of sustainability, such as energy efficiency, is not only ineffective but also risks undermining more radical, and needed, change, by promoting technological fixes that reinforce an unsustainable status quo. As noted by Kreps [26], technology in general, and ICT in particular, is generally not geared towards sustainability but rather the opposite: not only are there negative sustainability-effects throughout the value chain of ICT (see Table 1), ICT is also mainly adopted for purposes other than sustainability that contributes to negative environmental and social effects.

WG 9.9 strongly supports the idea that ICT can play a vital role in promoting transitions towards more environmentally, socially, and economically sustainable futures. While the discourse concerning the role for ICT to contribute to sustainability is still overly optimistic, my main ambition in this chapter has been to present a sample of new and promising perspectives on ICT and sustainable development that, in contrast to conventional research, has the potential to drive more radical societal transformations rather than to uphold an unsustainable status quo.

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