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Conceptualizing sustainability in the context of ICT. A literature review analysis.

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***Abstract*—This paper examines the conceptualization of sustainability in the context of information and communication technology (ICT) research. Through an inductive text analysis of sixteen literature reviews spanning from 2014 to 2023, key themes and concepts are identified, highlighting the complex relationship between ICT and sustainability. ICT is perceived both as an enabler and a problem for sustainability. Furthermore, the terminology and concept of sustainability in the context of ICT remain unclear. The emergence of digitalization as a novel socio-technical phenomenon poses additional challenges for conceptual alignment. While a holistic view of sustainability in ICT is desired, business and social implications receive less attention. The paper summarizes and discusses the developments in research on this topic over the past decade.**

***Index Terms*—Sustainability in ICT, sustainability by ICT, digital sustainability, digital transformation and sustainability.**

I. Introduction

ENVIRONMENTAL challenges have become one of the most pressing contemporary issues for humankind. They are paired with social and economic transformations. For that matter, sustainability research has become a topic of interest as it promises practical solutions for these challenges [1–3]. It is postulated that fundamental sustainability transformations at the macro-, meso- and micro-level are required to address the manifold and complex challenges on the social, economic, and environmental levels involving multiple actors [4]. At the same time, digitalization has become a global and ubiquitous [5] phenomenon, which now is quasi-irreversible after COVID-19 [6]. This raises the question if and how these two megatrends – digitalization and sustainability – are intertwined or apt to drive deep transformations [7–9]. Digitalization is a socio-technical phenomenon [10] that enables the utilization of novel "*technologies, communication methods, business functions, and models*" [6, p. 15] to achieve different objectives. ICT is the backbone of digitalization. It provides hardware and software solutions that enable digitalization. Thus, ICT deeply impacts the economy [11] and enables socio-technical megatrends commonly referred to as SMACIT, that is, social platform, mobile, analytics, cloud computing, and internet of things [8, 10].

The term and concept of sustainability originate from forestry and originally describe the approach to harvest just the amount of wood that regrows [12, 13]. The concept became popular in 1987, when the World Commission on Environment and Development published the Brundtland Report, which provided a seminal description of the sustainability concept [12] by distinguishing three pillars [13]: environmental, economic, and social sustainability, also referred to as planet, profit, people [3, 12]. Additionally, the Brundtland report defined sustainable development, whose aim is to satisfy "*the needs of the present without compromising the ability of future generations to meet their own needs*" [13, p. 684].

Today, the sustainability concept is applied to a variety of other – complex, novel, and broad – problem spaces [14] such as ICT. Consequently, the term has become a multi-layered concept [15]. In the context of ICT, the concept of sustainability remains opaque [16].

This paper aims to provide guidance, clarity, and an overview for both researchers and practitioners in the field on how the concept of sustainability is related to ICT. Such conceptual alignment will support them operationalizing actions and strategies to achieve sustainability goals. Given the fundamental conceptual challenges of applying sustainability to the domain of ICT, this paper aims to address three research questions:

RQ 1: *How is the concept of sustainability discussed in the context of ICT?*
RQ 2: *What are the key concepts and themes that characterize the relationship between sustainability and ICT?*
RQ 3: *How has this relationship evolved over the past ten years?*

Thematic track: Information Systems Management

In the context of this paper, a *concept* is a mutually exclusive, well defined, and known insight from extant literature on that topic. A concept can become a subcategory and can be mapped to a well-known and well discussed research *theme* [17]. For example, the terminological misalignment regarding sustainability in the context of ICT is a *theme* but is discussed at two different *conceptual* levels: sustainability in the context of ICT, as well as sustainability in the context of digitalization or digital transformations. While both strands of discussion are mutually exclusive on a *conceptual* level, they form a *theme* inasmuch they inherently are terminological debates. For the analysis, an inductive text analysis was applied to identify *concepts* and *themes* from literature reviews on sustainability in ICT.

A five-step process was applied to identify themes and concepts [17]. First, it was decided to focus on literature reviews from the past ten years that treat the topic of sustainability and ICT on a holistic and conceptual level. Second, searches for relevant literature reviews on Scopus, Web of Science, and EBSCO were performed. Inclusion and exclusion criteria were applied, and search queries were reformulated to retrieve pertinent content. Third, the retrieved literature reviews were assessed as to whether they match the initially defined search criteria. Literature reviews that met the inclusion criteria were added to the final sample for further analysis. Hence, a selective strategy was chosen for creating the sample for analysis. Fourth, the sampled literature reviews were carefully examined and scrutinized using open, axial, and selective coding, and comparative analysis to synthesize research findings and gaps. From these findings, conceptual commonalities were induced and mapped to *concepts*. The *concepts* were eventually also subsumed to overarching *themes*. Fifth, the findings are eventually presented in the following chapters.

II. Methodological approach

A. Search strategy

Scopus, Web of Science, and EBSCO were used to find relevant literature reviews. Only articles, reviews, or conference proceedings in academic journals dating from between the years 2014 through 2023 and written in English language were considered. Additional restriction criteria, such as selecting a set of subject areas (Scopus), categories (Web of Science), and databases (EBSCO), were applied. The search query was constructed such that it retrieves matches in the title of documents to limit the number of matches. The following keywords were applied and concatenated using the OR- and AND- operators: ((*digitalization* OR *digital* OR *ict* OR (*information system*) OR (*information science*)) AND ((*sustainability* OR *sustainable* OR (*problem* OR *solution*)) AND (*literature* OR *review* OR *concept* OR *research* OR *definition*). The results that were found in the three different databases were then merged and duplicates were eliminated. A first temporary sample was chosen based on carefully studying the abstracts. Only literature reviews that cover sustainability in the context of ICT holistically were considered. That is, they must refer to all sustainability pillars, treat the topic of sustainability in the context of ICT in general, and not in context of a specific industry, sector, technology, or application scenario. Table I shows the applied search approach for retrieving relevant literature reviews.

To refine the result set, another round of reading and assessment was performed. As a result, some literature reviews were discarded because they did not meet the inclusion criteria: for example, literature reviews focusing on sustainability for smart cities, efficient manufacturing, industry 4.0, or business models were neglected. Reviews that address a specific industry or sector, for instance, textile industry, or fishery, were discarded, too. Two reviews were incorporated in the analysis despite showing a clear tendency towards a specific sustainability pillar [8, 18]. However, those literature reviews actively tried to integrate their focus area into the greater context of sustainability and ICT. Additionally, forward- and backward citations were used to identify pertinent research articles.

An additional "sanity-check" on Google Scholar was performed to identify potentially overlooked literature reviews. For that, the same keywords were applied that were used to retrieve relevant literature from Scopus, Web of Science, and EBSO databases. Finally, sixteen literature reviews remained for the in-depth analysis. Table V in the appendix lists the literature reviews that were sampled for the analysis.

TABLE I.
SEARCH APPROACH (MATCHES ON *TITLE*-PROPERTY) FOR LITERATURE SELECTION FROM SCOPUS, WEB OF SCIENCE, AND EBSCO

Property	Inclusion criteria	Scopus	Web of Science	EBSCO
Subject area	Computer science OR business, management, and accounting OR social sciences OR engineering OR environmental science	407		
	Computer science OR environmental sciences OR green sustainable technology OR environmental studies OR management OR business OR engineering		204	
	Business source premier OR green file			81
Document types	Articles, conference papers, reviews, and proceeding papers in academic journals	361	192	69
Publication Years	2014 to 2023	297	147	55
Language	English	270	154	50
Thematic focus	Literature reviews that treat sustainability in ICT holistically	15	7	2
# Total after merging and deduplication		**#16**		

B. Data analysis

The sampling and data synthesis processes, including the conceptualization and thematization steps, are illustrated in Fig. 1.

First, open coding was performed by carefully reading the sampled literature reviews and coding findings and research gaps. As a result, a total of 97 findings and gaps were synthesized: 59 findings (61%) and 38 gaps (39%). Next, axial coding was applied by inducing *concepts* and *themes* from the findings and gaps. Thirteen different *concepts* and five *themes* were induced, and the 97 individual findings and gaps were classified accordingly. Selective coding was then applied to identify connections, interdependencies, and validity of the concepts and themes.

Themes and concepts were then compared to each other to avoid overlaps or fuzziness with regards to their content. The concepts and themes eventually enabled addressing all three research questions. The concepts and themes that were identified address RQ1, that is, understanding *how the concept of sustainability is discussed in the context of ICT*. They also directly address RQ2, whose aim is to understand *what the key concepts and themes are that characterize the relationship between sustainability and ICT*. To answer RQ3, which is to understand *how the relationship between sustainability and ICT has evolved over the past ten years*, an additional step was performed: the identified themes and concepts were analyzed as to which dimensions they are composed of, how the meaning and importance of those dimensions have evolved, and which additional dimensions have emerged by validating them against a conceptualization proposal from 2014 [16].

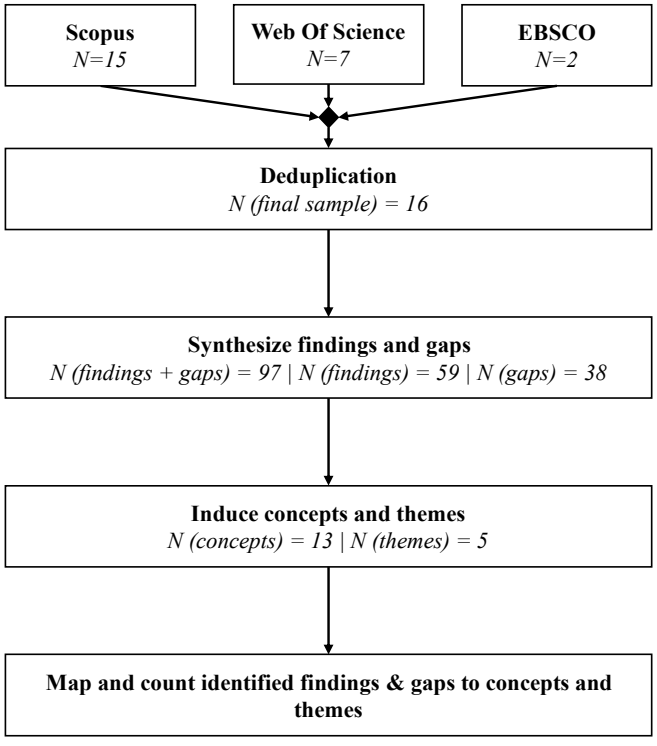

Fig 1. Literature sample and data synthesis approach

III. Findings

A. Concepts and themes

Our analysis of the findings and gaps in the analyzed literature reviews identified thirteen concepts, which were then grouped and mapped into five themes: (A) application, (B) sustainability concept, (C) impact, (D) mitigation, and (E) stakeholders. The concepts (1) application scenarios, (2) application sectors, (3) application technology, and (4) geographic perspectives were mapped to the theme *application*. The theme *sustainability concept* is divided into the concepts: (5) need to align concepts of digitalization, ICT, digital sustainability, and digital transformations and (6) terminological misalignment of sustainability in the context of ICT. Further, the *impact*-theme is composed of the categories (7) ICT as enabler, (8) ICT as problem, (9) ICT as problem and enabler and (10) the measurement of impacts of ICT on sustainability. The theme of *mitigation* consists of the concepts (11) mitigation strategies to address sustainability challenges and the (12) need for an interdisciplinary and holistic approach to sustainability in ICT. The theme *stakeholders* is defined by one concept, which is the (13) role of stakeholders and governance.

Table II shows the concepts and themes that were identified and are used to directly address RQ1 and RQ2. The following paragraphs explain the detected themes and concepts in detail.

Table II.
Themes and concepts identified addressing RQ1 and RQ2

Theme	Concept	ID
Application	Application scenarios	A#1
	Application sectors	A#2
	Application technology	A#3
	Geographic perspectives	A#4
Sustainability concept	Need to align concepts of digitalization, ICT, digital sustainability, and digital transformations	B#5
	Terminological misalignment sustainability in the context of ICT	B#6
Impact	ICT as enabler	C#7
	ICT as problem	C#8
	ICT as problem and enabler	C#9
	Measurement of impacts of ICT on sustainability	C#10
Mitigation	Mitigation strategies to address sustainability challenges	D#11
	Need for an interdisciplinary and holistic approach to sustainability in ICT	D#12
Stakeholders	Role of stakeholders and governance	E#13

B. Aspects of discussing sustainability in the context of ICT

The famous Brundtland report assigned ICT a leading role in achieving sustainability goals [19]. Today, the concept of sustainability in ICT is discussed under two competing yet intertwined concepts (C#9): *ICT as enabler* (C#7) or *problem for sustainability* (C#8). Research lists different application areas where ICT functions as an enabler for efficiency, for

example, by reducing the overall energy consumption [6, 20], and is thus considered a historic opportunity [8, 11]. On the other hand, ICT directly impacts the environment, for example, via the hardware value chain for which raw materials need to be extracted, and energy is required for producing, using, refurbishing or reusing, and finally for disposing hardware as e-waste [5]. Also, operating large data centers, the backbone for supporting an increased usage of cloud-based services [21], requires significant energy [22]. Additionally, there are negative indirect impacts such as obsolescence, induction, and rebound effects [19, 23, 24]. Consequently, the theme of *mitigation* (D#11 and D#12) is the prevailing strand of discussion in literature. Also, the presentation of concrete proposals on how to *measure the impacts of ICT on sustainability* (C#10) is of importance in that context [6, 23, 25]. Another negative consequence is the social divide between those participating in digitalization and those being left out or behind due to missing skills or not keeping up with using the benefits of using digital technologies [9, 26, 27]. Such negative spillover effects of technology adoption beyond the environmental dimension are widely neglected [3, 6, 27]. Also, adverse environmental consequences of novel technologies, such as bit coin mining, have been insufficiently considered [3, 6, 27].

However, the analyzed literature reviews show a tendency towards describing *ICT as enabler* (C#7). We identified that seven, i.e., 7% of all findings and gaps, referred to the consideration of *ICT as both a problem and enabler* (C#9) for sustainability. This finding aligns with what is reported in other literature reviews. For example, one study reports that 58% of their examined studies focus exclusively on the positive effects, while only 15% analyzed focused on negative effects [9]; another review found 52% of papers in their sample that describe ICT solutions as enabler [28]. Different enablement scenarios are mentioned in the analyzed reviews, for example, promoting renewable energy, driving energy efficiency [7, 8, 28], ensuring pollution and waste control that help create smart cities [8], managing energy demand and supply [8, 28], platforms for helping establish a circular economy [29], promoting sustainable mobility [27], or enabling education for sustainability [19]. However, there is little research on how ICT-based solutions can enable deep sustainability transformations, such as supporting the move to more sustainable agriculture [28]. There is also criticism that the belief that digital solutions will consistently result in positive sustainability outcomes represents an inherent risk (*digital solutionism*) [19].

Table III shows the distribution of the thirteen induced categories based on the findings and gaps identified in the sampled literature reviews. ICT as enabler for sustainability is the most mentioned finding – and ranks low in terms of being a research gap.

TABLE III.
FREQUENCY OF CONCEPTS AND THEMES IDENTIFIED IN THE SAMPLED LITERATURE REVIEWS

Theme	Concept	[#] Finding	[#] Gap	[#] Total
Mitigation	Need for an interdisciplinary and holistic approach to sustainability in ICT	9	12	21
Impact	ICT as enabler	14	0	14
Mitigation	Mitigation strategies to address sustainability challenges	3	8	11
Sustainability concept	Need to align concepts of digitalization, ICT, digital sustainability, and digital transformations	3	7	10
Impact	Measurement of impacts of ICT on sustainability	5	4	9
Stakeholders	Role of stakeholders and governance	6	3	9
Impact	ICT as problem and enabler	5	2	7
Application	Application scenarios	4	0	4
Application	Geographic perspectives	2	2	4
Application	Application technology	4	0	4
Impact	ICT as problem	2	0	2
Sustainability concept	Terminological misalignment of sustainability in the context of ICT	1	0	1
Application	Application sectors	1	0	1
Grand Total		59	38	97

C. Concepts and themes characterizing the relationship between sustainability and ICT

Twenty-one, that is 22% of the identified findings and gaps, emphasize the need for an *interdisciplinary and holistic approach to sustainability in ICT* (D#12) [3, 6, 7, 25, 26, 28]. There is agreement that all three pillars are intrinsically interconnected and cannot be considered in isolation [9, 27]. Particularly, social aspects such as the social divide caused by digitalization are thematized [18, 19]. Three papers mention that there is comparably little attention in management literature on the topic [6, 7, 26]. Another challenge pointed out is that the economic and environmental sustainability pillars can overlap. For example, topics such as the circular economy are considered both a social [28] and environmental aspect of sustainability [8]. Within the economic pillar, key topics of discussion are how ICT-supported digital solutions drive open innovation [29], or how digital technology – in combination with technology savvy human capital – is crucial for businesses to improve their products and services [30]. It is further pointed out that adopting a more interdisciplinary and systemic approach is essential to overcome the biases, limitations, and gaps identified in the current research landscape. Collaboration and engagement with multiple disciplines are required to understand the systemic nature of digital transformation and the link between digitalization and sustainable development [6, 9, 31].

Mitigation strategies to address sustainability challenges (D#11) are referred to in eleven, that is 11% of all findings and gaps. Though, the discovered and proposed strategies to mitigate sustainability impact do vary. The need for incorporating sustainability into strategic decision-making in organizations with the goal to establish sustainable business models is underlined [8]. The importance of operationalizing and providing guidance for sustainability is also mentioned to be important, as the actual acting stakeholders need guidance on how to act sustainably [16]. Business innovation is brought forward, too, as a possible strategy [30]. Other strategies mentioned are the focus on digital education [19] as well as the implementation of policies [19, 28]. Policies are crucial to establish sufficiency-oriented strategies and transformations at the structural level, which are underrepresented in research [28]. The sampled literature reviews show differences regarding the focus on where these policies ought to be applied. While it is acknowledged that individual users drive sustainability outcomes through their choices [6, 27], it is also proposed that only regulations and policies can ensure sustainable behavior [28]. This applies to all actors: individuals, and business organizations. However, it is conceded that it is comparably feasible to establish regulations for hard- or software providers, but employing policies for organizations or individuals is complex and difficult to monitor [28]. In this context, it is pointed out that it will be challenging to lower service standards without impacting an ICT provider's business by affecting customer expectations [27]. Overall, while the sources agree on the importance of sustainability strategies, they differ in their focus and approach to achieving sustainability goals. One the one hand, the emphasis on consistency and sufficiency strategies driven by policies are highlighted [28], while the need to examine how incentive systems or broad sustainability goals impact individuals' behaviors and beliefs is stressed out, too [6, 27].

The broad semantic and conceptual scope of the term sustainability is subject to academic discussions: the term is described to be implicitly normative [1, 32–35] and polysemous [36, 37]. More recently and importantly, the *need to align the concepts of digitalization and ICT, digital sustainability, and digital transformations* (B#5) emerged as a new important aspect [3, 7, 8, 25, 29, 31], which further contributes to the *terminological misalignment of sustainability in the context of ICT* (B#6). Ten, that is 10% of all identified findings and gaps, stressed out the lack of a description for the relationship and terminology for how sustainability and digitalization are connected. Hence, a paradigm-shift is suggested [31] to understand the connection between the two interdependent concepts [3]. Also, a clear delineation of the concepts of green IS, which focuses on the sustainable use of technology, and green IT, which aims to achieve sustainability goals by leveraging technology, is recommended [25]. The terminological discussion is further characterized by its focus on integrating environmental sustainability principles into business models and organizational strategies, as well as the alignment between organizational strategy and digitalization. It is highlighted that a deeper understanding of the environmental and social implications [18] of digitalization is needed. Therefore, a public goods approach is suggested to consider deep social, economic, and environmental impacts in the context of digitalization and the ubiquitous use of technology [27]. To conclude, the topic of how digitalization and digital transformation, sustainability, and sustainability transformations are connected is considered important, but there is not yet a terminological alignment for the scientific discourse on that topic.

Also, the *role of stakeholders and governance* (E#13) can be synthesized as a theme within sustainability in ICT – nine, that is 9% of all gaps and findings, refer to it. Stakeholders need to address challenges in operationalizing sustainability in ICT research [16]. In business organizations they are responsible for incorporating and driving for strategic sustainability goals [8, 25]. There is a need to better understand how the different organizational departments and functions can collaborate to achieve sustainability goals or implement sustainability initiatives, and what the role the IT department can play in that context [25]. Furthermore, the importance of practitioners and researchers for collaboration across disciplines to conduct comprehensive sustainability research is stressed [6]. Governmental actors are expected to design and implement policies that can enforce and encourage sustainable behaviors for individuals, individuals in organizations and ICT manufacturers and providers [28]. One study also mentions trading-blocs or countries as actors [3]. However, a sharp distinction between business and governmental actors is noticed, whereby the former is associated with sustainable business model creation, and the latter with policy development [7]. Finally, political participation and activism, for example via grassroot movements, and public goods approaches [27], are described to be required for fostering broad consensus on sustainability-specific matters [28]. To conclude, stakeholders in sustainability for ICT range from individuals to supra-national organizations; consequently, the range of ownership and responsibilities to drive sustainability outcomes is broad. Another emerging theme is the variety of *application* (A#1-4) areas to which sustainability is applied. Sustainability is applied to different *application sectors* (A#2) and *scenarios* (A#1) in conjunction with different ICT-enabled *technologies* (A#3) [6, 7, 25, 28]. This comprises sectors such as agriculture, rural communities, manufacturing, and logistics, libraries, digital learning, smart cities, healthcare, tourism, digital learning, production, or the energy sector [7]. Within each sector, ICT-supported sustainability solutions are applied, for example, for e-waste management, pollution control or efficient manufacturing [3] different technologies such as 3D-printing, IoT, automation or big data are used [6]. Finally, three reviews highlight the limited *geographical perspective* (A#4) and the lack of comparative research in understanding the relationship between digital transformation and sustainability. It is concluded that studying different countries and

contexts is required to achieve a more robust and generalizable understanding [7, 30, 31] of sustainability in the context of ICT.

IV. Discussion

One of the earliest and a widely cited literature review in the sample dates from 2014. It is used to gauge the evolvements in the research field over the past ten years [16]. Table IV summarizes the sustainability dimensions presented as in [16], and specifies the thematic and conceptual evolvements that have occurred. New dimensions that have emerged over the past ten years are marked in grey and added to the row '*Additions*', which covers the novel aspects '*Application areas*' and '*Geo(graphic) perspective*'. The thematic and conceptual evolvements are summarized in the column '*Thematic and conceptual evolvements*' and are highlighted in grey, too. These additions address RQ3 on *how the relationship between sustainability and ICT has evolved over the past ten years*.

The conceptualization proposal provided in [16] first describes the conceptual misalignment of sustainability in ICT. It is found that academic literature on sustainability in the context of ICT implicitly assumes that the conceptual dimensions of the sustainability concept are common knowledge. As a result, no further specification or definition of the concept is provided, and only references to other sources, which attempt to clarify the concept, are provided [16]. This conceptual and terminological under-specification can also be confirmed in the literature reviews analyzed for this paper. However, the theme that has emerged in the context of terminological ambiguity is the need to align *the concepts of digitalization and ICT, digital sustainability, and digital transformations* (B#5) [7, 8, 18, 25, 29, 31].

It is also observed that the three sustainability pillars are widely used to describe sustainability in ICT. It is pointed out that the economic and ecological perspectives, referred to as eco-effectiveness and eco-efficiency goals, overlap [16]. This view is valid in the more recent literature reviews; however, the importance of a holistic approach to sustainability in ICT is emphasized, recognizing the interconnectedness of economic, social [18], and environmental pillars. It is widely acknowledged that these pillars cannot be considered in isolation and that social aspects, such as the social divide caused by digitalization [18, 19], are of utmost importance, although it is conceded that social implications of digitalization need further research [3, 6, 7, 25, 27].

The second aspect of the definition, as provided in [16], is that sustainability is attributed in the literature to four categories of *reference objects*: first, individual and organization stakeholders, who drive sustainable development. Second, enablers, which allow stakeholders to act in a sustainable manner. *Stakeholders* are differentiated into *individuals*, *individuals in organizations* and *organizations*. Third, *consequences*, which are the result of sustainable activities. Finally, *sustainable activities* are tied to all entities, that is stakeholders, actors, and consequences [16]. All these four categories of reference objects hold true – but the reference objects and their roles can be updated and augmented.

Table IV.
Conceptualization of sustainability in ICT and its evolvements over the past ten years to address RQ3

Dimensions		Findings from [16]	Thematic and conceptual evolvements
Dimensions of the concept of sustainability in context of ICT as in [16]	Definition	Implicit assumptions on sustainability dimensions prevail in analyzed literature.	Focus on how digitalization, ICT, digital sustainability, and digital transformations are linked and can be conceptualized.
	Pillar	Environmental and economic pillars overlap. Holistic approach is considered important.	Increased focus on interdisciplinary and holistic approaches. Topics such as social impacts, e.g., social divide, receive increased attention.
	Enablers	Allows stakeholder to act sustainably (ICT artifacts, sustainability goals, strategies, etc.)	The concept of ICT as enabler prevails, but there is increased attention on negative side-effects and consequences.
	Stakeholder	Individuals and individuals in organizations	Increased attention on role of civil society, organizational, and governmental stakeholders, and their importance for mitigation strategies. Acknowledging gap on how individual behaviors are impacted by beliefs or social opinions.
	Activity	Activities links stakeholders, and enablers to sustainable consequences.	Evolved conceptualization of mitigation strategies (sufficiency, consistency, efficiency). Relationship between sustainability and digitalization, and digital transformations poses new areas for research.
	Consequences	Result of a sustainable activity. No differentiation between positive or negative consequences.	Consensus that there is a need for a more balanced view, in which negative social consequences receive more attention. Novel measurement and assessment approaches (Life-cycle-, enabling-, structural effects).
Additions	Application areas	Sector or industry (e.g., agriculture, industry 4.0, healthcare, etc.)	
		Technologies (e.g., big data, machine learning, etc.)	
		Scenarios (e.g., e-waste management, pollution control, etc.)	
	Geo-perspective	Local, regional, national, transnational, global perspectives	

Due to the socio-technological development in the context of digitalization, the fundamental role of ICT in sustainability – ICT as enabler or part of the problem – remains a seminal strand of discussion and hence a key part of the sustainability concept in the context of ICT. The range of stakeholders is actively discussed. It is acknowledged that the roles of individuals and how their beliefs or social norms impact sustainability behaviors [27], the roles of policy makers in enforcing

sustainability regulations [28], or the role of organizational stakeholders in initiating sustainability programs [25], are areas for further exploration. There are also advancements with regards to how different stakeholders can be mapped to different mitigation strategies [24].

In terms of consequences, the research field has provided advanced models and categorizations to better assess and understand impacts on the different sustainability pillars holistically. One example is the seminal LES model that differentiates life cycle, enabling- and structural effects [38].

The role of activities to achieve sustainability goals remains uncontested, but research has also delivered frameworks such as the sustainability mitigation strategies [24] – sufficiency, consistency, and efficiency – and impact measurement approaches [23] that are suited to guide and classify sustainability-oriented actions.

The role of ICT as an enabler is also further specified by analyzing concrete digital solutions enabled by novel digital technologies such as big data, or artificial intelligence in the context of a specific sector and specific scenarios are explicitly mentioned [6, 7]. Geographical aspects have gained more attention, which is also expressed in publication addressing specific national or regional aspects. Hence, the application scenarios, including sector-, scenario-, and technology-, and geographic-specific views, can be added as an additional dimension in a conceptualization matrix for sustainability in the context of ICT.

V. Conclusion

This paper aimed to address three research questions with regards to the concept of sustainability in the context of ICT.

For RQ1 it was shown that the role of ICT as either an enabler or problem for sustainability remains an important aspect in the discussion. ICT is predominantly seen as an enabler for sustainability that creates opportunities for efficiency-gains, energy reductions, or facilitates smart cities. However, the negative impacts such as the environmental footprint caused throughout the hardware lifecycle or the social divide created by dividing society into those participating in digitalization, and those who do not, attract increasing attention. Hence, practitioners and researchers should actively look for and transparently point out potential negative side-effects and consequences when planning to apply or investigate ICT-enabled solutions to achieve sustainability goals.

Regarding RQ2, the analysis confirmed that there is continuous terminological misalignment of sustainability in ICT, but with the important modification that the focus now is on integrating the concepts of digitalization and digital transformation, which is expressed by the term of *digital sustainability* [7, 25]. The overarching importance of an interdisciplinary and holistic approach to sustainability in the context of ICT and digitalization is stressed out as a requirement to address all three sustainability pillars. Therefore, it is important for both practitioners and researchers to look at sustainability in the context of ICT holistically and to tackle sustainability-related initiatives and projects in an interdisciplinary manner.

By addressing RQ3, it was revealed that important evolvements of the sustainability concept over the past ten years occurred: recent technologies, and new digital solutions, which are often global and international phenomena, broadened the range of application scenarios for the concept of sustainability. Also, the role of stakeholders and the mitigation strategies associated with or applied by them have seen further amendments and specifications.

As a result, future research should consider an interdisciplinary approach to better understand the complex connections and interdependencies between stakeholders, ICT, digitalization, and sustainability transformations to explore innovative solutions for sustainable digital transformation [28]. But to manage the scope and complexity of the topic, research should focus on specific application areas or technologies. More recent technologies such as artificial intelligence [7, 39–41] or digital twins are already being discussed in the context of sustainability [7, 42]. More targeted research can help narrow the research scope to an applicable and practical level. Another opportunity for further research is how stakeholders and practitioners in organizations can implement sustainability initiatives in their respective organizations and then measure the benefits that those initiatives yield [25] .

The limitations of this study are its selective approach and its focus on the most recent literature in the field: articles published between 2021 and 2023 represent 81% of the examined corpus. The sampling step can result in the exclusion of relevant content and hence it must be acknowledged that synthesizing more papers could have attributed additional insights. Also, the terminological misalignment and the absence of well-established keywords for research on sustainability in context of ICT and digitalization can result in excluding pertinent literature reviews. These shortcomings and additional potential gaps are an opportunity for further research.

Appendix

Figure 2 summarizes the total count of findings and gaps, mapped to the five synthesized themes.

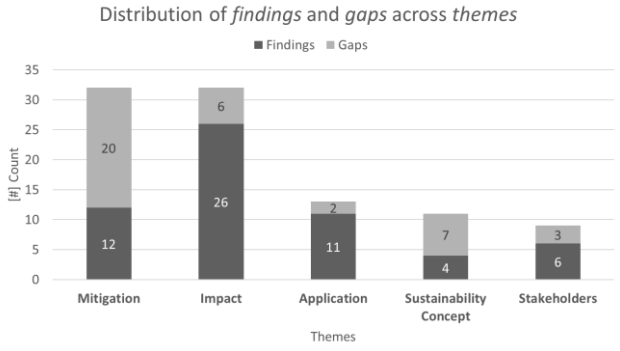

Fig 2. Distribution of themes

Table V lists the sampled literature reviews including coding results, differentiated by themes, concepts, as well as findings and gaps.

TABLE V.
LITERATURE CODING RESULTS

Theme		Application					Sustainability concept			Impact						Mitigation				Stakeholder	
Concepts		A#1	A#2	A#3	A#4		B#5		B#6	C#7	C#8	C#9		#C10		D#11		D#12		E#13	
Finding (F) / Gap (G)		F	F	F	F	G	F	G	F	F	F	F	G	F	G	F	G	F	G	F	G
Author	**Published**																				
J. Bieser and L. Hilty	2018													2		1					
F. Chasin	2014								1								1		1	2	
A. K. Feroz, H. Zo, and A. Chiravuri	2021	1						1									2				
I. Guandalini	2022		1	1	1			2											4	1	1
Y. Karki and D. Thapa	2021					1	1	3									2	1			
J. Kotlarsky, I. Oshri, and N. Sekulic	2023			1			1			1					1				1	1	1
A. Kuntsman and I. Rattle	2019	1								2	1	3		1							
S. Lertpiromsuk and P. Ueasangkomsate	2022					1				3											
M. Mouthaan, K. Frenken, L. Piscicelli, and T. Vaskelainen	2023									1				1				3	1	1	
P. Perera, S. Selvanathan, J. Bandaralage, and J.-J. Su	2023	1			1		1				1										
G. Robertsone and I. Lapiņa	2023			1				1		3			1								
A. Rosário and J. Dias	2023									4						1		2			
P. Sacco, E. R. Gargano, and A. Cornella	2021			1								1			2			1		1	
T. Santarius and J. Wagner	2023	1										1	1			1	1		3		1
G. D. Sharma, D. Reppas, G. Muschert, and V. Pereira	2021																	2	1		
D. J. Veit and J. B. Thatcher	2023													1	1		2		1		

[A] Application – (1) *Application scenarios*, (2) *Application sectors*, (3) *Application technology*, (4) *Geographic perspectives*

[B] Sustainability concept – (5) *Need to align concepts of digitalization, ICT, digital sustainability, and digital transformations*, (6) *Terminological misalignment sustainability in the context of ICT*.

[C] Impact – (7) *ICT as enabler*, (8) *ICT as problem*, (9) *ICT as problem and enabler*, (10) *Measurement of impacts of ICT on sustainability*

[D] Mitigation – (11) *Mitigation strategies to address sustainability challenges*, (12) *Need for an interdisciplinary and holistic approach to sustainability in ICT*

[E] Stakeholders: (13) Role of stakeholders and governance

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