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The research landscape of ICT for sustainability: harnessing digital technology for sustainable development

Pre-print version

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Abstract—Within the growing debate about sustainability issues, a variety of research communities emerged to connect the fields of sustainable development and ICT. Each of them addresses the link between sustainable development and digital technologies from a slightly different angle. However, the overlaps and blurred boundaries in the scope of research exist. Taking “Doughnut economics” as a foundation and inspired by the LES model, we propose a new conceptual framework to structure the ICT for Sustainability (ICT4S) research landscape. The new model encompasses both environmental and social effects in line with socio-ecological systems thinking. We go one step further and propose to incorporate a decision-making dimension to represent the research of the governance, strategies and policies with respect to ICT effects. We proceed by exploring how this framework could be used to position research fields and communities according to their scope of interest and, by doing so, find synergies between research communities and within the ICT4S landscape. Our aim is to contribute in creating tools to foster dialogue and bridge fragmented research fields and communities interested in ICT impacts on sustainable development.

Index Terms—Sustainable Development, ICT4S research landscape, LES model, Doughnut economics, digitalization

I. INTRODUCTION

There is a growing debate about the role of digital Information and Communication Technology (ICT) in sustainable development (Fig. 1). The ICT for Sustainability (ICT4S) conference series started in 2013 [1] and has produced a number of proceedings that presented research on many facets of the link between ICT¹ and sustainability [2]. Hilty and Aebischer [3] presented a first attempt to structure the emerging research field ICT4S and its relationship to other research domains which also question the role of digital technology and the digital economy in sustainability. In this paper, we present an update of this approach and propose a new conceptual framework based on the Doughnut model [4] to structure the research landscape of ICT4S and related fields. What

¹In this paper “ICT” is used as a term to refer to all digital information and communication technologies. It is used interchangeably with terms “digital technology” and “IT”.

research connected to digital technologies, their application and impact, is being done and where are the white spots in this interdisciplinary research landscape? The paper proceeds along the following questions: 1) What definition and theory of Sustainable Development should be chosen to clarify the role of digital technologies with regard to this political goal? 2) How can we conceptualize the various impacts of ICT on Sustainable Development? 3) How can we map the research communities addressing the link between ICT and aspects of Sustainable Development?

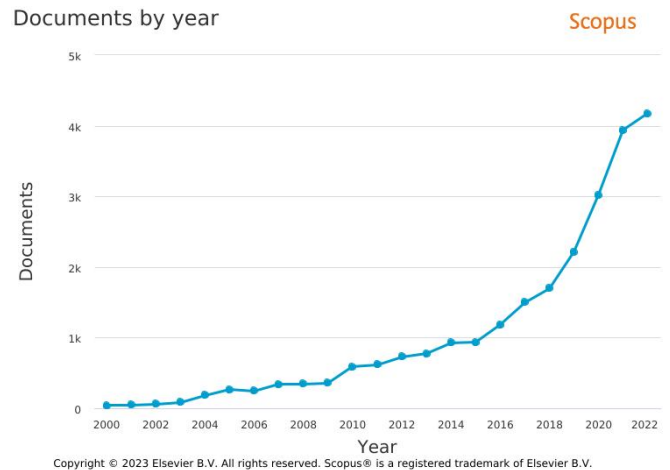


Fig. 1. From 2000 there is a growing number of articles and conference papers published regarding sustainability issues and different ICT topics. SCOPUS database, only English articles and conference papers, keywords used: (“DIGITAL” OR “ICT” OR “COMPUTING” OR “INFORMATICS”) AND (“SUSTAINABILITY” OR “SUSTAINABLE DEVELOPMENT”).

II. THEORIES ON SUSTAINABILITY

To make sustainable use of something means to use it in a way that does not compromise its ability to fulfill its function in the long term. Most people would agree to the idea that

human society should make sustainable use of this planet. When people disagree about sustainability, then that may be because:

- They are thinking of different time horizons (next year, next two generations, eternity?);
- They may value things differently, resulting in different priorities for what should be sustained (their own business, local communities, their country, human rights, all life on earth, etc.);
- They are making different assumptions about the possibility of replacing the functions of the natural ecosystem with technical solutions in the future (“everything will be replaceable”, “some essential functions will never be replaceable”, “technology won’t save us anyway”).

Time horizons, values, and assumptions about a technological future make sustainability a rather relative concept [3]. In an economic context, sustainability is often accompanied by a substitutability (replaceability) discussion. In a political context, the question of justice comes on top of the discussion. Sustainable Development in particular requires finding a balance between intra- and intergenerational justice under resource constraints.

We therefore differentiate between the concept of sustainability (as in “sustainable use”) and the normative-political concept labelled “Sustainable Development”. To put it short, Sustainable Development is sustainable use of the planet by people under the condition of intra- and intergenerational justice.

Different discussions emerged to structure the idea of Sustainable Development. In development literature, Sustainable Development is often seen as the process to sustain a healthy economic, ecological and social system for human development [5]. In numerous sources, Sustainable Development is defined as a process depending on three pillars: economic, social and environmental sustainability. This three-pillar model suggests that sustainable development can be realized as the balancing of trade-offs between seemingly equally important goals within the three pillars. This has the disadvantage of giving rise to simplistic solutions that lack a deeper analysis of replaceability as well as an explicit reflection of the justice question.

Alternative manifestations conceptualize the three aspects (nature/environment, society, economy) as nested, acknowledging that the economic system is part of human society and human society is part of nature.

Yet the theoretical underpinnings of the three aspects (“pillars”, “dimensions”) of sustainability and the idea of putting them into some sort of “equilibrium” are far from clear, and this representation is criticized for lacking rigor and being embedded in political ideologies [6]. Some scholars have also extended the notion of three dimensions and added additional ones, such as institutional [7] or technical [8].

In recent years, an approach that more systematically relates planetary and social boundaries with economic activity, called “Doughnut Economics”, has been discussed. This theoretical framework starts with the normative setting that “wellbeing

depends on enabling every person to lead a life of dignity and opportunity, while safeguarding the integrity of Earth’s life-supporting systems” [4]. Based on this framework, Sustainable Development can be defined as a process that satisfies human needs without overshooting planetary boundaries (Fig. 2).

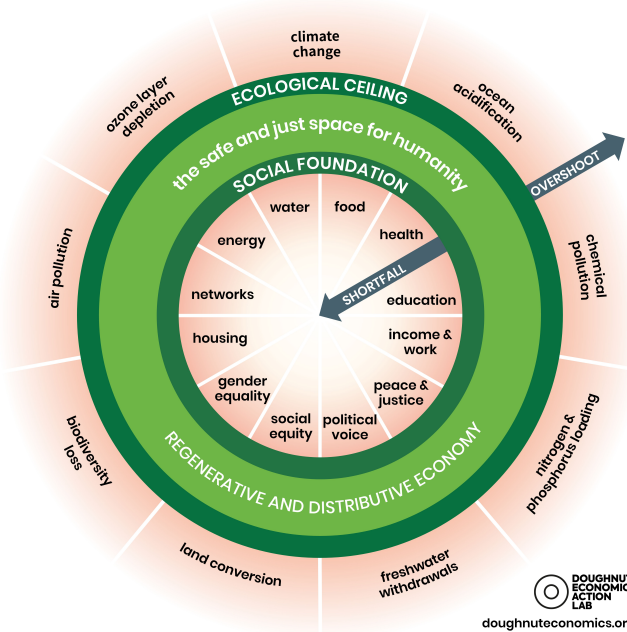


Fig. 2. The Doughnut of social and planetary boundaries. Credit: Kate Raworth and Christian Guthier. CC-BY-SA 4.0

The outer boundary of the Doughnut, called the ecological ceiling, consists of the 9 indicators defined by the planetary boundaries’ framework proposed by scientists [9]. The inner boundary, called the social foundation, consists of 12 social priorities which overlap with the UN Sustainable Development Goals (SDGs). A key feature of SDGs is that they are interdependent and interlinked goals, meaning that achieving one goal might lead to achieving another [5]. However, a positive impact on one goal might equally produce negative spill-over effects on other goals.

In the Doughnut model, economic goals are an integral part of the social foundation. In our interpretation, the process of staying within the safe operating space includes the decision-making in all functional systems of human society, including the economic, the political, the legal, the education system, etc. The advantage of using this model lies in allowing for the complexity of the global socio-ecological system and clearly articulating that the main goal is human well-being, which is seen as dependent on a variety of factors and not reduced to GDP growth [10].

In this paper we position within the socio-ecological systems thinking based on the Doughnut framework and combine it with existing conceptual frameworks of ICT impacts on Sustainable Development.

III. STRUCTURING THE IMPACTS OF ICT ON SUSTAINABLE DEVELOPMENT

The so-called first Kranzberg's law states that technology is neither good nor bad; nor is it neutral [11]. In order to assess the impacts of any technology (digital ICT in our case) on the success of reaching a given goal (Sustainable Development in our case), we have to look at several aspects of the technology:

- The life cycle of the products involved, including extraction and processing of the raw materials, manufacturing, distribution, use, recycling, and final disposal;
- The way these products are designed and how design decisions influence the life cycle;
- The application of the technology, including the functions it provides to its direct users and other stakeholders, what it enables them to do;
- The long-term structural change enabled or driven by the technology, how it transforms society and its functional systems.

For the case of ICT, the production of the hardware requires energy, other natural resources and human labor, which means that the manufacturing phase of ICT has a direct negative impact on the environment and creates positive or negative effects for the people employed. The design of hardware and software has long-lasting effects on the environment and people through the whole life cycle, including enabling effects that are fundamentally changing many application domains. The omnipresence of ICT implies that these effects, which can be positive or negative, are not constrained only to ICT industry, but spill over to other sectors. As a result, the presence and application of ICT lead to structural changes, influencing the economic, legal, social and ecological environment.

In the existing literature there have been a few attempts to propose frameworks to structure the complex relationship between ICT and Sustainable Development. Berkhout and Hertin [12] and Hilty [13] proposed the three orders of ICT environmental effects and classified them in positive and negative effects. Later evolutions of these frameworks took a more neutral view [14] and a mention of societal side [3]. Other scholars proposed issue-specific [15] or scope-specific [16] frameworks. While these frameworks have focused mostly on ICT effects on the environment and do not account for the influence of decision making, the present paper departs from the extant literature by using the four aspects of technology mentioned above to structure potential impacts and adding the basic idea of the Doughnut model of having environmental and social boundaries and a "safe and just space for humanity" in between, which includes the decision making.

Before elaborating further on this framework, we provide a condensed overview of the current discussion of the relationship between ICT and Sustainable Development, which has stimulated this new framework.

IV. SUSTAINABLE DEVELOPMENT IN THE ICT DISCOURSE

Many studies [17], [18] see ICT as merely an enabler to advance sustainable development goals. In the UN SDGs,

for example, ICT is mentioned as instrumental in 4 goals. However, the presumption of ICT's neutrality suppresses questions about the values and politics of ICT themselves, making their unsustainability invisible [19]. The research network "Digitalization for Sustainability" argues that unless digital technologies and practices are incorporated into a thoughtful plan to replace or reduce harmful practices, it is unlikely that sustainability goals will be achieved. Even if they are achieved, it will likely be by chance rather than through a systematic and deliberate sustainability program [20].

Dalal and Pauleen [21] take one step further and argue that as technological pervasiveness advances in all spheres of our lives, we have not succeeded in developing effective ways to think about long-term impacts of technology-induced changes. For the field of Information Systems (IS), they call for IS wisdom which could help navigate the way in addressing sustainability challenges while taking account of stakeholder concerns, ethics, and long-term consequences in the research, design, and implementation of ICT systems. Using Aristotle's 3 approaches to knowledge—*episteme*, *techne*, and *phronesis* – they argue that there is a lot of work already done on the rational scientific knowledge of IS phenomena (*episteme*) and on concrete practices of building ICT (*techne*). However, they urge to introduce more "practical wisdom" (*phronesis*) in IS research which would deliberate the foundational values while responding to challenges created by the increasingly more powerful field of ICT. Dalal and Pauleen focused on the IS research field, and we believe that their argument about wisdom should be extended to the whole ICT community.

Mann and colleagues [22] add a different angle to the criticism in how sustainability is regarded by the ICT research community. They argue that sustainability is too often treated as environmental-only problems and then reduced to singular problems, such as energy or carbon. They invite the research community to prioritize "socioecological restoration", taking the position that systems are equally social as biophysical. This is in line with our observation that the current attempts to structure the ICT impacts are more focused towards environmental effects rather than taking a more comprehensive approach with regards to Sustainable Development. In addition, Santarius et al. [23] point that studies focusing on different order of impacts fail to "discuss policy solutions that systematically address all those levels".

The need to include societal impacts and policy solutions within the ICT for Sustainability research has been also stressed in the original definition and scope of ICT4S, defined in the "Conference Recommendations" formulated by the participants of the first ICT4S conference: "The transformational power of ICT can be used to make our patterns of production and consumption more sustainable. However, the history of technology has shown that increased energy efficiency does not automatically contribute to sustainable development. Only with targeted efforts on the part of politics, industry and consumers will it be possible to unleash the true potential of ICT to create a more sustainable society" [1, p. 284].

In 2015, Hilty and Aebischer [3] provided the first overview

of the scope that different research communities addressed in their discourse about ICT and sustainability. They discussed the overlaps and blurred boundaries between different research fields, subfields and research communities.

Based on the above, the present paper attempts to address the following existing limitations:

- 1) The misalignment of ICT and Sustainable Development agendas;
- 2) The lack of inclusion of both types of ICT effects – to society and to environment – in the same debate;
- 3) The lack of tools helping to position the research and identify synergies with existing research communities to systematically address sustainable development issues in ICT discourses.

V. ICT4S LANDSCAPE MODEL

Inspired by the Doughnut model and building on the “LES model” introduced by Hilty and Aebischer [3], we propose a new conceptual framework to structure the research around ICT and Sustainable Development (Fig. 3).

The vertical axis categorizes the effects stemming from ICT. The LES model was based on “Lifecycle impacts, Enabling impacts, and Structural impacts” (Fig. 4). In the new model, we are adding a new level – design effects. In this vein, the levels become:

- 1) Impacts of producing, operating and disposing of technology: As in the original model, this level “refers to the effects caused by the physical actions needed to produce the raw materials for ICT hardware, to manufacture ICT hardware, to provide the electricity for using ICT systems (including the electricity for non-ICT infrastructures, such as cooling), to recycle ICT hardware, and finally to dispose of non-recycled waste” [3].
- 2) Impacts of designing technology: This refers to effects resulting from design decisions taken in developing hardware, software, data formats, system architectures, user interfaces, etc.
- 3) Impacts of applying technology: Enabling impacts concern the positive and negative effects resulting from actions of users and other stakeholders that are enabled when applying ICT.
- 4) Structural change: The final level refers to “ICT impacts that lead to persistent changes observable at the macro level. Structures emerge from the entirety of actions at the micro level and, in turn, influence these actions” [3].

The horizontal axis is inspired by the Doughnut model. In this regard we attempt to further the integration of Sustainable Development agendas when discussing ICT effects. The middle column represents decision-making regarding ICT, the left and right columns represent the impacts of ICT on the social foundation (left side) and on the environmental ceiling (right side). In the original Doughnut model, the space in between social foundations and ecological ceiling is called “the safe and just space for humanity”. Ensuring that this space is achieved

and maintained depends on decisions we, human-beings, make and what type of impacts we generate on society and environment. Our model reflects this by introducing a decision-making column in the center which influences “impact to society” and “impact to environment”. While the columns “impact to society” and “impact to environment” reflect the research which covers the impacts of different ICT effects (*what*), the “decision-making” column refers to research that investigates purpose, decision-making, strategies, policies and governance regarding ICT (*so what*).

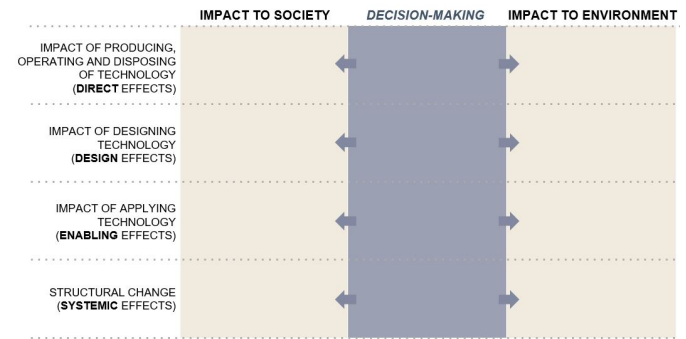


Fig. 3. ICT4S research landscape framework. Inspired by the Doughnut model[4] and built on the “LES model” (Fig. 4).

In this vein, we attempt to create a conceptual framework which reflects socio-ecological systems thinking and addresses the previously identified limitation with regards to divided discussions about environmental and social effects of ICT. At the same time, the framework allows to put into perspective the decision-making or governance processes needed for staying within the “safe and just space for humanity” with regards to all four levels of ICT effects.

VI. MAPPING RESEARCH COMMUNITIES USING THE ICT4S LANDSCAPE MODEL

Given our proposed ICT4S landscape model, we explore here how it could be used as a tool in structuring the existing research communities interested in links between ICT and Sustainable Development.

We have proceeded along the following steps:

- 1) Establishing a collection of articles representing a research field or community. To identify the studies relevant for the review, we conducted a keyword search using Elsevier’s Scopus data base. Taking the research field called “Green IT” as an example, we searched for “TITLE-ABS-KEY (“Green IT” OR “Green ICT” OR “Green Computing”). Only English language papers were included. If there were more than 200 results, we excluded conference papers, conference reviews, editorials and book chapters. Considering the multifaceted subject of Sustainable Development and the wide ranging application of ICT, the restrictions in the disciplinary scope of the journals were applied only when there were more than 1000 results. In that case, disciplines like medicine or chemistry were excluded.

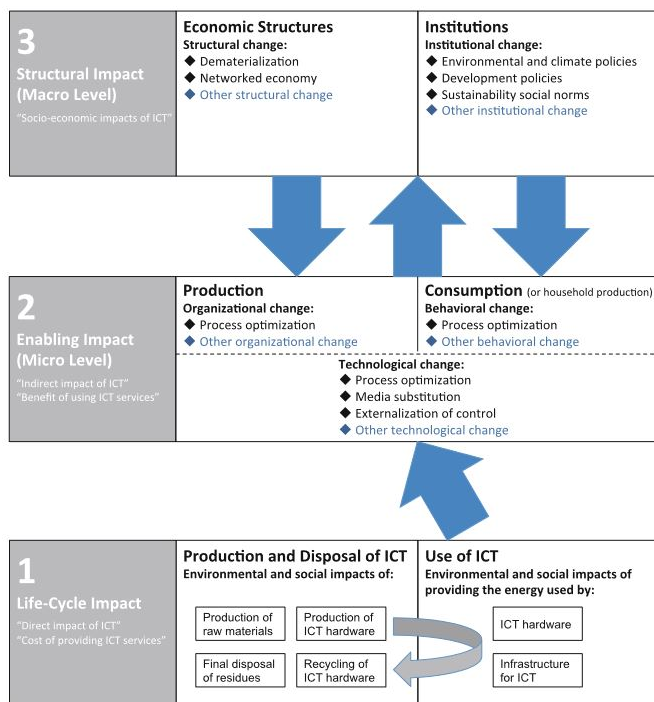


Fig. 4. The original LES model [3].

- 2) Keyword analysis. The results were exported and analyzed using VOS software² which allowed to construct and visualize co-occurrence networks of main terms corresponding to the social, environmental impacts or decision-making process.
- 3) Definition analysis. By using the definitions proposed by researchers in their papers, we cross-referenced our findings in Step 2 and attempted to establish which order of effects were covered by definitions. Recognizing that definitions might change over time, priority was given to the newest and most cited papers according to Scopus.
- 4) Cross-reference with literature review. Where possible, systematic literature review papers were identified. According to Kitchenham and Charters [24], "A systematic literature review is a means of evaluating and interpreting all available research relevant to a particular research question, topic area, or phenomenon of interest". Therefore, these types of papers were used to critically analyze the existing scope of a research field and cross-reference with our observations and interpretations from Steps 2 and 3.

Using the described methodology, we mapped eight research communities on the proposed ICT4S landscape framework (Fig. 5):

- Sustainable Software Engineering (SSE)
- Corporate Digital Responsibility (CDR)
- Green Information Systems
- Green ICT

²www.vosviewer.com/

- Environmental Informatics
- Sustainable HCI
- ICT & Ethics
- ICT for Development (ICT4D)

The model is not meant to present a hierarchy between research domains or assign more importance to some fields than to others. It is rather a tool to explore the likely overlaps and establish potential synergies between separated research communities.

In our example, the Sustainable Software Engineering (SSE) community has been identified to focus on direct and design effects of software on both society and environment and to cover the questions of how to make decisions to maximize the positive impact of software. The environmental side of the questions is also covered by Green ICT community and Environmental Informatics, and in that intersection an overlap between some research exists. Whereas the decision-making research around SSE might also fall within the interests of researchers involved in Green IS or Corporate Digital Responsibility fields.

Sustainable HCI (SHCI) is also interested in both types of impacts – to society and to environment – and treats the questions of how to design systems that contribute to sustainable development. The origins of Sustainable HCI can be traced to the CHI 2007 conference where E. Blevis [25] argued that sustainability should be a central focus of Human-Computer Interaction (HCI). Since then, this field has gained momentum. A new emergent tendency in this field is to explore non-anthropocentric angle, which considers non-human actors as part of the social issues. Scuri et al. [26] argue that this allowed to emphasize the interdependency of social and environmental impacts and position SHCI research at their intersection.

ICT & Ethics, on the other hand, is a very large field, focusing mostly on ICT impacts to society and related governance. This field covers a myriad of research topics such as data governance issues which have also furthered the discourse about ethics in AI, surveillance, privacy protection and ethics of algorithms [27] and as such might overlap with SHCI and Corporate Digital Responsibility research.

ICT for Development (ICT4D) also discusses the impact of ICT to society, more precisely in addressing issues in the development of low- and middle- income countries (LMICs), which are often referred to as "the Global South". The research is centered around the question "how can ICT foster development?" leading to a presumption that ICT has to play a central role in solving development challenges. For a long time ICT4D has been seen as a niche research area, but since this field is gaining its maturity there have been suggestions that it could find useful synergies with the more general IS field in furthering important social agendas [28].

Corporate Digital Responsibility yet is a new field which focuses solely on decision-making process within organizations. Recognizing that digitally induced impacts on society and environment are of different nature when compared to other technologies and that organizations do have a responsibility to

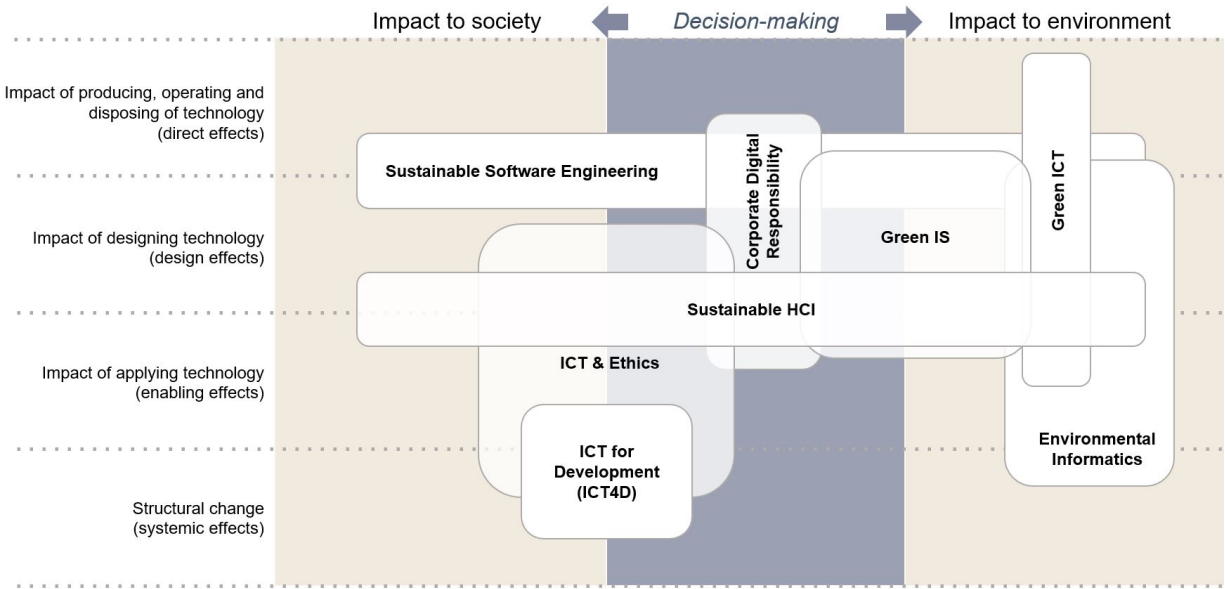


Fig. 5. Example of mapping research communities using the ICT4S landscape model

act upon them [29] led to the development of this field, which might find synergies with topics treated by Green IS or ICT & Ethics communities.

It is not in the scope of this paper to pursue in providing an exhaustive list of all research fields, communities and subfields covering the subject of ICT and Sustainable Development. Rather, we have attempted to illustrate the diversity of the emerging research communities and to explore how the proposed ICT4S landscape framework could be used to find overlaps and boundaries between them to advance research in a structured way. Table 1 contains the summary of a larger set of communities that take interest in links between ICT and Sustainable Development and which could also be visually mapped on the framework, such as Sustainable AI, Social Informatics, Community Informatics, ICT in STS and Computational Sustainability.

VII. APPLICATIONS AND FURTHER RESEARCH

The proposed ICT4S landscape model aims to serve as a framework for positioning research in the larger context of Sustainable Development and ICT effects. We have illustrated with examples how it can be used to establish a mapping of research communities. With an exception of CDR field, the discussed communities were selected based on the original Hilty and Aebischer paper [3] in which the LES model has been introduced. CDR and other research communities mentioned in Table 1 were introduced based on the authors' familiarity with them and on the secondary sources. Further research using a Systematic Literature Review methodology [24] would be worth considering to confirm and extend the mapping.

We also hope that research communities will position themselves in this framework. This could stimulate a discussion and encourage more clarity and structure in the whole field. In par-

ticular, it could help to advance the interdisciplinary dialogue by identifying communities which investigate similar topics from different perspectives and could complement each other. The presented framework may also be useful in screening for potential research gaps. Researchers may start with potential research topics, look at different levels of impacts, and then check the relevant research fields and communities to confirm the existing research status.

VIII. CONCLUSIONS

While research on the links and implications of ICT on Sustainable Development become increasingly complex, there is a need for more structure and systematic knowledge to develop interdisciplinary perspectives and to bridge gaps between already existing research communities.

This exploratory article proposed to use the Doughnut model to clarify the role of digital technologies with regards to Sustainable Development and, based on the LES model, developed an extended conceptual framework to structure the existing research around ICT effects and Sustainable Development. While the Sustainable Development discourse often refers to the three-pillar model, it has the disadvantage to give rise to a simplistic notion of equal trade-offs between environmental, social and economic goals. The Doughnut model, on the other hand, characterizes the "safe and just space for humanity" to be achieved only while respecting environmental constraints (environmental ceiling) and social foundations which involve the economic part of the societal system. In the context of ICT, the above points could be extended in finding ways to harness ICT as an enabler to foster the well-being of all stakeholders (including future generations) while at the same time mitigating the negative impacts of ICT with respect to the existing ecological and social boundaries.

Based on this view, we have proposed a conceptual framework to structure the ICT4S research landscape. In addition to direct, enabling and systemic effects of ICT, mentioned in the LES model (and similar in earlier approaches), we included design effects which result from choices made when developing hardware, software, UX etc. We argued that the resulting four types of effects in general manifest in positive or negative impacts to society and to environment, but it is the decision-making process which shapes the nature of impacts. We pointed out that it is important to understand and therefore to investigate how decisions around ICT affect environmental and social impacts of ICT. The existing academic discourse tends to isolate ICT impacts to society from impacts to environment (and to overlook the impacts that occur via changing decision-making processes), resulting in a gap between ICT and sustainability agendas. To address these limitations, we integrated the principles of the Doughnut model in our framework. By proposing our new conceptual framework to structure ICT4S landscape, we contribute to expanding the conceptual tools available to help to bridge research communities.

Using this conceptual framework, we have explored how some of the existing research communities could be mapped and how their scope could be defined in order to find synergies

with other communities. We hope that this model could also contribute to the discussions about the scope of existing research and raise new questions - such as: Do sustainable AI or ICT & Ethics communities address the questions of decision-making process by AI in creating a safer space for humanity? What political strategies could help to align ICT structural effects to both society and environment? – and allow to identify some research gaps.

Our proposed framework and methodology do not come without their limitations. The employed methodology to map the research communities is based on secondary sources and our own subjective interpretations. The research communities presented in Figure 5 is only an example and not representing the whole universe of research communities existing in the intersection of ICT and Sustainable Development.

While this article has shown the challenge of structuring the research around ICT and Sustainable Development, we have also argued that it is an indispensable effort if we aim to foster the interdisciplinary research that is needed to redirect digitalization in the direction of Sustainable Development. Only if research communities work together, can we harvest the potential of ICT in a truly sustainable manner.

ACKNOWLEDGMENT

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TABLE I: Summary of a few communities that take interest in links between ICT and Sustainable Development. List non-exhaustive.

Research community	Description	Scope of ICT effects	Scope of Impacts	Examples of publishing channels
Community Informatics	The research of how ICT affects communities [30] which also recognizes the community voice in designing the ICT systems [31].	Design effects Enabling effects	Impact to society	The Journal of Community Informatics
Computational sustainability	It is defined as aiming to “identify, formalize, and provide solutions to computational problems concerning the balancing of environmental, economic, and societal needs for a sustainable future” [32]. By bringing computational ideas, thinking and methodologies, this field focuses on computational challenges to address environmental, economic and societal issues.	Enabling effects	Impact to society Impact to environment	Sustainable Computing: Informatics and Systems
Corporate Digital Responsibility (CDR)	CDR “intends to minimize the adverse effects of digitalization while maximizing the positive impacts of corporate digital activities. In this vein, CDR seeks to ensure an ethical and responsible development, deployment, and use of digital technologies and data.” [33]. Even if the scholarly conceptualization of CDR is still in its infancy, it is perceived as an increasingly important subject for all economic actors in the realization of their sustainable development policies [34][29].	Direct effects Design effects Enabling effects	Decision making	Business and Information Systems Engineering
Environmental informatics	The focus is on applying ICT for tasks of the environmental sector (environmental protection, management, research and planning), but the field expanded towards research that also reduces the environmental footprint of the ICT sector itself.	Design effects Enabling effects	Impact to environment	Proceedings of EnviroInfo Advances and new Trends in Environmental Informatics (book series) Journal of Environmental Informatics Environmental Modelling and Software Proceedings of the iEMSs
Green ICT (Often synonymously used with Green Computing [35])	In 2008, S. Murugesan defined “Green IT” as “the study and practice of designing, manufacturing, using, and disposing of computers, servers, and associated subsystems [...] efficiently and effectively with minimal or no impact on the environment.” [36]. If Green ICT usually focuses on actions through which ICT could become more “environmentally friendly” some scholars distinguish it from Green by ICT (also: Green through ICT) which, according to them, refers to ICT as an enabler for sustainable development by means of ICT [37].	Direct effects Design effects Enabling effects	Impact to environment	Proceedings of IEEE Communications In Computer And Information Science Sustainability
Green IS	In comparison to Green ICT, Green IS promises “a much greater, organization-wide potential to measure, monitor, report and reduce the firm’s environmental footprint, but the transformation of the business with the help of Green IS requires a holistic long-term strategy.” Green IS strategy is defined as “the organizational perspective on the investment in, deployment, use and management of information systems (IS) in order to minimize the negative environmental impacts of IS, IS-enabled products and services, and business operations.” [38].	Direct effects Design effects Enabling effects	Impact to environment Decision making	International Conference On Information Systems Sustainability Proceedings Of The Annual Hawaii International Conference On System Sciences
ICT & Ethics	Under the name “ethics of computing”, ICT experts and philosophers have been discussing ethical issues of designing and using computers since the 1970s, often with the practical aim to develop ethical guidelines or codes of conducts for professional societies in the ICT field. An acceleration in digital development has led to a more intense focus on data governance issues which has also furthered the discourse about surveillance, privacy protection, ethics in AI, and ethics of algorithms [27].	Design effects Enabling effects Systemic effects	Impact to society Decision making	Journal of Information Communication and Ethics in Society Ethics And Information Technology Journal of Business Ethics
ICT for Development (ICT4D)	It addresses ways of how ICT helps to address issues in the development of low- and middle- income countries (LMICs), which are often referred to as “the Global South” [28].	Enabling effects Systemic effects	Impact to society Decision making	Information Technology For Development Electronic Journal Of Developing Countries

TABLE I – continued from previous page.

Research community	Description	Scope of ICT effects	Scope of Impacts	Examples of publishing channels
ICT in STS	Science, Technology and Society (STS) studies include diverse methods, disciplines and audiences and digital ICT is only one of the many technologies this domain explores. STS addresses the role that science and technology play in the development, politics, and organization of the society and the way in which social, political, and economic arrangements shape scientific and technical work [39]. In this vein, STS explores the impacts digital ICT has on society. Internet studies, social construction of technology, social engineering, socio-cybernetics are the research topics which can be found within the STS studies.	Direct effects Design effects Enabling effects Systemic effects	Impact to society Decision making	Information Communication and Society Philosophy and Technology Science Technology and Human Values Science, Technology and Society
Sustainable AI	Sustainable AI is defined as “a movement to foster change in the entire lifecycle of AI products (i.e. idea generation, training, re-tuning, implementation, governance) towards greater ecological integrity and social justice.” [40]. Researchers perceive that AI could act as an enabler to harness sustainable development and at the same time its own footprint should be minimized [41].	Design effects Enabling effects	Impact to society Impact to environment Decision making	Journal Of Cleaner Production Advances In Intelligent Systems And Computing
Sustainable HCI	In CHI 2007 conference, E.Bleviss argued that sustainability should be a central focus of Human-Computer Interaction (HCI), presented the concept of Sustainable Interaction Design (SDI) and reasoned that SDI could be viewed “as the notion that representations and interpretations of interaction design should as well denote and account for the effects of a design on the environment and sustainable behaviors [25]. Since then this field has gained momentum and covered different perspectives on how HCI addressed Sustainable Development.	Design effects Enabling effects	Impact to society Impact to environment Decision making	Conference On Human Factors In Computing Systems Proceedings DigitalTechnology And Sustainability Engaging The Paradox ACM Transactions On Computer Human Interaction
Social Informatics	“The interdisciplinary study of the design, uses and consequences of information technologies that takes into account their interaction with institutional and cultural contexts” [42].	Design effects Enabling effects Systemic effects	Impact to society	Lecture Notes of the Institute for Computer Sciences, Social Informatics and Telecommunications Engineering Proceedings of the Association for Information Science and Technology Communications in Computer and Information Science
Sustainable Software Engineering (SSE)	Sometimes also called “Green and Sustainable Software Engineering”, it investigates the environmental and social effects of software engineering practices.	Direct effects Design effects	Impact to society Impact to environment Decision making	ACM International Conference Proceeding Series

REFERENCES

- [1] “ICT4S 2013: Proceedings of the First International Conference on Information and Communication Technologies for Sustainability,” in *ICT4S*, L. M. Hilty, B. Aebischer, G. Andersson, and W. Lohmann, Eds., ETH Zurich, 2013. DOI: 10.3929/ethz-a-007337628.
- [2] “ICT4S conference series.” (), [Online]. Available: <https://conf.researchr.org/series/ict4s> (visited on 10/23/2022).
- [3] L. M. Hilty and B. Aebischer, “ICT for Sustainability: An Emerging Research Field,” in *ICT Innovations for Sustainability*, ser. Advances in Intelligent Systems and Computing, L. M. Hilty and B. Aebischer, Eds., vol. 310, Switzerland: Springer International Publishing, 2015, pp. 3–36. DOI: 10.1007/978-3-319-09228-7_1.
- [4] K. Raworth, *Doughnut Economics: Seven Ways to Think Like a 21st-Century Economist*, Penguin Random House. London, 2017.
- [5] J. Mensah, “Sustainable development: Meaning, history, principles, pillars, and implications for human action: Literature review,” *Cogent Social Sciences*, vol. 5, no. 1, S. Ricart Casadevall, Ed., 2019. DOI: 10.1080/23311886.2019.1653531.
- [6] B. Purvis, Y. Mao, and D. Robinson, “Three pillars of sustainability: In search of conceptual origins,” *Sustainability Science*, vol. 14, no. 3, pp. 681–695, 2019. DOI: 10.1007/s11625-018-0627-5.
- [7] J. H. Spangenberg, “Environmental space and the prism of sustainability: Frameworks for indicators measuring sustainable development,” *Ecological Indicators*, vol. 2, no. 3, pp. 295–309, 2002. DOI: 10.1016/S1470-160X(02)00065-1.
- [8] P. Lago, S. A. Koçak, I. Crnkovic, and B. Penzenstadler, “Framing sustainability as a property of software quality,” *Communications of the ACM*, vol. 58, no. 10, pp. 70–78, 2015. DOI: 10.1145/2714560.
- [9] W. Steffen, K. Richardson, J. Rockström, *et al.*, “Planetary Boundaries: Guiding Human Development on a Changing Planet,” *Science*, vol. 347, no. 6223, 2015. DOI: 10.1126/science.1259855.
- [10] W. Vandenhole, “De-Growth and Sustainable Development: Rethinking Human Rights Law and Poverty Alleviation,” *Law and Development Review*, vol. 11, no. 2, pp. 647–675, 2018. DOI: 10.1515/ldr-2018-0033.
- [11] M. Kranzberg, “Technology and History: ”Kranzberg’s Laws”,” *Technology and Culture*, vol. 27, no. 3, pp. 544–60, 1986. DOI: 10.2307/3105385.
- [12] F. Berkhout and J. Hertin, “De-materialising and re-materialising: Digital technologies and the environment,” *Futures*, vol. 36, no. 8, pp. 903–920, 2004. DOI: 10.1016/j.futures.2004.01.003.
- [13] L. M. Hilty, *Information Technology and Sustainability: Essays on the Relationship between ICT and Sustainable Development*. Books On Demand, 2008.
- [14] E. Williams, “Environmental effects of information and communications technologies,” *Nature*, vol. 479, no. 7373, pp. 354–358, 7373 2011. DOI: 10.1038/nature10682.
- [15] N. C. Horner, A. Shehabi, and I. L. Azevedo, “Known unknowns: Indirect energy effects of information and communication technology,” *Environmental Research Letters*, vol. 11, no. 10, p. 103001, 2016. DOI: 10.1088/1748-9326/11/10/103001.
- [16] S. Naumann, M. Dick, E. Kern, and T. Johann, “The GREENSOFT Model: A reference model for green and sustainable software and its engineering,” *Sustainable Computing: Informatics and Systems*, vol. 1, no. 4, pp. 294–304, 2011. DOI: 10.1016/j.suscom.2011.06.004.
- [17] G. George, R. K. Merrill, and S. J. D. Schillebeeckx, “Digital Sustainability and Entrepreneurship: How Digital Innovations Are Helping Tackle Climate Change and Sustainable Development,” *Entrepreneurship Theory and Practice*, vol. 45, no. 5, pp. 999–1027, 2021. DOI: 10.1177/1042258719899425.
- [18] T. N. Nchofoung and S. A. Asongu, “ICT for sustainable development: Global comparative evidence of globalisation thresholds,” *Telecommunications Policy*, vol. 46, no. 5, p. 102296, 2022. DOI: 10.1016/j.telpol.2021.102296.
- [19] M. van der Velden, “ICT and Sustainability: Looking Beyond the Anthropocene,” in *This Changes Everything – ICT and Climate Change: What Can We Do?*, D. Kreps, C. Ess, L. Leenen, and K. Kimppa, Eds., ser. IFIP Advances in Information and Communication Technology, Cham: Springer International Publishing, 2018, pp. 166–180. DOI: 10.1007/978-3-319-99605-9_12.
- [20] D. F. S. (D4S), “Digital Reset. Redirecting Technologies for the Deep Sustainability Transformation,” Technische Universität Berlin, Berlin, 2022. [Online]. Available: <https://depositonce.tu-berlin.de/handle/11303/17406> (visited on 10/12/2022).
- [21] N. Dalal and D. J. Pauleen, “The wisdom nexus: Guiding information systems research, practice, and education,” *Information Systems Journal*, vol. 29, no. 1, pp. 224–244, 2019. DOI: 10.1111/isj.12196.
- [22] S. Mann, O. Bates, and R. Maher, “Shifting the maturity needle of ICT for Sustainability,” in *5th International Conference on Information and Communication Technology for Sustainability*, ser. EPiC Series in Computing, vol. 52, EasyChair, 2018, pp. 209–226. DOI: 10.29007/d6g3.
- [23] T. Santarius, J. C. T. Bieser, V. Frick, *et al.*, “Digital sufficiency: Conceptual considerations for ICTs on a finite planet,” *Annals of Telecommunications*, 2022. DOI: 10.1007/s12243-022-00914-x.
- [24] B. Kitchenham and S. M. Charters, “Guidelines for performing systematic literature reviews in software

- engineering version 2.3,” *Engineering*, EBSE-2007-01, vol. 45, p. 1051, 4ve 2007.
- [25] E. Bleviss, “Sustainable interaction design: Invention & disposal, renewal & reuse,” in *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, San Jose California USA: ACM, 2007, pp. 503–512. DOI: 10.1145/1240624.1240705.
- [26] S. Scuri, M. Ferreira, N. Jardim Nunes, V. Nisi, and C. Mulligan, “Hitting the Triple Bottom Line: Widening the HCI Approach to Sustainability,” in *CHI Conference on Human Factors in Computing Systems*, New Orleans LA USA: ACM, 2022, pp. 1–19. DOI: 10.1145/3491102.3517518.
- [27] S. Rogerson, K. W. Miller, J. S. Winter, and D. Larson, “Information systems ethics – challenges and opportunities,” *Journal of Information, Communication and Ethics in Society*, vol. 17, no. 1, pp. 87–97, 2019. DOI: 10.1108/JICES-07-2017-0041.
- [28] S. Sahay, M. Sein, and C. Urguhart, “Flipping the Context: ICT4D, the Next Grand Challenge for IS Research and Practice,” *Journal of the Association for Information Systems*, vol. 18, no. 12, pp. 837–847, 2017. DOI: 10.17705/1jais.00479.
- [29] L. Lobschat, B. Mueller, F. Eggers, *et al.*, “Corporate digital responsibility,” *Journal of Business Research*, vol. 122, pp. 875–888, 2021. DOI: //doi.org/10.1016/j.jbusres.2019.10.006.
- [30] D. O’Neil, “Assessing community informatics: A review of methodological approaches for evaluating community networks and community technology centers,” *Internet Research*, vol. 12, no. 1, pp. 76–102, 2002. DOI: 10.1108/10662240210415844.
- [31] J. M. Carroll and M. B. Rosson, “Wild at Home: The Neighborhood as a Living Laboratory for HCI,” *ACM Transactions on Computer-Human Interaction*, vol. 20, no. 3, 16:1–16:28, 2013. DOI: 10.1145/2491500.2491504.
- [32] C. Gomes, T. Dietterich, C. Barrett, *et al.*, “Computational sustainability: Computing for a better world and a sustainable future,” *Communications of the ACM*, vol. 62, no. 9, pp. 56–65, 2019. DOI: 10.1145/3339399.
- [33] C. A. Mihale-Wilson, D. J. Zibuschka, R. B. GmbH, J. Zibuschka, and K. V. Carl, “Corporate Digital Responsibility – extended conceptualization and empirical assessment,” *ECIS 2021 Research Papers*, no. 80, p. 17, 2021. [Online]. Available: https://aisel.aisnet.org/ecis2021_rp/80.
- [34] C. Herden, E. Alliu, A. Cakici, *et al.*, ““Corporate Digital Responsibility”: New corporate responsibilities in the digital age,” *Sustainability Management Forum – NachhaltigkeitsManagementForum*, vol. 29, 2021. DOI: 10.1007/s00550-020-00509-x.
- [35] S. Butt, M. Ahmadi, and M. Razavi, “Green Computing: Sustainable Design and Technologies,” in *2020 5th International Conference on Innovative Technologies in Intelligent Systems and Industrial Applications (CITISIA)*, Sydney, Australia: IEEE, 2020, pp. 1–7. DOI: 10.1109/CITISIA50690.2020.9371781.
- [36] S. Murugesan, “Harnessing Green IT: Principles and Practices,” *Green Computing*, p. 10, 2008.
- [37] S. Naumann, E. Kern, M. Dick, and T. Johann, “Sustainable Software Engineering: Process and Quality Models, Life Cycle, and Social Aspects,” in *ICT Innovations for Sustainability*, ser. Advances in Intelligent Systems and Computing, L. M. Hilty and B. Aebischer, Eds., vol. 310, Cham: Springer International Publishing, 2015, pp. 191–205. DOI: 10.1007/978-3-319-09228-7_11.
- [38] F. Loeser, “Green IT and Green IS: Definition of Constructs and Overview of Current Practices,” in *Proceedings of the Nineteenth Americas Conference on Information Systems*, Chicago, Illinois, 2013, p. 13. DOI: 10.13140/2.1.3065.6962.
- [39] D. Morrison, “Science, Technology, and Society Studies,” in *Encyclopedia of the Anthropocene*, Elsevier, 2018, pp. 331–337. DOI: 10.1016/B978-0-12-809665-9.10310-6.
- [40] A. van Wynsberghe, “Sustainable AI: AI for sustainability and the sustainability of AI,” *AI and Ethics*, vol. 1, no. 3, pp. 213–218, 2021. DOI: 10.1007/s43681-021-00043-6.
- [41] L. H. Kaack, P. L. Donti, E. Strubell, G. Kamiya, F. Creutzig, and D. Rolnick, “Aligning artificial intelligence with climate change mitigation,” *Nature Climate Change*, vol. 12, no. 6, pp. 518–527, 6 2022. DOI: 10.1038/s41558-022-01377-7.
- [42] R. Kling, “What Is Social Informatics and Why Does It Matter?” *D-Lib Magazine*, vol. 5, no. 1, 1999. DOI: 10.1080/01972240701441556.