



# Themes of a Research Agenda for Sustainable Human Centred Design

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**Abstract.** The synergies and the relevant interdisciplinary existing between Sustainability and Ergonomics (HFE) are paramount to document the cultural evolution of design interventions that can be made when creating innovative artefacts, such as products, services, and product-service systems, since both disciplines aim at investigating the interactions between humans and living ecosystems. However, studies linking Sustainability and HFE mainly tackle the problems at the macro-scales, though several interplays between human behaviours, creative practices, and contexts of use can be identified at the micro-scales within the Human Centred Design domain (HCD). Ergonomic interventions performed under the Sustainability domain should employ design-driven strategies, which means that there is the need to further investigate the interdisciplinary contributions under a HCD lens (e.g.: investigations made at the human dimension). A research agenda for future explorations on Sustainable HCD is proposed in this work. The agenda is composed by six main research themes that employ design-driven scenarios to frame the complex set of open research topics pointed out by HFE in relation to Sustainability goals. Results achieved in this study set a body of knowledge through which systematically explore the possible contributions that Sustainable HCD may produce at all design scales, and for which a choral research effort is needed of all HFE community.

**Keywords:** Human centred design · Sustainability · Research agenda · Research themes

## 1 Introduction

A holistic interplay between human behaviors, creative design practices, and the sustainable quality of contexts of use where actions are performed can be found within the official definition of ‘Ergonomics’ (HFE) endorsed by International Ergonomics Association (IEA) [1]<sup>1</sup>, and this relation can be observed both at the micro and the macro

<sup>1</sup> Ergonomics (or Human Factors) is the scientific discipline concerned with the understanding of interactions among humans and other elements of a system, and the profession that applies theory, principles, data, and methods to design in order to optimize human well-being and overall system performance.

scale. Thus, the micro-behaviors expressed at the (inter-)personal level generate direct effects on living ecosystems, whereas products and services are usually designed to support people to achieve suitable levels of well-being; at the same time, macro-behaviors consolidated within large-scale social groups play a fundamental role on how to address the development of complex functional architectures and sets of solutions, such as systems of products and services, built environments, and product-service systems (PSS). Such relations are also echoed by interdisciplinary findings achieved within Design for Sustainability studies [2, 3] where it has been proved that negative anthropic actions significantly affect the capability of human systems to properly achieve suitable levels of Sustainable Development.

It is therefore possible to affirm that both HFE and Sustainability express common interests, values, and interdependences when included within a design domain (or scenario)<sup>2</sup>, and the importance of humans that operate informed actions through designed systems of solutions and within defined context of use is universally recognized as a key aspect to consider [4]. It can also be observed that because Sustainability does not only refer to ecological qualities; instead, the HCD intervention should be intended as a set of actions through which operate coherent interventions linking humans and living ecosystems. The relevance of this connection is also echoed by Demirel and Duffy [5] that clearly affirm the need to employ a sustainable HCD approach to deal with the degeneration of the ecology while providing alternative criteria for considering customer requirements. Therefore, human-centered design interventions link HFE to sustainable scenarios.

The International Organization for Standardization (ISO) defines the HCD as ‘*an approach to systems design and development that aims to make interactive systems more usable by focusing on the use of the system and applying HFE and usability knowledge and techniques*’ [6]. HCD is one of the pillars of HFE and it is proven that design interventions centered on humans produce remarkable improvements the lifecycle of the designed solutions [7]. Over time, the relevance of HCD has also been discussed by important authors against modern design theories [8–11] since it employs multidisciplinary research frameworks that consider humans in the whole product lifecycle, from conception stages to testing and final use.

Three relevant aspects can be identified from the analysis of studies considered in this introductory part: (i) Evidence suggests that HFE and Sustainability seem to be connected, but mainly the macro-level (i.e.: Organizational Ergonomics) [12–14]; (ii) Both domains can be connected through a HCD-based lens, whereas vertical and horizontal synergies should be further investigated to understand the interdisciplinary research and design opportunities [15]; (iii) Human-centered/-oriented designs (e.g.:

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<sup>2</sup> A preliminary bibliometric analysis performed on Scopus (April 2022) on journal articles and conference proceedings published since 2000 has revealed the existence of 214 peer-reviewed publications containing links between Human Centred Design (the design area of HFE) and Sustainability. The query used was: (TITLE-ABS-KEY (“human centred design”) OR TITLE-ABS-KEY (“human-centred design”) OR TITLE-ABS-KEY (“human centered design”) OR TITLE-ABS-KEY (“human-centered design”) OR TITLE-ABS-KEY (hcd) AND TITLE-ABS-KEY (sustainab\*)) AND (LIMIT-TO (LANGUAGE, “English”)) AND (LIMIT-TO (SRCTYPE, “j”) OR LIMIT-TO (SRCTYPE, “p”)) AND (LIMIT-TO (PUBSTAGE, “final”)).

products, services, etc.) and studies (e.g.: speculative analyses, theoretical studies, new tools, etc.) contribute to achieve the aims of Sustainability; therefore, through informed design strategies addressing the challenges of present and future society, HCD is able to converge the HFE criteria within sustainable design scenarios. Accordingly, there is the need to further explore the synergies between HCD and Sustainability to better understand mutual influences and relevant themes for future design studies in HFE.

## 2 Aim and Methods

This work proposes a research agenda for Sustainable HCD, which is based on the analysis of disciplinary and interdisciplinary synergies, research opportunities and promising design topics between HCD and Sustainability. The goal is to provide evidence of the most promising themes to be used within HCD domain to tackle the complexity of Sustainability at suitable design scales. Relevant knowledge developed in the last years is used to provide evidence about the validity of agenda's themes.

Secondary research methods in the form of literature review [16] and systematic analysis [17] are used to conduct the study and the preliminary research questions, as well as understanding the synergies between HCD for Sustainability. A scenario-building methodology [18, 19] – *a design-oriented methodology to discover and systematize the available knowledge to ideate likely conditions for scientific advances, alongside to build engaging narratives to communicate the promising areas to work on* – helps to set up the best conditions through which implementing the agenda. Hence, the agenda is the result of qualitative analyses resulting from the previous points. Finally, deductive considerations and cultural speculations are also proposed in the last part of this work.

At the cultural level, this study aims to raise the attention and the interest of the scientific community in the fields of Design and HFE (see: [15]) on the need to explore relevant interdisciplinary research themes for novel studies and activities that require new expertise, research skills, and competencies. Therefore, this work underlines the need to develop new investigations and common discussions to clarify terminological biases that often limit constructive debates and production of knowledge within the research communities.

## 3 Understanding Synergies Between HCD for Sustainability

The exploration of common research topics linking HCD and Sustainability aims to identify patterns and a set of comparable elements to be used for creating the design research scenario, useful to focus the attention only toward the most relevant domains where Sustainable HCD interventions can produce relevant effects.

### 3.1 The Influence of Sustainability on HCD Studies

As briefly discussed before, the role of Sustainability is paramount in Design [2, 5]. Studies developed in the last thirty years documented an evolution of the design culture that moved from materialism and the analysis of products' ecological qualities to the

investigation of systemic relations within socio-technical systems having high social qualities [2]. The attention toward the green growth [20, 21], the recognition of the value of the social dimension related to different consumption models [22] as well as the development of an agenda of actions to tackle the complex challenges of future years [23] influenced the studies in HCD with the raise of the ‘Green Ergonomics’ model [24, 25].

In terms of implementation of Sustainability principles into HCD, Lange-Morales et al. [26] suggest reconsidering the relevance of Sustainability’s values, such as respect for human rights, respect of the Earth, appreciation of complexity, respect of diversity, respect of transparency and openness, and respect of ethical decision-making, to operate the needed (inter-)disciplinary design interventions. This interpretation is also consistent with the studies developed by Moray [27] and by Marano et al. [28], which place the discussions within global scenarios where the evolution of the human behaviors is needed to start the transition toward sustainable ways of living (Moray) and for which innovative research avenues are needed to trigger the investigation of new designable sustainable scenarios (Marano et al.).

Relevant elements that can be found within Sustainability studies (re [23]) have therefore the task to raise the attention of designers and design researchers in looking at the bigger picture. This statement seems to be coherent with a study made by Dul et al. [29], which describes the need to design systems of solutions at the micro-scale that promote a better – sustainable – well-being by focusing on instances observable at the macro-scale. However, a warning on this need is pointed out by Martin et al. [30], which say that the contribution of HCD to Sustainability is still limited to intentions and conceptual development, despite there is a rational continuity with design actions that are consistent with the goals of Sustainability (re [23]).

The last studies considered in this phenomenological analysis [29, 30] reveal an interesting affinity with the Ezio Manzini’s angle about ‘localism’, the ‘scenario of resiliency’ and the need to move toward systems of enabling solutions that generate new ideas of (sustainable) well-being [31, 32]. Therefore, it can be said that Sustainability influences the HCD research by raising the attention on relevant macro-themes through which later start HCD studies, visions, and strategies for sustainable interventions that have a direct account on human scales, behaviors, and well-being conditions, which comprise the dimension where the HFE interventions can better express their values.

### 3.2 HCD’s Responses to Sustainability Pushes

Whether Sustainability is called to identify promising areas where to address the attention of scientific communities, HCD is paramount to narrowing down the field of theories, approaches, methods, and tools needed to operatively implement the transition toward sustainable conditions at the micro-scale. However, as discussed before, the framework of knowledge on this phenomenon lacks consistent developments [23] and conjectural convergences.

In considering the HCD dimension more, Demirel and Duffy [5] provide an interesting analysis on the role of HCD within the Sustainability debate by proposing a design framework that encompasses four stages of product development. In this work, authors identify the well-being as the common element linking the two areas. This interpretation

is therefore fully coherent with studies conducted in Design [2, 28, 29, 32], whereas the emphasis is more addressed on the process, rather than on the individuation of common patterns to be scaled within research speculations. Yet, the lack of proper a contextualization seems to lead toward the recognition of an endogenous disciplinary complexity [33] suggesting the futility of perpetrating speculative terminological iterations, such as finding logical patterns to justify the ‘HCD for Sustainability’ idiom.

Conversely, interesting interpretations can be found in the work of Lange-Morales et al. [26] which helps to bring the attention on the cross-sectorial intersections between HCD interventions and Sustainability values, such as: the quality of life, the need of multidisciplinary approaches, and the idea of values (against needs). Interestingly, this is an exegesis already proposed by Marano et al., [28] whose study moves toward the definition of suitable design scenarios, rather than the vertical alteration of design topics having a sort of ‘sustainable ergonomic quality’.

Therefore, the most coherent impact that HCD might produce in relation to Sustainability pushes is the identification of specific elements that can be used to define a design scenario where later the HCD culture can make an evolution. Conceptually, this assumption is relevant as it shifts the emphasis toward new research domains, while three interesting analyses made by Mason [34], Sherwin [35], and Sevaldson [36] support this new speculative conjecture. Synthetically, Mason discusses the limits of HCD approach in considering the contexts of use, suggesting that this lack triggers implications on the social dimensions that is paramount to consolidate a sustainable intervention because referred to human well-being; Sherwin suggests that insight-based HCD methods struggle to articulate or capture more abstract sustainability needs, and the relevance of this aspect is instead remarked by Design for Sustainability studies; finally, Sevaldson indicates that often design actions for Sustainability are not a naturally integrated result of human centric worldviews, and consequently often implying actions that are against the interests of users.

This analysis proves that HCD is mostly asked to address, through contextualized actions, all interventions that put the sustainable wellbeing at the center of the research process. Therefore, HCD plays an important role in refining the quality of design scenarios set up from Sustainability pushes, by considering both contextual features at the local scale (e.g.: the Manzini’s angle about localism [32]) and methodological advances that are proper of HFE discipline [33].

## 4 Building the Design Scenario for Sustainable HCD Studies

It becomes clear that any HCD intervention performed under the Sustainability domain must employ design-driven learning processes needed to link local communities, situational actions often performed by technological equipment, and living ecosystems, either virtual or physical. Therefore, any design becomes an informed HCD process within a scenario of change aiming to achieve new sustainable qualities. Furthermore, the idea of design scenario is paramount when it comes Sustainability, and consequently Design for Sustainability, as it reduces the endogenous complexity of information to consider. Consequently, the design scenario is intended as a powerful instrumental element used to imagine future living conditions mixing bottom-up instances and top-down design

strategies. According to Manzini et al., [37] a design scenario is ‘*a designable vision of something complex and articulated based on a clear motivation – what is the aim? – and a practicality – the actions to undertake to favor its implementation*’.

Elements of the design scenario considered for this study obviously come from the previous discussed domains – Sustainability and HCD – and are needed to deal the systemic complexity of notions and interdisciplinary foci raised in the last years within transition studies [38]. Sustainable instances at the bigger picture provide evidence on the strategic trajectories that the human-centered design interventions should consider in order to produce significant and desirable effects in terms of sustainable well-being; conversely, HCD is asked to contextualize the sustainable scenario at the local scale, by applying specific methodologies and tools meeting the different contextual conditions [36, 37]. Therefore, the scenario of Sustainable HCD acts as a multiplier of the sustainable localism needed to achieve new levels of well-being.

This scenario is not only able to produce important cultural advances in terms of promising concepts to address future studies in HCD, and by extension HFE, but it is also able to identify new themes for cross-sectorial experimentations – themes of a Research Agenda on Sustainable HCD. In addition, this interpretation is coherent with the arguments discussed in the Sect. 3.2 about the mitigation of cultural biases [33].

## 5 Themes of the Research Agenda on Sustainable HCD

Results obtained in the previous stages show that there are promising grounds for developing new scenario-led studies and research avenues linking HFE and Sustainability, which are focused on human-centered design-oriented scopes. This remarks the need and the opportunity to define a research agenda for Sustainable HCD.

Since the Sustainability perspective in Design studies has broadened its scopes both in terms of goals and in the breadth of the fields of action [39, 40], some research themes can be assumed as particularly relevant to document the potential contribution of HCD within Sustainability studies. However, themes have a twofold nature: they are both ‘detailed’ to suggest clear research indications and topics for promising studies, and ‘open’ to give scholars the needed freedom to operate interdisciplinary personalization depending on the testing grounds considered for their studies.

The six clusters of interdisciplinary design themes proposed in this work range from product design to system design dimensions, from spatio-social to socio-technical systems, from transition studies to unexplored areas for HCD. Such areas are later compared against relevant levels of Sustainability, such as [2].

In relation to the ‘*product innovation*’ level: Exploring innovative human-centered patterns connecting creative practices with transition studies to ideate new design approaches focused on improving the quality of existing/new products. Possible design areas to investigate are, but not limited to: Product Life Cycle Design, Eco-Design, and Design for Environmental Sustainability. These areas suggest the need to integrate more HCD qualities to sustainable artefacts, when these are made at the product innovation scale; therefore, the attention is on how to converge/integrate the ecological qualities with the ergonomic qualities that products must have at the human scale.

In relation to the ‘*product-service system (PSS) innovation*’ level, two sub-themes have been identified: (i) Exploring the combination of HCD methodologies in Design

for Sustainability fields, which could suggest new studies on the usability of sustainable products, services, and systems of solutions that have a direct and indirect impact in relevant areas such as Design for Sustainable Behavior, Systemic Design, Sustainable Service Design. (ii) To ascertain vertical and horizontal explorations on sustainable systems, networks, and services, which might suggest the need to understand more how HCD improves the design of large-scale solutions, mainly intangible, and how HCD addresses the research on sustainable networked applications.

In relation to the '*spatio-social innovation*' level, three sub-themes can be discussed: (i) Exploring the implications made by sustainable architecture and the design of smart cities on individuals and social communities, which suggests the need to develop novel studies on how the HCD approaches can implement the current design practice, along with the analysis of human factors in the creation of living places, both at the micro and at the macro scales [41]. (ii) Understating relevant implications on Civil, Structural, and Environmental Engineering, which points out the need to assess the HCD aspects in the technical design of sustainable living ecosystems and places. (iii) Clustering the cultural design aspects belonging to sustainable reflective practices by exploring the role of HCD in relation to the evolution of speculative creative thinking and contextual studies.

In relation to the '*socio-technical system innovation*' level, four sub-themes contain innovative elements for new studies: (i) Exploring how to promote radical changes by framing complex patterns, systemic problems, and societal needs (i.e.: energy, food, water, health, job, security, transport) supporting the transition to new sustainable socio-technical systems by effectively including individuals and communities (e.g.: Co-Design). (ii) Implementing Sustainable Design Thinking and Design-Driven Innovation [42], because these disciplines may promote the adoption of creativity-led research patterns, cross-sectorial methods, and interdisciplinary developments useful to converge HCD and Sustainability. (iii) Consider more the contribution of Human-Computer Interaction (HCI) and User Experience Design (UX) for sustainable applications, which means considering the opportunity to perform studies linking humans and communities with technology-mediated artefacts and design practices. (iv) Understand the positive implications occurred in sustainable manufacturing, including 3D Printing; for example, what is the role of Sustainable HCD in the design of new sustainable manufacturing processes that use the LCA and LCD as assets for the competitiveness of SMEs? [43].

In relation to the level concerning '*social equity and cohesion*' [40], two relevant sub-themes can be found: (i) Developing consistent clarifications on the role of Sustainable HCD around topics like (Design for) human diversity, disability, special population, etc., opening to the idea of inclusive system [44], and how the design practice can benefit from the contributions of HFE methodologies to meet Sustainability-related studies. (ii) Analyze the role of User Research into transition studies in term of inter-, cross-, and multi-disciplinary interplay between HFE and Sustainability (at the human scales), including recent advances on Design for Social Inclusion.

Finally, in relation to the level of '*transition studies*': Further investigate the contribution of transition studies to link HFE and HCD. Examples could relate to, but not limited to: Circular Economy, distributed systems for delocalised manufacturing, and product-service systems (PSS).

## 6 Conclusion and Discussion

This work provided evidence documenting the need to develop new studies on Sustainable HCD, to properly investigate the explicit and hidden links between HFE and Sustainability. A research agenda containing six clusters of research themes has been proposed to promote effective ergonomic design interventions (re HCD) that are consistent with the modern idea of Sustainability. As discussed by Ezio Manzini [45, 46], the transition toward Sustainability requires a discontinuity from the previous consumption models, along with focused learning processes needed to trigger holistic scenarios for sustainable living. Therefore, the role of design is paramount to properly implement these studies on HFE.

As recalled by Sevaldson [36] and by Borthwick et al. [47], to embrace Sustainability, HCD needs to switch from an anthropocentric perspective to a multi-centric position, also widening the design foci toward non-humans and more-than-human needs, including the planet protection and systems problems in general. User-Centered Design (UCD) approach has to go beyond the user/custom-oriented notion used to set up the design interventions by including the awareness of indirect – but equally relevant – subjects involved in the other stages of the system life cycle, such as people in the production, recycling, and dismissal processes [48]. Thus, the consideration of systems boundaries has to be expanded within large, spatio-temporal contexts including both future impacts on (human) users in the long run and negative effects of its use and misuse on society, including risks prevention of unintended consequences [49]. Therefore, community engagement needs to be better integrated within the more consolidated individual perspective of UCD – more oriented toward Co-Design practices – in order to match people perception and behaviour, as well as individual user beliefs and reactions used to design creative solutions for multiscale problems [50, 51].

Sustainable HCD can even play a strategic role in transition studies [52]. It has been observed that the new set of research issues raised in the last years requires novel interdisciplinary methodologies that cannot employ traditional design approaches. Updates are therefore needed and must be shared with the design community to assess all possible disciplinary limitations, between research opportunities and challenges. Design-led human-centred interventions can therefore support proper interdisciplinary explorations linking the three dimensions of Sustainability – environmental, social, economic – with the four areas of HFE. The design side of the ergonomic interventions is the aspect where researchers and ergonomists can properly address Sustainability.

In conclusion, this work demonstrated that future design and research explorations on Sustainable HCD can be started (at least) in some promising testing grounds – here called as ‘clusters of research themes’ – which reflect the most contemporary design interests of the research community working on Design for Sustainability. Therefore, this work also points out the need to complete these studies and to start a choral research action toward structured convergences to rediscuss theories, methodologies, and tools.

## 7 Relevance of the Study

This work provides qualitative discussions and focused analyses on different sustainable scenarios (i.e.: clusters) and research themes converging HCD and Sustainability.



It introduces a set of research topics that are considered as relevant to start promising research investigations and design experimentations ranging from Product Design to Service Design, from Architecture to Urban Planning, from Computer Science to intelligent Systems, from Manufacturing to Innovation Management. This study contributes to enrich the cultural and scientific debate within the Human Factors research community [15] by providing evidence and interdisciplinary discussions needed to trigger studies on ergonomically coherent sustainable design scenarios and sets of solutions that meet both the HCD principles and the Sustainability criteria.

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