Mapping of Possible Pathways to Sustainable Design in Social Robotics.

Susanne Hägglund[1[0000-0002-4941-6811]] Malin Andtfolk[2[0000-0001-9380-3619]]

Sara Rosenberg[3,2[0000-0002-8938-7939]] Sören Andersson[1[0000-0003-0418-185X]]

Linda Nyholm[4[0000-0002-3324-5966]]

[1] Experience Lab, Faculty of Education and Welfare studies,
Åbo Akademi University, Rantakatu 2, Vaasa, 65100, Finland
[2] Department of Caring Science, Faculty of Education and Welfare Studies,
Åbo Akademi University, Rantakatu 2, Vaasa 65100, Finland
[3] Pharmaceutical Sciences Laboratory, Faculty of Science and Engineering,
Åbo Akademi University, Turku, Finland
[4] Department of Caring and Ethics, Faculty of Health Sciences,
University of Stavanger, Stavanger, Norway

susanne.hagglund@abo.fi

Abstract. It's imperative that all sectors adapt to global warming, including technology designers and researchers exploring social robotics in healthcare. However, sustainability is a complex concept, and its operationalization mechanisms are not easily defined. In this document, we share a collaborative team reflection of possible pathways to sustainable design of an AI-augmented, socially assistive robot prototype application. Our mapping suggests that empirical and conceptual studies, within the research and design team and with stakeholders, may address all three dimensions of sustainability - environmental, economic, and social - at a micro, meso, and macro level. The map of possible pathways is neither a complete collection nor a silver bullet to a fully sustainable technological solution. Nonetheless, we hope that it furthers the discussion regarding possible ways to include sustainability as a tool in the design box and to research sustainable design in social robotics.

Keywords: Sustainable design; Sustainability and AI; Sustainable AI; Indicators of sustainability; Social robotics; Human-Robot Interaction; Healthcare.

1 Introduction

The integration of sustainable design principles in the field of Human-Robot Interaction (HRI) has gained increasing attention in recent years. In Europe, this evolution is partly driven by the evolving regulatory landscape, most notably countries' responses to the Paris Agreement international treaty on climate change [1], European Commission's Green Deal roadmap for climate neutrality by 2050 [2], the forthcoming European Union Artificial Intelligence (AI) Act [3] and the Corporate Sustainability Reporting Directive, currently in force [4]. These legislative initiatives underscore the imperative of incorporating sustainability into the development and deployment of AI and social robotic technologies. Furthermore, the Intergovernmental Panel on Climate Change report [5] and the Lancet Countdown on health and climate change [6] unequivocally emphasize the pressing need for concerted global action to mitigate climate change and related health harms, mandating contributions from all sectors, including technology, science, and healthcare.

Against this backdrop, this document serves as a reflective exploration and mapping of possible pathways to sustainable design within the realm of HRI, and in particular social robotics, in a community pharmacy context. Our analysis is rooted in an ongoing research and development project, providing a practical lens through which we assess and discuss sustainability in the design of a socially assistive robot application in a high-stake, heavily regulated medication safety context in Finland. The aim is to document and share our multidisciplinary mapping of possible paths towards sustainable design out of a research and design perspective. We hope to contribute to the discussion on sustainability indicators and concrete pathways to integrating sustainability in HRI and social robotics design.

2 Definition of concepts

2.1 Sustainability

Despite its recent prominence, the concept of sustainability remains unclear and multifaceted [7]. As explained by Mensah [8] through a systematic literature review, sustainability encompasses a tripartite structure comprising the domains of environment, economy, and society. These fundamental pillars are independent yet intertwined and offer internal synergies, trade-offs, and tensions. A fundamental tenet of sustainability lies in the equitable allocation of resources and benefits, both within and across generations, thereby underscoring the significance of inter- and intragenerational equity. It is important to acknowledge the enduring implications of sustainability, which extend across temporal horizons, encompassing both immediate and enduring consequences. Any progress in meeting present needs must be accomplished without compromising the ability of future generations to meet their own needs [8], [9].

2.2 Sustainable AI

Sustainability is dynamic by its character, meaning that it must be continuously reassessed as the world, with its resources and social structures, evolves and new technological innovations are being implemented in society. AI has been considered a double-edged sword in addressing sustainability challenges [10], [11]. AI-supported solutions may contribute to progress on environmental, economic, and social challenges and can facilitate climate action [10], [11], [12], [13]. The European Union emphasizes [14] that digital technologies, including AI, are critical enablers for attaining its Green Deal objectives and the United Nation's Sustainable Development goals [15] in many sectors.

However, they may also bring about new risks due to bias, environmental costs, and misalignment with human values, thus hampering sustainability progress [10], [11], [12], [16]. Moreover, albeit digital technology may provide support for human beings in adapting lifestyles towards a sustainable future, the process is likely to include tension, conflict, and trade-offs between values [7], [13], [17].

The concept of sustainable AI does not merely refer to a mechanism contributing to a sustainable, climate-neutral, and circular society. It is also an object of attention itself where its circular lifecycles and energy use are impacts that may be evaluated and addressed in the phases of designing, implementing, and finally using AI-systems [11], [18], [19]. Sustainable AI has been defined by van Wynsberghe [11] 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". This perspective extends the focus to a reduction of greenhouse gas emissions and computing power of the technical solutions and of the systems where they are implemented.

Regardless of the focus, it is imperative that technology designers and researchers acknowledge the urgency of addressing sustainability in their work and their own agency in designing for a more sustainable future [17]. Here, we reflectively explore possible pathways to sustainable design within the realm of human-robot interaction (HRI) in a community pharmacy context. We conceptualize designing AI-supported technological innovations sustainably as a comprehensive and holistic approach to sustainability that balances the design of technological solutions and long-term viability on a systemic level.

2.3 Sustainable design of a social robotics application in a community pharmacy context

A short introduction of the project PharmAInteraction will help the reader position our work and we also refer to earlier work for more context and depth [20], [21]. We explore if and how a socially assistive robot, Furhat in our case, may assist pharmacists and customers in medication processes of emergency contraceptive pills at community pharmacies. From a Research through design perspective [22], we co-create a robot application prototype with target group customers and pharmacists to answer the research question. Iterative user research and studies focusing on the ethical and juridical aspects, medication safety, human trust, trustworthiness of the embodied robot, and conversational AI either have been carried out or are ongoing. As we see it, trust and trustworthiness are fundamental to all aspects of sustainability. If a robot fails to be trustworthy and humans consequently mistrust it, environmental, economic, and social costs are likely to occur in most stages of the implementation process.

As a complement to evaluations of trust, we aim to address environmental, economic, and social sustainability dimensions of HRI between the customer, the pharmacist, and the robot in medication processes. However, standardized indicators for sustainability of social robotics applications are complex and not easily defined [23]. Here, we share a mapping of possible pathways to sustainability in the early design phase of innovating and developing a socially assistive robot application prototype.

3 Mapping of pathways

The team reflection structure follows an approach often applied in social sciences, that of micro-, meso-, and macro-levels [24]. Societies, systems and (inter)national and/or legal goals operate on a macro-level; meso-levels are enacted in groups of professionals or organizational users, whereas micro-level refers to the specific, individual, technological application. We present the envisioned pathways to strengthened sustainability under each of these levels, outlining a holistic and multidimensional approach [7]. Bolte and colleagues [19] suggest complementing an alleged paradigm of following checklists and guidelines with an ethics of desirability, where previously unheard actors share their needs and wants. Acknowledging strengths of both approaches, empirical studies, and rational reflection, and adhering to both is the hallmark of a human-centered AI [25], which influences our work. Therefore, we explore pathways to sustainable design of HRI using both conceptual and empirical studies, within the team only and together with stakeholders (see Figure 1).

Figure 1. Designing for sustainability in social robotics may draw upon both conceptual and empirical studies, within the team and together with stakeholders.

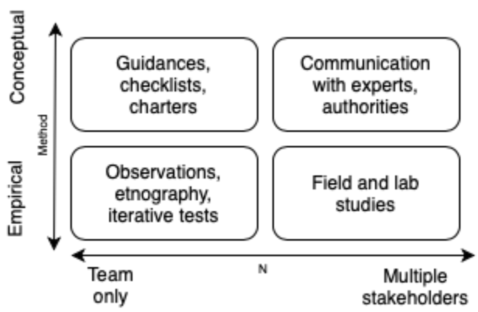

Figure 1 illustrates the sustainable design pathways derived from collaborative team reflection, aimed at a community pharmacy context. We found that team activities such as collaborative expertise sharing during design and in-house iterative testing may address all dimensions of sustainability, at all levels, micro/meso/macro. Additionally, individuals or team members may enhance sustainability by employing tools like charters, checklists, and guides to evaluate and design the robot application. Similarly, involving stakeholders in the process can contribute to sustainability across different dimensions. In parallel, sustainable design efforts on all levels may also incorporate conceptual and empirical methods, such as user testing in controlled laboratory settings, field testing, and the use of interviews and questionnaires to address sustainability dimensions. Sections 3.1, 3.2, and 3.3 describe the pathways, series of steps and actions to coming closer to sustainable design, derived from the collaborative team reflection. The sustainability dimensions that each action addresses are in italic for increased readability.

3.1 Micro level

At the microlevel, the central focus pertains to the design of the technological solution. However, our comprehensive approach to sustainable design necessitates a concurrent consideration of work processes, both at the individual level and within the team context. Consequently, we incorporate these dual facets into the description below of pathways to economic, environmental, and social sustainability.

Environmental. A *reduced ecological footprint* may be addressed by measuring and evaluating carbon footprint and climate impacts of the application with the Hiilineutraali Suomi tool [26]; by mapping ecological footprint and climate impacts of robot hardware, LLMs, and cloud services through discussions with the service providers; designing for reducing the amount of pharmaceutical waste through adequate drug information and drug use as part of the robot medication counseling; designing for high human control paired with safe, reliable, and trustworthy AI, which in turn strengthens environmental preservation, by adhering to the HCAI framework [25]; being mindful of redundant data collection, management, and storage; optimizing energy efficiency; considering metrics for sustainable ICT public procurements in Finland, such as Mitvidi evaluation tool [27], in the application design; and lastly by participating in the discussion on sustainable AI, preferably through hybrid conferences, thus limiting flying.

Circular economy may be favored by internalizing green coding practices; minimizing stored and transferred data; improving software efficiency; designing for mindful deployment of robot features and use cases through consulting guidelines, such as Green ICT: A Producer's Guide [28];https://greenict.fi/en/greenict_producerguide/ keeping continuous within-team reflections regarding regenerative approaches in design processes; building upon previous, own and colleagues' research on Swedish LLM training [29]; designing for easy future updates of the application, and lastly mapping Life expectancy and Life cycle assessments of ICT hardware with service providers.

Favoring sustainable use of natural resources and low energy consumption of the application by design through consulting guidelines [28] and in our own work while designing, testing, researching the human-robot interaction, traveling, meeting up, and collecting, sharing, and storing data files increases *use of renewable energy sources*.

Economic. Sustaining economic growth and *prosperity in the long term*, while safeguarding resources from harmful effects and overexploitation, could be achieved by conducting expert interviews with legal and pharmaceutical scholars to understand if and how the application could be made lawful, robust, economically sustainable, and compatible with the strictly regulated pharmaceutical field now, and in the future. Additional steps to achieve this goal include conducting interviews with pharmaceutical professionals, scholars, and staff to explore if and how the application may address shortages of pharmaceutical staff and choosing solid and long-term soft- and hardware suppliers.

A more *short-term approach* concerns measuring how reliable and trustworthy the application is perceived in terms of drug information, data protection, and ability to recognize human speech through iterative tests with end users and staff, while considering acquiring the ISO standard ISO/IEC TR 24028:2020 [30]. We also identify the following pathways that may support a more short-term economic growth: designing for easy and transparent data access and collection for sustainability auditing [25]; conducting user experience and usability tests with end-users and staff through mixed methods and triangulation of qualitative and quantitative methods [31].

Further, economic sustainability has a dimension of *social justice* that is addressed by including many voices in the co-creation process, both in the field and in laboratory settings, while acknowledging the dark sides of co-creating with stakeholders [32]; considering customers' current and future AI literacy in the design of the application [33]; designing for oversight, auditing, and addressing errors by adhering to a Human-Centered AI framework [25].

Social. Maintaining social balance and harmony by promoting and protecting *human rights, social justice, and equity,* while ensuring that current fundamental needs of individuals are met in a way that benefits future generations, may be addressed by designing the application in line with the European Charter of Human Rights [34], designing the application in line with official regulations and laws, e.g., the Regulation (EU) 2016/679 (General Data Protection Regulation) [35] and the EU Artificial Intelligence Act [36]. Within-team reflections on Recommendations for a Good AI Society [37] and/or co-creation events with end-users [32] further aim to promote this aspect, as do designing for diversity in terms of language features and cultures in the application, communicating extensively about the application and use case and including many different groups and individuals in user testing. Lastly, conducting expert interviews on the topic of diversity and inclusion in the fine-tuning and model training process, and making sure the training input is diverse in terms of age, language, cultural background, serves as a step towards safeguarding equity and human rights.

In our case, *health and well-being* is an important dimension due to the use case context and content of the application. We found that pathways to strengthening well-being and social sustainability at a micro level may include designing the application in line with Ethics Guidelines for Trustworthy AI [38], in particular the section "Societal and Environmental Well-being"; designing for safety and robustness and conduct iterative tests to control for these factors that are crucial in high-risk contexts like pharmacies and medication safety; mapping safety risks of foundation models should LLMs be implemented in medication counseling, through discussions with the service providers and within-team activities; holding within-team activities of drafting scenarios of high human control and autonomy to opt out of interacting with a robot; conducting co-creation processes with customer representatives and staff regarding robot features, competences, and automation level [32]; and continuous monitoring of advancements in policymaking, regulation, and technological innovations regarding safety for informed decision making.

3.2 Meso level

This level focuses on the design of the interaction between the application and the environment. It offers opportunities to include voices of staff, community, customers, and authorities, to complement the alleged framework paradigm.

Environmental. Pathways to *reduced ecological footprint* include adhering to the Humanity-centered design philosophy [39] and considering the possibilities of including non-human stakeholders in the co-creation process; reflecting upon and considering new design methods out of a More than human centered design approach [40], [41], that take animals, plants, and microbes but also autonomous technologies into account in the design processes; and lastly consulting regulations by Fimea [42], [43] and The Association of Finnish Pharmacies [44] regarding pharmaceutical waste management, sustainability strategies, as well as pharmacies' own instructions in the design process.

Economic. Conducting qualitative ethnographic studies and field observations of context and environment at pharmacies as stand-alone methods and as the fourth step in a Care-Centered Value Sensitive Design framework [45], [46] could contribute to *resource efficiency*, as may conducting interviews with pharmacy staff to deepen knowledge on the potential of social robotics and AI to address shortages of staff.

Social. The social dimension of sustainability may be addressed by conducting *ethical evaluations* of the application through Care Centered Value Sensitive Design framework [45], [46,]; by carrying out empirical laboratory studies with customer representatives and staff focusing on fundamental human rights, equal rights and opportunities concerning language and by conducting evaluations of the application through the lenses of ethics, data protection and fair use of data, integrity, and bias [35], [47]. Co-creating with an emphasis on end-user trust in AI-supported robots [48] promotes ethical dimensions in AI design, as do the aspects of privacy protection, agents' role and task in the pharmacy, and level of automation [49]. Additional pathways include co-creating and iteratively testing the application with diverse customer representatives with a variety of AI-literacy [33], to ensure inclusion and equity regardless of personal and socioeconomic factors; and lastly designing for explainability and transparency to foster user control, autonomy, and users' informed decisions as to interacting with the robot or not.

At the meso-level, *working conditions* emerge as an important dimension to address through adopting a multi-disciplinary approach where pharmaceutical scholars and health scientists are part of the team. Moreover, co-creating with an emphasis on staff trust [50], [51] in AI-supported solutions, the competence of a conversational robot, privacy protection, role and task in the pharmacy, and level of automation could strengthen sustainable working conditions of the pharmacy staff, as would assisting pharmacies' own carbon footprint assessments and sustainability auditing by sharing data regarding energy use and environmental impact of the application and consult pharmacies' sustainability strategies [43].

3.3 Macro level

When we design robots, we are also designing values and shaping our future society in the very same process. Hence, we find it valuable to address sustainability at a macro level at the initial stages of the research and design process.

Environmental. One pathway to increased sustainable design at this level is taking a step back to reflect within the multidisciplinary team and with stakeholders, in the light of rapid technological evolution coupled with new reports on climate change, upon whether technology truly has a solid role at all to play in *environmental preservation* and in *reaching the UN Sustainable Development*

Goals. Considering benefits, disadvantages, costs, and trade-offs potentially provoking negative environmental impacts and reflecting upon possible futures by applying Speculative design practices [52] may prove helpful here.

Economic. Learning and staying up to date, building upon the solid expertise and experience of the multidisciplinary team and integrating safe emerging technology promotes sustainability through *extending the lifespan* of the digital solution. *Re-use* in the sense of sharing knowledge, code, and results to inform future projects, also on other SAR platforms than used in this project may strengthen economic sustainability. An additional pathway may be to design for a sustainable implementation early in the design phase by applying the Implementation Research Logic Model [53]; to apply user study results on values and trustworthiness of AI-supported solutions in pharmacies; and to stay informed by policies, scientific results, legislative and regulatory frameworks to understand and address sustainability challenges and risks associated with AI.

Social. Our joint reflection identified civic engagement as a pathway, by participating in public arenas to engage in dialogues with civic society and disseminate results with the scientific community. Integrating received *user needs, feedback, fears, and expectations* in future updates of the application builds upon this pathway. Further, applying Tetrad theory as a framework for an analysis of *long-term effects on society, culture, and social life* of socially assistive robots and AI-assisted applications [54] may prove beneficial, as would addressing whether the designed AI-assisted application indeed has a role to play in reaching the UN Sustainable Development Goal #3. Methods include individual reflections, within the multidisciplinary team through methods such as Possible futures and Speculative design practices [52], expert interviews, and user studies.

Aspects of health and well-being and working conditions are found at a macro level too. Designing for well-being by considering negative long-term effects of automation, such as *deskilling and alienation,* is a possible pathway, where methods include multi-disciplinary team reflections and user studies [55]. Additional tasks include carrying out steps 5-6 of the Care-centered value sensitive design framework [45], [46], exploring both positive and negative impacts of AI-assisted applications on the distribution of roles and responsibilities, long-term human–human relationships, and on the care values, as well as carrying out co-creation workshops with pharmacy staff regarding potential long-term effects on the vocation, e.g., education, life-long learning, status, and availability, and on the pharmacy as an institution, e.g., access, trustworthiness, societal role. Lastly, staying informed by future policies and statements regarding AI-assisted applications and socially assistive robots by pharmaceutical societies, e.g. The International

Pharmaceutical Federation, is a valid pathway towards sustainable design of social robotics, targeting social dimensions at a macro level.

4 Discussion

The scope of our project PharmAInteraction requires us to choose between these pathways to sustainable design of social robotics. Further, the co-creation approach presupposes that we do not make design decisions alone and in advance, but together with stakeholders to certain extents. We have already taken steps towards social sustainability through co-creation mechanisms, e.g., user experience tests with pharmacists and representatives of customers, ethical and legal evaluations, and trustworthiness assessments. Our next step is to reflect upon the identified methods presented in section 3 and possible pathways to address environmental and economic sustainability, without neglecting the social dimension.

We do not seek to conclude that we design a fully sustainable technological solution, or that we have resolved sustainable AI design, should we proceed with all the steps. Risks of greenwashing, i.e., the practice of emphasizing sustainable aspects of a product while downplaying environmentally damaging ones, may be mitigated by being transparent about remaining challenges. There are indicators and mechanisms that we have not considered or failed to address, and we are fully aware that section 3 is far from complete. Moreover, we are restricting our focus to empirical and conceptual studies, carried out within the team or with stakeholders, thereby excluding approaches such as agent-based computational models or predictive analytics. There are also factors at all stages of the design phase, of which we do not assert control. One example in a late implementation phase is the rebound effect following Jevons paradox, where efficiency or energy gains are offset by increased volumes [56]. Another is the fact that technology is evolving rapidly which often makes it a moving target in research. Variables risk becoming outdated faster than mechanisms such as guidance, survey factors, or legislative regulations are. Yet, addressing sustainability in research and aiming for it as an outcome in the design is a crucial exercise to carry out. Moreover, merely relying on past successes is not an option. Constant improvement and analysis of technology, individuals, pharmacy context and practice, regulations, and policymaking are required.

5 Conclusion

All societal sectors must adapt to global warming and the healthcare sector is no exception [6], [57]. Further, it's important that we not only consider how technology may act as a solution, assisting in adapting healthcare to climate change, but also design socio-technological solutions that do not entail negative consequences for sustainability [25], [39], [58]. When technology development aspires to design reliable, safe, and trustworthy systems, digital solutions may play a role in supporting progress in environmental preservation and reaching the Sustainable Development Goals [25].

Beyond legislation concerning carbon neutrality by 2035 [59] and procurement reasons, we wish to focus on sustainability in our own work for ethical reasons as well. Al-Emran and Griffy-Brown [16] encourage practitioners to integrate sustainable practices to the development process to ensure that the technology aligns with sustainable development principles and the same goes for researchers as well in Research through design-projects. The present document is an overview of our mapping of possible pathways to include sustainability as a tool in our design box and to research sustainable design in social robotics.

We hope to inspire other research and design teams with tools for and metrics of sustainable AI design and to contribute to the discussion on how the field of HRI may address the decisive question of sustainability in designing and researching AI-supported solutions in the healthcare sector.

Acknowledgments. The authors thank all individuals who contributed to the work. This work was supported by grants from Svenska kulturfonden and Högskolestiftelsen i Österbotten and by the strategic research profiling area Solutions for Health at Åbo Akademi University [Academy of Finland, project# 336355]. Chat GPT-3.5 was used to transform bullet points to a draft Introduction text, which was audited for content and complemented with text by main authors. Chat GPT-3.5 was prompted for a "rich, clear, academic language" of a draft version of Section 2.1.

CRediT author statement.

First author: Conceptualization, Methodology, Investigation, Formal analysis, Visualization, Writing – original draft preparation, review and editing, Funding acquisition. **Author 2**: Methodology, Investigation, Writing - review and editing, Project administration, Funding acquisition. **Author 3**: Methodology, Investigation, Writing - review and editing, Funding acquisition. **Author 4**: Methodology, Investigation, Writing - review and editing, Funding acquisition. **Author 5**:

Methodology, Investigation, Writing - review and editing, Project administration, Funding acquisition.

References

1. Paris Agreement international treaty on climate change, 196 Parties at the UN Climate Change Conference (COP21), France, December (2015). https://unfccc.int/process-and-meetings/the-paris-agreement
2. European Commission: The European Green Deal, COM(2019) 640 final, December (2019). https://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=CELEX:52019DC0640
3. European Parliament: EU AI Act, December (2023). https://www.europarl.europa.eu/news/en/press-room/20231206IPR15699/artificial-intelligence-act-deal-on-comprehensive-rules-for-trustworthy-ai
4. European Commission: Directive (EU) 2022/2464 of the European Parliament and of the Council (2022). https://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=CELEX:32022L2464
5. Intergovernmental Panel on Climate Change (IPCC): Climate Change 2021 – The Physical Science Basis: Working Group I Contribution to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge, Cambridge University Press, (2023). https://doi.org/10.1017/9781009157896
6. Romanello, M., di Napoli, C., Green, C., Kennard, H., Lampard, P., Scamman, D. et al.: The 2023 report of the Lancet Countdown on health and climate change: the imperative for a health-centred response in a world facing irreversible harms, The Lancet, (2023). https://doi.org/10.1016/S0140-6736(23)01859-7
7. Hägglund, S., Fagerström, L., Nyholm, L: Promoting Human and Planetary Health Simultaneously by Addressing Sustainability on a Holistic, Multidimensional Level in the Design and Use of SARs, International Journal of Caring Sciences, 15 (1), pp. 650-654 (2022)
8. Mensah, J.: Sustainable development: Meaning, history, principles, pillars, and implications for human action: Literature review, Cogent Social Sciences, 5:1, (2019). https://doi.org/10.1080/23311886.2019.1653531
9. United Nations (UN): Report of the World Commission on Environment and Development: Our Common Future, (1987). https://sustainabledevelopment.un.org/content/documents/5987our-common-future.pdf
10. Zhao, J., Gómez Fariñas, B. Artificial Intelligence and Sustainable Decisions, Eur Bus Org Law Rev 24, pp. 1–39 (2023). https://doi.org/10.1007/s40804-022-00262-2
11. van Wynsberghe, A.: Sustainable AI: AI for sustainability and the sustainability of AI, AI and Ethics 1, pp. 213-218, (2021). https://doi.org/10.1007/s43681-021-00043-6
12. Global Partnership on AI, CLIMATE CHANGE AND AI Recommendations for Government Action, (2021). https://www.gpai.ai/projects/climate-change-and-ai.pdf
13. Vinuesa, R., Azizpour, H., Leite, I., Balaam, M., Dignum, V., Domisch, S., Felländer, A., Langhans, S. D., Tegmark, M., Fuso Nerini, F.: The role of artificial intelligence in

achieving the Sustainable Development Goals, Nature Communications, 11(1), (2020). https://doi.org/10.1038/s41467-019-14108-y
14. European Parliament and European Council: DECISION (EU) 2022/2481 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 14 December 2022 establishing the Digital Decade Policy Programme 2030, Official Journal of the European Union. L 323/4, (2022). https://eur-lex.europa.eu/eli/dec/2022/2481/oj
15. United Nations (UN): Transforming our world: the 2030 agenda for sustainable development, (2015), https://sdgs.un.org/2030agenda
16. Al-Emran, M., Griffy-Brown, C.: The role of technology adoption in sustainable development: Overview, opportunities, challenges, and future research agendas, Technology in Society, Volume 73, (2023). https://doi.org/10.1016/j.techsoc.2023.102240
17. Boll, S., Väänänen, K., Bidwell, N., Hassenzahl, M., Neuhaus, R.: A Human-Computer Interaction Perspective to Drive Change towards Sustainable Future (Dagstuhl Perspectives Workshop 23092), in Dagstuhl Reports, Volume 13, Issue 2, pp. 199-241, Schloss Dagstuhl - Leibniz-Zentrum für Informatik (2023). https://doi.org/10.4230/DagRep.13.2.199
18. Hägglund, S., Nyholm, L.: Possibilities and challenges while designing and implementing AI-supported welfare technology in healthcare. In: Sustainability Science Days, May 23-26, 2023, Pathways of Hope, Knowledge, Actions, Solutions. Book of Abstracts, (2023). https://www.helsinki.fi/en/conferences/sustainability-science-days-2023/abstract-book
19. Bolte, L., Vandemeulebroucke, T., van Wynsberghe, A.: From an Ethics of Carefulness to an Ethics of Desirability: Going Beyond Current Ethics Approaches to Sustainable AI, Sustainability 2022, 14 (2022).
20. Rosenberg, S., Andtfolk, M., Hägglund, S., Wingren, M., Nyholm, L.: Social robots counselling in community pharmacies – Helping or harming? A qualitative study of pharmacists' views. Exploratory Research in Clinical and Social Pharmacy, Volume 13, (2024). https://doi.org/10.1016/j.rcsop.2024.100425
21. Hägglund, S., Andtfolk, M., Rosenberg, S., Wingren, M., Andersson, S., Nyholm, L.: Unga vuxna apotekskunders behov vid köp av akuta p-piller vid apotek och Sociala, assisterande robotar och förutsättningar för medicineringssäkerhet på apotek ur farmaceuters synvinkel, Social- och hälsovetenskapsdagarna, Vaasa, Finland, (2023). https://doi.org/10.5281/zenodo.7898266
22. Zimmerman, J., Forlizzi, J.: Research Through Design in HCI, in Olson, J., Kellogg, W. (eds) Ways of Knowing in HCI, Springer, New York, NY, (2014). https://doi.org/10.1007/978-1-4939-0378-8_8
23. Nishant, R., Kennedy, M., Corbett, J.; Artificial intelligence for sustainability: Challenges, opportunities, and a research agenda, International Journal of Information Management, Volume 53, (2020). https://doi.org/10.1016/j.ijinfomgt.2020.102104
24. Karsh, B.T., Waterson, P., Holden, R.J.: Crossing levels in systems ergonomics: a framework to support 'mesoergonomic' inquiry, Appl Ergon, Jan;45(1), pp. 45-54 (2014). https://doi.org/10.1016/j.apergo.2013.04.021
25. Shneiderman, B.: Human-Centered AI, Oxford University Press, Oxford UK, (2022)
26. Hiilineutraali Suomi, (2023). http://laskurit.hiilineutraalisuomi.fi/verkkopalvelu/
27. MitViDi Project, (2023). https://mitvidi.tt.utu.fi/mitvidityokalu
28. Green ICT Project, (2023). https://greenict.fi/en/greenict_producerguide/

29. Espinosa-Leal, L., Forss, T., Hägglund, S., Kuvaja-Adolfsson, K., Rautanen, K., Shcherbakov, A.,Tigerstedt, C.: TaFiDiAI: Taligenkänning för Finlandssvenska Dialekter genom Artificiell Intelligens (Version 1), (2022). https://doi.org/10.5281/zenodo.7495136
30. International Organization for Standardization and International Electrotechnical Commission: TR 24028:2020. Information technology - Artificial intelligence - Overview of trustworthiness in artificial intelligence, (2020), https://www.iso.org/obp/ui/en/#iso:std:iso-iec:tr:24028:ed-1:v1:en
31. Corrales-Paredes, A., Sanz, D.O., Terrón-López, M-J., Egido-García, V.: User Experience Design for Social Robots: A Case Study in Integrating Embodiment, Sensors, 23(11), (2023). https://doi.org/10.3390/s23115274
32. Nyholm, L., Viklund, E.W.E., Vaartio-Rajalin, H., Forsman, A., Hägglund, S., Rydgren, M., Nordmyr, J.: Delaktighet genom samskapande metoder för utveckling av innovationer inom social- och hälsovård, Hoitotiede, 34(4), (2022)
33. Long, D., Magerko, B.: What is AI Literacy? Competencies and Design Considerations. In: Proceedings of the 2020 CHI Conference on Human Factors in Computing Systems (CHI '20). Association for Computing Machinery, New York, NY, USA, pp. 1–16 (2020). https://doi.org/10.1145/3313831.3376727
34. European Union: Charter of Fundamental Rights of the European Union (2007/C 303/01), Official Journal of the European Union Volume 50, (2007), https://fra.europa.eu/sites/default/files/charter-of-fundamental-rights-of-the-european-union-2007-c_303-01_en.pdf
35. European Union: Regulation (EU) 2016/679 of the European Parliament and of the Council of 27 April 2016 on the protection of natural persons with regard to the processing of personal data and on the free movement of such data, and repealing Directive 95/46/EC (General Data Protection Regulation), Official Journal of the European Union, L 119, 4.5.2016, pp. 1–88 (2016)
36. European Commission: 2021/0106(COD) Proposal for a Regulation of the European Parliament and of the Council. Laying down harmonised rules on artificial intelligence (Artificial intelligence act) and amending certain union legislative acts, (2021), https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52021PC0206
37. Floridi, L., Cowls, J., Beltrametti, M., Chatila, R., Chazerand, P., Dignum, V. et al.: AI4People—An Ethical Framework for a Good AI Society: Opportunities, Risks, Principles, and Recommendations, Minds & Machines 28, 689–707, (2018). https://doi.org/10.1007/s11023-018-9482-5
38. High-Level Expert Group on AI (AI HLEG): The Assessment List for Trustworthy Artificial Intelligence (ALTAI) for self assessment, European Commission, Brussels, (2020). https://doi.org/10.2759/002360
39. Norman, D.: Design for a better world. Meaningful, sustainable, humanity centered, MIT Press, London, (2023)
40. Rosén, A.P., Normark, M., Wiberg, M.: Towards more-than-human-centred design: Learning from gardening, International Journal of Design, 16(3), pp. 21-36 (2022). https://doi.org/10.57698/v16i3.02
41. Stead, M., Coulton, P., Pilling, F., Gradinar, A., Pilling, M., Forrester, I.: More-than-Human-Data Interaction: Bridging Novel Design Research Approaches to Materialise and Foreground Data Sustainability. In: Proceedings of the 25th International Academic

Mindtrek Conference (Academic Mindtrek '22), Association for Computing Machinery, New York, NY, USA, pp. 62–74 (2022)
42. Fimea: How should medicines be disposed of? (2023a) https://fimea.fi/en/for_public/correct-use-of-medicines/how-to-dispose-of-medicines
43. Fimea: Fimea Sustainability Report 2022 (2023b). https://vuosikertomus.fimea.fi/en/sustainability
44. The Association of Finnish pharmacies: Vastuullinen apteekki (2016). https://www.apteekkariliitto.fi/media/3-apteekkariliitto.fi/apteekkitieto/julkaisut/vastuullinen-apteekki_esite_screen3.pdf
45. van Wynsberghe, A.: Designing Robots for Care: Care Centered Value-Sensitive Design, Sci Eng Ethics 19, pp. 407–433 (2013). https://doi.org/10.1007/s11948-011-9343-6
46. van Wynsberghe, A.: Service robots, care ethics, and design, Ethics Inf Technol (2016) 18, pp. 311–321 (2016). https://doi.org/10.1007/s10676-016-9409-x
47. IEEE Global Initiative on Ethics of Autonomous and Intelligent Systems: Ethically Aligned Design. A Vision for Prioritizing Human Well-being with Autonomous and Intelligent Systems, (2019)
48. Christoforakos, L., Gallucci, A., Surmava-Große, T., Ullrich, D. Diefenbach, S.: Can Robots Earn Our Trust the Same Way Humans Do? A Systematic Exploration of Competence, Warmth, and Anthropomorphism as Determinants of Trust Development in HRI, Front. Robot. AI 8:640444 (2021). https://doi.org/10.3389/frobt.2021.640444
49. Saßmannshausen, T., Burggräf, P., Hassenzahl, M. Wagner, J.: Human trust in otherware – a systematic literature review bringing all antecedents together, Ergonomics, 66:7, pp. 976-998 (2023). https://doi.org/10.1080/00140139.2022.2120634
50. Stevens, A.F., Stetson, P.: Theory of trust and acceptance of artificial intelligence technology (TrAAIT): An instrument to assess clinician trust and acceptance of artificial intelligence, Journal of Biomedical Informatics, Volume 148 (2023). https://doi.org/10.1016/j.jbi.2023.104550
51. Gulati, S., Sousa, S., Lamas, D.: Design, development and evaluation of a human-computer trust scale, Behaviour and Information Technology, vol. 38, no. 10, pp. 1004–1015 (2019). https://doi.org/10.1080/0144929X.2019.1656779
52. Ringfort-Felner, R., Neuhaus, R, Dörrenbächer, J, Hassenzahl, M.: Design Fiction - The Future of Robots Needs Imagination, in Meaningful Futures with Robots – Designing a New Coexistence, eds. J. Dörrenbächer, R. Ringfort-Felner, R. Neuhaus & M. Hassenzahl (Chapman & Hall), pp. 114-130 (2023)
53. Smith, J.D., Li, D.H. Rafferty, M.R.: The Implementation Research Logic Model: a method for planning, executing, reporting, and synthesizing implementation projects, Implementation Sci 15, 84 (2020). https://doi.org/10.1186/s13012-020-01041-8
54. Euchner, J.: Marshall McLuhan and the Next Normal, Research-Technology Management, 64:6, pp. 9-10 (2021). https://doi.org/10.1080/08956308.2021.1974777
55. Klapperich, H., Uhde, A., Hassenzahl, M.: Designing everyday automation with well-being in mind, Pers Ubiquit Comput 24, pp. 763–779 (2020). https://doi.org/10.1007/s00779-020-01452-w
56. York, R., Adua, L., Clark, B.: The rebound effect and the challenge of moving beyond fossil fuels: A review of empirical and theoretical research, WIREs Climate Change, 13(4), (2022). https://doi.org/10.1002/wcc.782

57. Miller, F.A., Xie, E.: Toward a Sustainable Health System: A Call to Action, Healthc Pap. Oct;19(3), pp. 9-25 (2020). https://doi.org/10.12927/hcpap.2020.26377
58. Ceschin, F., Gaziulusoy, I.: Design for Sustainability. A Multi-level Framework from Products to Socio-technical Systems, Routledge, New York, (2020)
59. Finlex: Climate Act (423/2022), (2022). https://www.finlex.fi/sv/laki/smur/2022/20220423