A Thematic Analysis of Environmental Sustainability in Software-Intensive Business: Understanding Practices, Barriers, and Benefits

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Abstract. Software-intensive businesses play a dual role in environmental sustainability by enabling efficiency and resource optimization while contributing to environmental impact through energy use, software evolution, and hardware dependence. This study examines how environmental sustainability is manifested in software-intensive organizations and what factors hinder or motivate sustainable practices. Based on 22 semi-structured interviews with 38 individual participants from two Finnish Green ICT projects (2022–2025), thematic analysis identified practices across organizational, process, product, and external aspects. Key barriers include low prioritization, unclear roles, limited client influence, and lack of expertise, while benefits relate to competitiveness, reputation, and efficiency. The study emphasizes the need for shared understanding, integrated competencies, and measurable metrics to enhance sustainability in the software industry.

Keywords: Environmental Sustainability, Software-Intensive Business, Sustainable Software Development, Green ICT, Thematic Analysis

1 Introduction

Software-intensive businesses play a dual role in environmental sustainability. Advanced software systems enable efficiency gains, resource optimization, and process dematerialization, yet the energy demands of data centers, continuous software updates, and hardware dependencies contribute significantly to growing carbon footprints. As digital transformation accelerates, understanding how software-intensive business models align with environmental goals is essential for sustainable development. Awareness of the ICT sector's environmental impact has grown globally, and in Finland, both policymakers and companies have recognized its significance. Finland was the first country to publish an ICT Climate Strategy in 2021 [1], addressing environmental impacts across hardware, software, resources, and emerging technologies. Despite this progress, environmentally sustainable practices remain limited in software-intensive organizations, revealing a persistent gap between research and practice [2], [3]. To address this gap, this study examines how sustainability is manifested in software-intensive businesses, the challenges they face, and the drivers that support environmentally sustainable practices. This research is guided by the following questions:

RQ1: How is environmental sustainability manifested in software-intensive organizations?

RQ2: What factors hinder or motivate software-intensive organizations to implement environmentally sustainable practices?

2 Background

The modern concept of sustainability, introduced in the Brundtland Report, defines sustainable development as meeting present needs without compromising the ability of future generations to meet theirs [4]. It emphasizes balancing environmental, social, and economic dimensions within the limits of natural resources [5], [6]. Contemporary sustainability science expands this view by recognizing the interdependence and non-linear dynamics of Earth systems [7]. The planetary boundaries framework identifies nine critical Earth system processes, six of which have already been exceeded [8], [9], underscoring the urgency of embedding sustainable practices across all sectors, including technology.

Software-intensive business (SiB) refers to organizations in which software plays a central role in value creation, delivery, and operations. Schönhofen et al. [10] describe this shift as a move from product-centric innovation to cross-industry collaboration, encompassing both software producers and software-dependent industries. The research field, grounded in software engineering, information systems, and economics, was formally consolidated at the Dagstuhl Seminar 18182 [11], [12], identifying four core themes: software product management, software ecosystems, Continuous X and Agile practices, and software startups. The domain focuses on sustainable value creation and delivery within and across organizations, responding dynamically to technological, economic, and environmental change [12].

In this context, environmental sustainability in SiB has emerged as both a challenge and an opportunity. ICT sector accounts for approximately 2.1-3.9% of global greenhouse gas emissions [13]. This includes not only operational energy use but also emissions from hardware manufacturing, distribution, and disposal. The software sector therefore plays a dual role: it enables "Green by IT" solutions that enhance efficiency and eco-innovation, yet it also contributes to environmental burdens through "Green IT" concerns such as energy consumption and material waste [14], [15]. Despite growing awareness of ICT's dual impact [16], [17], the practical implementation of sustainable software practices remains limited. Recent studies identify barriers such as the lack of standardized metrics, insufficient training and governance, and weak alignment between sustainability and corporate strategy [18], [19] and indicate that the benefits of sustainable practices are largely business- and value-oriented [20].

Prior studies examine sustainability across both software processes and software products [21]–[23]. They have also studied the environmental impacts of software in the corporate context [24], but have also identified the differentiation of software companies from traditional industries because it produces intangible products, complicating the assessment of environmental impacts [25]. The challenge of responsibility of software emissions and energy consumption is also discovered in earlier studies [26] [27]. Effective organizational change, particularly the deep integration of sustainability, requires a foundation of shared mental models and clearly communicated goals across stakeholder groups [28].

3 Methodology

3.1 Data collection

To address our research questions, we conducted semi-structured interviews between 2022 and 2025 within two national Green ICT projects, with total number of 22 of interviews. During the first project, 31 participants from 15 organizations were interviewed during 06/2022–02/2023, all with experience in software procurement and environmental sustainability. During the second project 8 participants from seven organizations were interviewed in 03–05/2025 for this ongoing project. One organization and participant was interviewed twice (P9), once in both projects, resulting in total 21 different organizations and 38 individual participants. Table 1 presents the interviewee IDs, industry categorization of the interviews, organization headcount, and the role of the interviewee.

Table 1. Interview organizations and participants. P9 was interviewed twice, once in year 2022, once in year 2025.

ID	Industry category	Org. headcount	Sample size	Role of the participants in the company
P1	Education	250-999	2	IT Manager, Lead IT Designer
P2	Public Procurement	250-999	2	Legal Expert
P3	Public Procurement	250-999	3	Legal Expert, Lead Product Manager, Senior Management Specialist
P4	City	over 1000	3	Project Manager, ICT Project Manager, Senior ICT Specialist
P5	Education	over 1000	4	IT Service Manager (n=2), Systems Architect, Digital Architect
P6	City	over 1000	2	Project Manager, Development Manager
P7	Software Services and Consulting	50-249	1	Executive Leadership
P8	Software Consulting	250-999	1	Sustainability Manager
P9	Software Consulting	50-249	1	Executive Leadership
P10	Consulting	over 1000	5	Executive Leadership, Senior Software Expert, Service Designer, Procurement Expert, Service Architect
P11	Software Consulting	50-249	1	Account Manager
P12	Software Consulting	10-49	1	Lead Architect
P13	Consulting	10-49	2	Design lead, Software Developer
P14	Software Consulting	10-49	2	Executive Leadership, Expert
P15	Software Services	10-49	1	Senior Developer
P16	Software Consulting	1-9	1	Executive Leadership
P17	Software Consulting	over 1000	2	Business Development Manager, Senior Consultant
P18	Software Consulting	50-249	1	Sustainability and Operations Leader
P19	Software Consulting	50-249	1	Executive Leadership
P20	Software Consulting	1-9	1	Technical Team Lead
P21	Software Consulting	10-49	1	Executive Leadership
			38	

3.2 Thematic analysis process

After the transcription of the interviews, we reviewed the data following Braun & Clarke's thematic analysis process [29]. In the analysis phase, we did not use seed codes, but the codes were derived from the data guided by the research questions. We reviewed the transcripts, coded them, and built initial themes (see Figure 1, upper boxes). After further analysis and review of the initial themes, we identified six final themes: *organization*, *software process*, *software product*, *external factors*, *barriers*, and *benefits*. The first four themes address RQ1, while the last two address RQ2.

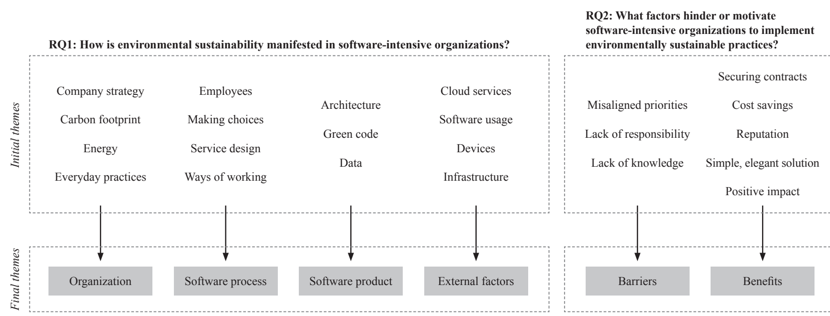

Fig. 1. Initial and final themes and the research questions.

4 Results

4.1 Environmental sustainability in software-intensive businesses

We found that the practice of environmental sustainability takes diverse forms and operates from multiple aspects within ICT organizations. Environmental sustainability is observed across four primary aspects: organization, software development process, software product, and external factors. In the organization aspect, sustainability is fundamentally a strategic concern, evidenced by organizations incorporating it into their goals (P10, P12, P15) and calculating or preparing to calculate their carbon footprint (P8, P10, P13, P12, P14). While its importance is widely acknowledged, the maturity of implementation varies. Common practices include managing business travel, event food, office energy use, and energy sourcing (P4, P8, P9, P14, P16). Efforts such as extending computer lifetimes (P18) and using digital tools to reduce travel and paper use (P4) are common, though some organizations only minimally address the topic (P7). The software process focuses on ways of working and human choices, adding a sustainability perspective to service design and early development phases (P8, P9, P10). Sustainability is linked to individual choices (P11, P16, P18), such as selecting carbon-neutral hosting (P9) or writing energy-efficient code (P7), with organizational values indirectly guiding these practices (P11). The software product aspect highlights technical attributes such as green code and architectural simplicity. Sustainability is associated with creating simple, maintainable, adaptable, and modular architectures (P9, P16). Practical measures focus on data efficiency, including minimizing transferred bytes through deferred media loading and using content delivery networks (P8), aiming for lean software with minimal waste (P9). Finally, external factors include cloud infrastructure, hardware, and the software's usage phase. The environmental impact of cloud services is a frequent discussion point (P4, P12), and hardware and infrastructure are seen as major sources of emissions, though organizations have limited influence over user device replacement cycles (P8).

4.2 Barriers and benefits of implementing sustainable practices

Our analysis revealed both clear barriers and distinct benefits in implementing environmental sustainability. Among the barriers, the most significant challenges are prioritization and unclear responsibilities (P7, P9, P11). Environmental considerations often remain secondary to cost, quality, or safety in corporate planning (P21). Implementation is further limited by a lack of knowledge, specialized skills, and a sustainability-oriented mindset (P18), with success depending on the availability of such expertise (P6). This shortage is linked to the topic's novelty (P21) and developers' limited time to acquire new competencies (P19). In contrast, the benefits of prioritizing sustainability are substantial, including commercial and reputational gains. Sustainable criteria are increasingly required for public procurement and tender eligibility (P5, P18), expanding business opportunities and client bases. Digital transformation initiatives, such as paperless operations and remote work, offer dual advantages of environmental improvements and cost savings (P4, P17, P20). Commitment to sustainability strengthens branding and reputation (P17, P11), helping attract both employees and clients (P11). Sustainability is also seen as a component of software quality, emphasizing simple and efficient solutions that minimize resource use (P9). Many organizations additionally focus on projects with measurable environmental impact, such as those achieving concrete resource savings (P11).

5 Discussion

Our first RQ examined how sustainability is manifested in software-intensive businesses. We identified four main aspects through which environmental sustainability appears: organization, software process, software product, and external factors. In practice, these aspects are deeply interconnected. For example, ways of working manifest at the software process level but are influenced by the organization and further shape the software product. Or organizational strategies and structures shape software processes that, in turn, influence the resulting products, while external conditions such as clients and market expectations affect how software is developed and used. Indirect links also exist, as organizational choices can determine product characteristics and external factors can drive process-level decisions. These interdependencies illustrate the complex and context-dependent nature of sustainability in software-intensive businesses. Despite years of discussion within software context, sustainability still lacks shared definitions, practices, and metrics. Our findings contribute by providing an empirically grounded and more holistic understanding of how environmental sustainability manifests within software-intensive businesses.

Our second RQ examined the barriers and benefits of implementing sustainable practices. The main barriers involve low prioritization and unclear roles and responsibilities. Environmental considerations often fall on individual developers or, in some cases, on customers. Consultants especially reported limited influence over sustainability when clients were unwilling to modify existing technologies. Another major barrier is the lack of knowledge and of a sustainability-oriented mindset. As the IT industry evolves rapidly, sustainability skills are rarely prioritized, and a fragmented understanding of sustainability further hinders skill development. The identified benefits of sustainable practices are mainly business- and value-driven, including cost savings, contract opportunities, enhanced reputation, and elegant solutions. These findings align with previous studies. While barriers appear across all four aspects, the benefits are primarily concentrated at the organizational and external levels. However, as some themes extend across multiple aspects, further research is needed to clarify where the benefits most strongly emerge within software processes and products.

Overall, our findings highlight the need for a stronger shared organizational commitment, integrated sustainability competencies, and measurable metrics within software-intensive businesses. The observed challenges related to prioritization and limited sustainability awareness reflect the absence of a shared mental model of environmental goals across organizations, which is essential for achieving lasting systemic change [28]. As a final analysis, we propose a three-step roadmap to address these challenges in software-intensive businesses. First, organizations should build a shared understanding of environmental sustainability and define what it means within their specific contexts. Second, this understanding should be integrated into everyday practices. Third, measurable metrics should be established and monitored. These steps should be implemented in this specific order.

6 Conclusion

We studied and identified how environmental sustainability is manifested in software-intensive organizations and how related challenges and benefits appear at different aspects. We identified four aspects (organization, software process, software product, and external stakeholders) where practices, constraints, and responsibilities differ, creating diversity in the maturity. We also identified conflicts between roles (clients vs. consultants, management vs. teams). We suggest a joint understanding of environmental sustainability within the organization at every level. This further enables shared practices together with measurable metrics.

References

[1] T. Ojala and P. Oksanen, "Climate and Environmental Strategy for the ICT Sector," Ministry of Transport and Communications, Tech. Rep., 2021.

[2] H. Noman et al., "An Exploratory Study of Software Sustainability at Early Stages of Software Development," *Sustainability*, vol. 14, no. 14, p. 8596, 2022.

[3] C. C. Venters, R. Capilla, E. Y. Nakagawa, *et al.*, "Sustainable software engineering: Reflections on advances in research and practice," *Information and Software Technology*, vol. 164, 2023.

[4] G. Brundtland, *Our Common Future: Report of the World Commission on Environment and Development*, 1987.

[5] T. Kuhlman and J. Farrington, "What is Sustainability?" *Sustainability*, vol. 2, no. 11, pp. 3436–3448, 2010.

[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.

[7] B. Walker and D. Salt, "A Crash Course in the Science of Resilience," in *The Community Resilience Reader*, D. Lerch, Ed., Washington, DC: Island Press/Center for Resource Economics, 2017, pp. 163–178.

[8] J. Rockström, W. Steffen, K. Noone, *et al.*, "A safe operating space for humanity," *Nature*, vol. 461, no. 7263, pp. 472–475, 2009.

[9] K. Richardson, W. Steffen, W. Lucht, *et al.*, "Earth beyond six of nine planetary boundaries," *Science Advances*, vol. 9, no. 37, eadh2458, 2023.

[10] F. Schönhofen, S. Schockert, and G. Herzwurm, *ISO 16355 in Software-Intensive Business*, 2018.

[11] S. Jansen, "There's No Business Like Software Business: Trends in Software Intensive Business Research," in *Software Business*, S. Hyrynsalmi et al., Ed., vol. 370, Cham: Springer International Publishing, 2019, pp. 19–27.

[12] P. Abrahamsson et al., "Software Business, Platforms, and Ecosystems: Fundamentals of Software Production Research (Dagstuhl Seminar 18182)," en, Schloss Dagstuhl – Leibniz-Zentrum für Informatik, Tech. Rep., 2018, pp. 164–198.

[13] C. Freitag et al., *The climate impact of ICT: A review of estimates, trends and regulations*, 2021.

[14] V. C. Coroama and L. M. Hilty, *Energy consumed vs. energy saved by ICT–A closer look*, 2009.

[15] L. Charfeddine and M. Umlai, "ICT sector, digitization and environmental sustainability: A systematic review of the literature from 2000 to 2022," en, *Renewable and Sustainable Energy Reviews*, vol. 184, p. 113 482, 2023.

[16] F. Berkhout and J. Hertin, "De-materialising and re-materialising: Digital technologies and the environment," *Futures*, vol. 36, no. 8, pp. 903–920, 2004.

[17] S. Naumann et al., "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.

[18] S. U. Lee et al., "A survey of energy concerns for software engineering," *Journal of Systems and Software*, vol. 210, p. 111 944, 2024.

[19] L. Abdullai, A. Sipilä, and J. Porras, "Green ICT Adoption and Challenges: Evidence from the Finnish ICT Sector," in *Software Business*, N. Carroll, A. Nguyen-Duc, X. Wang, and V. Stray, Eds., vol. 463, Cham: Springer International Publishing, 2022, pp. 337–343.

[20] J. A. Purwandani and G. Michaud, "What are the drivers and barriers for green business practice adoption for SMEs?" *Environment Systems and Decisions*, vol. 41, no. 4, pp. 577–593, 2021.

[21] B. Penzenstadler and H. Femmer, "A generic model for sustainability with process- and product-specific instances," in *Proceedings of the 2013 workshop on Green in/by software engineering*, Fukuoka Japan: ACM, 2013, pp. 3–8.

[22] K. U. Sarker et al., "SQ-Framework for Improving Sustainability and Quality into Software Product and Process," *International Journal of Advanced Computer Science and Applications*, vol. 11, no. 9, 2020.

[23] S. McGuire et al., "Sustainability is Stratified: Toward a Better Theory of Sustainable Software Engineering," in *2023 IEEE/ACM 45th International Conference on Software Engineering (ICSE)*, Melbourne, Australia: IEEE, 2023, pp. 1996–2008.

[24] E. Jiménez et al., "Towards a software industry corporate social responsibility reference model for software sustainability," *Sustainable Development*, vol. 32, no. 4, pp. 3471–3494, 2024.

[25] A. Sipilä, L. Partanen, and J. Porras, "Carbon Footprint Calculations for a Software Company – Adapting GHG Protocol Scopes 1, 2 and 3 to the Software Industry," in *Software Business*, S. Hyrynsalmi, J. Münch, K. Smolander, and J. Melegati, Eds., vol. 500, Cham: Springer Nature Switzerland, 2024, pp. 442–455.

[26] L. Partanen, A. Sipilä, and J. Porras, "Energy consumption and CO2 emissions of a software – who is responsible?" In *ICSOB-C 2023 Software Business: PhD Retreat and Posters & Demos Track 2023*, 2023.

[27] L. Partanen et al., "Mapping of the system of software-related emissions and shared responsibilities," in *2025 IEEE/ACM 9th International Workshop on Green and Sustainable Software (GREENS)*, Ottawa, ON, Canada: IEEE, 2025, pp. 39–46.

[28] P. M. Senge, *The fifth discipline: the art and practice of the learning organization*, 1st ed. New York: Doubleday/Currency, 1990.

[29] V. Braun and V. Clarke, "Using thematic analysis in psychology," *Qualitative Research in Psychology*, vol. 3, no. 2, pp. 77–101, 2006.