Generative Artificial Intelligence and the Impact on Sustainability

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Abstract: An increasingly popular subcategory of Artificial Intelligence (AI) is Generative AI (GAI), which encompasses technologies capable of creating new content, such as images, text, and music, often resembling outputs made by humans. The potential impact by GAI on sustainability is multifaceted. On the positive side, generative AI can aid in optimizing processes, developing innovative solutions, and identifying patterns in large datasets related to sustainability. This can lead to more efficient resource management, reduced energy consumption, and the creation of more sustainable products. However, there are also potential negative impacts, such as increased energy consumption associated with training and running generative AI models, as well as the potential for unintended consequences or biases in the generated content. Additionally, overreliance on generative AI may lead to reduced human oversight, which could undermine holistic, interdisciplinary, and collaborative approaches to sustainability. The aim of this paper is to explore the potential impacts on sustainability by generative artificial intelligence through a review of prior research on the topic. The study was conducted with a scoping literature review approach to identify potential impacts by generative AI on sustainability. Data were collected through a search in the database Scopus during the spring semester of 2024. Keywords, relevant for the study, were combined with Boolean operators. Papers identified through the search underwent a manual screening process by the authors, in which papers were selected for inclusion or exclusion in the study based on a set of criteria. Included paper were then analyzed with thematic analysis, according to the guidelines by Braun and Clarke. A categorization matrix, based in prior research on sustainability, supported the analysis and deductive coding of collected data. Results of the study highlight generative AI's potential impact on sustainability that relate to both environmental aspects, economic aspects, and social aspects of sustainability. These different aspects of sustainability impact make this research an important contribution for deepening the understanding of generative AI and its potential consequences for society. Findings of the study provide theoretical contribution, implications for practice, and recommendations for future research on generative AI and sustainability.

Keywords: Generative AI, Sustainability impact, Environmental sustainability, Economic sustainability, Social sustainability

1. Introduction

The release of ChatGPT in November 2022 by OpenAI has stimulated implementations of generative artificial intelligence (GAI) in various areas such as academia, business, healthcare and in society at large. AI has been a useful part of processes in numerous areas for several years, but the emergence of GAI applications such as ChatGPT, Gemini, and DALL-E could be considered a new AI spring with applications that are user-friendly and have a promising performance potential. (Kanbach et al, 2024) The umbrella term GAI encompasses technologies capable of creating content in different modalities, such as images, text, music and videos (Rabowsky, 2023), that often resembles content made by humans. The potential impact by GAI on individuals, organizations and sustainability could be described as a double-edged sword (Gursoy & Cai, 2024).

On the positive side, GAI can contribute to optimizing processes and identifying patterns in large datasets related to sustainability. This could result in more efficient resource management, reduced energy consumption, and the creation of more sustainable products. There are optimistic research studies claiming that GAI might contribute to biodiversity, water resource conservation, renewable energy, energy conservation and sustainable transportation systems (Nishant, Kennedy & Corbett, 2020), which could help companies lower their carbon footprint and preserve sensitive natural heritage sites and national parks. Moreover, AI may also be useful in combating the climate change by providing a more comprehensive understanding of climate change scenarios and carbon emission analyses (Gursoy & Cai, 2024).

On the negative side, there are also potential negative impacts, such as increased energy consumption associated with training and running generative AI models (de Vries, 2023), as well as the potential for unintended consequences or biases in the generated content (Shuford, 2024). Interacting with a GAI tool has been estimated to "likely cost 10 times more than a standard keyword search", and as a standard Google search has been reported to use 0.3 Wh of electricity, the electricity consumption of a GAI tool could be as high as approximately 3 Wh per interaction (de Vries, 2023). An example of unpleasant bias in GAI systems is the facial recognition technology used by law enforcement agencies. A research study found that facial recognition technology showed significantly lower accuracy rates for individuals with darker skin tones. A bias that can lead to severe consequences such as wrongful arrests and convictions. (Shuford, 2024)

Finally, overreliance on AI may lead to reduced human oversight, which could undermine holistic, interdisciplinary, and collaborative approaches to sustainability. With this background, it is important that AI researchers and practitioners are aware of the potential impact that generative AI may have on sustainability. The aim of this paper is to explore the potential impacts on sustainability by generative AI through a literature review of prior research on the topic.

2. Theoretical Framework

Sustainability has been defined as the development that meets the needs of the present without compromising the ability of future generations (WCED, 1987; Gursoy & Cai, 2024). The concept of sustainability has been broadly acknowledged as multidimensional, the various dimensions have evolved over time and have often been treated as separate branches. One common representation of sustainability depicts it with the three sub concepts of environmental, economic, and social sustainability as intersecting circles (Purvis, Mao & Robinson, 2019). While yet another representation depicts the same three sub concepts as pillars holding up the overarching concept of Sustainability as the roof (Purvis, Mao & Robinson, 2019).

Although this paper uses the sustainability concepts and the sub concepts of environmental, economic, and social sustainability; it does not make any claim on which type of representation (pillars, circles or other) that is best suited for capturing the nuances of the concepts. The concepts of environmental, economic, and social sustainability are further described below.

The sustainability concept comprises the relationships between humans and nature with a concern on the global environmental problems. Two examples of global environmental problems are industrial pollution and climate change (Giovannoni & Fabietti, 2013). The environmental sustainability concept is not a completely isolated branch, but a concept that is related to economic sustainability. Ideas of a sustainable link between environment and business have been suggested several decades ago. With ecologically friendly strategies and green marketing as a way to attract the environmentally conscious consumers (Sharma et al., 2010).

The further alignment to environmental sustainability, recycling and circular economy are important components of Industry 4.0 (Tang et al., 2022). Economic sustainability also involves companies' and organizations' resilience to crisis, where the recent Covid-19 pandemic is an example of a global crisis with economic challenges. Moreover, the Covid-19 pandemic also has illustrated the relationship between economic sustainability and social sustainability, and how they are intertwined in a severe crisis. (Rai et al., 2021) In a circular economy, the economic growth should be aligned with social responsibility and a general enhancement of sustainability (Upadhyay et al., 2021).

The concept of social sustainability overlaps with corporate social responsibility in the concern of well-being for humans and society through a thoughtful management of social resources (Panigrahi et al., 2019). Other important main aspects of social sustainability are the alleviation of poverty, the respect for justice and human rights, employees' general welfare and work transparency (Kumar & Rahman, 2017; Govindan, Shaw & Majumdar, 2021). A suggested indicator of social sustainability is urban green space accessibility (Du & Zhang, 2020), which is one of several areas where social sustainability connects with environmental sustainability as well as with economic sustainability.

3. Method

The study was conducted as a scoping literature review to explore and map (Munn et al., 2018) the potential impacts on sustainability by GAI systems, as this has been highlighted in prior research. The processes of data collection and data analysis are described in subheadings below.

3.1 Data Collection

Data were collected through a search in the Scopus database in the Spring semester of 2024. The query string combined keywords Generative, Artificial Intelligence, and Sustainability in a search of papers' titles, abstracts, and keywords. The full query string used was:

> (TITLE-ABS-KEY (generative) AND TITLE-ABS-KEY (artificial AND intelligence) AND TITLE-ABS-KEY (sustainability))

The initial search identified 60 potentially relevant papers to be included in the study. Search filters were then applied which brought down the number of potentially relevant papers to 26. The search filters were: Open Access, English language, journal articles, and conference papers. The 26 papers then underwent full paper screening in which 4 papers were excluded for not addressing potential impact on sustainability by generative AI. This resulted in 22 papers being included in the study for further analysis (depicted in Table 2). A summary of inclusion and exclusion criteria are presented in Table 1.

Table 1: Inclusion and exclusion criteria for selected papers

Inclusion	Exclusion
Open Access	Not Open Access
English	Not English
Journal article or conference paper	Not journal article or conference paper
Address (potential) impact on sustainability by generative artificial intelligence	Does not address (potential) impact on sustainability by generative artificial intelligence

3.2 Data Analysis

Data analysis was conducted with a deductive thematic analysis and supported by the sustainability concept, with environmental, economic, and social sustainability as subcategories. After creating a spreadsheet categorization matrix, comprised by the sustainability subcategories, the analysis followed Braun & Clarke's (2006) six phases for thematic analysis.

1. Data familiarization, through paper screening and repeated reading.
2. Generate initial codes, by collecting relevant extracts from the data in the categorization matrix.
3. Searching for themes, by arranging and re-arranging codes, based on similarities and differences, in the categorization matrix.
4. Reviewing themes, by reconsidering arrangements, or clusters, of codes to create coherent patterns.
5. Defining and naming themes, based on the content in the codes and related research.
6. Producing the report, by structuring the presentation of themes according to the categorization matrix.

4. Results and Analysis

This section presents the results and analysis of the 22 included papers (Table 2) and discuss implications of the findings for sustainability. Findings are presented and discussed according to the three sub concepts of sustainability.

Table 2: Included papers

Number	Paper
1	Adiasto, K. (2024). SustAInable Employability: Sustainable Employability in the Age of Generative Artificial Intelligence. *Group & Organization Management*, 10596011241238792. https://doi.org/10.1177/10596011241238792
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3	Alshahrani, A. (2023). The impact of ChatGPT on blended learning: Current trends and future research directions. *International Journal of Data and Network Science, 7*(4), 2029–2040. https://doi.org/10.5267/j.ijdns.2023.6.010
4	Aseeva, A. (2023). Liable and Sustainable by Design: A Toolbox for a Regulatory Compliant and Sustainable Tech. *Sustainability, 16*(1), 228. https://doi.org/10.3390/su16010228
5	Currie, G. M., Hawk, K. E., & Rohren, E. M. (2024). The potential role of artificial intelligence in sustainability of nuclear medicine. *Radiography*, S1078817424000671. https://doi.org/10.1016/j.radi.2024.03.005
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Number	Paper
7	Eglash, R., Robert, L., Bennett, A., Robinson, K. P., Lachney, M., & Babbitt, W. (2020). Automation for the artisanal economy: Enhancing the economic and environmental sustainability of crafting professions with human–machine collaboration. *AI & SOCIETY, 35*(3), 595–609. https://doi.org/10.1007/s00146-019-00915-w
8	Emmert-Streib, F. (2023). What Is the Role of AI for Digital Twins? *AI, 4*(3), 721–728. https://doi.org/10.3390/ai4030038
9	Fathoni, A. F. C. A. (2023). Leveraging Generative AI Solutions in Art and Design Education: Bridging Sustainable Creativity and Fostering Academic Integrity for Innovative Society. *E3S Web of Conferences, 426*, 01102. https://doi.org/10.1051/e3sconf/202342601102
10	Gallent Torres, C., Zapata González, A., & Ortego Hernando, J. L. (2023). El impacto de la inteligencia artificial generativa en educación superior: Una mirada desde la ética y la integridad académica [The impact of Generative Artificial Intelligence in higher education: a focus on ethics and academic integrity]. *RELIEVE - Revista Electrónica de Investigación y Evaluación Educativa, 29*(2). https://doi.org/10.30827/relieve.v29i2.29134
11	Haluza, D., & Jungwirth, D. (2023). Artificial Intelligence and Ten Societal Megatrends: An Exploratory Study Using GPT-3. *Systems, 11*(3), 120. https://doi.org/10.3390/systems11030120
12	Lin, Y. (2022). Rhetoric, Writing, and Anexact Architecture: The Experiment of Natural Language Processing (NLP) and Computer Vision (CV) in Architectural Design. *Proceedings of the 27th International Conference of the Association for Computer-Aided Architectural Design Research in Asia (CAADRIA)*, 343–352. https://doi.org/10.52842/conf.caadria.2022.1.343
13	Rampini, L., & Cecconi, F. R. (2022). Artificial intelligence in construction asset management: A review of present status, challenges and future opportunities. *Journal of Information Technology in Construction, 27*, 884–913. https://doi.org/10.36680/j.itcon.2022.043
14	Reddy, S. (2024). Generative AI in healthcare: An implementation science informed translational path on application, integration and governance. *Implementation Science, 19*(1), 27. https://doi.org/10.1186/s13012-024-01357-9
15	Richards, D., Worden, D., Song, X. P., & Lavorel, S. (2024). Harnessing generative artificial intelligence to support nature-based solutions. *People and Nature, 6*(2), 882–893. https://doi.org/10.1002/pan3.10622
16	Šedlbauer, J., Činčera, J., Slavík, M., & Hartlová, A. (2024). Students' reflections on their experience with CHATGPT. *Journal of Computer Assisted Learning, jcal*.12967. https://doi.org/10.1111/jcal.12967
17	Spiegelhalter, T., & Werner, L. C. (2022). Methods for In-Silico Environmental Resilience, 2018 to 2100. *IOP Conference Series: Earth and Environmental Science, 1078*(1), 012139. https://doi.org/10.1088/1755-1315/1078/1/012139
18	Tomar, P., & Grover, V. (2024). Transforming the Energy Sector: Addressing Key Challenges through Generative AI, Digital Twins, AI, Data Science and Analysis. *EAI Endorsed Transactions on Energy Web, 10*. https://doi.org/10.4108/ew.4825
19	Tortora, L. (2024). Beyond Discrimination: Generative AI Applications and Ethical Challenges in Forensic Psychiatry. *Frontiers in Psychiatry, 15*, 1346059. https://doi.org/10.3389/fpsyt.2024.1346059
20	Vidmar, M., Fleck, J., & Williams, R. (2023). AI and Data in Engineering and Innovation: Towards a Sustainable Future? *2023 IEEE International Conference on Engineering, Technology and Innovation (ICE/ITMC)*, 1–2. https://doi.org/10.1109/ICE/ITMC58018.2023.10332336
21	Vimpari, V., Kultima, A., Hämäläinen, P., & Guckelsberger, C. (2023). "An Adapt-or-Die Type of Situation": Perception, Adoption, and Use of Text-to-Image-Generation AI by Game Industry Professionals. *Proceedings of the ACM on Human-Computer Interaction, 7(CHI PLAY)*, 131–164. https://doi.org/10.1145/3611025
22	Zang, Z., & Ding, W. (2024). Eco-Centric Generative Design Workflow: Extending Sustainability in Architecture. In F. Ying, L. C. Jain, R. Wan, Q. Wu, & F. Shi (Eds.), *Frontiers in Artificial Intelligence and Applications*. IOS Press. https://doi.org/10.3233/FAIA240006

4.1 Environmental Impact

The analysis identified two themes related to environmental sustainability: Resources and Nature-based. The theme of Nature-based is supported by codes from Almaz et al. (2024), De Villiers et al. (2024), and Richards et al. (2024). The codes highlight potential positive impacts of GAI on environmental sustainability. For example, that GAI can be used for farm planning (Richards et al., 2024), identifying, and potentially finding solutions for, sustainability issues (De Villiers et al., 2024), and that GAI could be combined with biomimicry principles to create sustainable and visually stunning structures in architecture (Almaz et al., 2024).

The theme of Resources is supported by codes from Currie, Hawk and Rohren (2024), Tomar and Grover (2024), Tortora (2024), Zang and Ding (2024), Emmert-Streib (2023), Fathoni (2023), Haluza and Jungwirth (2023), Vidmar, Fleck and Williams (2023), Lin (2022), Rampini and Cecconi (2022), and Spiegelhalter and Werner (2022). The codes highlight both potential positive impacts and potential negative impacts of GAI on environmental sustainability. For example, it is brought up that GAI could support in minimizing the use of resources (Fathoni, 2023; Haluza & Jungwirth, 2023; Rampini & Cecconi, 2022) and make energy sources, such as wind energy, more efficient (Emmert-Streib, 2023; Tomar & Grover, 2024). On the other hand, codes also note that GAI require energy to perform computational tasks (Currie, Hawk & Rohren, 2024) and that the training of these AI models require huge amounts of energy and physical infrastructure which is likely to continuing to increase (Tortora, 2024).

4.2 Economic Impact

The analysis identified one theme related to economic sustainability: Optimization. The theme is supported by codes from Almaz et al. (2024), Currie, Hawk and Rohren (2024), De Villiers et al. (2024), and Zang and Ding (2024). The codes highlight mainly potential positive impacts of GAI on economic sustainability. For example, that GAI can optimize architectural design by enabling the possibility of quickly generating multiple options for design, which can save both resources and time (Almaz et al., 2024; Zang & Ding, 2024). Further, it is noted that GAI could optimize accounting and management by providing organizations with improved information efficiency, accessibility, and accuracy, which would be a reduced burden to many companies (De Villiers et al., 2024). However, Currie, Hawk and Rohren (2024) emphasize that there is a delicate balance between potential economic (and sustainability) gains and human values, which becomes evident in contexts such as medicine.

4.3 Social Impact

The analysis identified four themes related to social sustainability: Understanding, Well-being, Trust and equity, and Sustainable workforce. The theme of Sustainable workforce is supported by codes from Adiasto (2024) and Currie, Hawk and Rohren (2024). The codes highlight mainly potential positive impacts of GAI on social sustainability. For example, that GAI could be used to prevent burnouts and relieve strained workforce of pressure by automating repetative and less cognitive demanding tasks, which could free up time for more human-centered tasks (Currie, Hawk & Rohren, 2024). However, it has also been noted that GAI could be a double-edged sword. Meaning that it could support in completing tasks faster, but that does not neccissarily imply that employes will get more free time. They could instead be asked to perform more tasks in the same time, and if so, will they be compensated with a higher salary? (Adiasto, 2024)

The theme of Trust and equity is supported by codes from Currie, Hawk and Rohren (2024), Aseeva (2023), and Vidmar, Fleck and Williams (2023). The codes highlight mainly potential negative impacts of GAI on social sustainability. For example, that GAI has issues with explainability due to its black box nature which undermines trust in the technology (Vidmar, Fleck & Williams, 2023). Further, it is noted that even though GAI could be used to address inequity and social asymmetry, it also has the potential of weding the gap of equity (Currie, Hawk & Rohren, 2024). The theme of Well-being is supported by codes from Currie, Hawk and Rohren (2024), Reddy (2024), Vimpari et al. (2023), and Lin (2022). The codes highlight potential positive impacts of GAI on social sustainability. For example, that GAI could, if responsibly introduced, enhance affordability, quality and accessibility in healthcare (Reddy, 2024), by supporting physicians with automated patient pre-readings and identifying potential urgent health issues which could save lives (Currie, Hawk and Rohren, 2024). GAI could also add to professionals' well-being by affording self-realization and artistic expression through co-creation between human and AI (Vimpari et al., 2023).

The theme of Understanding is supported by codes from De Villiers et al. (2024), Šedlbauer et al. (2024), Alshahrani (2023), Fathoni (2023), Gallent Torres et al. (2023), and Eglash et al. (2020). The codes highlight potential positive impacts of GAI on social sustainability. For example, that GAI could support understanding of sustainability (Šedlbauer et al., 2024), foster sustainable creativity (Fathoni, 2023), and engagement, motivation and self-directed learning through the use of AI chatbots (Alshahrani, 2023) in education. It is also noted that GAI could be used for empowerment and social justice (Eglash et al. (2020), and to increase engagement and understanding of company information and support organizations in communicating impact of sustainability initiatives (De Villiers et al., 2024).

5. Concluding Discussion

The findings presented in the previous section are summarized in Figure 1, which also shows how the themes align in a positive-negative impact continuum regarding GAI in relation to sustainability. The themes have been classified based on the frequency of positive or negative in the codes that aggregated the themes.

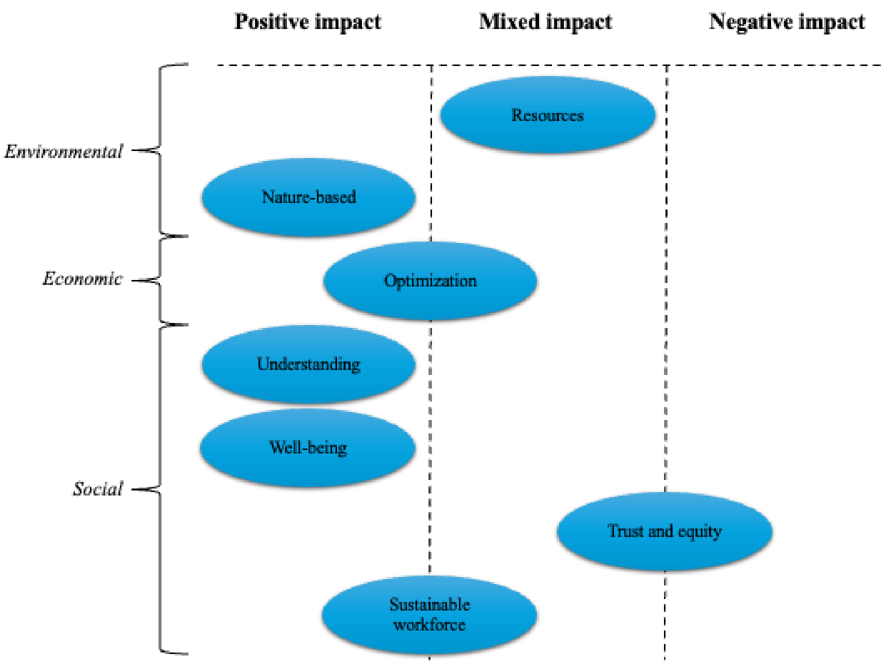

Figure 1: Found GAI themes alignment in a positive-negative impact continuum on sustainability

Despite that there were no exclusion criteria based on publication years, the entire result set were published within the past 4 years. Based on the analyzed result set it seems to have been a general positive attitude towards GAI's ability to handle sustainability issues during this period. This leads to the preliminary conclusion that the recent years has been a new spring for AI, and GAI in particular, which also has been highlighted in previous research (Olhede & Wolfe, 2018; Maclure, 2020). Moreover, there are also researchers that expects this third spring of AI to be followed by a third AI winter (Hajkowicz et al., 2023). To further confirm this, the study should be extended and more thoroughly conducted, for example through a systematic literature review.

Future research should also seek to balance the positive findings in this paper by exploring more of the negative impact of GAI to sustainability. Challenges such as energy consumption, physical infrastructure, and ethical and legal issues are important to consider in the exploration of GAI's capabilities. Further, authors of this paper would suggest that future research develop more specific and detailed definitions of GAI and associated technologies. This would allow for more accurate investigations of different AI technologies impact on sustainability.

It should be noted that this literature review was conducted with a limited approach, with limited number of papers and not including any tests of results, such as analysis of the evolution of publications, cluster analysis, analysis of future lines of research and so forth. The justification for this being to provide an initial exploration of potential GAI impacts on sustainability, which should be extended in future research. An important next step is therefore to include more databases in the literature search, such as Web of Science, to provide a more comprehensive dataset. Inclusion and exclusion criteria could also be revised to include, for example, papers that are not Open Access. This could potentially have negative impact on readers ability to reach included papers for themselves but would also contribute to a more comprehensive understanding of the research field. These adjustments to the ongoing research should also have a positive impact on the number of included papers.

To further widen and strengthen the literature review, alternative keywords for generative AI and sustainability should be added to the query string, as well as backward and forward searches based on the included papers. Tests of the results should be included as part of the methodology.

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