Artifical Intelligence and Sustainability: Technology as an Enabler and Challenges. The Examples of Google and Microsoft

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Dissertation written under the supervision of Professor

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Dissertation submitted in partial fulfilment of requirements for the MSc in Management, at the Universidade Católica Portuguesa, 06.01.2025.

Abstract

Title:
Artifical Intelligence and Corporate Sustainability: Exploring the Dual Role of Technology as an Enabler and Challenge through Microsoft and Google's Strategies for the Tech Industry

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Abstract:
This Thesis examines the role of Artificial Intelligence (AI) in advancing corporate sustainability within the technology industry and focuses on studies of Microsoft and Google. Growing environmental challenges and stakeholder pressure prompts tech giants to integrate AI into their corporate sustainability strategies. While AI holds potential for positive environmental impact, its deployment also presents significant challenges which includes energy consumption and ethical concerns. A mixed-methods approach was adopted, to encompass literature review, case study analysis and expert interviews. The study investigates the alignment of AI initiatives with sustainability goals, challenges of the sustainable integration of AI and best practices in the technology sector. The analysis reveals that both Microsoft and Google leverage AI to enhance energy efficiency, reduce carbon emissions, reduce water usage, and advance circular economy practices. Their initiatives contribute to key Sustainable Development Goals (SDGs), such as SDG 6 (Clean Water and Sanitation), SDG 7 (Affordable and Clean Energy) and SDG 12 (Responsible Consumption and Production). However, challenges persist, which includes high energy demands of data centers and algorithmic transparency. The thesis identifies best practices for AI-driven sustainability, such as AI-powered innovative systems and the use of renewable energy in data center operations. It also highlights the need for balancing technological advancements with ethical and environmental responsibilities. The thesis underscores the dual role of AI as a solution and a challenge in corporate sustainability and offers actionable insights for technology companies and policymakers who strive for a sustainable future.

Keywords: Artificial Intelligence, Corporate Sustainability, Technology Industry, Energy Efficiency, Carbon Emission Reduction, Circular Economy, Responsible AI, Ethical AI, Climate Action, Sustainable Innovation

Sumário

Título:
Inteligência Artificial e Sustentabilidade Empresarial: Explorando o duplo papel da tecnologia como facilitador e desafio através das estratégias da Microsoft e da Google para a indústria tecnológica

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Resumo:
A presente tese analisa o papel da Inteligência Artificial (IA) na promoção da sustentabilidade no setor tecnológico, com foco na Microsoft e Google. A pressão ambiental e das partes interessadas leva estas empresas a integrar a IA nas suas estratégias de sustentabilidade. Embora tenha potencial para gerar impactos ambientais positivos, a IA também apresenta desafios significativos, como o alto consumo de energia e preocupações éticas. Adotou-se uma abordagem de varios métodos, incluindo revisão de literatura, análise de estudos de caso e entrevistas com especialistas, para investigar o alinhamento das iniciativas de IA com os objetivos de sustentabilidade, os desafios da sua integração e melhores práticas do setor. A análise demonstra que Microsoft e Google utilizam IA para aumentar a eficiência energética, reduzir emissões de carbono, otimizar o uso de água e promover a economia circular. As suas iniciativas contribuem para os Objetivos de Desenvolvimento Sustentável (ODS), como ODS 6 (Água Potável e Saneamento), ODS 7 (Energia Acessível e Limpa) e ODS 12 (Consumo e Produção Responsáveis). Contudo, desafios como a significativa procura energética dos data centers e questões de transparência algorítmica permanecem. A tese identifica práticas recomendadas, como sistemas inovadores alimentados por IA, uso de energias renováveis e maior eficiência em data centers. Por fim, destaca a necessidade de equilibrar avanços tecnológicos com responsabilidades éticas e ambientais, sublinhando o duplo papel da IA como solução e desafio na sustentabilidade empresarial e oferecendo recomendações para empresas e decisores políticos.

Palavras-chave: Inteligência Artificial, Sustentabilidade Empresarial, Indústria Tecnológica, Eficiência Energética, Redução de Emissões de Carbono, Economia Circular, IA Responsável, IA Ética, Ação Climática, Inovação Sustentável

Acknowledgements

This thesis marks the culmination of an incredible journey, one that would not have been possible without the unwavering support and guidance of several individuals to whom I owe my deepest gratitude.

First, I would like to express my heartfelt thanks to my supervisor, Professor Nuno Moreira da Cruz, for his invaluable guidance, constructive feedback, and consistent encouragement throughout this process. His expertise and mentorship have been instrumental in shaping the direction and depth of this work.

I am profoundly grateful to the experts from Microsoft and Google who generously shared their time and insights during the interview process. Their willingness to contribute their knowledge and experiences has enriched this thesis immensely.

To my family, your unconditional love and encouragement have been my anchor. Thank you for your endless support and belief in me, even from afar. Your words of motivation gave me strength during moments of doubt.

To my friends, thank you for your patience and understanding as I dedicated myself to this project. Your companionship and humor helped me stay grounded.

Finally, to my better half, your unwavering support, care, and encouragement have been my greatest source of strength. Thank you for standing by me through this challenging yet rewarding journey.

This thesis is not just a reflection of my effort but also a testament to the collective support of those who stood by me. I dedicate this work to all of you.

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List of Abbreviation

AI	=	Artificial Intelligence
CS	=	Corporate Sustainability
CO2	=	Carbon Two Emission
DC	=	Data Centers
EE	=	Energy Efficiency
EC	=	Energy Consumption
e.g.	=	For example
EW	=	Electronic Waste
OE	=	Operational Efficiency
R&D	=	Research and Development
SDG	=	Sustainable Development Goal
SC	=	Supply Chain
SCM	=	Supply Chain Management
TI	=	Technology Industry
TC	=	Technology Company

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1. Introduction

1.1. Research Purpose

Environmental problems and stakeholder pressure drive companies to prioritize sustainability as part of their long-term strategies. Therefore, big tech companies such as Google and Microsoft started recently to realize that artificial intelligence (AI) can be used to meet these goals (Yasin et al., 2023). AI is basically a technology which enables a machine to exactly do what a human would do so that it is automated does not have the necessity of any manual programming (Rahman et al., 2023). To integrate AI within their corporate sustainability (CS), the companies need to have a clear direction and understanding of AI and implement this within their strategy as part of their strategy formulation and strategy implementation. This will provide answers to the questions of what AI initiatives are carried out and how these initiatives are undertaken which are part of formulating a CS strategy (Nandakumar et al., 2010; Ruekert & Walker, 1987). A study of Boston Consulting Group from year 2022 showed clearly that the leader of organizations believe that AI can have a positive impact on fighting against climate risks especially by helping to reduce emissions. 87% of the 1005 global leaders answered that they believe AI can have a positive impact on sustainability within organizations (Maher et al., 2022). AI has therefore lots of opportunities which will be analyzed in more detail within the thesis. In general, AI can help to enhance CS development by improving environmental governance, social responsibility and resource efficiency which would lead to advantages within supply chain management (SCM) and operational efficiency (OE) (Chu et al., 2024). But as opportunities arise, AI also has some major challenges which would need to be tackled within their integration into CS within the technology industry (TI). A major challenge of AI is the environmental cost which arises during AI development. The demand for energy in developing AI will increase exponentially which will be a minimum of ten times bigger than the current energy usage. This high level of energy consumption (EC) will be achieved in 2026 so that the AI EC can be compared with the annual EC of a small country such as Belgium (Ren & Wierman, 2024; Strubell et al., 2019; van Wynsberghe, 2021). Big technology companies (TC) are leading in the way of AI-driven sustainability initiatives to show how AI can be aligned with CS. The thesis will have a deep dive for Microsoft and Google by analyzing their AI initiatives to achieve their CS goals and derive best practices for the TI.

1.2. Research Aim Question

To have a clear understanding of the aim of this thesis, there were 3 research questions developed. These research questions were developed as part of structuring the thesis and to guide to the solutions of deriving best practices for the TI for integrating AI within their CS. To research the new area of AI and sustainability further, the following research questions were developed as a guidance and will be answered throughout the thesis:

1. How can AI technologies enhance corporate sustainability in the technology industry?
2. What challenges arise from aligning AI for sustainability with sustainable AI goals?
3. What are the best practices for aligning AI with corporate sustainability within Google and Microsoft?

Therefore, the key focus areas of the thesis are the following: Strategic alignment of AI with sustainability, challenges of AI and best practices for the TI.

1.3. Outline

The thesis is divided into six sections. The first section explains the research questions and the aim of the thesis and gives an introduction into the area of AI and sustainability. In section two current literature is analyzed to get a better understanding of the topics of AI and sustainability within the TI. Afterwards, the methodology of the research and what kind of research was conducted throughout the thesis is explained in detail in the third section of the thesis. In section four the author explains insights of Microsoft and Google in terms of general information, their current CS strategy, and their impact for the TI. Afterwards, the results of the research are presented in section five. Finally, the thesis is concluded with a conclusion section which represents the sixth section of the thesis. Hereby, the author will discuss the findings and answer the research questions and recommend best practices for the TI for implementing AI into CS. The conclusion section with a discussion and limitations part of the thesis.

2. Literature Review

2.1. Corporate Sustainability Strategy in the Technology Industry

2.1.1. Defining Corporate Sustainability

To understand CS, it is first important to derive the definition of the corporate strategy as CS plays a crucial part of the corporate strategy. Collis and Mongomery (1998) describe the corporate strategy as a way of creating value by handlings its business activities (Collis & Montgomery, 1998). Based on this definition, Lynch (2006) created three areas of corporate strategy. The first is strategic analysis which is linked to stakeholders as the company should create benefits and values for the stakeholder in which shareholders are also included. Hereby, it is important that the company analyzes and creates its mission, vision, goals and sustains its relationship with the environment and resources which it has. The second area is strategy development which describes the process of developing and selecting an option for rolling out the strategy by maintaining success with stakeholders. These strategies were created with the resources the company has which were analyzed during the first stage. The third stage is the strategy implementation which is the core of the corporate strategy process as the company will execute its chosen strategy by always managing the resources and sustaining the relationship with the environment. Therefore, it is important that the company chooses a strategy which is sustainable in the long-term to be competitive and create value (Lynch, 2006). The area of sustainability is gaining more importance in the context of the business´ world. Therefore, companies are in need to derive a CS strategy which is focused on trying to reduce their damages to the environment and increasing their efforts through strategies to maintain a sustainable future (Lacy et al., 2012). There is no definition of CS, so that there has been several definitions throughout the management literature (Montiel & Delgado-Ceballos, 2014). But mainly the CS definition was formed by Brundtland (1991) report´s which first described CS as generations to meet their needs (World Commission on Environment and Development, 1991). Furthermore, the CS is described as a long-term process in the business world. More recently there has been a new definition which describes CS as a construct which should sustain and expand economic growth, create shareholder and stakeholder value, corporate reputation, customer relationship, quality of products, ethical business practices and sustainable jobs. Therefore, CS should not be seen only as a process to less arm the environment. It should be defined as a process of producing the output in the way that it can run indefinitely for the future without harming the nature or society (Hart & Dowell, 2011). Therefore, the current CS is described as a three pillar conception of social economic and environmental sustainability which intersect with each other as shown in Figure 1 (Purvis et al., 2019).

Figure 1

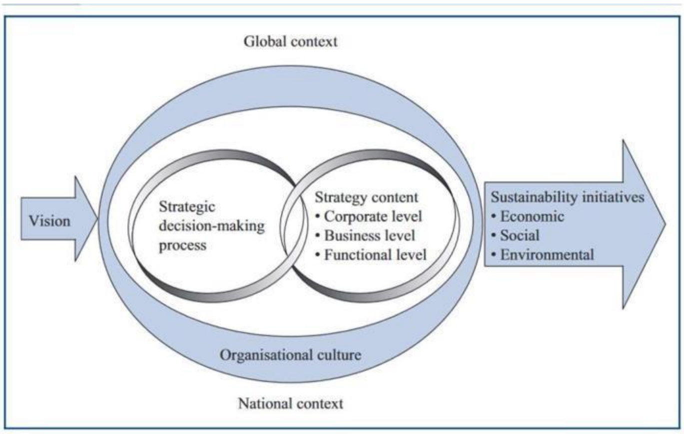
The Three Intersecting Circles of Sustainability

Note. Copied from Purvis et al. (2019), p. 682

Since CS is an important factor, it should also be implemented into the corporate strategy by analyzing the sustainable challenges and taking actions to achieve success for the present and the future of the environment and company (Baumgartner, 2014; Klettner et al., 2014). Sustainability should always be addressed as a strategic issue rather than an operational issue. Therefore, sustainability is seen as part of the corporate strategy and the different dimensions need to be addressed within the strategic decision-making process of the company. Furthermore, the sustainability factor needs to be addressed within the strategy content level which includes the corporate, business, and functional level of a company. This will give the company the chance to identify pain points of sustainable practices within the company and develop improvement plans (Bonn & Fisher, 2011). Bonn and Fisher (2011) developed a framework for how companies need to integrate sustainability into their corporate strategy which is shown in Figure 2.

Figure 2

Sustainability as an Integral Part of Strategy



Note. Copied from Bonn and Fisher. (2011), p. 6

2.1.2. The Technology Industry

Before taking a closer look at the sustainability drivers in the TI, it is important to derive a definition of the TI. The TI is characterized by driving innovative products and processes for its customers and always evolving with the new market trends (Grinstein & Goldman, 2006). The TI is characterized by working in one of these areas: computer, computer-aided design, software, automated testing equipment or telecommunication (Jackson & Dunn-Jensen, 2021). Hereby companies can be split into three main technological sectors in which the companies are specializing. The first is having high levels of research and development (R&D) expenses which have the goal of creating new product innovation. The second is having high levels of R&D expenses which have the goal of creating new process innovation and having cost benefits through them. The third one is having low levels of R&D expenses and only restricted engineering skills throughout the company (Papaioannou, 2004; Peneder, 2003). The organization for economic cooperation and development further defined the TI as the main driver for building tools to assess software and services for different industries (*OECD Annual Report 2006*, 2006). The worldwide information technology spending reached 4,9 trillion U.S. dollars which includes PCs, tablets, mobile phones, software, communication services and data center (DC) systems. It is expected that the worldwide IT spending will rise to 5,3 trillion U.S. dollars in 2024. TI is currently receiving the highest number of investments as their services and software are crucial for businesses to maintain and increase successful business productivity. The spending within the TI will continuously grow other time as part of digital transformation and usage of AI, process automation and different cloud solutions (Sherif, 2024). The US has the highest market share. It accounts for 40,7% of the global market share in 2023. Asia Pacific is the second biggest with a market share of 36%. They are followed by Western Europe with a market share of 13,8% in 2023. The current trend shows that the TI will grow at a compounded annual growth rate of 9.47% from 2023 to 2028 ("Information Technology (IT) Sector ICT Market Size and Forecast (by Country, IT Solution Area and Vertical) to 2028," 2024).

2.1.3. Sustainability Drivers in the Technology Industry

There are several types of sustainability drivers in the TI which can have a positive impact on sustainability. TC are in the forefront to develop pollution emission controls to manage emissions and waste which reflects corporate social responsibility (Pei, 2023). Furthermore, there is a huge investment in energy conservation and emission reduction technologies through tech companies. These are essential for sustainable development in the TI and therefore need investment in innovations to reduce the environmental impact by improving production services and consumption services through energy efficiency (EE) and optimized SCM and smart-grids solution that lower emissions (Rezazadeh & Bohnsack, 2023). On the product side TC are innovating eco-friendly products which increases the demand for green products by implementing and innovating eco-friendly designs to their portfolio. Green product sales is an important factor within the TI for long-term sustainability (Heikkurinen & Bonnedahl, 2013; Mohr & Shooshtari, 2003). Disruptive digital technologies such as AI can have the potential to monitor closely and protect the environment within the TI and help companies to reach the sustainable development goals (SDG) (Hellemans et al., 2022). The World Economic Forum suggests that digital technologies can reduce emissions by 20% by 2050 and therefore achieve the net-zero policy of the International Energy Agency. The responsible use of digital technologies is also a sustainability driver within the TI. Digital solutions can enhance sustainability (World Economic Forum, 2022).

2.1.4. SDGs and their Relevance

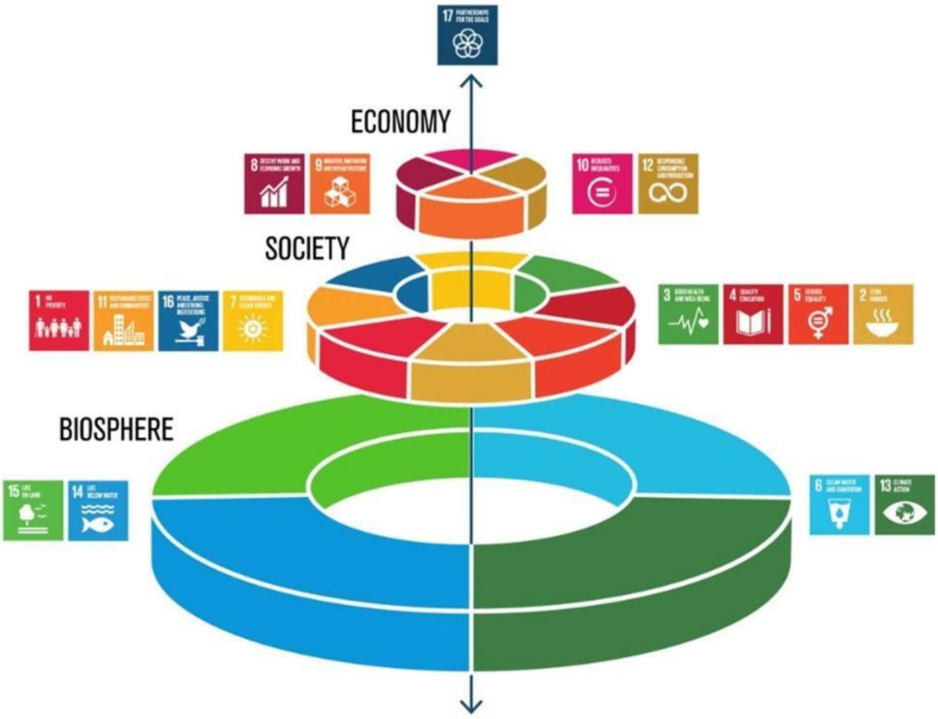
CS goes hand in hand with the SDGs of the United Nations. These were established in 2015 as a blueprint to achieve sustainable development in 2030. Therefore, it is important for companies to base their CS around the SDGs to make sure to achieve their sustainability goals and align their sustainability strategies with global goals. The UN developed 17 goals with 169 targets which address the global challenges: poverty, inequality, climate change, environmental degradation, peace and justice. The SDGs focus on economic, social, and environmental sustainability. All the SDGs are integrated and indivisible so that the goals are interconnected so that achieving one goal can also lead to progress in another goal. Global partnerships are crucial in achieving the SDGs so the UN also wants companies to focus on building collaborations between nations and industries. The key SDGs for the TI are:

SDG 9: Industry, Innovation, and Infrastructure
SDG 12: Responsible Consumption and Production
SDG 13: Climate Action

The SDG 9 focuses on building resilient infrastructure and fostering innovation, whereas the SDG 12 focuses on resource efficiency and waste reduction. SDG 13 focuses on the need for urgent action on climate change. Technology hereby plays a crucial role (United Nations, 2024). However, there is also criticism about the SDG agenda. It faced criticism for being imprecisely formulated and that it lacks on clear ambition and meaningful substance. The SDGs fail to recognize the reciprocal dependency between humanity and the ecosystems which plays an essential part for sustainable development. This results since the SDGs have too many objectives and indicators which makes it difficult for companies to prioritize and set clear goals. Furthermore, the SDGs are not standardized as some are framed as means to an end and other are already ends (Holden et al., 2017). Nevertheless, the SDGs present a solid foundation in which cooperations can rely on and define their corporate strategy by trying to implement and focus on key SDGs and set goals around these (Bergman et al., 2018). In Figure 3 are the 17 SDGs listed in their different dimensions: Biosphere, Society or Economy. All SDGs as an overview are attached within the Annex (Annex 1).

Figure 3

Example of an integration of the UN SDGs with a tripartite nested model of sustainability



Note. Copied from Bergman et al. (2018), p. 5

2.2. Artificial Intelligence and Corporate Sustainability in the Technology Industry

2.2.1. Artificial Intelligence Definition

AI is defined as the development of computer systems. These have the ability to do tasks such as visual perception, translation, decision-making and speech recognition which usually are done by humans by using human intelligence for the different tasks (Dhiman et al., 2024). John McCarthy (2007) was one of the first to give a definition on AI. He described AI as a scientific and engineering discipline which has a key focus on the development of intelligent machines and intelligent computer programs. It is similar in nature to the task of using computers to understand human intelligence (McCarthy, 2007). The definition of AI has slightly changed over time. One of the most used recen definitions in literature is of Russen and Norvig (2021). They describe AI as the study of intelligent agents which execute actions through different applications of functions. The tasks are given to the agents through the commands of the environment which they are working at (Russell & Norvig, 2021). The goal of AI is to interpret, learn and drive results from different data types. One common and widely spread type of AI is Generative AI (Gen AI) which is founded on transformer machine learning predictors which also includes the generative pretrained transformer (GPT). This also includes the application of its chatbot called ChatGPT (Sætra, 2023). Through the enormous amounts of data, AI creates an output based on the user´s input and a text which is hardly distinguishable from a text created by human intelligence. Through the variety of large language models, AI is currently being used globally to enhance productivity (Bilgram & Laarmann, 2023). AI touches different points which include productivity, inclusion, environmental effects, and equality. These triggers can be effected through AI in the short as well as in the long-term and can either have a positive or negative impact on sustainability, society and economy (Dwivedi et al., 2023).

2.2.2. The Role of AI in enhancing Corporate Sustainability for the Technology Industry

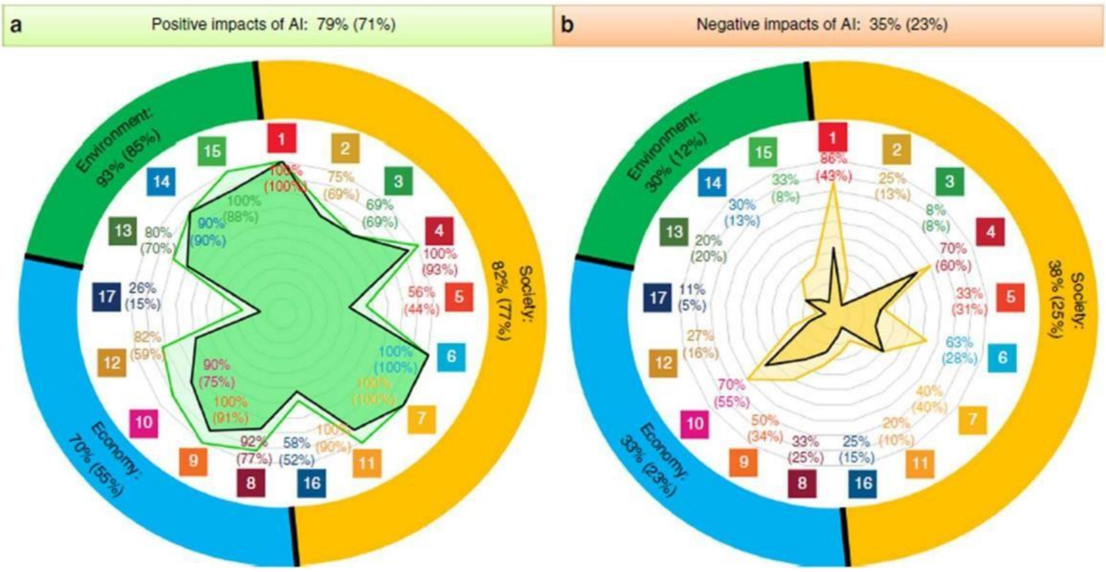
AI has a key role in the CS of companies, especially within the TI. It is used to enhance the speed of decision-making, innovation, SCM and customer experience (Dubey et al., 2019; Moradi & Dass, 2022). TCs use AI mostly to meet their sustainability goals (van Wynsberghe, 2021). AI can promote sustainability in the areas of climate forecast, EE, and health technology. Examples hereby include routing optimization to reduce fuel consumption or EE through different locations or cloud infrastructures (Kalaitzi & Tsolakis, 2022). AI within CS refers to the strategic orientation of a company in regards to AI and sustainability which also needs to be aligned with the business strategy to generate long-term value for the company and achieve competitive advantage for the future (Lloret, 2016; Tsolakis et al., 2022). TCs are integrating AI into their CS strategy to enhance sustainability practices, especially in the areas of carbon two emissions (CO2) reduction and resource efficiency through SCM optimization (Chen & Prentice, 2024; Kassem et al., 2021). Overall, AI can have a positive impact on CS in regards of improvement in environmental management, social responsibility, and corporate governance. Furthermore it can automatically promote corporate sustainable development of a company (Bahoo et al., 2023).

2.2.3. The Role of AI in achieving the SDGs Target within the Technology Industry

AI has a significant impact on achieving the SDGS target within the TI targets across all SDGs. That means that AI has an impact of 79% in total on all targets. Figure 4 shows the summary of positive and negative effects of AI on all SDGs. The percentages at the top reflect the proportion of targets which are influenced by AI. The percentages within the inner circle reflect the proportion of AI´s influence for each SDG (Vinuesa et al., 2020).

Figure 4

Summary of positive and negative impact of AI on the various SDGs



Note. Copied from Vinuesa et al., 2020, p.234

The TI leads the integration and usage of AI to enhance sustainability in the areas of cloud computing, data analytics and machine learning which contributes to the SDG targets of Industry, Innovation, and Infrastructure. By enabling AI, TCs can improve OE by optimizing manufacturing processes and advance greener technologies through cloud and AI-driven DCs which all contributes to SDG 12 targets of sustainable consumption and production and to the SDG 13 targets of Climate Action (Rolnick et al., 2023; Strubell et al., 2019). Furthermore, AI has a crucial role for enabling smart grids, autonomous vehicles and intelligent infrastructure systems which are all positively contributing to the SDG 11 targets of smart city development by optimizing urban EC, transportation networks and waste management (Rolnick et al., 2023). The TI´s role in promoting ethical AI use is another component which can have a positive impact on the SDG targets. TCs try to address ethical implication of AI by creating frameworks which ensure that AI systems are transparent, fair, and aligning with social responsibility standards. Therefore, it has a positive contribution to the SDG 10 targets of Reduced Inequalities and SDG 16 targets of Peace, Justice and Strong Institutions (Strubell et al., 2019; Vinuesa et al., 2020). Overall, the TI has a significant impact of leveraging AI for achieving the SDG targets and advance global sustainability efforts. This can only be achieved by having ethical AI practices which are aligning with social, economic and environmental goals and contribute positively to the SDGs (Vinuesa et al., 2020).

2.3. Challenges and Opportunities in AI Integration for Sustainability in the Technology Industry

2.3.1. Opportunities in AI Integration for Sustainability in the Technology Industry

AI can be divided into different segments to have a clear understanding of the opportunities through AI in terms of sustainability. AI can have opportunities for EE in the TI. It can optimize EC across the DC and corporate infrastructure so that the energy footprint of the companies can be significantly reduced. This can include improvements in cooling systems, server efficiency and smart-grid technologies which are used by TCs (Vinuesa et al., 2020). AI algorithms, for example (e.g.), reinforcement learning (RL) and decision support systems (DSS) can predict EC patterns and adjust different systems to improve EE (Kar et al., 2022). Furthermore, AI-powered tools and AI-driven big data analytics can be used by TCs to monitor and track CO2 emissions in real-time so that detailed reporting can be established. Based on these reports, the companies can derive CO2 emission reduction strategies which can be included within their CS. AI systems can also provide information into carbon offset opportunities which can also be used by companies to optimize their operations and SCM based on their CS goals (Kaack et al., 2022; Sipola et al., 2023). Additionally, AI can enhance circular economy in electronic waste (EW) management of TCs. The focus hereby relies on optimizing resource recycling, product lifecycle management and sustainable product design through AI, to ensure that resources are reused and EW is minimized (Cowls et al., 2021; Shayganmehr et al., 2021). In addition to that, AI can be used to make SCM more sustainable within the TI. It can enable real-time data analytics to integrate SCM operations. The goal hereby is to promote the efficient use of resources and reduce logistics-related CO2 emissions. This can lead to reduction in the environmental impact of global SCMs (Huang et al., 2023; Kaack et al., 2022). Another opportunity is that AI can be used for predictive maintenance systems in technology infrastructures such as cloud computing facilities and server farms in which it can lead to reduced equipment failure rates and cut down resource waste and increase OE (Huang et al., 2023). Furthermore, AI can improve environmental governance in the TI through real-time monitoring of environmental factors and decision-making systems. Companies can optimize their CS strategies and environmental compliance (Nishant et al., 2020).

2.3.2. Challenges in AI Integration for Sustainability in the Technology Industry

One of the biggest challenges of AI systems within the TI is the high EC. Especially the EC in large DCs, which hosts cloud services and different AI applications, is very high as they require high amounts on computing power which contributes to a growing carbon footprint within the companies (Strubell et al., 2019). Furthermore, the scale of data processing which is required for AI systems within the DCs can lead to increased EC and cooling needs, This has a direct impact on climate change (Widdicks et al., 2023). But training large AI models for natural language processing or deep learning algorithms has also a high EC and creates a conflict between AI´s potential to support CS within the TI and its environmental cost. Therefore, these environmental costs can outweigh the sustainability benefits of AI applications so that TC are required to be careful within the balance of innovations with their environmental goals which are aligned to CS (Cowls et al., 2021; Kaack et al., 2022). This negative effect can be seen e.g., in the training of the BLOOM language model which consumed 433 megawatt/hour and emitted 25 tons of CO2 emissions which is equivalent to power a US home for 41 years (Luccioni et al., 2022). Another challenge is the ethical concern in using AI. Bias in AI algorithms, data privacy concerns and transparency of AI systems can present challenges for the responsible integration of AI within CS in the TI. This can lead to challenges in AI systems where AI is embedded into decision-making processes (Falk & van Wynsberghe, 2024). Explainability of AI models is also a challenge especially with complex AI algorithms which can affect millions of users on a global scale. Hereby, AI systems need to be understandable and auditable to derive AI-driven sustainability initiatives within the TI (Widdicks et al., 2023). Besides that, AI mentions challenges in its ideological construct. Sustainable AI is embedded in a hegemonic socio-economic system where it is techno-solutionist driven. This means that the technology is seen as the solution to the problems which are created by the capitalist system itself and allows companies to present AI as both, the problem solver and enabler of sustainability, but at the same time focusing on reinforcing profit maximization, data extraction and AI advancements (Schütze, 2024).

3. Methodology

3.1. Research Approach

The research approach of the thesis follows a two-way approach. To derive the findings, the author will follow a qualitative research approach. First, there will be a case study analysis in which four articles in total will be compared with each other. The case study approach emphasizes to get an understanding of the context-specific issues within the companies (Mills et al., 2010). This case study approach will be bundled with expert interviews to gather more insights and ensure to have valif qualitative insights from experts in the field which will be analyzed with the Mayring (2019) approach (Mayring & Fenzl, 2019). The best approach for the thesis is the qualitative method approach as insights in strategic decision-making for CS and AI cannot be gathered by quantitative research. Furthermore, case study analysis combined with expert interviews allow for an in-depth exploration of both the literature-guided practices and real-world experiences in the field of AI and CS.

3.2. Research Sample and Data Collection

The research design of the qualitative case study analysis follows a multiple case study approach. Different case studies of both companies will be used to identify unique and common patterns of both companies (Baxter & Jack, 2015; Mills et al., 2010). The list of articles chosen for the qualitative case study analysis can be found in Table 1.

Table 1. Case Study Reports

Google	Microsoft	Sources
Accelerating Climate Action with AI	Accelerating Sustainability with AI: A Playbook	(Luers et al., 2023) (Maher et al., 2023)
How can we advance sustainability? Environmental Sustainability Report FY 2023	Environmental Report FY 2023	(Google, 2024) (Microsoft, 2024a)

Note. Own illustration

The research design of the expert interviews follows a structured design by using a questionnaire guide. This ensures that detailed professional knowledge is properly extracted. The questions allow open-ended answers for the interviewers so that experts can share in-depth perspectives and practical experiences (Mayring & Fenzl, 2019). The data collection follows the approach of analyzing these case studies within the following key categories which are based on the literature review: EE, Carbon Emission, EW Management, SCM, SDGs. There are 22 questions derived from the literature review in chapter 2 and the specific areas are explored within the case studies. The questionnaire with all 22 questions is attached to the annex under annex 2. Therefore, the questions for the expert interviews will be within these key categories: EE, Carbon Emission, EW Management, SCM. Furthermore, the key categories will be expanded by opportunities and challenges of AI within CS. This method will guarantee that the case study analysis and expert interviews can be compared and analyzed. As interviewees would like to hold on to their right of anonymity, the participants will be identified in terms of I1 and I2. The selection categories for choosing the interviewees were based on their specialized knowledge and direct involvement in CS and AI initiatives. Based on these categories, the 2 expert interviews were conducted which are shown in Table 2.

Table 2. Introduction of Expert Interviewees

ID	Company	Position	Interview Length
I1	Google	Business Manager Executive	32:29
I2	Microsoft	Business Manager Sales Excellence	30:14

Note. Own illustration

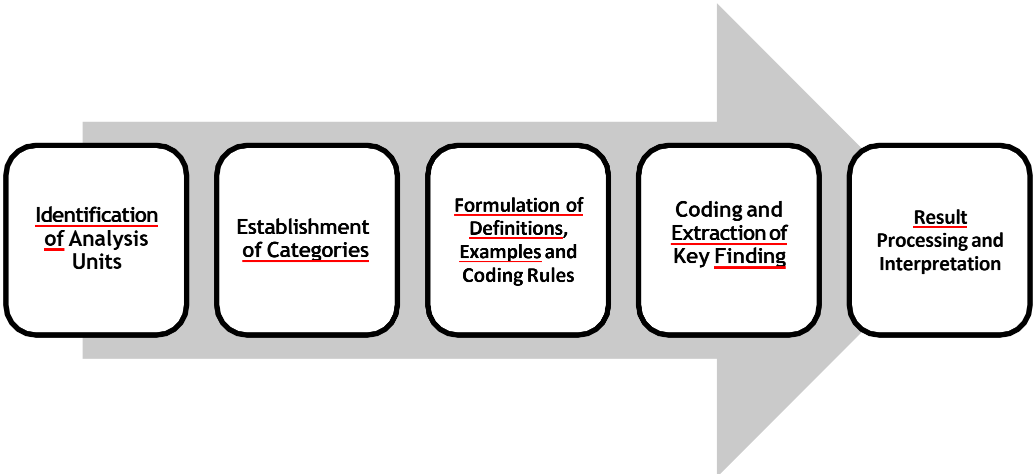
The interviews were conducted virtually through Microsoft Teams. All of the interviews will be analyzed by using the qualitative content analysis approach according to Mayring (2019). Furthermore, the coding of the interviews will follow a deductive approach which defines categories beforehand. These categories were mentioned above. The coding framework of the deductive approach is attached in annex 3.

3.3. Data Analysis

The data analysis is based on the qualitative content analysis approach by Mayring (2019) to categorize and interpret the interview transcripts and compare with the case study analysis to derive meaningful patterns and insights into the research questions (Mayring & Fenzl, 2019). The interview protocols are attached to the annex and can be found in annex 4 and 5. When determining the analysis technique, a structured content analysis according to Mayring (2019) was carried out. The aim of this technique is to reduce the material to the most important findings and to structure them and assign them to the predetermined categories. As the interviews followed a structured approach, the coding also needs to be done deductively according to Mayring (2019) (Mayring & Fenzl, 2019). Therefore, the author will categorize the findings of the interviews on the pre-defined key categories which are mentioned in section 4.2. of the thesis. Hereby, interview transcripts and the cases will be broken down into meaningful segments which allows efficient categorization into the pre-defined categories by analyzing the most used words and phrases throughout the cases and interviews. The coding guide in annex 3 will be used so that the categorization process can be presented in a comprehensible manner. The answers of the interview participants were limited to a minimum by selecting the most important statements that belong to a category. This step is called paraphrasing. The qualitative content analysis takes place on a content level and is therefore without the inclusion of affective factors that could influence the result (Mayring & Fenzl, 2019). Due to the limited scope of the thesis, Mayring´s (2019) quality criteria were not analyzed in the further course of the thesis. For this purpose, the qualitative content analysis could be tested for its reliability, in which it is analyzed whether the analysis leads to the same results in a second run (Mayring & Fenzl, 2019). The author also used a deductive approach for the case study analysis so that insights from the case studies were directly derived. The author will hereby analyze the case studies on the same key categories as for the expert interviews to analyze common patterns and differences (Mills et al., 2010). The process of the data analysis is shown in Figure 5.

Figure 5

The Data Analysis Process.



Note. Own illustration based on Mayring & Fenzl (2019) and Mills, Durepos et al. (2010)

After analyzing the case studies and expert interviews, analytic generalization will take place. Based on the results of the case study analysis and expert interviews, a holistic conclusion will be drawn on the role of AI in CS within the TI and best practices will be derived.

4. Overview of Microsoft and Google

4.1. The Industry Role of Microsoft versus Google

Microsoft is a technology-driven business with a focus on empowering people and enterprises to have greater success. It was founded in 1975 by Bill Gates and Paul Allen. The original focus was on software development for personal computers and changed over time towards intelligent cloud and intelligent edge technologies. Besides that, Microsoft develops and implements software services and devices to always keep people and business on track with cutting-edge technologies. Microsoft operates in the information technology sector, with key revenue streams from software licensing, cloud services, advertising, and gaming consoles. It also produces a wide range of video games within the gaming industry. Furthermore, Microsoft also engages in developing, manufacturing, and selling devices. These devices include different kinds of personal computers, tablets, gaming and entertainment consoles, smart devices as well as technological accessories. The company has currently a focus on cloud computing and AI. Therefore, Microsoft Azure is a central element of its strategy for driving business growth, competitiveness, and sustainability. Microsoft shows a strong emphasis in further developing AI as it has integrated Azure OpenAI in different products like Microsoft 365 Copilot which has the goal to improve productivity and business intelligence of companies (Microsoft, 2024a). The market dominance of Microsoft is due to its well-established platforms such as Windows and Office Suite which have the highest market share with 72% as of February 2024 despite the competition from Linux and MacOS (Sherif, A., 2024). Microsoft always tries to leverage its brand reputation, customer loyalty and technological capabilities to remain a significant player in the TI. Besides, it always invests in emerging technologies and partnerships (Microsoft, 2024a).

Google was founded in 1998 by Larry Page and Sergey Brin with the aim to organize the world´s information and make it for everyone accessible and useful. It was originally founded to create a search engine and diversified into other areas such as online advertising, productivity tools, video sharing and mobile technology. Currently, it also provides services in newer areas such as cloud computing, mobile applications and internet-connected services with the aim to maintain market leadership and remain competitive in the TI (Google, 2024). Google controls a substantial share of the global search engine market with 91.61% in October 2024, which makes it a leading platform for businesses. Its aim is to connect businesses with consumers (Global Stats, 2024). Furthermore, Google has entered and become a leader in new fields especially through its development of the android operating system which provides Google a dominant position within the mobile operating system market. Besides, Google´s cloud services also compete with similar offering from competitors within the TI such as Microsoft Azure and Amazon Web Services, which was established as part of their diversification strategy. A significant part of Google´s strategy within the TI is based firstly on their continuous innovation in existing services and enhancing the user experience on its platforms and secondly on their flexible and risk-taking approach towards new innovations such as AI and solar power technologies to reduce EC and support sustainability (Google, 2024).

4.2. Corporate Sustainability Strategy of Microsoft versus Google

Microsoft is following a long-term CS strategy with long-term goals until 2030. This includes that Microsoft wants to be carbon negative by 2030 by reducing operational emissions (Scope 1 & 2) and support carbon removal projects. In fiscal year 2023, Microsoft contracted 19.8 gigawatt of renewable energy assets in 21 counties and contracted 5 million metric tons of carbon removal towards carbon-negative target. Furthermore, Microsoft is committed to become water positive by replenishing more water than consumed within their DCs. The water usage in DCs acquired around 7,843,744 cubic meters water in fiscal year 2023. Microsoft focuses on DC efficiency through their power usage effectiveness program which reduces server power consumption and server density maximization. Besides that, they try to design their new DCs with support of AI to consume zero water for cooling and use alternative water sources, e.g., reclaimed, and recycled water. It is also committed to zero waste by reducing campus waste and improving hardware and packaging circularity. Through this initiative, Microsoft achieved a reuse and recycling rate of 89.4% for cloud hardware in the fiscal year 2023. Besides, the company tries to protect more land than used in operations by 2030. Therefore, it tries to improve biodiversity near campuses and DCs. Microsoft exceeded its goals by legally protecting 15.849 acres of land in the fiscal year 2023. The original target was set at 11.00 acres. The strategic approach of Microsoft´s CS strategy is holistic. It divides the sustainability work into 3 main areas: Microsoft Sustainability, Customer Sustainability and Global Sustainability. Microsoft Sustainability describes the accountability for their operational footprint across campuses, DCs and products. Customer Sustainability described the effort of providing solutions for clients to track, measure and optimize their sustainability, e.g., Microsoft Cloud for sustainability. Microsoft Cloud is developed to help customers connect data which is related to sustainability and gain insights for managing CO2 emissions across operations. Global Sustainability describes Microsoft´s effort of promoting to enable societal conditions for a net-zero economy through their policy, advocacy and supporting innovation. Microsoft also drives their strategic approach by technological contributions, especially in scaling impact with green technologies. The company tries to leverage AI and cloud technology to accelerate sustainability goals including using AI to analyze EE and support biodiversity. Examples and a deep dive will be made on the further research of the thesis. Microsoft´s CS goals are directly aligned with the SDG´s. The company is committed to 4 initiatives which are directly linked to the SDGs 4 to 17. The commitments and goals are shown in Figure 6 (Microsoft, 2024a, 2024b).

Figure 6

The SDG Alignment of Microsoft.

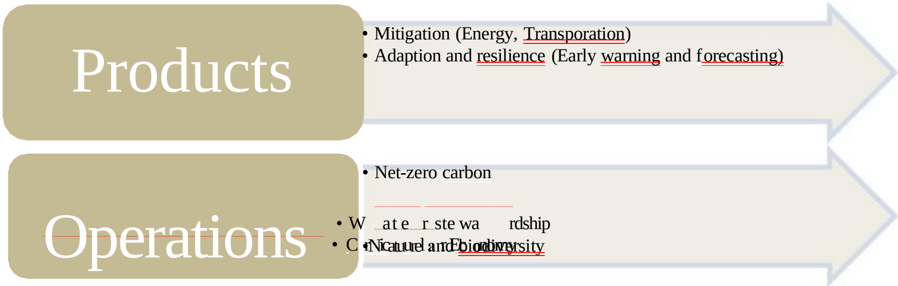
Note. Copied from Microsoft, 2024b, p.3

The company mentions 3 key SDG´s which are followed within their CS strategy. SDG 13 deals with climate action and Microsoft is committed to reduce their carbon footprint and become carbon negative by 2030 as they want to achieve more than 5 million metric tons of annual carbon removal starting in 2030. SDG 6 has the goal of clean water and sanitation worldwide. Microsoft is committing to SDG 6 by water-positive initiatives and replenishing the water within their DCs. SDG 15 is having the goal to protect life on land which is also one of the key SDGs of Microsoft as it wants to protect more land than used in operations and promotes diversity near its campuses and DCs (Microsoft, 2024b).

Google on the other hand also brings up a detailed CS strategy with different initiatives. The CS strategy of Google is divided into product and operations. Each of them has sub-categories which are crucial to set the targets and achieve successfully their sustainability initiatives. The sustainability strategy of Google is shown in Figure 7.

Figure 7

The Corporate Sustainability Strategy of Google.

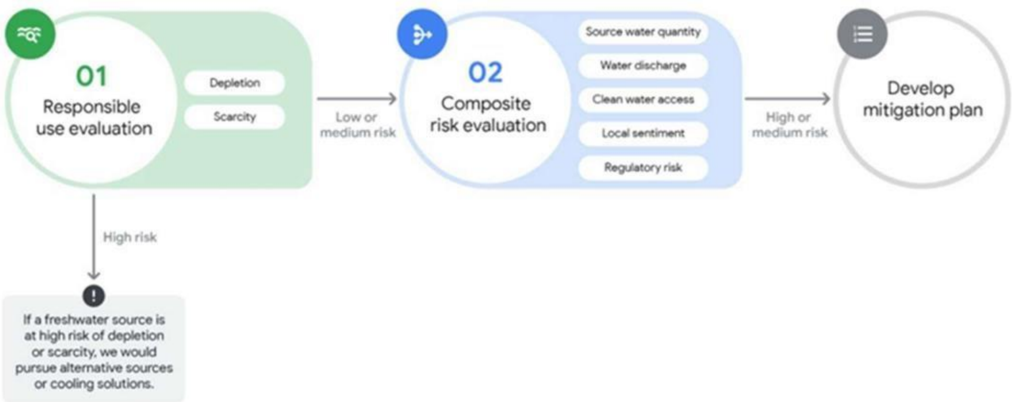


Note. Own illustration based on Google, 2024, p.5

The goal of Google is to achieve net zero emissions across all operations and value chain by 2030 and committed to running 24/7 carbon-free energy across all their grids where they operate. The company also implemented a new Google renewable energy addendum which describes and expects to achieve a 100% renewable energy match by 2030 from their suppliers. In fiscal year 2023, Google replenished 18% of its freshwater consumption through water projects which tripled the progress compared to fiscal year 2022. In 2022, Google replenished 271 million gallons of water and in 2023 the company replenished 1 billion gallons of water. They also increased their 38 water projects in 2022 to 74 water projects in 2023. Google created a water risk framework to assess the watershed health in DCs and support climate-conscious cooling solutions through carbon-free energy availability, watershed health and analyzing future needs. The two-tier framework of how Google assesses this water risk is shown in Figure 8 (Google, 2023, 2024).

Figure 8

The two-tier water risk framework approach.



Note. Copied from Google, 2023, p.5

In terms of energy and CO2 reduction, Google achieved 100% renewable energy matching for 7 consecutive years globally in 2023. Furthermore, the company signed a 4 gigawatt of clean energy generation capacity contract in 2023 for the following locations: United States of America, Belgium and Australia. It was the highest amount of gigawatt since the beginning of Google. 10 of Google´s grid regions achieved more than 90% of carbon-free energy and achieved an average of 64% carbon-free energy globally within their DCs and offices in 2023. Another key aspect of their CS strategy is the promotion of circular economy and EW management. The packages for new products which were launched in 2023 were at least 99% plastic-free. Furthermore, 8 DCs of a total of 28 achieved their sustainability initiative of zero waste to landfill which accounts for 29% overall. They also diverted 82% of food waste from landfill which was a slight decrease to 2022 (85%) as of limited composting infrastructures in certain regions. Google outlines 3 SDGs through their CS initiatives. As Google tries to create a net-zero carbon future, they are aligning their targets in regards of SDG 13 which deals with the topic of climate action. Besides, Google has a strong focus on water projects as SDG 6 is crucial for their further success which deals with the topic of clean water and sanitation. This is part of their CS strategy in terms of water stewardship. Google´s products are designed to encourage the users to make sustainable choices. Therefore, it also has a strong alignment and focuses on SDG 12 which deals with responsible consumption and production. Their sustainability-related information reaches over 1 billion users annually. This helps them to make informed decisions in regards to sustainability (Google, 2023, 2024).

4.3. Commitment to Sustainability and Artificial Intelligence of Microsoft versus Google

Microsoft shows a high commitment to integrate AI within their CS initiatives to achieve their goals. Hereby, they try to leverage AI to optimize energy usage in DCs, reduce carbon footprints and promote circular economy by reuse and recycling initiatives. Furthermore, the AI for Good lab of Microsoft develops solutions in terms of addressing global challenges which includes environmental protection, healthcare and crisis response (Microsoft, 2024a). It is also particularly interested in promoting digital and AI skill development to empower communities, enhance workforce inclusion and create economic opportunities by always aligning with responsible AI practices which embeds ethical standard to ensure transparency and safety (Microsoft, 2024b).

Google also outlines a high commitment to AI for enabling their CS strategy. First, they use AI for sustainability by having different projects on traffic optimization and flood forecasting towards climate action. AI driven data and Google Earth engine gives access to environmental data for researchers and policymakers so that they can support global sustainability. Second, Google uses AI for efficiency and partnerships. Google´s AI hardware and model optimization emphasizes EE and reduces CO2 emissions from AI training. Partnerships with Google give startups, who are sustainability-focused, the opportunity to use the knowledge of AI within their "Google for Startups Accelerator" program to promote innovative climate solutions (Google, 2024).

5. Findings

5.1. Findings Microsoft versus Google Case Study Analysis

The case study analysis shows that there are unique and common patterns between Microsoft and Google regarding their use of AI for CS. In the following, the author will present key findings in the categories which were chosen and explained in chapter 4.2. For EE, Microsoft has implemented green software principles to enhance EE and minimize CO2 emissions from software use (Microsoft, 2024a). Furthermore, Microsoft DCs have employed liquid cooling, which has reduced reliance on traditional cooling and enhanced EE, while also reducing peak power demands by approximately 7%. Furthermore, Azure Quantum, which was combined with AI accelerated identification of low-cost catalysts producing hydrogen and improved energy storage by reducing computation time by up to 50% (Luers et al., 2023). On the other hand, there is Google which also achieved success in regards of EE by using AI. Google´s DCs achieved an average power usage effectiveness of 1.10, which is more efficient than the TI average of 1.58. Therefore, Google could provide nearly four times more computing power compared to 5 years ago without additional EC (Google, 2024). Through AI use for fuel efficient routing in Google Maps, it has helped to reduce 2.4 million metric tons of CO2 emissions. This is comparable to taking off 650,000 cars off the road annually. Google also implemented AI for their grid-integration which helped them with demand response optimization to shift non-critical tasks off-peak times and improve thereby the grid reliability and ensure minimal EC at peak hours (Maher et al., 2023). In regards of carbon emission, Microsoft leverages AI to monitor and manage scope 1, 2 and 3 emissions through real-time tracking and collaboration with research institutions for carbon capture technology. Creating a climate report with scope 1, 2 and 3 emissions helps companies to set realistic, measurable and verifiable emission reduction targets and achieve them in a targeted manner (Microsoft, 2024a). Scope 1 emissions are direct greenhouse gas emissions of the company. Scope 2 emissions are the company´s indirect emissions resulting from the purchase of energy. Scope 3 emissions are also indirect emissions resulting from the company´s upstream and downstream value chain (Teske et al., 2022). Microsoft also collaborates with its partners to develop low-carbon materials for construction which contributes to an emission reduction for construction projects and accounts for 20% of the global CO2 emissions (Luers et al., 2023). However, Google also tries to reduce its carbon emissions by using AI. Google achieved a 63% reduction in emissions from electricity use in 2023 with power-purchasing-agreements. Besides, they also created an aviation task-force with other companies such as American Airlines. Hereby they utilize AI to reduce aviation-related CO2 emissions through research and testing (Maher et al., 2023). In regards of EW management, Microsoft runs circular centers to enhance recycling and reuse of cloud hardware. The company achieved a recycling rate of 89% for decommissioned servers and components in 2023 (Microsoft, 2024a). Furthermore, Microsoft uses AI and robotics in recycling to sort and recycle EW. The goal is that efficiency within the material recovery process can be improved and enhanced (Luers et al., 2023). On the other hand, Google also uses AI within their EW management. Google is committed to zero waste to landfill for its DCs. 29% of Google-owned DCs reached this target in 2023. Additionally, 34% of the plastic used in Google´s product hardware came from recycled materials in 2023 (Google, 2024). In regards of SCM, Microsoft has integrated AI to track their emissions across their supply chain (SC). The AI4Good lab of Microsoft enhances transparency in SC emissions as it tracks the footprint of each product in its lifecycle (Luers et al., 2023). Furthermore, the company uses net-negative embodied carbon alternatives in construction materials, e.g., concrete. This led to a reduction in CO2 emissions by 65% compared to conventional materials within their SC (Microsoft, 2024a). Google is also using AI within their SC. Through AI-optimized transportation routes, it helps to improve their SC´s environmental footprint as fuel consumption is being reduced. The company uses AI to help businesses and cities monitor their SC emissions and identify high-emission areas so that intervention can take place, if necessary. Google also focuses on reducing virgin material use in its product, so that their goals of 50% renewable or recycled content by 2025 can be reached (Google, 2024). In regards of SDGs, Microsoft and Google are both creating an impact for the SDGs through their AI-driven initiatives. Within the papers and interviews, it was clear that both companies have a focus to enhance EE in their DCs. The goal is to utilize AI to reduce power usage and minimize carbon emission. This aligns closely with SDG 7 (Affordable and Clean Energy) and SDG 13 (Climate Action) as the aim is to provide affordable and efficient energy solutions and minimize the impact on climate. Both companies demonstrate their efforts to these goals through their renewable energy integration and emission reduction strategies. Similarly, the EW management practices adopted by the 2 companies show their commitment to SDG 12 (Responsible Consumption and Production). The use of AI to enhance product lifecycle management, maximize hardware reuse and reduce EW shows a significant commitment towards reduction of waste and responsible consumption of both companies. Besides, both companies also have a significant role in promoting SDG 9 (Industry, Innovation, and Infrastructure) as both invest in AI to discover clean energy solutions and integrate AI in smart city initiatives. The goal is to improve urban EE and transport optimization. Another significant aspect which is important by considering their SDG alignment is the water management of both companies as it is a critical challenge for both companies due to their DC operations. Microsoft and Google have both made considerable strides in replenishment of water to counterbalance their usage. This aligns with SDG 6 (Clean Water and Sanitation). Both Microsoft and Google provide clear examples of AI´s positive contribution to global sustainability, for SDG´s 6, 9, 12 and 13. But at the same time the negative implication of AI within Figure 4 are also evident within Microsoft and Google. Both companies require high EC and CO2 emissions which highlights their need for careful management to ensure that AI innovations contribute net positive benefits to sustainability (Google, 2024; Microsoft, 2024b).

In regards of common patterns, it is evident that Microsoft and Google use AI-driven optimization. They want to improve DC efficiency and enhance grid-reliability. Both companies emphasize to reduce peak energy demands and adopt cutting-edge technologies. Besides, they use both AI for CO2 emission monitoring and implement AI-based tools to improve effectiveness of carbon capture and emission reduction. As helping to achieve the SDGs, they also partner with various stakeholders to develop innovative materials or reduce CO2 emissions from their operations. Furthermore, they invest both in circular economy principles and recycling efforts. They integrate AI to optimize EWM and minimize hardware disposal and EW. Apart from that, Microsoft, and Google use AI tools to track emissions and SC. This is achieved due to their transparency and improvement in sustainability across their operations. Both companies promote the use of sustainable materials within their SC to further reduce emissions.

There are also challenges which were described in the literature review and need to be considered in the future of AI and using AI for CS. These challenges are also visible within the case studies which were analyzed. Both Google and Microsoft operate large DCs that also host their AI work and require therefore significant energy for this operation. Google achieved a power usage effectiveness of 1.10. This is efficient compared to industry averages. But it still contributes to high EC due to the computational power required for AI models (Google, 2024). Microsoft, with a power usage effectiveness of 1.12 faces the same dilemma as Google (Microsoft, 2024a). Both companies also noted that the energy needs increase due to increased AI demands. Google mentioned within their environmental report of 2024 that due to the rise in AI workloads in their DCs, they had a 37% increase in emissions (Google, 2024). Microsoft had a slightly lower increase in emissions than Google with 29.1% compared to their 2020 baseline (Microsoft, 2024b). Both companies argue that the increase in their emissions happens due to infrastructure improvements for new technological advancements such as AI. Furthermore, both companies also experience high-water usage within their DCs. Water is essential for cooling purposes. They try to mitigate these risks by water replenishment initiatives. Microsoft has almost doubled their water usage from year 2020 to year 2023 as they used around 8 million cubic meters of water in 2023 compared to around 4 million cubic meters in 2020 (Microsoft, 2024a). Google has a slightly lower increase in their water usage compared between year 2020 and year 2023. In 2020 they used around 3.5 million cubic meters of water and in 2023 it was around 6 million cubic meters of water used (Google, 2023, 2024). The integration of AI into CS has also introduced challenges related to algorithmic bias and ethical considerations. Both companies are aware of these concerns and try to mitigate these risks. Microsoft has adopted responsible AI practices by collaborating with ethical AI councils. Therefore, Microsoft collaborate with governments and institutes to always monitor and track ethical concerns (Microsoft, 2024b). Google has also similarly emphasized transparency in AI usage and their risks of ethical concerns and bias. However, Google does not explain within their reports how to mitigate these risks and ensure responsible AI for CS initiatives. Both companies are aware of this challenge but need to derive a detailed roadmap on how to overcome this barrier of ethical concern and bias.

5.2. Findings Microsoft versus Google Interviews

In the following the expert interviews will be analyzed based on the Mayring methodology and the coding which was conducted after the interviews. The interview protocols related to both expert interviews can be found in annex 4 and 5 within the annex section. Both companies use AI to optimize EC in DCs to manage server workloads, optimize cooling systems and balance energy to improve EE. Google and Microsoft try to employ AI into EW management to extend equipment life and reduce unnecessary EC. Furthermore, both have the target of being carbon neutragl or negative by 2030 which shows that they also align AI-driven EE with their CS objectives. In terms of CO_2 emission reduction, both companies use AI to monitor CO_2 emissions, forecast CO_2 emission levels and optimize offset strategies. They also use AI-driven optimization for logistic purposes such as transportation and supplier engagement to minimize CO_2 output generated by SC and improve overall SC sustainability. AI is also used within the assessment of the suppliers´ environmental impact to optimize resource usage and provide visibility into the origins of the materials. Besides, Google and Microsoft use AI to extend the lifecycle of electronic products, predict failures and automate sorting processes to improve recycling and refurbishment. Within the interviews it was clear that both companies use AI to promote circularity in EW management to ensure the maximum of reuse which is possible for the components. Both companies acknowledge the high energy demand of training the AI models as one of the biggest challenges within their AI integration into CS so that they invest in EE AI algorithms and research. Microsoft and Google also urge the ethical and transparent use of AI as important which needs to be considered in the development and deployment of AI models for CS (I.1 and I.2).

Throughout both interviews, there were also differences between both companies visible especially within the approach of how to use AI for CS. Microsoft employes a more experimental infrastructure approach, e.g., the underwater DC project called Natick, to utilize AI and optimize physical environments (I.2). Google takes a more hardware-centric approach, e.g., with their development of their AI specific tensor processing units to make DC operations energy efficient (I.1). Furthermore, Microsoft has integrated sustainability into its cloud platform by introducing a sustainability calculator on Azure so that Microsoft can track and analyze their emissions and give their customer the opportunity to do the same (I.2). This highlights a strong platform-driven approach. On the other hand, Google uses in-house AI dashboards for real time monitoring of emissions which shows their preference on focusing on internal optimization rather than creating generalized tools for a broader industry use (I.1). Microsoft enhances automation and robotics, e.g., AI-driven robots to disassembly EW, to enhance the efficiency of waste processing (I.2). Google enhances more a computer vision and predictive analytics approach to classify and sort waste. Their aim is to have smart resource allocation and forecasting so that Google can maximize the value of electronic components throughout their lifecycle (I.1). Besides that, Microsoft integrates blockchain technology alongside AI ti provide transparency and verification in its SC (I.2). Google employes AI to optimize logistics and routing and focuses more to improve operational efficiencies and minimize environmental impact (I.1). Both companies also have a different focus on AI opportunities. Microsoft focuses more on climate risk modeling and renewable energy integration so that they can predict climate risks and create resilient solutions to enable proactive and systemic changes (I.2). Google focuses more on innovating customer-driven solutions, e.g., renewable energy forecasting and carbon capture, which highlights their focus on developing solutions beyond their operations in this matter to not only influence their own CS but also the broader sustainability landscape of the TI (I.1). Lastly, Microsoft mitigates AI´s energy impact through external partnerships, e.g., OpenAI and distributed energy loads, while Google prioritize more in-house optimizations of models and infrastructure to reduce energy demand by accelerating AI (I.1, I.2).

The differences between Microsoft and Google give them not only uniqueness but could also be potentially a competitive advantage for the future. Google´s development of tensor processing units provides an energy-efficient solution for AI workloads and for their CS. Google is also developing currently AI-based tools like flood hub and wildfire detection to address climate challenges globally as it is also a pillar of their CS which also adds a unique aspect to its sustainability approach. Microsoft on the other hand leverages its Azure platform with AI by providing scalable solutions for carbon tracking and renewable energy optimization which positions Microsoft as a leader in integrating AI with cloud services for CS. But also, the partnership of Microsoft with OpenAI gives them a competitive advantage as Microsoft profits from OpenAI which is a leader in AI and could benefit from its cutting-edge research to make their technology more efficient.

5.3. Summary of all Findings

Both companies, Microsoft, and Google leverage AI to enhance energy EE. AI is in both companies central for CO2 emission strategies which are part of their CS. Microsoft and Google are both committed to recycling and reuse, especially on circular economy principles. Furthermore, both companies are using AI to enhance the sustainability of their SCs through different technologies such as blockchain. In regards of SDGs, both companies align their CS with several SDGs. The most important ones for both companies are: SDG 6 (Clean Water and Sanitation), SDG 7 (Affordable and Clean Energy), SDG 9 (Industry, Innovation and Infrastructure), SDG 12 (Responsible Consumption and Production) and SDG 13 (Climate Action). Both companies face significant challenges in the implementation of AI for CS. These challenges are primarily related to high energy and water consumption of DCs and the ethical consideration of AI. Their approach of using AI for CS differs from each other and highlights their unique approaches in their AI implementation for CS. All the main findings of Microsoft´s and Google´s use of AI within their CS is shown in Table 3. This comparison table summarizes the key initiatives and approaches of both companies which were evident during the case study analysis and expert interviews.

Table 3. Summary of Findings of the use of AI in CS for Microsoft and Google

Category	**Microsoft**	**Google**	**Similarities/Differences**
Energy Efficiency	Green software, liquid cooling, Azure Quantum for energy efficiency	1.10 PUE, AI for Maps fuel efficiency, grid demand response	Both use AI for energy efficiency. Microsoft focuses on cooling and quantum, Google on PUE optimization.
Carbon Emissions	AI for scope 1, 2, 3 emissions, low-carbon materials, Azure calculator	AI for urban insights, aviation emissions, power purchasing	Both use AI to reduce emissions. Microsoft focuses on real-time monitoring, Google on urban insights and aviation.
Electronic Waste Management	Circular centers, AI robotics for sorting, 89% recycling rate	Zero waste to landfill, AI sorting, recycled materials in hardware	Both focus on recycling and reuse. Microsoft uses robotics, Google emphasizes zero waste and recycled materials.
Supply Chain	AI to track emissions, net-negative materials, blockchain transparency	AI for logistics optimization, 50% renewable/recycled content goal	Both track supply chain emissions. Microsoft uses blockchain, Google focuses on logistics optimization.
Sustainable Development Goals	Aligns with SDG 7, 9, 12, 13 via AI initiatives and circular economy	Similar alignment with SDGs 7, 9, 12, 13	Both contribute to SDGs through energy efficiency and waste management.
Challenges	High energy/water usage, responsible AI through ethical councils	Increased energy/water use, AI ethics transparency, TPU focus	Both face energy, water, and ethical challenges.
Unique Approaches	Underwater data centers, OpenAI partnership, Azure sustainability tools	TPU development, flood hub, wildfire detection tools	Microsoft focuses on experimental approaches and partnerships and Google on hardware innovation and global climate tools.

Note. Own illustration

6. Discussion and Conclusion

6.1. Discussion of Findings

AI can be seen as a driver of CS in the TI and enhance it if it is used properly. The literature suggested that AI has a great potential to enhance CS by optimizing resources, EE and decision-making processes (Chu et al., 2024). Microsoft and Google use AI to drive their CS initiatives. They want to enhance EE in DCs and reduce CO2 emissions which confirms the finding on AI´s role in sustainability management. Furthermore, the literature highlights AI´s potential to optimize EC (Huang et al., 2023). This is also confirmed through the findings of the case study analysis as Microsoft´s liquid cooling system and Google´s power usage effectiveness of 1.10 shows how AI supports the use of energy in an efficient way. AI is also used to promote circular economy. Both companies also use unique approaches to integrate AI into their CS in terms of experimental approach versus hardware innovation approach. Based om this, it can be concluded that the examples show how Google and Microsoft are using AI to enhance CS which was the first research question of the thesis.

But there are also some challenges in AI integration within CS as seen in literature and confirmed throughout the case study analysis and expert interviews. A major challenge of AI in CS is the high EC, especially in DC of TCs. The literature highlighted this challenge with the high EC of training large AI models (Strubell et al., 2019). Both companies have an increase in their emissions due to AI-driven workloads as described in section 5. Another major challenge within these DCs is the high-water consumption which is used to cool the AI infrastructure. Microsoft´s water usage doubled, and Google had a slightly lower increase in year 2023 as described in section 5. This highlights that there is the need to research other technological advancements for cooling systems. The literature review also pointed out that ethical concerns could arise related to AI, e.g., algorithmic bias and data privacy. Therefore there is the need for explainability (Russell & Norvig, 2021). Throughout the expert interviews it was clear that both companies acknowledge these concerns. Microsoft collaborates with ethical AI councils and Google highlighted the importance of transparency but did not mention specific mitigation measures either in the expert interview nor in the case studies. This clearly shows the gap in how AI´s ethical challenges are managed between the two companies. Ethical concern and bias are still a section which is unknown of its outcome and how much it could affect society so that there is further research and mitigation strategies needed to address these challenges. Besides, there are also trade-offs between technological advancements and CS goals. The findings reveal that both companies have difficulties with the environmental cost of AI which raises concerns about the balance between CS goals and AI advancements. This is a clear confirmation of the literature´s notion which describes the conflict between AI´s benefit and its energy demands (Kaack et al., 2022). Based on this, it can be concluded that the examples show the broader challenges of AI for CS which also includes Google and Microsoft and gives an answer to the second research question which deals with the challenges that lie ahead of using AI in CS.

6.2. Best Practices for the Technology Industry

Best practices are essential for TCs to implement successfully AI into their CS. Based on all the findings throughout the case study analysis and expert interviews, the author will derive general best practices based on Microsoft´s and Google´s success or failure towards AI implementation for their CS. This will also answer the last research question which is about the best practices for implementing AI into CS within the TI. TCs can implement AI into their green software development which could lead to less EC from these software applications. Another best practice is that TCs can try to utilize AI-driven cooling solutions like liquid cooling to reduce reliance on traditional methods and improve efficiency. This could also lead to a significant reduction in peak power demand. Furthermore, TCs could utilize quantum computing combined with AI to optimize their resource consumption and reduce computational times which would also lead to improvements in EE. Besides, there is also a great potential for implementing AI-powered carbon tracking systems that cover the scope 1, 2 and 3 emissions. The companies could track and manage their CO2 emissions across the value chain and help other companies by adopting systematic emission reduction strategies through their tracking system. Another opportunity to accelerate AI into CS could be to use AI for demand response optimization to enhance grid reliability and reduce peak-hour EC. Further, TCs could establish circular centers that incorporate AI and robotics for automated sorting and recycling of EW to improve efficiency and contribute to circular economy. There is another opportunity for TCs by setting the goal of zero waste in DCs and prioritizing recycled materials in hardware by using AI for the recycling process. There are also some opportunities regarding SCM and the use of AI for TC within their CS. TCs can use AI-based emission tracking to create transparency throughout their SC and track CO2 footprint of every component across the lifecycle. Besides, TCs could adopt AI-driven insights to source net-negative or low-CO2 materials to reduce SC emissions further. Another opportunity for TCs is to combine AI with blockchain technology to provide greater transparency in SCs and ensure the authenticity of materials used. TCs could also create AI platforms for CO2 tracking and emission monitoring which would allow customers to use these tools as well to make sustainable choices. Another opportunity for TCs could be to leverage AI and data analytics to track and implement water replenishment projects to compensate for high water usage in DCs. Additionally, TCs could then implement zero water cooling techniques by using AI for their DCs, especially in water-scarce regions. TCs also need to think of responsible AI and ethical use of AI. Therefore, TCs could establish AI councils to collaborate with external experts to oversee AI systems for bias, transparency and ethical concern and ensure alignment with sustainable goals. Besides, TCs can ensure AI systems are understandable and auditable by creating transparent documentation and guidelines which would lead to responsible use and minimize unintended consequences. Lastly, TCs can collaborate with various sectors to develop AI solutions that tackle global sustainability challenges. These collaborations could multiply their sustainability impact beyond company boundaries and drive their CS further.

6.2. Limitation and Further Research

There are also some limitations which were faced during the development of the thesis and further research would be necessary to get a deep knowledge of the topic. Due to the timing of the thesis being close to the end of the fiscal year, it was difficult to find availability of industry experts for interviews which potentially impact the depth of qualitative data, especially primary data from the interviews. The data was primarily collected from a restricted number of reports of Microsoft and Google and industry-specific interviews. This limited scope may not capture all diverse perspectives, especially outside of Western and English-speaking countries. Another limitation is the potential of bias in the case selection. The case studies were selected based on available data from the company websites. This could lead to bias as it possibly highlights positive AI use cases over more negative or neutral instances. Furthermore, AI applications have not been standardized across industries which makes it challenging to compare the results directly. The rapid evolution of AI technology means that some findings may already be partially outdated in terms of AI and CS. This also leads to the next limitation which is the unanticipated consequences which could arise. Despite all efforts to identify unintended effects of AI for CS in the TI, the unpredictability of AI means that some consequences would be only visible over time and therefore beyond the research period of this thesis. Lastly, most data and all expert opinions were gathered from Europe and North America which may lead to geographical bias. Perspectives from other countries and regions, especially developing countries, were not analyzed in depth. Therefore, there is further research needed to overcome some of the limitations. Future studies could explore AI and CS in additional sectors like healthcare, construction, and education to really understand more diverse applications and impacts and derive some similarities and differences between industries. A longer-term study could provide insights into the consequences of AI over time, specifically unintended consequences that might require years to fully manifest. Regional comparison can also be a helpful tool to understand the use of AI within CS better. Comparative studies which focus on different regions by also including areas like Africa and Southeast Asia could provide more holistic perspectives on AI´s impact on CS and similarities and differences could be analyzed between different regions. As a next step it would be helpful to add a quantitative dimension to the current qualitative insights gathered within the thesis, to enhance the robustness of findings, specifically the unintended environmental and social consequences of AI development and deployment. Furthermore, there could be an addition to this research by investigating the role of regulatory frameworks and how effective they are in terms of mitigating negative impacts and unintended consequences of AI. Lastly, the research can be used to further derive AI in CS and crisis management. Given the role of AI during the COVID-19 pandemic, further research could assess how AI can be leveraged to manage future crises by also minimizing the unintended consequences which could arise.

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Annex

Annex 1: Sustainable Development Goals

Annex 2: Questionnaire Interview

Introduction:

1. What is your name?
2. Which position/role do you have within the company?

Energy Efficiency:

3. How does your company use AI to improve energy efficiency in its operations?
    a. Follow-up: Can you provide specific examples, such as optimizing data centers or office spaces?
4. What kind of AI models or algorithms have proven most effective in reducing energy consumption?
5. How do AI-driven energy efficiency measures align with your company's overall sustainability goals?
6. Are there any initiatives for minimizing the energy requirements of AI itself while still achieving efficiency gains?

Carbon Emission:

7. In what ways is AI being used to monitor or reduce carbon emissions within the company?
    b. Follow-up: Are there any specific metrics or tools used to track these reductions?
8. Can you explain how AI is helping to achieve carbon neutrality or offset goals set for your company?
9. What is the role of AI in assessing and optimizing carbon footprints for both internal processes and external supply chains?

Electronic Waste Management:

10. How is AI being integrated into your company's electronic waste management strategies?
    c. Follow-up: Are there specific AI applications aimed at optimizing recycling processes or reducing e-waste?
11. What role does AI play in managing the lifecycle of electronic products, including refurbishing, recycling, or disposal?

Supply Chain:

12. How does your company use AI to improve sustainability in the supply chain?
    d. Follow-up: Can you provide examples of how AI has helped optimize resource usage or reduce waste?
13. In what ways does AI help to enhance supply chain transparency?
14. Are there AI-driven initiatives to monitor suppliers' environmental and social impacts?

Opportunities:

15. What do you believe are the greatest opportunities for leveraging AI to enhance sustainability at your company?
    e. Follow-up: Are there new initiatives or technologies that you are particularly optimistic about?
16. How do you see AI driving competitive advantages in terms of sustainability for the technology industry?

Challenges:

17. What are the main challenges your company faces in using AI to achieve sustainability goals?
    f. Follow-up: Do these challenges stem more from technological, organizational, or regulatory factors?
18. In what ways do AI's energy requirements conflict with sustainability efforts, particularly in the context of reducing carbon footprints?
19. What strategies are employed to mitigate ethical concerns, such as transparency or fairness, related to the use of AI in sustainability?

Closing:

20. Do you have any additional insights regarding AI and sustainability that have not yet been covered?
21. Is there anything you would like to add to further clarify or elaborate on any points discussed today?
22. Thank you and remind them responses will remain anonymous and will provide summary of findings once research is completed.

Annex 3: Coding Guideline for Case Study Analysis and Expert Interview

1. Energy Efficiency	All statements aimed for energy efficiency through the use of AI are included in this category.	Microsoft has also integrated AI into its Project "Natick" (underwater data centers), where AI manages cooling and energy consumption.. (I2)
2. Carbon Emission	All statements aimed for reducing carbon emission through the use of AI are included in this category.	Google has internal tools and dashboards that provide real-time insights into our carbon footprint. These tools leverage AI to analyze data from various sources and provide actionable intelligence for emission reduction.. (I1)
3. Electronic Waste Management	All statements aimed for sustainable electronic waste management through the use of AI are included in this category.	Microsoft's Circular Centers, where AI is employed to analyze and refurbish returned devices, to ensure that more components are reused instead of being discarded. (I2)
4. Supply Chain	All statements aimed for efficient sustainable supply chains through the use of AI are included in this category.	We also use AI to forecast demand and optimize inventory management, minimizing waste from overstocking or obsolescence. (I1)
5. Opportunities	All statements aimed for opportunities through the use of AI for sustainability are included in this category.	By leveraging Azure and AI capabilities, Microsoft aims to assist industries in predicting climate-related risks and implementing proactive sustainability measures. (I2)
6. Challenges	All statements aimed for challenges through the use of AI for sustainability are included in this category.	The energy consumption of AI, especially for training large models, can be significant. (I1)

Annex 4: Interview Protocol I1

Qualitative Analyzation (Mayring)			
1. Definition of the Material	The basis of the qualitative content analysis is an interview with a specialist in the field of AI and sustainability at Google, who can provide an overview of the use of AI in the area of corporate sustainability.		
3. Formal Characteristics of the Material	The interview was recorded as an audio file and then transcribed.		
4. Direction of the Analysis	The analysis of the interview will focus on the content of the material, which will be analyzed in more detail later on. No additional analysis of the author will be carried out.		
5. Theoretical Differentiation of the Question	The question of the analysis is linked to the definitions of AI and sustainability explained in the theoretical foundation section. The central question is how and what impact AI has on sustainability initiatives within the technology industry in order to derive best practices.		
6. Determination of the Analysis Technique and Categorization	Due to the three research questions of the thesis, a structuring analysis was chosen so that the category system is formed deductively. This means that a category system is created in advance based on the theoretical background. After the interview, the findings from the interviews are assigned to the individual categories and paraphrased.		

	Afterwards, the paraphrases are generalized and reduced. The defined categories are: 1. Energy Efficiency 2. Carbon Emission 3.Electronic Waste Management 4.Supply Chain 5. Opportunities 6. Challenges		
7. Definition der Analyseeinheiten	Each expert interview conducted counts as one evaluation unit. In the context unit, whole sentences of the interviewer may fall under a category so that the context is guaranteed. The coding unit represents the smallest material component that may be assigned to a category. In this case, a single word may also be assigned to a category if this is possible and the context is not falsified.		
	Paraphrasing	**Generali-zation**	**Reduc-tion**
1) Energy Efficiency	- At Google Cloud, we leverage AI in several ways to boost energy efficiency. Primarily, we focus on optimizing our data centers, which are massive consumers of energy. AI helps us in areas like cooling optimization, server utilization, and workload distribution. - For example, we use AI to predict and manage the cooling needs of our data centers in real-time. This ensures we're only using the energy absolutely necessary to keep things running	AI plays a pivotal role in enhancing energy efficiency by optimizing operations, predicting energy needs, and reducing unnecessary energy consumption, especially in energy-	AI-driven energy optimi-zation Predic-tive energy demand manage-ment Reduc-tion in

	smoothly. Similarly, AI helps us maximize how we use our servers, avoiding idle resources and consolidating workloads for peak efficiency. - Machine learning models, particularly those focused on time-series analysis and prediction, have been incredibly effective. These models allow us to forecast energy demand, identify anomalies, and optimize resource allocation dynamically. - Energy efficiency is a core pillar of Google's overall sustainability strategy. Our goal is to operate on carbon-free energy 24/7 by 2030, and AI plays a crucial role in achieving that. By minimizing our energy consumption, we directly reduce our carbon footprint and contribute to a more sustainable future.	intensive facilities like data centers. Machine learning algorithms enable dynamic resource allocation and anomaly detection.	energy consump -tion
2) Carbon Emission	- AI is a powerful tool for monitoring and reducing our carbon emissions. We use it to track emissions across our operations, identify hotspots, and simulate the impact of different reduction strategies. - We have internal tools and dashboards that provide real-time insights into our carbon footprint. These tools leverage AI to analyze data from various sources and provide actionable intelligence for emission reduction. - AI helps us model and optimize pathways to carbon neutrality. By simulating different scenarios and	AI contributes significantly to monitoring and reducing carbon emissions by providing real-time analytics, identifying emission hotspots, and modeling reduction scenarios. AI-driven tools enable data-driven	AI for emission monito-ring Carbon reduc-tion mode-ling Data-driven carbon neutra-lity

	predicting the impact of various initiatives, we can make data-driven decisions to achieve our carbon offset goals.	decisions and strategies aimed at achieving carbon neutrality.	strate-gies
3) Electronic Waste Management	- AI is becoming increasingly important in our e-waste management strategies. We're exploring its use in areas like automated sorting of e-waste, optimizing recycling processes, and predicting the lifespan of electronic components. - For instance, we're looking at how computer vision can help identify different types of e-waste, enabling more efficient sorting and processing for recycling. We're also using AI to predict when components might fail, allowing us to proactively refurbish or recycle them before they become waste. - AI helps us make more informed decisions about the lifecycle of our electronic products. By predicting failure rates, optimizing refurbishment processes, and identifying the most sustainable end-of-life options, we can minimize waste and maximize resource recovery.	AI is instrumental in managing electronic waste through the automation of sorting, recycling, and predicting the lifespan of electronic components.	Auto-mated e-waste sorting Recyc-ling optimi-zation Predic-tive lifespan analysis

4) Supply Chain	- We use AI to enhance the sustainability of our supply chain in several ways, including optimizing logistics, reducing waste, and sourcing sustainable materials. - For example, AI helps us optimize delivery routes (Google Maps), reducing fuel consumption and emissions. We also use AI to forecast demand and optimize inventory management, minimizing waste from overstocking or obsolescence. - AI helps us gain greater visibility into our supply chain, enabling us to track the origin of materials, monitor transportation (projects like Chorus), and assess the environmental impact of each stage.	AI enhances sustaina-bility within supply chains by optimizing logistics, improving inventory management, reducing overproduction, and sourcing sustainable materials.	Logis-tics and inven-tory optimi-zation Environ-mental impact reduc-tion Supply chain visibility
5) Opportunities	- I believe the greatest opportunities lie in using AI to further optimize our operations, reduce our environmental footprint, and enable our customers to do the same. We're particularly excited about advancements in areas like carbon capture technology, renewable energy forecasting, and sustainable product design. - We're investing in AI research and development to accelerate progress in these areas and unlock new possibilities for sustainability. - AI can be a key differentiator for companies committed to sustainability. By leveraging AI to	AI offers immense opportunities for advancing sustaina-bility by optimizing operational efficiency, minimizing environmental footprints, and supporting customers in adopting sustainable practices. AI can be a key enabler of competitive	Operat-ional efficien-cy improve-ments Renew-able energy fore-casting Sustai-nable product innova-tion

	optimize resource usage, reduce emissions, and create more sustainable products and services, companies can gain a competitive edge while contributing to a healthier planet.	advantage for environmentally-conscious organi-zations.	
6) Challenges	- One of the main challenges is ensuring that AI itself is developed and deployed in a sustainable way. The energy consumption of AI, especially for training large models, can be significant. We also face challenges in data availability, algorithmic bias, and ensuring transparency in our AI systems. - The energy demands of AI, particularly for large-scale training and inference, can be a concern. We're actively working to minimize this impact through research into more energy-efficient algorithms, hardware acceleration, and responsible AI practices. - Ethical considerations are paramount in our AI development and deployment. We're committed to transparency, fairness, and accountability in our AI systems. We have internal review boards and ethics guidelines to ensure that our AI solutions are used responsibly and ethically in the pursuit of sustainability.	The sustaina-bility of AI itself is a critical challenge due to the high energy demands of training and deploying large-scale models. Issues like data accessibility, algorithmic bias, and ethical concerns also need to be addressed.	High energy demands of AI Ethical conside-rations in AI develop-ment Respon-sible and transpa-rent AI practices

10. Interpretation of Results	The interpretation of the results is presented in chapter 5 of the thesis.	

Annex 5: Interview Protocol I2

Qualitative Analyzation (Mayring)			
1. Definition of the Material	The basis of the qualitative content analysis is an interview with a specialist in the field of AI and sustainability at Microsoft, who can provide an overview of the use of AI in the area of corporate sustainability.		
3. Formal Characteristics of the Material	The interview was recorded as an audio file and then transcribed.		
4. Direction of the Analysis	The analysis of the interview will focus on the content of the material, which will be analyzed in more detail later on. No additional analysis of the author will be carried out.		
5. Theoretical Differentiation of the Question	The question of the analysis is linked to the definitions of AI and sustainability explained in the theoretical foundation section. The central question is how and what impact AI has on sustainability initiatives within the technology industry in order to derive best practices.		
6. Determination of the Analysis Technique and Categorization	Due to the three research questions of the thesis, a structuring analysis was chosen so that the category system is formed deductively. This means that a category system is created in advance based on the theoretical background. After the interview, the findings from the interviews are assigned to the individual categories and paraphrased. Afterwards, the		

	paraphrases are generalized and reduced. The defined categories are: 1. Energy Efficiency 2. Carbon Emission 3. Electronic Waste Management 4. Supply Chain 5. Opportunities 6. Challenges		
7. Definition der Analyseeinheiten	Each expert interview conducted counts as one evaluation unit. In the context unit, whole sentences of the interviewer may fall under a category so that the context is guaranteed. The coding unit represents the smallest material component that may be assigned to a category. In this case, a single word may also be assigned to a category if this is possible, and the context is not falsified.		
	Paraphrasing	**General-ization**	**Reduc-tion**
1) Energy Efficiency	- Microsoft uses AI in various ways to improve energy efficiency. AI is deployed to monitor and optimize energy consumption across Microsoft's data centers and office spaces. In data centers, AI algorithms manage server workloads to reduce energy waste, balance power use, and ensure that operations are as energy-efficient as possible. - Microsoft has also integrated AI into its "Project Natick" (underwater data centers), where AI manages cooling and energy	AI improves data centers and office spaces, reduces energy waste through real-time monitoring, and cooling system optimizatio.	AI-driven energy optimi-zation Cooling manage-ment and work-load balan-cing

	consumption. - Microsoft's data centers use AI to optimize cooling systems, reducing the energy needed to keep servers at optimal temperatures. The AI system dynamically adjusts cooling parameters based on real-time temperature and workload data, minimizing energy consumption. - Azure's AI algorithms also work on workload distribution, allowing virtual machines and workloads to be moved around in data centers to balance energy demands effectively. - AI-driven energy efficiency aligns with Microsoft's sustainability commitment to become carbon negative by 2030.		
2) Carbon Emission	- AI is used to monitor carbon emissions from Microsoft's facilities and supply chain. - Microsoft's "Sustainability Calculator," built on Azure, is an AI-driven tool that helps track carbon emissions across different operations. The AI capabilities help in data analyzation, forecasting emissions, and adjustments recommendations to reduce the carbon footprint. - Microsoft uses AI to purchase renewable energy more efficiently and strategically. - We also utilize AI to analyze carbon offset projects to ensure they meet the expected environmental benefits, helping Microsoft achieve its carbon-negative goals by 2030.	AI tracks and analyzes carbon emissions, supports the sustainabi-lity calculator to forecast emissions, and recommend s reductions. AI optimizes renewable energy purchases and	AI for emission tracking and analysis Renew-able energy optimi-zation and offset verify-cation

	- AI algorithms help identify emission hotspots and optimize logistics, transportation, and supplier engagement to reduce carbon output.	evaluates carbon offset projects.	
3) Electronic Waste Management	- Microsoft uses AI to enhance e-waste recycling efficiency and reduce electronic waste. AI-driven robots are used to disassemble outdated devices and sort materials for recycling. - An example is Microsoft's Circular Centers, where AI is employed to analyze and refurbish returned devices, ensuring that more components are reused instead of being discarded. - AI tracks product usage data and predicts when equipment needs refurbishment or replacement, which helps extend the lifecycle of devices.	AI is instrumental in managing electronic waste through the automation of sorting, recycling, and predicting the lifespan of electronic components.	AI for recycling and device dis-assembly Device refur-bishment and lifecycle predic-tion Circular Centers for compo-nent reuse

4) Supply Chain	- AI is used to track the environmental impact of suppliers and optimize resource usage. AI helps in forecasting supply chain needs more accurately, reducing overproduction and minimizing waste. - AI has helped Microsoft optimize inventory levels and logistics and therefore reduced transportation emissions and waste across our supply chain. - AI-powered tools are used to track raw materials and their sourcing practices. Microsoft's blockchain-based systems, integrated with AI, help verify that suppliers meet environmental and social standards.	AI improves e-waste recycling efficiency through disassembly robots and facilitates reuse by refurbishing devices.	AI for supply chain environ-mental impact Inven-tory and logistics optimi-zation Supplier verify-cation via AI-block-chain inte-gration
5) Opportunities	- One of the greatest opportunities for us lies in using AI for climate modeling and risk assessment. By leveraging Azure and AI capabilities, Microsoft aims to assist industries in predict climate-related risks and implement proactive sustainability measures. - AI provides a competitive edge by enabling companies to optimize operations, reduce energy costs and innovate in carbon reduction techniques.	AI supports climate modeling, risk assessment, and sustaina-bility measures. AI provides operational advantages, including energy optimizatio n, cost reduction, and carbon	AI for climate risk mode-ling and sustaina-bility Ope-rational and carbon reduc-tion benefits

		reduction innovations.	
6) Challenges	- The main challenges include the high energy demands of training AI models, managing the complexity of data from diverse operations and aligning AI-driven insights with practical sustainability measures. - These challenges are: technological (energy consumption of AI models), organizational (data integration across departments), and regulatory (ensuring compliance across different regions) factors.	High energy demands for AI training, data complexity, and aligning AI-driven insights with practical sustaina-bility measures.	Energy consum-ption of AI models Data inte-gration and regu-latory com-pliance issues Ethical usage in AI develop ment
10. Interpretation of the Results	The interpretation of the results is presented in chapter 5 of the thesis.		