"Increasing sustainability in information technology – A systematic literature review"

Seminar paper

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Abstract

The increasing requirements by stakeholders and motivations of firms to adopt sustainable practices has led environmental sustainability practices and information technology (IT) to merge. Emerging from this development, the concept of Green IT describes the reduction of environmental impact in IT by implementing sustainable standards and practices in the whole IT product life cycle containing sourcing, operations and disposal. The existing research on this concept is extensively, but either outdated or show a narrow focus on a certain aspect of Green IT. Therefore, this paper provides an recent overview of the concept and develops a holistic framework taking antecedents and consequences for the implementation of sustainability in IT into account. Future research can use the framework as foundation to further examine individual and combinations of research streams. Practical value is served by providing managers a guideline of essential categories and topics for implementing sustainability in IT.

Keywords: "Sustainability in information technology", "Green IT", "Implementation", "Literature review"

Table of Contents

1 Introduction

The increasing visibility of climate change has led stakeholders such as customers, employees, investors (Fink, 2022) and governments (European Commission, 2019) to require firms to become more conscious about their environmental impact and act more sustainably. Consequently, sustainability has become a priority on strategic agendas of firms for the next years and receives substantial attention from CEOs (Gartner, 2022). Sustainability describes responsible conservation, deployment and reusage of resources, aiming to optimize social, environmental, and economic dimensions concurrently (Malhotra, Ross and Watson, 2013). Information technology (IT) has an ambiguous role regarding sustainability. Either IT is referenced to be a main cause for environmental issues due to its resource demand (Berkhout and Hertin, 2004), or IT is viewed as an enabler of sustainability measures (Faucheux and Nicolaï, 2011).

The concept of sustainability in IT is often referred to as "Green information technology" (Green IT) (Murugesan, 2008). Rather seldom the term "Green for IT" is used (Loos *et al.*, 2011). In the following work the terms "sustainability in IT" and "Green IT" are used interchangeably. Also, the social dimension of sustainability is not considered, rather the focus is on the environmental and economical dimensions. Green IT refers to practices of designing, manufacturing, using, and disposing of IT efficiently and effectively with minimal impact on the environment (Murugesan, 2008). It deals with the environmental issues of IT that arise from the high resources demand (Jenkin, Webster and McShane, 2011). A related research field emerged from Green IT which considers "Green information systems" (Green IS), sometimes "IT for green" (Faucheux and Nicolaï, 2011), which refers to information systems that contribute to sustainable business processes (Watson *et al.*, 2007). It deals with the role of information systems enabling sustainable business processes (Loeser, 2013). Due to stronger focus on practical relevance, the following work focuses solely on the aspect Green IT and therefore increasing sustainability in IT in context of organizations.

The changing stakeholder demands make sustainability in IT relevant for the managerial practice (Butler, 2011), extending beyond the IT department and becoming integral to every aspect of business (Watson, Boudreau and Chen, 2010). Thus, CIOs are required to adapt sustainable business practices in their IT departments. This work aims to establish a guideline for managers implementing Green IT measures in their organization.

Despite the existence of recent literature reviews to Green IT, they often focus only on specific aspects of the research field (Erek *et al.*, 2011). Several existing reviews are done as part of empirical studies and were therefore conducted with a narrowed scope (e.g. Asadi *et al.*, 2021). Also, they are lacking coverage of most recent studies, like by Saldanha *et al.* (2022).

Emerging from this state of research this literature review seeks to contribute to the existing research by developing a holistic view derived from the most relevant and recent academic literature.

The literature review addresses the following research questions: What are internal and external factors that drive the implementation of Green IT? How do organizations implement Green IT? What are consequences of Green IT implementation in terms of financial and non-financial outcomes?

The structure of this literature review consists of four chapters. First, the methodological approach is described. Second, the findings and identified categories and topics are presented. Third, the developed categories and topics are discussed, implications for managerial practice are derived as well as implications for future research and limitations are stated. Finally, the key findings are concluded and put into a bigger context.

2 Method

This literature review is following three steps in total to derive answers for the research questions. It includes a structured literature search process, a selection process after defined criteria and a qualitative analysis of the content. The goal was to identify the most relevant and highest quality literature for the proposed research field.

Literature search process: This work is following the proposed process by Webster and Watson (2002) for systematically searching literature. A variety of keywords were searched to ensure that a broad range of academic papers are considered in the selection process. The used keywords consist of "Sustainability in Information Technology", "Sustainability in Information Systems", "Green Information Technology", "Green Information Systems", "Green IT" and "Green ICT". Also, variants of the keywords were considered by varying the used search strings in the databases. The database used for the initial keyword search was EBSCO Business Source Complete in combination with the direct filter "peer-reviewed". In total 271 initial articles were derived by this procedure (Figure 1).

In addition, backwards & forwards search was conducted of the identified literature that went through the selection process successfully, as recommended by Webster and Watson (2002). In total 28 relevant additional literature was found by doing backwards & forwards research. The literature identified with that research methods was chosen solely by their relevance and no ranking quality criteria was applied to them.

Selection process: The initial literature was filtered by criteria to ensure that only suitable papers would be considered in the qualitative analysis. First, the found duplicate literature was removed, second literature without VHB-Ranking JQ3 or below B were removed from the prospect list. In total 71 literature remained after applying these filter criteria. After this filtering the content of the remaining literature was examined. Initially the title and keywords were scanned if they fit to the targeted research topic. Afterwards the abstracts of the articles were read and checked if they fit to the research domain. After this procedure 45 final literature was identified in total and used for the qualitative analysis of the literature review. The cut-off date for the search process and selection process was June 14, 2023.

Qualitative analysis: After the selection process was done the identified literature was analysed regarding used concepts and topics following the grounded theory analysis method (Wolfswinkel, Furtmueller and Wilderom, 2013). The iterative process was conducted in three steps. First, open coding was done by extracting abstract codes from the literature. Second, axial coding enabled to group related abstract codes into groups. Third, during the selective coding process the categories were refined and mapped to high-level main categories.

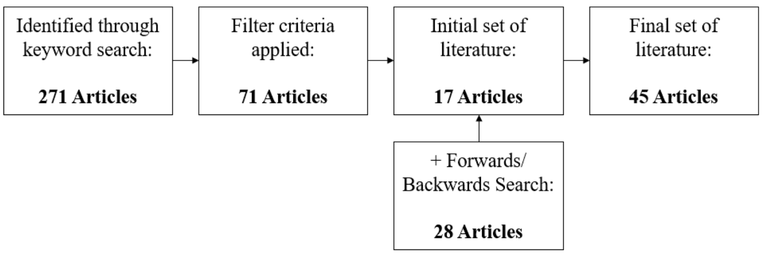

Figure 1. Research Process and final literature.

3 Results

The concept of Green IT is clearly defined within the research field. The identified literature regarding the topic sustainability in IT begins in 2004 with the publication of Berkhout & Hertin (2004). The concept Green IT started emerging in 2009 and reached its peak in 2011 in terms of number of paper publications (Figure 2). The topic has been receiving attention from government since 2008, which helped fostering the research field (Loos *et al.*, 2011). Furthermore, the concept is well researched conceptually as well as empirically (Figure 3).

During the search, a total of 12 existing literature reviews were identified. The most recent publication stems from 2021 but was specified to the research field "Green IT Adoption" (Asadi *et al.*, 2021). The most recent literature review dealing with the research field of Green IT in general was published in 2016 as a part of a research for an empirical study (Hu *et al.*, 2016). For the concept, many of these literature reviews exist as part of a grander, often empirical, study. A total of seven empirical studies that conducted a literature review as part of their research were included in this literature review (Erek *et al.*, 2011; Loeser, 2013; Molla, 2013; Deng and Ji, 2015; Hu *et al.*, 2016; Cooper and Molla, 2017; Asadi *et al.*, 2021). The amount of papers dealing solely with the aim of reviewing existing literature is lower compared to that. In total five literature reviews were found (Garg *et al.*, 2011; Jenkin, McShane and Webster, 2011; Ortwerth and Teuteberg, 2012; Malhotra, Ross and Watson, 2013; Tushi, Darshana Sedera and Recker, 2014) with latest publication beeing from Tushi, Darshana Sedera and Recker (2014).

In total 45 articles were used in the final analysis process. The following concept matrix visualizes the overview of the findings derived from these articles (Table 1). The concept matrix contains the three main categories following the proposed research questions: Antecedents, implementation & consequences. These main-categories are further split into the sub-categories internal or external factors as antecedents, sourcing, operations & disposal for implementation and financial or non-financial consequences. The next sections discuss these main categories alongside with the respective sub-categories in more detail.

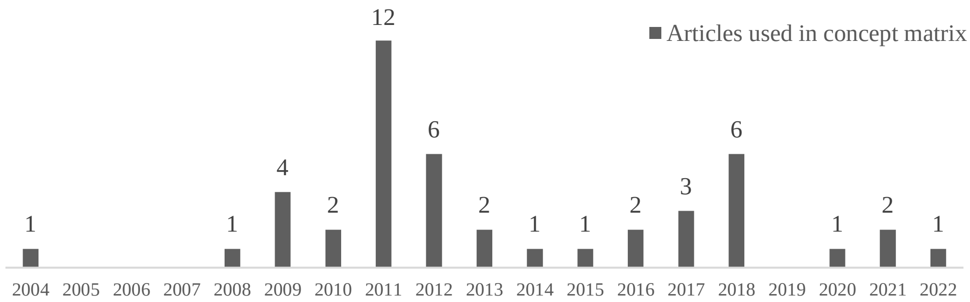

Figure 2. Identified literature.

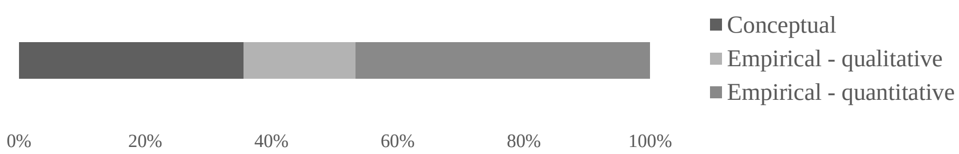

Figure 3. Type of identified literature.

Reference	**Antecedents**		**Implementation**			**Consequences**	
Author, Year	*Inter-nal*	*Exter-nal*	*Sourc-ing*	*Opera-tions*	*Dis-posal*	*Finan-cial*	*Non-fi-nancial*
Asadi et al., 2021	•			•			
Beloglazov, Abawajy and Buyya, 2012				•			
Berkhout and Hertin, 2004			•	•	•		•
Bohas and Poussing, 2016	•			•			
Bose and Luo, 2011	•	•	•	•		•	•
Butler, 2011		•	•	•	•		
Cecere et al., 2014			•	•	•		
Chan, 2021	•		•	•	•		
Chen et al., 2010		•	•	•	•		
Chou and Chou, 2012	•	•	•	•	•		•
Chuang and Huang, 2018	•		•	•	•		•
Cooper and Molla, 2017	•			•	•		•
Curry et al., 2012	•			•	•	•	•
Dalvi-Esfahani, Rama-yah and Nilashi, 2017	•		•	•			
Dedrick, 2010			•	•	•	•	•
Deng and Ji, 2015	•	•	•	•	•		•
DesAutels and Berthon, 2011			•	•		•	
Erek et al., 2011	•	•		•			•
Faucheux and Nicolaï, 2011	•		•				•
Garg et al., 2011				•		•	•
Hu et al., 2016		•	•	•	•		
Jain, Benbunan-Fich and Mohan, 2011				•		•	•
Jenkin, McShane and Webster, 2011	•			•	•		
Jenkin, Webster and McShane, 2011	•	•	•	•	•		•
Khuntia et al., 2018			•	•		•	
Loeser, 2013			•	•	•		
Loos et al., 2011	•			•		•	
Mann, Grant and Mann, 2009	•	•	•	•	•		
Masanet et al., 2020			•				
Molla and Abareshi, 2012	•		•	•	•		
Molla, 2013				•			•
Molla et al., 2009	•	•	•	•	•		

Molla, Cooper and Pittayachawan, 2009				•			
Murugesan, 2008			•	•	•		
Naumann et al., 2011			•	•	•		
Nishant, Teo and Goh, 2017			•	•		•	
Park, Eo and Lee, 2012			•	•	•		
Patón-Romero et al., 2018				•			
Przychodzen, Gómez-Bezares and Przychodzen, 2018	•		•	•		•	
Saldanha et al., 2022				•		•	
Sarkar and Young, 2009	•	•	•				
Uddin and Rahman, 2012	•	•	•	•	•	•	•
Yoon, 2018	•	•		•			
Zeng, Fu and Ouyang, 2018	•			•			
Zhang, Liu and Li, 2011		•	•		•	•	•

Table 1. Concept matrix.

3.1 Antecedents

The antecedents category describes reasons, motivations and other factors that drive firms to implement sustainability in their IT. It is further divided into two sub-categories: internal factors and external factors.

Internal factors include motivations for reducing costs or increasing efficiency, as well as organizational factors classified by management level.

Reducing costs is frequently cited internal factor that leads firms to implement sustainability in their IT. Green IT initiatives (Bose and Luo, 2011) and Green IT policies (Sarkar and Young, 2009) are emerging from the goal of cost reduction. Budget cuts are identified as a driver for Green IT initiatives (Bose and Luo, 2011), while Green IT policies are driven by efficient cost models stemming from managerial attitudes (Sarkar and Young, 2009). Managers are motivated by the overall economic opportunities that can be possibly achieved by strategies pursuing sustainability in IT, including cost savings, reduced IT operating and capital expenses (Erek *et al.*, 2011; Chou and Chou, 2012). Furthermore, cost reduction is considered to result from the efficient energy use of IT (Uddin and Rahman, 2012). Thus, these factors are often considered together.

Increasing efficiency is another internal factor for implementing sustainability in IT, leading to better resource utilization and asset management (Loos *et al.*, 2011). The growing restrictions of resources forces firms to reduce their resource consumption, which affects the implementation of Green IT initiatives (Bose and Luo, 2011). Firms also need to increase their IT efficiency to benefit from economic opportunities, including cost savings (Molla *et al.*, 2009; Erek *et al.*, 2011), higher earnings and market valuation (Przychodzen, Gómez-Bezares and Przychodzen, 2018), revenue growth, prevention of resource restrictions, risk mitigation, and efficient innovation (Erek *et al.*, 2011).

Several internal organizational factors affect the implementation of sustainability. The organizational factors can be broadly defined by the management level (normative, strategic, and operational) they are originating from.

Normative level alignment of organizations vision, goals and overarching sustainability strategy with IT sustainability is crucial (Curry *et al.*, 2012; Molla and Abareshi, 2012). Developing sustainability strategies and actions towards sustainable IT requires organizational belief in sustainability and a cultivated organizational green culture (Deng and Ji, 2015; Zeng, Fu and Ouyang, 2018). An organizational corporate social responsibility strategy is a driver for long-term investments in Green IT capital (Chuang and Huang, 2018) and Green IT adoption (Bohas and Poussing, 2016). Normative level factors need to be introduced by the top management of an organization by establishing consistent policies (Curry *et al.*, 2012). Furthermore, CIOs with a dominant promotion focus, meaning risk-seeking orientation, are more likely to practice green IT strategies in their organization (Chan, 2021). The support of top management is frequently named as a factor leading to implementation of sustainability in IT (Bose and Luo, 2011; Deng and Ji, 2015).

Strategic level, like management and leadership, also contribute to the implementation of sustainability in IT (Jenkin, Webster and McShane, 2011). The perceived priority, interpretation, and commitment of the strategic management for sustainability is a key driver of Green IT measures (Mann, Grant and Singh Mann, 2009; Asadi *et al.*, 2021), along with the appropriate allocation and commitment of funds and resources for Green IT projects (Mann, Grant and Singh Mann, 2009; Bose and Luo, 2011). The measures taken by managers to implement sustainability in IT are influenced by their own viewpoint, attitude towards Green IT, awareness of consequences of Green IT measures, and monetary cost-benefit assessments (Dalvi-Esfahani, Ramayah and Nilashi, 2017). The selection of measures can be affected by green informatization strategies and establishment of a dedicated Green IT group (Zeng, Fu and Ouyang, 2018), as well as reinforcement of sustainable principles and practices in the decision-making process (Curry *et al.*, 2012). However, the cost of greening IT and unclear business values can be a barrier to sustainability and hinder the adoption of Green IT (Molla *et al.*, 2009).

Operational level implementation of Green IT is fundamentally influenced by two factors: size and the industry type of the firm (Mann, Grant and Singh Mann, 2009; Bose and Luo, 2011; Przychodzen, Gómez-Bezares and Przychodzen, 2018). The number of employees determining the firms size also affect the adoption of sustainable IT measures of their organization. Employees need the capabilities to embrace trust and conduct the sustainable plans set by management (Zeng, Fu and Ouyang, 2018). As internal stakeholder, employees are both affected by sustainability measures implemented by the management and act as motivating factors themselves for Green IT adoption of their organization (Jenkin, Webster and McShane, 2011). Their awareness, commitment (Mann, Grant and Singh Mann, 2009), and perceived usefulness for sustainability and Green IT (Chou and Chou, 2012; Yoon, 2018) contributes to a sustainable culture that fosters Green IT innovation (Curry *et al.*, 2012). Individual employees' intentions to use Green IT are driven by their environmental beliefs, personal, descriptive, and voluntary norms (Yoon, 2018). Other factors influencing the employees for an implementation of environmental IT include motivations, incentives, internal & external connections, and prior experiences (Cooper and Molla, 2017). Besides employees, existing processes influence sustainability in IT and need to be prepared for Green IT initiatives (Bose and Luo, 2011). Internal resistance by the employees can be a barrier for establishing sustainable IT measures (Mann, Grant and Singh Mann, 2009; Faucheux and Nicolaï, 2011). Furthermore, employees may show knowledge gaps, practice gaps, opportunity gaps and knowing-doing gaps that can hinder the implementation of sustainability in IT (Jenkin, McShane and Webster, 2011).

External factors can be clustered into regulative, normative, and cultural-cognitive forces that affect Green IT implementation (Butler, 2011).

Regulative forces are a key external factor influencing a firm to implement sustainability in IT (Mann, Grant and Singh Mann, 2009; Molla *et al.*, 2009; Yoon, 2018). The regulations from governments are defined as contextual factors (Hu *et al.*, 2016) and a motivating force for environmental sustainability (Jenkin, Webster and McShane, 2011). Regulatory support, Legitimacy and compliance of local law are frequently stated as reasons for implementing Green IT practices (Bose and Luo, 2011; Erek *et al.*, 2011; Uddin and Rahman, 2012). Regulations and compliance requirements influence the design, production and performance of IT products and services toward more sustainable measure, including waste reduction, hazardous materials, chemicals or product life cycle assessments (Butler, 2011). Moreover, regulations can impact corporate policies and the inclusion of Green IT strategies within them (Sarkar and Young, 2009).

Normative forces affecting implementation of sustainability in IT primarily include industry standards and competitors. Industry wide standards, for example Energy Star, are one of the key drivers for Green IT (Mann, Grant and Singh Mann, 2009; Molla *et al.*, 2009; Chou and Chou, 2012). Additional standards, such as triple bottom line accounting of value chains, ISO 14001, EPEAT, GeSI or Green Grid, exert normative pressure on IT manufacturers (Butler, 2011). Furthermore, the competition intensity (Bose and Luo, 2011), industry norms & competitors' practices (Hu *et al.*, 2016) are important factors to consider. Competitive forces can be described as relative advantage, technological complexity, and compatibility (Deng and Ji, 2015).

Cultural-cognitive forces show a significant role in driving sustainability in IT, mostly driven by socio-cultural demands of stakeholders (Mann, Grant and Singh Mann, 2009; Jenkin, Webster and McShane, 2011). The adoption of Green IT is influenced by coercive pressures arising from powerful stakeholders (Chen *et al.*, 2010). Examples of cultural-cognitive pressure include the voluntary carbon disclosure project, green investors, social movements, and NGOs (Butler, 2011). Furthermore, the increasing environmental awareness and requirements of stakeholders, particularly customers, is a crucial contextual factor leading to sustainability in IT (Hu *et al.*, 2016). Customer requirements influence the inclusion of Green IT measures into corporate policies (Sarkar and Young, 2009). In recent time many firms try to align their public image with environmental concerns (Uddin and Rahman, 2012), which leads the design of IT to more environmental friendliness (Zhang, Liu and Li, 2011).

3.2 Implementation

In order to examine the implementation of sustainability IT, a common and established Green IT framework proposed by Murugesan (2008) was taken as structure to organize the findings. The framework classifies Green IT measures into three clusters: (1) sourcing, (2) operations and (3) disposal. (Murugesan, 2008; Molla, Cooper and Pittayachawan, 2009; Chou and Chou, 2012; Park, Eo and Lee, 2012; Loeser, 2013; Deng and Ji, 2015; Hu *et al.*, 2016; Chuang and Huang, 2018; Khuntia *et al.*, 2018; Zeng, Fu and Ouyang, 2018; Saldanha *et al.*, 2022)

Sourcing describes processes involved in the manufacturing and design of sustainable computers, servers, and IT-systems (Murugesan, 2008). It is part of the first order effects of sustainable IT, aiming to reduce environmental impact of IT production (Molla *et al.*, 2009; Molla and Abareshi, 2012; Deng and Ji, 2015), equipment and infrastructure (Loeser, 2013) and of IT material inputs (Cecere *et al.*, 2014). Sourcing focuses on incorporating ecological principles and energy efficient operations into the IT life cycle (Hu *et al.*, 2016; Chuang and Huang, 2018).

Sustainable manufacturing of IT artefacts is often regarded as the starting point for implementation (Murugesan, 2008; Hu *et al.*, 2016; Asadi *et al.*, 2021; Chan, 2021). The objective of Green IT manufacturing is to create computers and electronic devices with minimal environmental impact (Chou and Chou, 2012), including energy consumption, water, and other substances emissions (Berkhout and Hertin, 2004). It aligns with the concepts environmental design or product stewardship.

Environmental design or *Green design* (Zhang, Liu and Li, 2011) emphasizes the reusability of IT components, reduction of toxic chemical usage for production (Murugesan, 2008; Dedrick, 2010; Butler, 2011) and improvements of energy efficiency (Dedrick, 2010) during the IT design process (Chen *et al.*, 2010; Chou and Chou, 2012; Dalvi-Esfahani, Ramayah and Nilashi, 2017; Chan, 2021). This approach is related to the concept product stewardship of IT (Nishant, Teo and Goh, 2017).

Product stewardship represents environmentally friendly practices that aim to reduce the use of toxic substances and natural resources (Faucheux and Nicolaï, 2011) throughout a products lifecycle (Butler, 2011; Faucheux and Nicolaï, 2011). It extends across the entire supply chain, dealing with upstream and downstream activities (Chen *et al.*, 2010). Environmental impact is minimized throughout the manufacturing, sourcing and design-process (Jenkin, Webster and McShane, 2011) as well as the selling or usage of IT (Naumann *et al.*, 2011). Also, packaging materials (Butler, 2011; Naumann *et al.*, 2011) and end of lifecycle programs (Chen *et al.*, 2010), environmental-friendly disposing (Chen *et al.*, 2010; Butler, 2011) in form of refurbishing (Chou and Chou, 2012) or recycling of products (Butler, 2011; Chou and Chou, 2012) are considered. Thus, product stewardship focuses on holistic management of IT artefacts during their life cycle.

IT procurement focuses on the supply chain upstream (Chen *et al.*, 2010), which involves the relation to suppliers (Khuntia *et al.*, 2018; Przychodzen, Gómez-Bezares and Przychodzen, 2018). Green IT procurement adresses asset management, capital costs, and operating costs (Park, Eo and Lee, 2012) with a focus on purchasing environmentally friendly technology components (Mann, Grant and Singh Mann, 2009) and energy efficient hardware (Chen *et al.*, 2010). Suppliers are expected to adhere to Green IT Standards (Khuntia *et al.*, 2018), that are established by firms via policies in their asset management (Bose and Luo, 2011) or by policy makers (Masanet *et al.*, 2020). These may impose increased requirements for suppliers regarding recycling or law carbon measures (Uddin and Rahman, 2012).

Green IT standards are linked to product stewardship and procurement (Murugesan, 2008). These standards and policies aim to promote efficiency and implement environmental measures in the IT lifecycle (Sarkar and Young, 2009; Masanet *et al.*, 2020). Various regulatory guidelines, such as waste reduction, packaging, and hazardous materials, as well as Eco-Labels (Desautels and Berthon, 2011), Energy Star (Chen *et al.*, 2010) or ISO certifications (Desautels and Berthon, 2011; Faucheux and Nicolaï, 2011; Patón-Romero *et al.*, 2018) play a part in Green IT standards. Each of these guidelines has emerged as independent research areas, further expanding the scope of the concept.

Operations in the context of Green IT refer to adoption of sustainability practices in the usage of IT (Murugesan, 2008). For firms pursuing Green IT transformation, optimizing operations for environmental friendliness and efficiency is a crucial aspect (Molla and Abareshi, 2012; Deng and Ji, 2015; Zeng, Fu and Ouyang, 2018). Implementation of sustainability in IT in operations deals with the topics pollution prevention, energy efficiency, IT-infrastructure and virtualization.

Pollution prevention aims to optimize processes to reduce carbon emissions (Molla, Cooper and Pittayachawan, 2009; Butler, 2011; Erek *et al.*, 2011; Chuang and Huang, 2018), greenhouse gas emissions (Molla, Cooper and Pittayachawan, 2009; Dedrick, 2010), and general waste (Jenkin, Webster and McShane, 2011) associated with IT (Molla *et al.*, 2009; Chen *et al.*, 2010; Nishant, Teo and Goh, 2017). The measures are applied to production, infrastructure, devices, and hardware (Berkhout and Hertin, 2004), with a focus on reducing carbon emissions through compliance with low carbon policies, carbon emissions management practices (Uddin and Rahman, 2012), and measuring the carbon footprint (Curry *et al.*, 2012; Uddin and Rahman, 2012) or total environmental footprint of IT (Molla, Cooper and Pittayachawan, 2009).

Energy efficiency is a crucial aspect of Green IT, additionally to pollution prevention measures (Murugesan, 2008; Butler, 2011; Desautels and Berthon, 2011; Erek *et al.*, 2011; Jenkin, McShane and Webster, 2011). It describes incorporating energy-efficient operations in the IT lifecycle (Hu *et al.*, 2016) via software induced energy consumption reduction measures (Naumann *et al.*, 2011). It involves cost advantages linked to optimal energy usage (Saldanha *et al.*, 2022) and optimal utilization of existing energy resources (Chuang and Huang, 2018; Khuntia *et al.*, 2018), as well as cost advantages resulting from usage of less inputs and minimization of waste (Saldanha *et al.*, 2022). The main focus is reduction of power consumption and thus overall energy usage (Jain, Benbunan-Fich and Mohan, 2011; Khuntia *et al.*, 2018; Yoon, 2018). Energy efficient measures are applied to corporate IT assets and infrastructure (Molla, Cooper and Pittayachawan, 2009), ranging from efficient hardware and software design and usage (Dedrick, 2010; Chou and Chou, 2012; Dalvi-Esfahani, Ramayah and Nilashi, 2017) to optimization of data centers (Dedrick, 2010; Dalvi-Esfahani, Ramayah and Nilashi, 2017). Exemplary energy efficiency measures include energy efficiency policies (Bose and Luo, 2011), low-power laptops instead of desktops (Curry *et al.*, 2012), thin clients and optimization of data center power usage (Dalvi-Esfahani, Ramayah and Nilashi, 2017).

IT infrastructure, mainly data centers, is a key area where pollution prevention and energy efficiency measures are frequently implemented (Murugesan, 2008; Loeser, 2013; Molla, 2013; Yoon, 2018) driven by minimization of operational costs and environmental impact (Beloglazov, Abawajy and Buyya, 2012). The implementation of sustainability in IT infrastructure considers server assets, support infrastructures, building facilities (Park, Eo and Lee, 2012) focusing on energy costs, carbon emission rate, workload and CPU power efficiency (Garg *et al.*, 2011). Additionally, the office environment, including PCs, printers and other equipment can be viewed as an IT infrastructure subject to Green IT operations (Park, Eo and Lee, 2012; Loeser, 2013). Measures are implemented to reduce power consumption and enhance energy and material efficiency in severs, support infrastructures, and hardware (Molla, Cooper and Pittayachawan, 2009; Dedrick, 2010; Loos *et al.*, 2011; Dalvi-Esfahani, Ramayah and Nilashi, 2017; Saldanha *et al.*, 2022). Optimization of data centers involves considerations about buildings and infrastructure such as air-flow management, power delivery (Molla, Cooper and Pittayachawan, 2009) and efficient cooling systems (Molla, Cooper and Pittayachawan, 2009; Khuntia *et al.*, 2018; Przychodzen, Gómez-Bezares and Przychodzen, 2018; Saldanha *et al.*, 2022). The specific measures are dependent on the location of the data center, as different locations require different optimization strategies (Dedrick, 2010; Garg *et al.*, 2011). Examples of sustainability in IT practices include re-designing or retrofitting of data centers to be more environmental friendly (Cooper and Molla, 2017), server consolidation, power usage effectiveness tracking to optimize cooling, scheduling policies (Garg *et al.*, 2011; Beloglazov, Abawajy and Buyya, 2012) and load management with dynamic allocation across multiple data leveraging varying location conditions (Loos *et al.*, 2011).

Virtualization is closely associated with the implementation of sustainability in IT infrastructure and overall operations (Khuntia *et al.*, 2018; Przychodzen, Gómez-Bezares and Przychodzen, 2018) and it is frequently used in Green IT (Jain, Benbunan-Fich and

Mohan, 2011). An IT virtualization strategy aims to identify and utilize sever virtualization (Mann, Grant and Singh Mann, 2009; Curry *et al.*, 2012; Uddin and Rahman, 2012; Chan, 2021) facilitated by architectural structure principles (Beloglazov, Abawajy and Buyya, 2012). These principles deal with database reconfigurations (Mann, Grant and Singh Mann, 2009), server consolidation (Curry *et al.*, 2012), and optimization and consolidation of data storage (Chan, 2021). An effective measure is the energy-aware allocation of data centers resources to their respective virtual machines, minimizing migrations and increasing overall efficiency (Beloglazov, Abawajy and Buyya, 2012).

Disposal is a crucial aspect of implementing sustainability in IT, as it addresses environmental issues arising from disposal activities (Molla *et al.*, 2009; Molla and Abareshi, 2012; Loeser, 2013). It describes the proper environmental disposal of computers, servers, and other IT systems (Deng and Ji, 2015; Chan, 2021), which can be achieved by enactment of recycling & low carbon enabler policies (Uddin and Rahman, 2012). The implementation of sustainable disposal practices is linked to sourcing practices due to shared environmental motivations, e.g. product stewardship shows relevance for sourcing and for disposal by considering end of life programs for IT artefacts (Chen *et al.*, 2010; Naumann *et al.*, 2011). Life cycle assessments also take sourcing and disposal of IT artefacts into account (Zhang, Liu and Li, 2011; Hu *et al.*, 2016; Cooper and Molla, 2017).

Waste management is crucial in implementation of sustainability in IT (Cecere *et al.*, 2014). It involves proper waste disposal, waste reduction and recycling and re-using of old IT artifacts (Park, Eo and Lee, 2012), while considering the total cost of ownership of IT (Murugesan, 2008). Proper waste disposal is essential to minimize environmental harm (Berkhout and Hertin, 2004; Jenkin, McShane and Webster, 2011), due to the short life cycles of IT products and their impact on waste generation (Butler, 2011). Waste reduction, mainly electronic waste (Dedrick, 2010), is achieved by recycling of retired computers and peripherals (Chou and Chou, 2012). Efficient recycling practices reduce the environmental impact of IT (Mann, Grant and Singh Mann, 2009; Dedrick, 2010; Butler, 2011; Chuang and Huang, 2018). Additionally, firms pursue the reuse and refurbishment of old computers to reduce their waste output (Jenkin, McShane and Webster, 2011; Chou and Chou, 2012). To conclude, firms implement "reduce, reuse and recycle"-strategies to effectively implement sustainability in their IT disposal process (Curry *et al.*, 2012).

3.3 Consequences

The consequences of sustainability in IT can be broadly divided into financial and non-financial consequences.

Financial consequences contain effects on revenue, costs, profitability, and efficiency.

Research indicates that a Green IT strategy positively moderates association between Green IT standards and *profits* (Saldanha *et al.*, 2022). Also, Green IT investments are positively linked with to profit impact (Khuntia *et al.*, 2018). Anouncements of Green IT generate positive returns and increase trading volume of shareholders (Nishant, Teo and Goh, 2017). Implementing sustainability in IT infrastructure, like green data centers, leads to higher profits due to efficient scheduling policies (Garg *et al.*, 2011) and increased returns on assets (Przychodzen, Gómez-Bezares and Przychodzen, 2018). Firms can leverage pricing incentives offered by utilities, insurance companies, and governments by establishing sustainability policies in IT (Uddin and Rahman, 2012).

Green IT also predicts a *reduction of costs* (Dedrick, 2010; Uddin and Rahman, 2012). These cost reductions include energy consumption, hardware acquisition, and maintenance and replacement costs (Jain, Benbunan-Fich and Mohan, 2011). Investments in sustainability in IT are positively associated with cost reduction and cost effectiveness (Khuntia *et al.*, 2018). Sustainable manufacturing in sourcing process of IT does not affect the prices of the products due to reduced margins, efficiency savings, and cost shifting (Desautels and Berthon, 2011). Virtualization contributes to lower hardware costs (Bose and Luo, 2011), while green data centers permanently lower margins and costs of goods sold (Przychodzen, Gómez-Bezares and Przychodzen, 2018).

Efficiency and resource utilization improvements enabled by sustainability in IT indirectly impact the financial performance (Zhang, Liu and Li, 2011; Curry *et al.*, 2012; Khuntia *et al.*, 2018). For example, virtualization enables more efficient utilization of given resources (Bose and Luo, 2011) or the optimized load management across green data centers provides additional savings (Loos *et al.*, 2011).

Non-financial consequences contain environmental outcomes and a better market position for firms implementing sustainability in IT.

IT can have both positive and negative *environmental effects* (Berkhout and Hertin, 2004). Green IT leads to improved environmental performance of firms (e.g. Jain, Benbunan-Fich and Mohan, 2011; Chou and Chou, 2012). Environmental performance involves controlling environmental factors through policies, targets, and indicators (Chuang and Huang, 2018). Various environmental impact concepts are researched (Faucheux and Nicolaï, 2011; Jenkin, Webster and McShane, 2011), including environmental-friendly consumption (Zhang, Liu and Li, 2011), ecological value (Molla, 2013), and environmentally effectiveness (Cooper and Molla, 2017). Green IT strategies support environmental value by mitigating risks (Chou and Chou, 2012), mostly focused on emissions reduction (e.g. Garg *et al.*, 2011; Uddin and Rahman, 2012).

Additionally, a non-financial consequence is a better *market position*. Firms gain competitive advantage through green IT measures (Erek *et al.*, 2011; Chuang and Huang, 2018). This advantage stems from new products and improved operational performance (Cooper and Molla, 2017), concluding to an increased economic value (Molla, 2013). Furthermore, firms can enhance their market position by offering improved services to customers (Bose and Luo, 2011; Chou and Chou, 2012), thereby increasing reputation (Cooper and Molla, 2017) and brand image (Chou and Chou, 2012; Uddin and Rahman, 2012). Sustainability in IT enhances customer retention, customer satisfaction, and thus customer profitability (Jain, Benbunan-Fich and Mohan, 2011). Finally, firms pursuing sustainability in IT gain an improved market position since they are prepared for compliance of future regulation and certifications (Uddin and Rahman, 2012).

4 Discussion

The field of sustainability in IT combines research streams regarding sustainability and information technology. The concept of Green IT has been extensively studied and is an established domain. It started with the consideration of natural resources as competitive advantage and the measures pollution prevention, product stewardship and clean technology (Hart, 1995). The application of that concept into IT started in the 2000s (Berkhout and Hertin, 2004) and was emerging around 2011 (Figure 2). While earlier articles were conceptual, recent literature is shifting towards empirical studies about the effects of Green IT. The concept of Green IT is more covered in lower-ranked journals due to its practical nature. Top-rated academic journals prioritize articles on Green IS, due to a more strategic and conceptual approach (Gholami *et al.*, 2016). Although several literature reviews on the concept Green IT have been conducted, they are either outdated (Hu *et al.*, 2016) or have a narrowed focus (Asadi *et al.*, 2021). The main contribution of this work is to deliver a holistic overview of the most relevant and recent literature considering the whole Green IT concept rather than focusing on a sub-theme.

Green IT is generally accepted in research as a concept that minimizes the environmental impact of IT. The proposed measures of the concept can be categorized into sourcing, operations, and disposal (Murugesan, 2008). This is depicted by the proposed concept matrix, where many articles satisfy all three sub-categories of implementation. However these articles differ by applying different frameworks from the sustainability literature.

The concepts for implementation of Green IT proposed in this study are derived from several articles using the same categorization (e.g. Chou and Chou, 2012; Loeser, 2013). It is focused on the product life cycle of IT: sourcing, use and disposal.

In contrast, the natural resource-based view by Hart (1995) is also commonly used to categorize Green IT. It describes that organizations can gain competitive advantage through sustainability by pollution prevention, product stewardship and clean technology (e.g. Chen *et al.*, 2010; Nishant, Teo and Goh, 2017).

Additionally, the typology by Berkhout and Hertin (2004) which categorizies Green IT into first, second and third order effects of information technology and sustainability is often applied. Green IT is part of the first order effects since it focuses on optimizing itself. This concept is often applied by studies to categorize the concept Green IT (e.g. Sarkar and Young, 2009; Erek *et al.*, 2011). The second and third order effects are viewing IT in a sustainability enabler role and deal with Green IS topics. A similar concept is existing but defined as type 0,1, 2 and 3 strategies (Jenkin, McShane and Webster, 2011; Jenkin, Webster and McShane, 2011).

Authors like Cecere *et al.* (2014) describe direct, enabling and systemic impacts of IT on the environment. As a result, the Green IT and Green IS topics are often viewed in combination rather than viewed independently (e.g. Dedrick, 2010; Curry *et al.*, 2012). Moreover, the sustainability framework of Dyllick and Hockerts (2002) describing eco-goals is often applied to the concept of Green IT (e.g. Molla, 2013). It describes concepts like eco-efficiency, eco-sustainability (Chou and Chou, 2012) and eco-innovation (Faucheux and Nicolaï, 2011; Cecere *et al.*, 2014) which are applied to Green IT. This difference of frameworks in the Green IT field is also noticed by other researchers (Bohas and Poussing, 2016).

The categorization into product life cycle of IT enables to make associations and relationships between the topics of Green IT visible. For example, procurement dealing with suppliers is already considered in the topic of product stewardship, which additionally takes disposal into account (Chen *et al.*, 2010; Naumann *et al.*, 2011). Furthermore, the topic energy efficiency is often associated with improved financial performance (Zhang, Liu and Li, 2011; Curry *et al.*, 2012; Khuntia *et al.*, 2018).

Articles often address all three implementation topics rather than individual aspects, which indicates that Green IT is a consistent concept. This could also arise from the circumstance, that for sourcing, operations and disposal several different own research streams emerge, e.g., supply chain theories, product stewardship, life cycle assessments, ISO standards, data center optimization or recycling concepts.

Besides Green IT the research field of Green IS shows significance. These two concepts often share topics (Gholami *et al.*, 2016) like teleworking, energy informatics or environmental management systems (Murugesan, 2008; Watson, Boudreau and Chen, 2010; Seidel, Recker and Vom Brocke, 2013). The framework by Berkhout and Hertin (2004) considers Green IT to be first order effects, while Green IS focuses on second order effects. Notably, the research fields are prominent in different type of research journals. While Green IS, being a strategic domain, is prominent in top ranked journals (e.g. Seidel, Recker and Vom Brocke, 2013), Green IT is having a practical orientation. Therefore, Green IT is less represented in top ranked journals (Gholami *et al.*, 2016).

From a managerial perspective, the work delivers an overview of Green IT, offering a holistic framework for implementation of sustainability in IT. By considering antecedents and consequences it offers a practical guideline for Green IT implementation by describing possible motivations and results. As part of IT strategy, the proposed framework supports CIOs in the implementation of sustainability in their IT department.

Future research in Green IT should focus on empirically testing and validating additional variables (Cooper and Molla, 2017; Chuang and Huang, 2018). While there are several studies regarding sub-categories, there is a relative low number of studies empirically researching the concept Green IT as a whole. The proposed framework considers antecedents and consequences and offers an opportunity to study the different combinations of variables on Green IT implementation. Research could provide an in-depth analysis of sub-categories within Green IT, since many sub-categories have own expansive research domains, e.g. data center (Beloglazov, Abawajy and Buyya, 2012) or virtualization (Bose and Luo, 2011). Furthermore, the related research field of Green IS could be compared to Green IT implementation. With the emergence of new technologies, like artificial intelligence, it can expected that the relevancy of Green IT research will further increase in the future.

This work is limited by the subjective selection of articles and analysis of topics and categories. This is attempted to minimize by documenting the process carefully making its replicable. Furthermore, the work is could not provide an in-depth analysis of each subcategory of Green IT, rather it has the goal to give an overview of the concept. Additionally, the focus of analysis laid on scientific journal and conference papers and other types of sources were not considered for analysis.

5 Conclusion

The goal of this work was to provide an overview of sustainability in IT. A framework was developed with the dimensions: antecedents, implementation, and consequences. Antecedents of sustainability contains internal factors and external factors affecting implementation of Green IT. The implementation of sustainability in IT is clustered into three categories: sourcing, operations and disposal. The consequences of implementation can be split into financial consequences and non-financial consequences.

This work contributes to the Green IT research field by providing a review of the most recent literature and examining the concept holistically. This work can be used by future researchers as a foundation to further examine individual and combinations of research streams. The practical value is served by providing managers who are implementing Green IT a guideline referring to the most essential categories and topics.

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