Review

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The Key Requirements for the Greening of Emerging IT Technologies: A Comprehensive Systematic Review

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The Key Requirements for the Greening of Emerging IT Technologies: A Comprehensive Systematic Review

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Abstract: The Information Technology (IT) industry is not only an emerging global sector but also has the potential to support various business verticals. The rapid pace at which we demand and process information, and the significant convenience it brings to our lives, is remarkable. However, it is important to recognize that the IT industry, particularly the general computing sector, significantly contributes to energy consumption and carbon emissions. This systematic review aims to identify the key requirements for greening emerging technologies. The main objective of this study includes examining sources of energy consumption and greenhouse gas emissions within the IT sector and exploring the potential of various IT technologies to improve energy efficiency. This review study adopted systematic review processes that involved filtering 1988 academic articles down to 374 relevant studies, focusing on seven technologies: cloud computing, mobile computing, Internet of Things, big data analytics, networking, blockchain technology, and AI. Findings of this review study reveal a classification framework for these technologies, highlighting their unique contributions and potential for energy savings. The study emphasizes the importance of adopting cross-technology techniques to enhance sustainability. This review study demonstrateds by developing a comprehensive understanding of each technology's role in energy conservation and proposing integrative approaches to greening IT. This work provides a valuable reference for organizations aiming to implement green practices and supports future research in sustainable IT solutions.

Keywords: Greening technologies; Emerging IT; Requirements

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1. Introduction

The human ecosystem has had two significant implications, as an outcome of worldwide industrial growth; the first is the depletion of natural resources, wherein the consumption is outpacing its renewal (Gielen et al., 2019; Akadiri et al., 2022). Stepping-up operations and searching for alternate energy measures and sources are prima; for retarding the current rate of resource depletion (Owusu & Asumadu-Sarkodie, 2016). Secondly, global industrial operations have led to manifold carbon emissions (Ahmed et al., 2022), known as Greenhouse Gases (GHG); which further lead to higher diseases, global warming and depletion of the protective Ozone layer (Gavurova et al., 2022).

The Information Technology (IT) industry besides being an emerging global IT is both an emerging global industrial vertical and has the potential to support distinct business verticals (Ali et al., 2020). The pace at which we demand information and the granularity of it is momentous, and how it eases our life are also colossal. However, it is to be noted that the IT industry, especially the general computing industry in general, contributes immensely to energy consumption and thus carbon emissions (Shuja et al., 2017; Belkhir & Elmeligi, 2018). Thus, there lies a need for intervention from multiple nodes like IT technologies, work processes, algorithms, infrastructure design and utilization and others; by which each of them needs to be redefined for energy efficiency, commensurate consumption and designing sustainable work processes (Koronen et al., 2020).

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Moreover, IT industries need to exhibit and enable responsible consumption; by just not reducing their carbon footprint, but also structuring systems such that industries from another sector can also foster green practices, in their routine operations (Freitag et al., 2021; Shuja et al., 2016). The advent of the IT industry has revolutionized the planet, communities and societies that we dwell in. The challenge of sustainability and energy consumption and aggravated deficit is attributed to the aviation, petroleum and manufacturing sectors (Barke et al., 2022); the major accountability also lies with the IT sector, owing to their escalated consumption patterns and carbon emissions (Freitag et al., 2021). Globally, the IT sector alone guzzles 2.4% of the consumption, which is forecasted to increase to 20%, annually (Koot & Wijnhoven, 2021). Concurrently the sector also equally contributes to 2.5% of the global carbon emissions, which equates to around 0.86 metric gig tonnes of CO_2 (Freitag et al., 2021; Bressler, 2021). This exorbitant and fatal consumption pattern and embedded carbon emissions necessitate 'Green' computing infrastructure and processes (Lannelongue et al., 2021).

Green computing is conceptualized for maximizing efficiency, exploring new energy sources, responsible consumption, and 're-usability', wherever possible. It calls for the use of sustainable materials/products for manufacturing practices; and the adoption of green initiatives in an array of industries, which are supported by IT management and monitoring tools (Nwankwo & Chinedu, 2020). The duality of resource efficiency for performance and energy consumption is pivotal. High-performance computing aggregates the use of diverse sources and alternative backup patterns (Roelich et al., 2015); which is exactly in contravention to the principle of energy efficiency. These practices necessitate the reduction of utilized resources and energy-proportionate computing methods. In the computing milieu, energy reuse can be emancipated as a cyber-physical association of IT resources, besides cooling of large-scale IT centres (Shuja et al., 2016; Bharany et al., 2022). Primarily, the use of renewable energy sources for computing and diminishing carbon footprint is required (Freitag et al., 2021). Industrialized operations that source e-waste and recycle/reuse the components can also significantly ameliorate the concern (Abdulaziz, 2022). Besides these, the allied industries are emulating the green-computing practices of IT industries; besides proliferating these initiatives in other industries/sectors, through systematic environmental monitoring practices and consciousness (Deng et al., 2014).

The recent past has witnessed the emergence of multiple technologies that enable scientific, industrial and social businesses through sustainable IT practices. Their induction into human lifestyles has been an outcome of their seamless offerings, about ease of communication, health monitoring and environmental safeguards (Peng et al., 2020; Benis et al., 2021). The current manuscript coagulates the published literature, around the concept of *Green Computing*, from the lens of emerging IT and green technologies. The current review handpicks cloud computing (Ali et al., 2020), mobile computing (Al-Ahmed et al., 2021), Internet of Things (IoT) (Zhang et al., 2021), big data analytics (Calza et al., 2020), software-based networks (Qureshi et al., 2020), blockchain technology (Diniz et al., 2021), and artificial intelligence (AI) (Dauvergne, 2022) as the benchmark IT technologies for review, here. The selection is based on metrics set for popularity, social integration, and future applications in smart environments (Keeler & Bernstein, 2021).

This review differentiates itself in encapsulating distinct IT Technologies, which could act as a reference to organizations in creating opportunities and understanding these technologies, to deliver their responsibilities well. So, we look forward to a three-fold contribution: First, aggregate decadal information on green technologies, their circuits, algorithms and architectures; and emerging IT technologies; second, underscore the infrastructure and inputs for the greening of these technologies; and lastly, accentuate trending research themes on the greening of this computing – IT Technologies.

The manuscript furnishes a prologue to the greening of trending IT technologies; by way of detailed review, planning and sustained methodology. Additionally, the structured classification framework that themes the detailed review can aid future cult of researchers in mapping understanding across the existent literature; and to identify gaps for future research.

2. Emerging IT Technologies Background

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Cloud computing, mobile computing, IoTs, big data, blockchain, software-based Networks, and AI are popular and widely used technologies and are often interdependent. They are expected to provide people and organizations with more reliable and intelligent services, and sustainable answers for several organizations' services and administrative challenges. This segment provides a succinct synopsis of these emerging IT trends.

2.1. Cloud Computing

Cloud computing is the recent breakthrough in Internet-based computing technologies that offer on-demand infrastructure, software and platform services on a pay-as-you-go basis (Jamal & Khan, 2020; Banger et al., 2022). In this era of computing technology, the cloud presents a flexible execution environment of assets from multiple partners and provides metered administration at various granularities (Grace & Gandhi, 2022). Jamal and Khan (2020) demarcated cloud computing as a modelling mechanism that offers ease of access and convenience to an authorized pool of configurable computing infrastructure of integrated server applications and embedded IT assistance that can be dispensed with negligible management intervention. Grace and Gandhi (2022) referred to cloud computing as special expert collaboration, where massive virtualized and flexible work is utilized through the internet. While Ogala et al. (2022) presented cloud computing as a set of network-based services with ubiquitous and on-demand network access to a set of programmable computing resources with scalable, cost-effective and low management efforts. The National Institute of Standards and Technology (NIST) identified five main characteristics of cloud computing such characteristic as offering broad network access, on-demand self-service, real-time scalability, resources pooling, and measured service throughout the utilization of pay-per-use concept (Ali et al., 2021). Other characteristics, such as flexibility, reliability, universality, inexpensive, and unlimited storage are identified by different researchers (Jamal & Khan, 2020; Grace & Gandhi, 2022; Banger et al., 2022)

Nowadays, cloud computing has become one of the dominant computing technologies to achieve substantial scale (Jamal & Khan, 2020). It has been utilized by both individuals and business organizations to run applications store data over the cloud and access them from anywhere and at any time of internet connection (Banger et al., 2022). Accordingly, the influence of cloud computing on businesses and individuals is obvious. For instance, cloud computing offers several benefits for individuals, such as huge amounts of online storage, high availability of everything at the touch of a button, high-end machines, and additional computational power in sort of virtual machines (Banger et al., 2022). Freelancer software developers now have the privilege to create applications and internet services to be offered worldwide (Banger et al., 2022). Researchers now can share and analyse data at a large scale (Banger et al., 2022). Moreover, the presence of the operated software over the cloud has changed many elements in business organizations' start-up and daily activities (Banger et al., 2022). Organizations can cut off their costs and expand their offering by using cloud services instead of purchasing and maintaining expensive hardware and software. Furthermore, cloud computing can significantly support the green environment due to the sharing of resources, which allows the consumption of smaller amounts of power and energy, and hence, carbon emission is reduced accordingly (Jamal & Khan, 2020).

2.2. Mobile Computing

Mobile computing is another emerging technological trend in the computing paradigm, where its applications are involved in multiple disciplines and domains (Elazhary, 2019; Nazir et al., 2019). The term "mobile" typically represents smartphones, yet it applies to all portable, wireless, programmable, and handheld devices that can be used anywhere and at any time (Zaidi et al., 2021). These devices include smartphones, tablets, smartwatches, and laptops. Smartphone devices have become an essential part of people's daily life activities. They are very useful for accomplishing several on-the-go activities of social communication and interactivity, data storage, and online shopping (Elazhary, 2019).

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Mobile computing provides remote and quality information services such as processing, storage, information and queries to mobile users (Nazir et al., 2019). It is a type of technology that enables computers and information devices to share data without the need for a physical connection (Ma et al., 2018). It is also can improve the accuracy of identifying relevant information and increase the productivity's efficiency (Ma et al., 2018). Accordingly, various mobile applications have been and are being developed by the research community for various application domains such as context-aware mobile applications, mobile health (m-health), mobile learning (m-learning), mobile government (m-government) (Nazir et al., 2019; Zaidi et al., 2021).

2.3. Internet of Things (IoT)

The IoTs is yet another breakthrough technology that is inviting the attention of the IT research fraternity; and has the potential to be one of the dominant research paradigms soon (Elazhary, 2019; Ramasamy & Kadry, 2021). IoT as a term was coined by Kevin Ashton in 1999, due to the linkage between Radio Frequency Identification systems (RFIDs) and sensors to the internet (Elazhary, 2019). In this linkage, data about things in the real world is gathered directly by computers to exceed the human-provided data limitation.

Due to this smart privilege of accessibility of smart devices with low cost, many researchers envisioned a smart world embedded with sensors, actuators, or other wearable devices connected to the internet to shape IoT applications, which aim to automate the extraction of data internet-connected things and to control them in an informed manner (Elazhary, 2019; Liao et al., 2020). IoT represents an evolutionary stage of the internet, which makes a global communication infrastructure between humans and machines more effective and automated (Ramasamy & Kadry, 2021). It constructs the global infrastructure that will change the fundamental aspects of our lives, starting from health services to manufacturing and supply chain, and from agriculture to mining (Ramasamy & Kadry, 2021). IoT appeared as a powerful technique with appliances in various domains like smart grid, smart city, smart industry, smart building, smart health, smart energy, and smart environment, water and food monitoring (Liao et al., 2020). IoT offers many technical benefits, including the ability to locate and trace in a short amount of time, intelligence swap and management of information, enhanced power solutions and decreased waste (Ramasamy & Kadry, 2021). Moreover, IoT comes with various characteristics such as safety, scalability, dynamicity, interconnectivity, and service-related things (Ramasamy & Kadry, 2021). Accordingly, mobile and cloud computing are inseparable technologies from the IoT due to the various services, applications, and devices offered to the IoT technology (Ma et al., 2018; Nazir et al., 2019). For instance, IoT through its smart sensing technology provides vital support for mobile medical data transmission and acquisition in real-time environmental conditions (Ma et al., 2018).

2.4. Big Data Analytics

Big data is a term that is used to refer to a collection of large, growing, and complex data sets that originated from heterogeneous and autonomous sources and require powerful technologies and advanced algorithms to process them (Awan et al., 2021; Wang et al., 2021). These datasets are very big as they are measured in Exabyte (Giri & Lone, 2014). Unlike traditional data, big data includes masses of structured, unstructured and semi-structured data that can be in the form of text, pictures, videos, maps and so on (Oussous et al., 2018). A few examples of big data include sensor networks, environmental sensors, patients' electronic records, bank records, online posted videos and photos, social media comments, and customer reviews and comments on e-commerce (Giri & Lone, 2014). The majority of data experts identify big data by six main characteristics volume, velocity, variety, veracity, valence, and value (Awan et al., 2021; Oussous et al., 2018). Due to this complexity, the traditional and existing database management and analytical tools became insufficient to handle and process big data (Haoxiang & Smys, 2021; Ageed et al., 2021). However, once advanced data management and analytics technologies are adopted, organizations can have new pivotal business

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opportunities through the development of innovative products and services, and the achievement of more effective and efficient business operations and decision-making (Oussous et al., 2018).

Academic and business communities identified big data as a breakthrough technological paradigm that dramatically can inspire public and private organizations in several application domains such as e-commerce, e-government, science, health, security, transportation and logistics, and IoT (Ageed et al., 2021; Haoxiang & Smys, 2021; Awan et al., 2021). In today's technology and knowledge-driven society, the intersection of big data and data mining is a strategic tool and a key development factor toward organizations' success, upgrade, and growth (Ageed et al., 2021). Due to this intersection of advanced analysis with training-calculating technology over a large pool of resources, the most valuable information and expertise are extracted and delivered to the user as a service for better decision-making in business intelligence and other applications of network instruction, spam filtering, recommendation systems, and health analytics (Awan et al., 2021).

2.5. Blockchain Technology

Blockchain is one of the emerging computing technologies that aims to store and transmit data in a more secure, transparent and decentralized way (Ali et al., 2021; Riđić et al., 2022). It has been widely accepted as a public or private shared ledger of all digital events or as a distributed database shared or run among the participating agents in the blockchain (Casino et al., 2019; Jaoude & Saade, 2019). From the technical aspect, blockchain is a distributed system in the form of blocks, which contains all the transactions done since its start and implements a set of agreed rules where neither the user nor the system operators can break them no one (Issaoui et al., 2019). Blockchain technology is associated with decentralization, anonymity, proof tampering, and audibility that offers a secure data management and transparent modelling process in such areas as supply chain management, emission trading, health care, smart city, and food and energy traceability (Issaoui et al., 2019; Ali et al., 2021).

Blockchain is one of the most recent technologies developed that emphasizes the innovations of the IoT, e-commerce, telecommunication, and AI revolutions (Riđić et al., 2022; Jaoude & Saade, 2019). It is also one of the recently developed technologies that may create new opportunities for all sectors, such as finance, supply chain, healthcare, government, education, accounting & auditing, e-voting, asset management, and identity management (Riđić et al., 2022; Jaoude & Saade, 2019). Such opportunities can be in sort of enhancing transparency, enhancing and fastening business processes, building trust, reducing cost, and ensuring security (McGhin et al. 2019; Katuwal et al., 2018). For instance, blockchain could play a vital role in records management and data sharing in the healthcare sector, or by allowing users to validate and synchronize the contents of a transaction ledger in the financial sector (Jaoude & Saade, 2019).

Several research studies have highlighted the potential benefits that may be observed by varied sectors and industries through the utilization of blockchain technology (Ali et al., 2021). For example, a study conducted by Beck et al. (2018) classified blockchain as a distributed ledger technology that provides confidence to the users. Moreover, various studies have shown that blockchain comes with the capability to decrease transactional obscurity, insecure states, and dubiousness, and to renovate economies and the social order profoundly through a reduction in the cost of transactions and the requirement for well-recognized and trustworthy third parties (Nærland et al., 2017; Clemons et al., 2017). Despite the several benefits offered by blockchain, some sectors as government and education still might see blockchain as a distracting technology that cannot be trusted and needs to be managed (Ali et al., 2021). Indeed, blockchain is still a new technology, and while there is considerable excitement regarding its potential benefits, there is also considerable inaccurate information and uncertainty regarding the potential utility of blockchain in general (Ali et al., 2021). For example, the application of blockchain in the circular economy (CE) is a promising field of study with enormous potential for achieving sustainability and green computing development (Francisco Luis et al., 2022). Blockchain technology comes with decentralization, anonymity, proof tampering and audibility features, which can be used in related cases to CE principles such as food and energy traceability, agriculture processes, and supply chain management. Blockchain can enable any CE project to obtain a secure platform of data management with transparent processes for end-users (Francisco Luis et al., 2022).

2.6. Artificial Intelligence (AI)

AI is the science of creating smart devices and machines in the form of different computer programs (Ali et al., 2023). It is also known as the technology of making computers so intelligent in a way that they can understand humans (Androutsopoulou et al., 2019). AI is one of the major turning points in the computer science field and revolutionary industry that allows developers to create intelligent machines that behave like humans, think like humans and make their own decisions (Vesnic-Alujevic et al., 2020; Dwivedi et al., 2021). From the general perception, AI is defined as the study, design and development of intelligent agents of computational systems that recognize their environment to be capable of taking actions and decisions to maximize the chances of success (Vesnic-Alujevic et al., 2020; Zuiderwijk et al., 2021). With the ultimate goal of creating consciousness, AI goes through reasoning, learning, perception, prediction, planning or controlling phases (Zuiderwijk et al., 2021).

Recently, AI has been recognized as a revolutionary computational system field for society's transformation toward automation and intelligence, which offers competitive solutions to several services and administrative challenges, regardless of the adopted industry or sector (Dwivedi et al., 2021; Alshahrani et al., 2021). According to Alshahrani et al., (2021), the global spending on AI by 2023 is expected to be around 98 billion dollars, which is approximately double the amount spent by 2019. This transformational impact of AI has led to significant academic and industrial interest. In recent years, AI techniques have been widely used in private and public sector services to support automation and to enhance the quality of decision-making as well as problem-solving through the implementations of such techniques and tools as natural language processing, conversational agents, robotics, expert systems, neural network, fuzzy logic, and machine learning (Alshahrani et al., 2022; Androutsopoulou et al., 2019)

AI applications offer varied benefits through their utilization in several public and private sectors such as healthcare, banking, media, tourism, retail, stock market, telecommunication, education, security, social welfare, public safety, supply chain and communications (Sousa et al. 2019; Androutsopoulou et al., 2019). Among the benefits that are offered by AI applications to these sectors are reducing cost, increasing productivity, decreasing dependency on human decision-making, solving resource allocation problems, creating new employment opportunities, improving public service delivery, improving citizen's and customer satisfaction, improving employee' workload, reducing the administrative burden of public organizations, advancing the communication channels between government and citizen or between private organizations and customers (Androutsopoulou et al., 2019)

3. Review Planning and Methodology

According to Kitchenham et al., a systematic review (SR) involves systematically identifying, evaluating, and interpreting accessible and available literature pertaining to a specific research question, topic, or area of interest (Kitchenham & Charters, 2007). It serves as a methodical approach to gathering, organizing, and evaluating existing research, ultimately pinpointing gaps in the current literature and suggesting potential avenues for future research (Dabić et al., 2020; Paul et al., 2021). By comprehensively exploring research directions, identifying shortcomings, and proposing potential research themes, SR contributes to advancing knowledge in various domains (Khatoon & Rehman, 2021).

Differentiated into domain, theory, and methodological reviews and various subcategories, SR plays a crucial role in addressing tailored challenges and is widely adopted across industrial sectors, particularly in energy and IT industries (Kamboj & Rahman, 2015). It serves as a valuable reference for understanding sector trends, shaping policies, and guiding professional practices (Moher et al., 2009). This systematic review is grounded in structured recommendations outlined by Watson (2015), which detail the comprehensive process of searching, executing, and reporting for such reviews. For professionals in IT and energy sectors, navigating through a vast array of volatile publications to

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inform evidence-based decisions can be daunting (Bastian et al., 2010). However, leveraging SR can provide a holistic, unbiased, and informed view of research studies to facilitate more robust decision-making and serve as a cornerstone for evidence-based practices (Abbas et al., 2008).

In order to ensure the rigor and effectiveness of a systematic review, it is essential to follow established protocols and guidelines that prioritize reproducibility, objectivity, transparency, and rigor (Boell & Cecez-Kecmanovic, 2015). By adhering to structured protocols proposed by leading scholars such as Kitchenham, Charters, Ali, and Watson, the SR process can be elevated to a standard of excellence (Tranfield et al., 2003). It is imperative to define clear objectives, articulate research questions, select appropriate methodologies, and establish a robust classification framework at various stages of the review process (Kitchenham & Charters, 2007; Ali et al., 2020). Implementing strict search criteria, employing quality assessments, and summarizing discussions are essential steps that should be meticulously executed to ensure the quality and integrity of the SR (Watson, 2015). The specific guidelines and procedures outlined in Figure 1 for this SR aim to provide a detailed roadmap for conducting a thorough, high-quality systematic review.

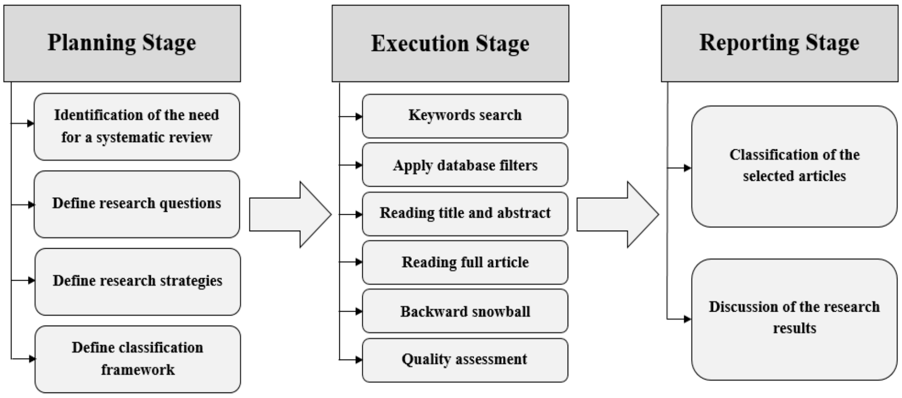

Figure 1. Systematic review stages.

3.1. Planning Stage

At the outset, this initial phase of the systematic review (SR) revolves around recognizing the necessity for conducting the review, with a focus on objectively synthesizing existing information related to a particular subject or phenomenon. Despite the presence of prior research, a lack of comprehensive systematic literature reviews persists due to various contributing factors. Conducting an SR serves the purpose of organizing these findings and literature, thereby facilitating a comprehensive analysis of existing theoretical and practical knowledge.

Following the establishment of the review's need, the next crucial step involves formulating precise research questions, which are fundamental to any SR (Paul et al., 2021). For the present SR, two central questions have been crafted: What are the essential prerequisites for the integration of environmentally friendly practices in emerging IT technologies? What are the findings of previous studies in this area, and what implications do they have for future research endeavors?

Subsequently, in the planning phase, the selection of relevant articles is executed as the third sequential step, where the article selection strategies aim to provide direct literature and evidence pertinent to the research questions. To mitigate biases, the initial selection of articles is based on defined protocols, with room for refinement during the search process (Dabić et al., 2020). Employing an integrated search strategy facilitated an automated search across various online repositories, complemented by manual screening of the retrieved articles.

An elaborate automated search strategy is deployed to encompass the most pertinent online repositories (Golder et al., 2014; Rosado-Serrano et al., 2018). For this systematic review, databases such as Direct, ACM Digital Library, IEEE Xplore, Emerald Insight, and Scopus were selected as relevant sources. A diverse array of filtering mechanisms and tools were applied to obtain relevant outcomes (McLean & Antony, 2014), followed by manual assessment. The iterative process involved

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initial screening based on article titles and subsequent abstract readings (Golder et al., 2014). This was followed by a thorough examination of the complete content of shortlisted articles to filter out irrelevant material (Ali et al., 2018). The utilization of the backward snowball technique in the third iteration entailed scrutinizing the references of reviewed articles to identify additional pertinent literature or seminal works (Wohlin, 2014), ensuring alignment with key research criteria such as language, temporal relevance, and publication nature. Articles that did not meet these criteria were excluded, with previously reviewed and redundant articles also eliminated. The remaining articles were considered for potential inclusion in the review study.

Table 1. Selection criteria.

Criteria	Inclusion	Exclusion	Rationale
Type of publication	Scholarly articles	Reports and any other sources	To ensure that the research retrieves information of academic level sources.
Peer-reviewed	Peer-reviewed	Non-peer-reviewed	To ensure the high quality of the used articles.
Publication year	Articles published from 2012 to 2022	Articles that published prior to 2012	To ensure the validity of the content in any article used in this research review. The pace of technology changes is relatively rapid and the past 10 years is an appropriate time period when the authors can observe the recent trends.
Language	English language	Any language other than English	English is the official language of research articles.

The subsequent phase, namely the fourth stage, involved the development of a research review protocol, which serves as a fundamental component for gaining insight into the current landscape of theoretical and practical viewpoints. A systematic review (SR) necessitates a predefined methodology to minimize the potential for bias. The present review study adopts a modified version of the comparative classification framework utilized in a previous IT literature review by Ali et al. (2018). Within this review, a tailored categorization framework encompasses seven specific technologies, each with distinct categories, and each category outlines various essential environmental considerations. The technologies and their respective categories are outlined as follows: Cloud computing technology: Encompassing cloud data centers (Ali et al., 2020). Mobile computing: Encompassing smartphones and mobile cloud computing (Al-Ahmed et al., 2021). Internet-of-Things (IoT): Encompassing Radio Frequency Identification (RFID), Wireless Sensor Networks (WSN), and Machine to Machine Communication (M2MC) (Zhang et al., 2021). Big data analytics: Encompassing data management systems (Calza et al., 2020). Networking: Encompassing network systems (Qureshi et al., 2020). Blockchain technology: Encompassing various use cases (Diniz et al., 2021). Artificial Intelligence (AI): Encompassing neural networks (Dauvergne, 2022).

All selected articles included in our review addressed these seven technologies outlined in the classification framework, namely cloud computing, mobile computing, Internet-of-Things, big data analytics, networking, blockchain technology, and AI. For detailed information on the steps and processes involved in article selection, please refer to the subsequent sections.

3.2. Execution Stage

The *execution phase* of our review study involved implementing the methodologies defined in the planning phase to identify relevant articles. The specific steps undertaken in this stage are as follows: Identification of Search Terms: An ongoing process of identifying search terms was conducted by compiling unique terms from seminal articles in the field (Hu & Bai, 2014; Paul et al., 2021). This process continued until all prominent terms were exhausted, adhering to the principles outlined earlier. The selected databases featured advanced search capabilities, allowing the use of both single and combined search terms. The keywords identified included: “information system” OR “information technology” OR “emerging technologies” OR “cloud computing” OR “mobile computing” OR “Internet of Things” OR “mobile technologies” OR “big data analytics” OR “soft-based networks” OR “blockchain technology” OR “artificial intelligence” AND “green technology” AND “requirement” AND “power” OR “energy”. Application of Filtering Tools: Filtering tools were applied to the databases to optimize search results (Zhang et al., 2014). Filters included thematic restriction (IT & energy), temporal restriction (publications between 2012-2022), document type restriction (published journal articles/conference papers), and linguistic restriction (English language publications). Manual Relevance Check: A manual review of titles and abstracts was performed to ensure relevance (Pucher, 2013; Ali et al., 2018). Relevance Analysis: Articles were further analyzed for their relevance to the research topic and theme (Ali et al., 2021). Backward Snowball Technique: This technique was employed to uncover articles that the automated search might have missed (Spanos & Angelis, 2016). Quality Assessment: A quality assessment criterion, adapted from Hu & Bai (2014), Ali et al. (2018), and Sadoughi et al. (2020), was applied. This included criteria such as: clarity of the research problem and questions, availability and description of data, thorough elaboration of methodology, and comprehensive presentation of research results.

This review utilized quality scores to evaluate the relevance of the results, ensuring that individual quality factors, such as validation methods, aligned with the study's objectives. After an initial selection, the quality assessment aimed to eliminate bias and enhance the validity of the systematic review. A total of 374 articles were identified and assessed based on criteria such as diligence, reliability, accuracy, and propriety to ensure relevance to research concepts and terms. Further criteria like originality, target relevance, and usability for future researchers and practitioners were also considered. The selected articles were taxonomically categorized based on primary research aims, methods, contributions, and results, facilitating the identification, extraction, classification, and synthesis of relevant data pertaining to research issues.

The review was conducted from January 11th, 2022, to May 10th, 2022, in accordance with the protocol established during the planning stage. The initial search using the defined keywords yielded a total of 1988 articles. Following the application of all the outlined steps, 374 research articles met the quality assessment criteria.

3.3. Summarizing Stage

The final selection of articles for this review study is summarized in Table 2. Initially, the keyword search identified 1988 unique articles. Applying the specified criteria reduced this number to 1250. A subsequent manual review focused on filtering out irrelevant articles, specifically targeting empirical and conceptual papers, resulting in the elimination of 568 articles and leaving 682 articles for further review.

An exhaustive review process followed, involving a thorough examination of each article’s objectives, research questions, research methods, and the quality of data and analysis techniques. This detailed reading identified 229 irrelevant articles, reducing the total to 453. The application of the backward snowball technique added 31 additional articles, bringing the total to 484. Finally, after applying the quality assessment criteria outlined in the previous stage, 110 articles were eliminated, resulting in a final count of 374 articles included in the review.

Table 2. Review search results.

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Databases	Automated Search		Manual Search		Backward Snowball	Final Results
	1st Strategy Keywords Result	2nd Strategy Apply Filters	3rd Strategy Title and Abstract	4th Strategy Reading Full Articles	5th Strategy Backward Snowball	6th Strategy Quality Assessment
Science Direct	340	193	114	76	80	68
ACM digital	291	155	98	54	63	48
IEEE Xplore	399	216	127	89	92	76
Emerald insight	487	372	169	110	117	88
Scopus	471	314	174	124	132	94
Total	**1988**	**1250**	**682**	**453**	**484**	**374**

To refine the extensive pool of 1988 academic articles down to the final 374, this review study employed multi-step selection process emphasizing both relevance and quality. This review approach is outlined as follows: (1) *Initial screening of the title and abstract*, this step conducted a preliminary review of the titles and abstracts of all 1988 articles. Articles that clearly did not pertain to the greening of emerging IT technologies were excluded. This included articles that focused solely on non-IT-related environmental studies or those unrelated to sustainable practices in IT. (2) ***Inclusion and exclusion criteria*, and this include inclusion criteria;** articles were considered if they addressed at least one of the seven key IT technologies (cloud computing, mobile computing, Internet of Things, big data analytics, networking, blockchain technology, and AI). Discussed aspects of energy efficiency, reduction of carbon emissions, or sustainable IT practices. Presented empirical research, case studies, or comprehensive reviews relevant to green IT technologies. **Exclusion criteria:** articles were excluded if they lacked a clear focus on environmental sustainability within the context of IT. Articles were purely theoretical without empirical data or practical applications. Also, articles were duplicates or preliminary versions of included studies. (3) ***Quality assessment*, and this include peer review status, in this step** reference was given to peer-reviewed journal articles, conference papers, and high-impact academic publications. **Research methodology, in this step** the review assessed the robustness of the research methodologies, prioritizing studies with clear, replicable methods and those that included quantitative data, experiments, or significant case study insights. (4) ***Relevance to greening technologies*. In this step the review include specificity to key technologies,** articles were further scrutinized to ensure they provided detailed insights or advancements specific to the seven key technologies identified. **Alignment with review objectives,** the review ensured that the selected articles aligned closely with the objectives of our review, focusing on energy consumption sources, greenhouse gas emissions, and potential energy-saving techniques across different IT technologies. This systematic and thorough filtering process ensured that the final 374 articles were highly relevant, of significant academic quality, and provided comprehensive coverage of the key requirements for the greening of emerging IT technologies.

3.4. Common Characteristics related to Selected Articles

3.4.1. Temporal distribution

The earliest literature on the topic of greening emerging IT technologies was published in 2012 (see Figure 2). The peak publication frequency occurred in 2018 with 63 articles, while the lowest frequency was in 2012 with 15 articles. The majority of publications were concentrated between 2017 and 2021, reflecting a recent interest in this research area.

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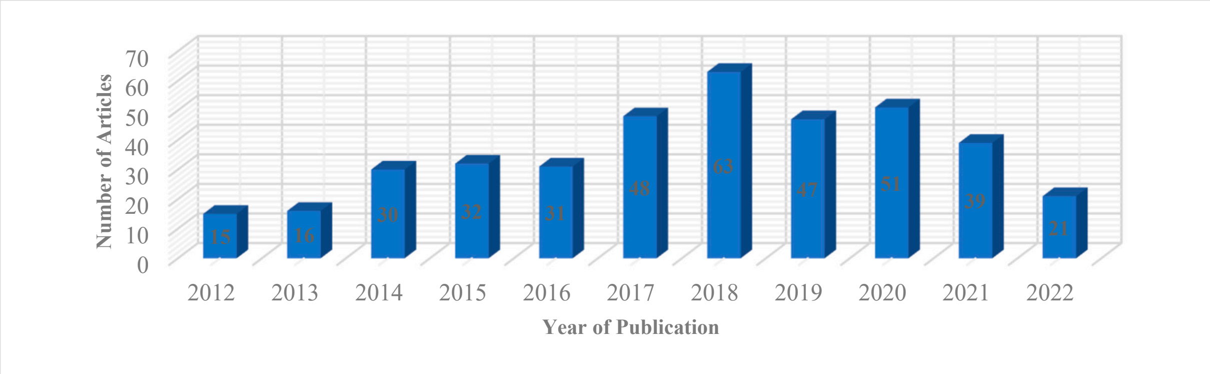

Figure 2. Publications by year.

3.4.2. Distribution of Articles by Database

Figure 3 illustrates the databases selected for this review study, including Science Direct, the ACM Digital Library, IEEE Xplore, Emerald Insight, and Scopus. The highest number of selected articles, 94, were sourced from the Scopus database, followed by 88 articles from Emerald Insight. Additionally, 76 articles were obtained from IEEE Xplore and 68 from Science Direct. The ACM Digital Library contributed the fewest articles, with a total of 48.

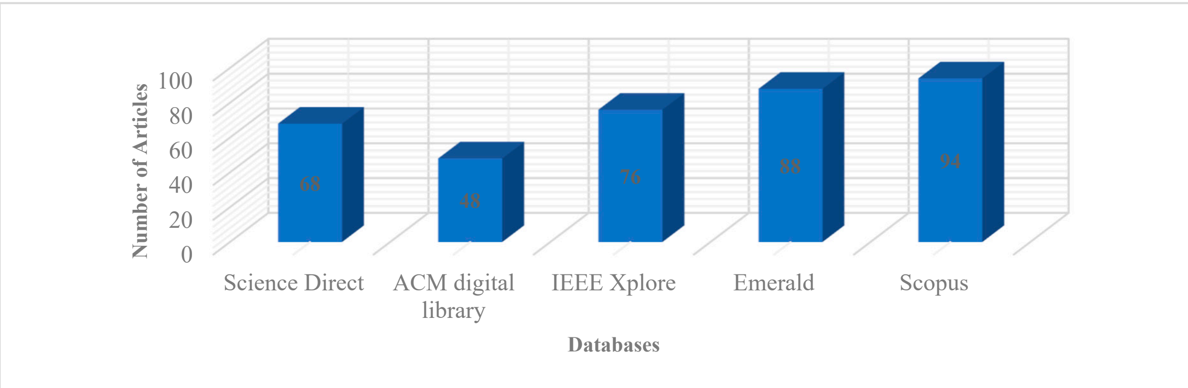

Figure 3. Publications by database.

3.4.3. Article distribution Affording to Classification Framework

The review is systematically categorized into seven distinct technologies: cloud computing, mobile computing, the Internet of Things, big data analytics, networking, blockchain technology, and artificial intelligence. Figure 4 presents the annual publication count for articles related to each technology. Overall, the number of articles published is as follows: cloud computing (n=75), mobile computing (n=77), Internet of Things (n=74), big data analytics (n=57), networking (n=45), blockchain technology (n=30), and artificial intelligence (n=30).

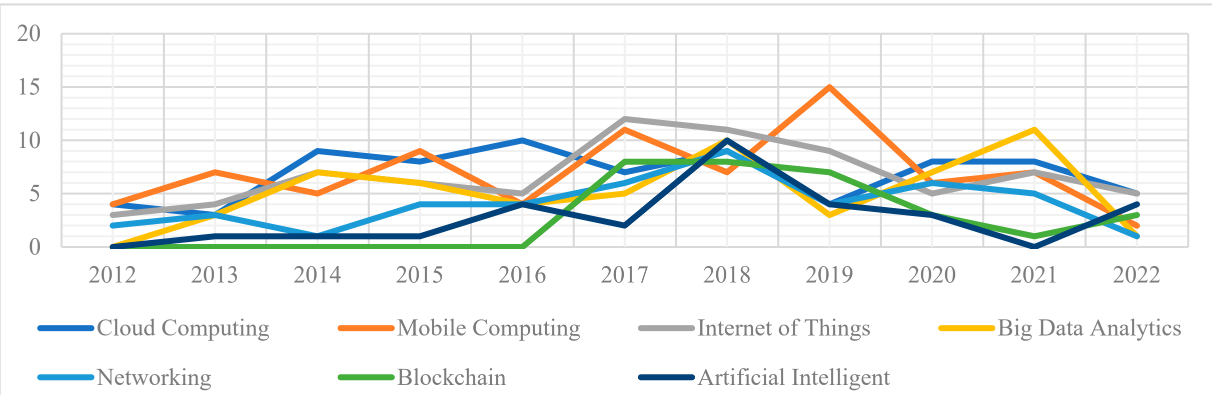

Figure 4. Research topics according to classification framework.

3.5. Research Synthesis and Propositions

In this SR, we have identified the key requirements for greening the emerging IT technologies. A multitude of different theoretical approaches are stated to classify and categorize the emerging IT technologies, on the basis of prior scientific research and theories (Brem & Viardot, 2015; Hamdan & Yahaya, 2016). This review study reveals seven different technologies, these technologies and their categories and the key requirements are some of most important hierarchical and interconnected for many different organizations within different sectors.

The research framework considered seven different technologies, namely cloud computing, mobile computing, Internet-of-Things, big data analytics, networking, blockchain technology, and AI. In addition, this review study identified several different categories with their key requirements to be greening technologies. All these technologies and their categories as well as their key requirements were grouped (see Table 3). The seven main identified technologies and their categories were classified based on their (1) Popularity which refers to the extent to which each technology is being adopted and implemented in various sectors. (2) Social integration which refers to the degree to which these technologies are embedded into daily life and organizational processes. (3) Future applications in smart environments which refers to the potential for future advancements and applications in creating smart, sustainable environments. These criteria were selected to ensure that the technologies included are relevant, widely adopted, and have significant potential for future development and impact. Examples of greening each technology are as follows: Cloud computing; utilization of energy-efficient data centers, adoption of renewable energy sources, and implementation of advanced cooling techniques. Example for this is Google's data centers use advanced cooling systems and artificial intelligence to optimize energy usage, reducing their carbon footprint significantly. Mobile computing; development of energy-efficient mobile devices, use of sustainable materials, and improved battery technologies. Example for this is Apple's iPhone recycling program and use of recycled aluminum in device manufacturing reduce e-waste and promote sustainability. IoT; deployment of low-power sensors, energy-harvesting devices, and smart grid technologies. Example for this is smart thermostats like Nest reduce energy consumption by learning user preferences and optimizing heating and cooling. Big data analytics: optimization of data processing algorithms to minimize energy usage and employing green data centers. Example for this is big data analytics used in smart cities to optimize traffic flow, reducing fuel consumption and emissions. Networking: implementation of energy-efficient networking equipment and protocols, and use of software-defined networking to optimize resource usage. Example for this is Cisco's energy-efficient Ethernet technology reduces power consumption during low data activity periods. Blockchain technology; transition to less energy-intensive consensus mechanisms and using blockchain for tracking and reducing carbon emissions. Example for this is the transition of Ethereum from Proof-of-Work (PoW) to Proof-of-Stake (PoS) significantly lowers energy consumption. Artificial Intelligence: development of energy-efficient AI algorithms and using AI to optimize energy consumption in various industries. Example for this is AI algorithms used by DeepMind to optimize cooling in Google's data centers, resulting in a 40% reduction in energy usage.

Table 3. Classification framework.

Technology	Category	Key Requirements	Sources

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Cloud Computing	Cloud Data Centre	• Resource management with virtualization. • Orchestrating with renewable energy, energy conservation and waste heat utilization. • Resource scheduling with path-breaking evolutionary algorithms	Mann et al. (2012); Sarood et al. (2012); Biran et al. (2012); Wang et al. (2012); Xiao et al. (2013); Jing et al. (2013); Kołodziej et al. (2013); Ebrahimi et al. (2014); Deng et al. (2014); Arroba et al. (2014); Huang et al. (2014); Tso et al. (2014); Zhang et al. (2014); Manvi and Shyam (2014); Wierman et al. (2014); Woodruff et al. (2014); Oró et al. (2015); Ali et al. (2015); Huang et al. (2015); Varasteh and Goudarzi (2015); Gutierrez-Estevez and Luo (2015); Hasan et al. (2015); Tarplee et al. (2015); Patel et al. (2015); Shailendra and Singh (2016); Yu et al. (2016); Vallejos et al. (2016); Shuja et al. (2016); Prakash et al. (2016); Choudhary et al. (2016); Madni et al. (2016); Meena et al. (2016); Tso et al. (2016); Davies et al. (2016); Khalaj et al. (2017); Khosravi et al. (2017); Shuja et al. (2017); Toosi et al. (2017); Ali and Shrestha (2017); Nada et al. (2017); Watson and Venkiteswaran (2017); Wan et al. (2018); Srichandan et al. (2018); Yang et al. (2018); Lin et al. (2018); Lykou et al. (2018); Antal et al. (2018); Mohamed et al. (2018); Liu et al. (2018); Jangiti and Sriram (2018); DeLovato et al. (2019); Usman et al. (2019); Haghighi et al. (2019); Al-Tarazi and Chang (2019); Peng et al. (2020); Moazamigoodarzi et al. (2020); Tarafdar et al. (2020); Zheng et al. (2020); Samriya and Kumar (2020); Anthony et al. (2020); Dvorak et al. (2020); Jin et al. (2020); Koot and Wijnhoven (2021); Zhuang and Ghouchani (2021); Kang et al. (2021); Ali et al. (2021); Chandra et al. (2021); Jorge-Martinez et al. (2021); Mohammadzadeh et al. (2021); Subbaraj et al. (2021); Monireh et al. (2022); Cao et al. (2022); Strazzabosco et al. (2022); Lumbreras et al. (2022); Ljungdahl et al. (2022).
Mobile Computing	Smart Phone	• Dynamic frequency scaling	Khune and Thangakumar (2012); Aggarwal and Abdelzaher (2013); Ahmad et al. (2015); Aslam et al. (2015); Xu et al. (2015); Begum et al. (2015); Baccarelli et al. (2016); Torous and Roberts (2017); Shuja et al. (2017); Tiwary et al. (2018); Chen et al. (2019); Dong et al. (2019); Kumar and Naik (2021); Alsamhi et al. (2021).

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	Mobile Cloud Computing	• Computational offloading. • Energy bug handling. • Energy efficient application development.	Shabtai et al. (2012); Lide Zhang et al. (2012); Pathak et al. (2012); Tian et al. (2013); Roy et al. (2013); Jing et al. (2013); Gautam and Akashe (2013); Chen et al. (2013); Hao et al. (2013); Jacquet et al. (2014); Boukettaya and Krichen (2014); Wang et al. (2014); Li and Halfond (2014); Gove (2014); Abbasi et al. (2015); Iwai (2015); Luporini et al. (2015); Avvari et al. (2015); Altamimi et al. (2015); Geng et al. (2016); Hoque et al. (2016); Liu et al. (2016); Banerjee et al. (2017); Shuja et al. (2017); Cruz and Abreu (2017); Hoque et al. (2017);Mao et al. (2017); Madhu et al. (2017); Pereira et al. (2017); Tamkittikhun et al. (2017); Vijayaraghavan et al. (2017); Reuben et al. (2017); Lakshmi et al. (2018); Ielmini and Wong (2018); Ganatra et al. (2018); Maute et al. (2018); Wu (2018); Akherfi et al. (2018); Yousafzai et al. (2019); Cruz and Abreu (2019); Boukoberine et al. (2019); Pramanik et al. (2019); Guliani and Swift (2019); Talal et al. (2019); Sidartha et al. (2019); He et al. (2019); Petersen et al. (2019); Palomba et al. (2019); Farooq et al. (2019); Ahmad et al. (2019); Georgiou et al. (2019); Kortbeek et al. (2020); Sarrafan et al. (2020); Balasingam et al. (2020); Mikulics et al. (2020); Shirvani et al. (2020); Wu et al. (2020); Satyaraj and Bhanumathi (2021); Mansour et al. (2021); Seo et al. (2021); Le (2021); Mehrotra et al. (2021); Maray and Shuja (2022); Hossain et al. (2022).
Internet-of-Things	RFID	• RFID tag sizes should be reduced. • Using communication algorithms and protocols	Duroc et al. (2012); Kong et al. (2014); Vahedi et al. (2014); Shaikh et al. (2015); Al-Fuqaha et al. (2015); Luvisi (2016); Arshad et al., 2017; Arshad et al. (2017); Moraru et al. (2017); Nowakowski (2018); Kamaludin et al. (2018); Shan et al. (2018); Sen et al. (2019); Kumar et al. (2019); Waltho et al. (2019); Kantareddy et al. (2019); Poongodi et al. (2020); Asci et al. (2020); Bhuiyan et al. (2021); Muzamane and Liu (2021); Albreem et al. (2021); Mabad et al. (2021); Farhan et al. (2021); Flanagan and McGovern (2022); Popli et al. (2022); Benhamaid et al. (2022); Tupe et al. (2022).

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	WSN	• Sleep mode activation during sensor idle time. • Wireless charging mechanisms that harvest environmental mechanisms. • Radio optimization. • Energy efficient routing and data collection are utilized for GWSN.	Fourty et al. (2012); Pedram (2012); Rodenas-Herraiz et al. (2013); Sheng et al. (2013); Aldeer (2013); Catarinucci et al. (2014); Kumar and Hancke (2014); Jeon et al. (2014); Cinquini et al. (2014); Shaikh et al. (2015); Al-Fuqaha et al. (2015); Catarinucci et al. (2015); LaPre et al. (2015); Zhu et al. (2015); Kang et al. (2016); Khan et al. (2016); Rekik et al. (2017); Syed et al. (2017); Shuja et al. (2017); Gomes et al. (2017); Gomes et al. (2017); Ha et al. (2017); Arshad et al. (2017); Sundaran et al. (2017); Wang et al. (2018); Singh et al. (2018); Weekly et al. (2018); Galmés and Escolar (2018); Osanaiye et al. (2018); Almobaideen et al. (2019); Aranzazu-Suescun and Cardei (2019); Kumar et al. (2019); Waltho et al. (2019); Alsamhi et al. (2019); Poongodi et al. (2020); Amutha et al. (2020); Gurusamy and Abas (2020); Bhuiyan et al. (2021); Loganathan and Arumugam (2021); Albreem et al. (2021); Yuan et al. (2021); Tupe et al. (2022).
	M2MC	• Intelligently adjustment of transmission powers. • Developing energy-efficient routing protocols. • Scheduling the activity in the machine domain. • Using energy harvesting techniques.	Alam et al. (2013); Giluka et al. (2014); Shaikh et al. (2015); Zhu et al. (2015); Al-Fuqaha et al. (2015); Ali et al. (2016); Shah and Yaqoob (2016); Li et al. (2017; Li et al. (2017); Xia et al. (2017); Twayej and Al-Raweshidy (2017); Yang et al. (2017); Arshad et al. (2017); Shah and Narmavala (2018); Montori et al. (2018); Farhan et al. (2018); Zhou et al. (2019); Kumar et al. (2019); Ni et al. (2019); Waltho et al. (2019); Poongodi et al. (2020); Bhuiyan et al. (2021); Romeo et al. (2020); Chaudhari et al. (2020); Albreem et al. (2021); Tupe et al. (2022); Dogra et al. (2022).
Big Data Analytics	Data Management Systems	• Outsourcing. • Green-Plum. • Green-Hadoop.	Xinhua et al. (2013); Wang and Khan (2013); Wu et al. (2014); Ahmed and Sabyasachi (2014); Elgendy and Elragal (2014); Mathew et al. (2014); Molla et al. (2014); Yang et al. (2014); Soliman et al. (2014); Tanwar et al. (2015); Mathew and Pillai (2015); Chen et al. (2015); Cheng et al. (2015); Shortall et al. (2015); Al-Jarrah et al. (2015); Fais et al. (2016); Wu et al. (2016); Mehmood et al. (2016); Hashem et al. (2016); Beneventi et al. (2017); Arshad et al. (2017); Shuja et al. (2017); Ahmed et al. (2017); He et al. (2017); Rehman et al. (2018); Wu et al. (2018); Wang et al. (2018); Kumari et al. (2018); Netto et al. (2018); Gu et al. (2018); Qiao et al. (2018); Tryfonos et al. (2018); Stergiou et al. (2018); Huang et al. (2018); Dash et al. (2019); Xu et al. (2019); Yassine et al.

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			(2019); Ganesan et al. (2020); Vrchota et al. (2020); Aceto et al. (2020); Miao et al. (2020); Jin et al. (2020); Thein et al. (2020); Jiang et al. (2020); Sandhu (2021); Valaskova et al. (2021); Benzidia et al. (2021); Awaysheh et al. (2021); Khashan (2021); Lv et al. (2021); Lyu et al. (2021); Liu et al. (2021); Bibri and Krogstie (2021); Oikonomou et al. (2021); Giudice et al. (2021); Karaaslan and Gezen (2022).
Networking	Networks	• Energy efficient protocols for routing. • Adaptive Link Rate (ALR) techniques.	Zeadally et al. (2012); Çavdar and Alagoz (2012); Bilal et al. (2013); Chen et al. (2013); Jain and Paul (2013); Soares et al. (2014); Wu et al. (2015); Tang and Pan (2015); Zhang and Hämmäinen (2015); Yan and Yu (2015); Haque and Abu-Ghazaleh (2016); Rawat and Reddy (2016); Duan et al. (2016); Herrera and Botero (2016); Taleb et al. (2017); Tao et al. (2017); Tuysuz et al. (2017); Son et al. (2017); Liang et al. (2017); Yousaf et al. (2017); Popoola and Pranggono (2018); Luitel and Moh (2018); Hsieh et al. (2018); Prajapati et al. (2018); Demirci et al. (2018); Afolabi et al. (2018); Son and Buyya (2018); Chaudhary et al. (2018); Ma et al. (2018); Assefa and Özkasap (2019); Jarrahi and Sawyer (2019); Caprolu et al. (2019); Toosi et al. (2019); Montazerolghaem et al. (2020); Abuarqoub (2020); Kiran et al. (2020); Sun et al. (2020); Chen (2020); Kaur et al. (2020); Hypolite et al. (2021); Yang and Gu (2021); Rathore et al. (2021); Hu et al. (2021); Alam et al. (2021); Prabakaran et al. (2022).
Blockchain Technology	Use Cases	• Distributed ledger. • P2P. • Green certificates.	Nærland et al. (2017); Clemons et al. (2017); Iansiti and Lakhani (2017); Dai and Vasarhelyi (2017); Kewell et al. (2017); Bano et al. (2017); Zhang et al. (2017); Castellanos et al. (2017); International Energy Agency (2018); Gürcan et al. (2018); Rogers (2018a); Rogers (2018b); Kawabata (2018); Beck et al. (2018); Katuwal et al. (2018); Zhang, et al. (2018); Issaoui et al. (2019); Andoni et al. (2019); Cong and He (2019); Casino et al. (2019); Jaoude and Saade (2019); McGhin et al. (2019); IEA (2019); Huang et al. (2020); Schletz et al. (2020); Alam et al. (2020); Ali et al. (2021); Jaradat et al. (2022); Riđić et al. (2022); Francisco Luis et al. (2022).
Artificial Intelligence	Neural Networks	• Learning automata	Bogdanov et al. (2013); Siomau (2014); Mirjalili (2015); Andri et al. (2016); Mrazek et al. (2016); Nurvitadhi et al. (2016); Chen et al. (2016); Benini (2017); Azzouni et al. (2017); Ding et al. (2018); Mohammadi et al. (2018); Boutaba et al. (2018);

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			Biswas and Chandrakasan (2018); Neftci (2018); Fyrbiak et al. (2018); Javaid et al. (2018); Shafik et al. (2018); Qiqieh et al. (2018); Zhong et al. (2018); Wu et al. (2019); Wang et al. (2019); Yaseen et al. (2019); Li et al. (2019); Gooneratne et al. (2020); Lei et al. (2020); Khan et al. (2020); Shafik et al. (2020); Zhao et al. (2022); Zhang et al. (2022); Misra et al. (2022); Armeniakos et al. (2022).

4. Research Discussion

4.1. Cloud Computing

This technology has demonstrated its effectiveness as a facilitator for a wide range of IT services (Ali et al., 2015). The increasing demand for cloud-based IT services and applications highlights the necessity for advanced data centers capable of accommodating multiple web servers, storage units, and network devices, collectively referred to as CDCs (Tso et al., 2014; Gutierrez-Estevez & Luo, 2015; Tso et al., 2016). These CDCs offer a variety of services ranging from high-performance computing to extensive data analytics for end-users (Shuja et al., 2017). These large-scale CDCs are strategically located in various zones to ensure consistent distribution, meet user requirements, and account for a significant portion of total IT energy consumption (Wierman et al., 2014; Shuja et al., 2016; Koot & Wijnhoven, 2021).

Furthermore, there is a shift in IT services from single-server operations to rack-mounted blade servers. This evolution in server design has increased electronic densities, power consumption, and subsequently, heat dissipation (Ebrahimi et al., 2014; Shuja et al., 2016; Moazamigoodarzi et al., 2020). It is noted that an idle server can consume up to 70% of the power consumed by a server running at full CPU speed (Arroba et al., 2014; Lin et al., 2018; Jin et al., 2020). Additionally, many servers within data centers are underutilized or not used at all, with studies estimating that around 10% of servers in data centers were never utilized (Varasteh & Goudarzi, 2015).

The utilization of direct energy and cooling energy in CDCs contributes to an increasing demand for such centers (Davies et al., 2016; Khalaj et al., 2017). Approaches towards environmentally friendly or "green" operations of CDCs can be broadly categorized into four groups: resource management through virtualization, sustainability through renewable energy and waste heat utilization, and resource scheduling using state-of-the-art evolutionary algorithms (Patel et al., 2015; Shailendra & Singh, 2016; Haghighi et al., 2019; Oró et al., 2015; Lykou et al., 2018; Meena et al., 2016; Jangiti & Sriram, 2018). Virtualization plays a crucial role in consolidating CDC resources, allowing for efficient resource management and energy optimization (Nam et al., 2017). This virtualization layer facilitates the organization and integration of CDC resources through various techniques such as resource migration and snapshotting (Shuja et al., 2017).

Sustainability initiatives in green computing aim to reduce the environmental impact of CDC operations, with efforts towards zero greenhouse gas emissions through the adoption of renewable energy sources (Zheng et al., 2020; Cao et al., 2022). The reusability of resources and efficient management of cooling systems in CDCs are significant goals in green computing practices (Prakash et al., 2016). Strategies such as utilizing heat emissions for other purposes, like cooling processes or district heating, are being explored to enhance the sustainability of CDC operations (Nada et al., 2017; Wan et al., 2018; Ljungdahl et al., 2022).

In conclusion, cloud data centers aim to provide IT services through an optimized pay-as-you-go model (Ali et al., 2021). Green cloud computing solutions focus on energy-efficient resource allocation and task optimization, often employing graph and tree-based structures to represent network, processor, and storage devices, as well as user tasks (Madni et al., 2016). Optimization models for cloud services prioritize task completion time and cost reduction while addressing energy consumption concerns (Samriya & Kumar, 2020). The challenge lies in balancing task completion time and energy consumption in multi-resource CDCs, which requires sophisticated optimization models and the utilization of evolutionary algorithms to find optimal solutions (Peng et al., 2020; Subbaraj et al., 2021).

4.2. Mobile Computing

Modern smartphones are equipped with substantial storage capacity and computational capabilities to handle resource-intensive tasks (Dong et al., 2019), reducing the reliance on stationary/desktop servers for computation (Xu et al., 2015; Tiwary et al., 2018). This advancement has increased the resource demands of smartphones (Torous & Roberts, 2017). The emergence of sensory-rich and media-rich smartphone tools and applications often utilizes features like GPS, accelerometers, and wireless radios to provide context-aware services, leading to increased operational, communicative, and energy requirements (Shuja et al., 2017). To address the trade-off between energy consumption and output, there is a pressing need for the development of energy-efficient systems (Chen et al., 2019; Kumar & Naik, 2021). Forecasting energy usage can help in designing efficient smartphone applications and system frameworks, enabling the identification of problematic applications and maintaining system integrity (Aslam et al., 2015; Alsamhi et al., 2021).

Enhancements in the design of smartphone hardware components can contribute to energy efficiency (Ganatra et al., 2018). The structural composition of the hardware components embedded in smartphones, such as Complementary Metal-Oxide-Semiconductor (CMOS), plays a crucial role in power consumption, comprising static and dynamic power consumption (Madhu et al., 2017; Lakshmi et al., 2018). Static power consumption is device-specific and pertains to the power consumed when a transistor is not in a switching state, while dynamic power consumption relates to power consumption during transitions between logic states (Reuben et al., 2017; Mikulics et al., 2020). Techniques like power gating and dynamic frequency scaling (DFS) are employed to manage power consumption in components like CPUs, optimizing energy usage while considering performance trade-offs (Sidartha et al., 2019; Shirvani et al., 2020). Addressing components that continue to consume power despite task completion, such as Wi-Fi and GPS functions, is crucial for extending battery life and efficient smartphone operation (Geng et al., 2016; Cruz & Abreu, 2017). Various software tools, like E-prof, are available to monitor smartphone energy consumption at a detailed level, influencing overall energy usage due to their profiling activities (Shuja et al., 2017).

Software-based green computing solutions play a significant role in managing the energy budget of smartphones, including mobile cloud computing for computational offloading, energy bug handling, energy monitoring, and optimization strategies (Pramanik et al., 2019; Mansour et al., 2021). These solutions enable smartphones to connect energy-intensive functions to remote cloud servers, enhancing device longevity and efficiency (Wu et al., 2020; Maray & Shuja, 2022). Energy bug detection and resolution are essential to address abnormal power consumption issues caused by defective components or application errors (Cruz & Abreu, 2019). Software tools like Automatic Detector of Energy Leaks (ADEL) are employed to identify energy bugs and control power inefficiencies in applications, placing additional responsibilities on programmers to deploy power management measures and ensure efficient operations (Georgiou et al., 2019; Kortbeek et al., 2020).

Smartphone energy estimation serves as the foundation for green computing practices, providing valuable feedback to developers for energy-conscious application development (Farooq et al., 2019). Various methods, such as component power modeling and code analysis, are used for estimating energy consumption in smartphone applications, utilizing techniques like state-of-charge prediction and base-cost energy analysis (Mehrotra et al., 2021). These approaches help in forecasting energy consumption patterns and guiding hardware or software improvements for achieving green smartphone operations (Pereira et al., 2017). The intricacies of energy consumption reduction through efficient code design and resource optimization techniques play a key role in maintaining sustainable smartphone operations (Vijayaraghavan et al., 2017).

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4.3. Internet of Things

Communication among various electronic devices without human and computer intervention is largely facilitated by the latest IoT technology (Kumar et al., 2019). Green IoT refers to a series of protocols implemented by IoT to enhance hardware and software efficiency practices (Arshad et al., 2017; Albreem et al., 2021), focusing on improving energy efficiency to reduce the environmental impact of modern services and applications (Poongodi et al., 2020; Tupe et al., 2022). Green IoT strives for eco-friendly operations through green production, redesign, and recycling/disposal practices (Waltho et al., 2019). The deployment of IoT technology involves enabling technologies, communication strategies, and embedded protocols, necessitating a discussion on benchmarking communication technologies and strategies in the context of green IoT.

4.3.1. Green Radio-Frequency Identification

Radio Frequency Identification (RFID) is a key enabler of IoT, consisting of RFID tags and readers (Flanagan & McGovern, 2022; Asci et al., 2020). RFID tags, equipped with radio-enabled microchips, act as transceivers, each bearing a unique ID and storing contextual data. These tags respond to queries from RFID tag readers, with a transmission range typically within a few meters and utilizing frequencies ranging from 124-135 kHz to ultra-high frequencies of 860-960 MHz (Muzamane & Liu, 2021). RFID tags are available in active and passive types, with active tags powered by embedded batteries and passive tags deriving power from reader signals.

To achieve green RFID practices, reducing tag size is essential to enhance recyclability, minimize non-degradable material use, and introduce sustainable options like printable, paper-based, and biodegradable RFID tags (Nowakowski, 2018; Sen et al., 2019). Energy-efficient communication algorithms and protocols are crucial for green IoT, focusing on dynamic power transmission adjustments, optimized tag estimation, and mitigating tag conflicts and unnecessary data receipt to conserve energy (Farhan et al., 2021; Popli et al., 2022; Benhamaid et al., 2022).

4.3.2. Green Wireless Sensor Network

Wireless Sensor Networks (WSNs) consist of resource-constrained nodes with limited computing, storage, and power capabilities, connected to a central sink node (Osanaiye et al., 2018; Almobaideen et al., 2019). These sensor nodes are equipped with sensors that monitor environmental conditions like humidity, temperature, and acceleration. IEEE 802.15.4 standard-based commercial WSN products employ energy-saving practices such as sleep mode activation, wireless charging mechanisms, radio optimization, and power-efficient routing strategies for green WSN operation (Gomes et al., 2017; Galmés & Escolar, 2018; Alsamhi et al., 2019; Gurusamy & Abas, 2020).

Cluster heads gather sensor data and transmit it to the sink node, leading to increased energy consumption near the sink due to heavy data aggregation. Optimizing energy usage involves periodic reporting, avoiding continuous monitoring to conserve energy and efficient content synchronization among nodes to reduce energy spikes (Yuan et al., 2021). Timely reporting intervals can minimize energy spikes associated with event-driven data reporting without the need for frequent message broadcasts to synchronize sensors.

4.3.3. Green Machine-to-Machine Communication

Machine-to-Machine (M2M) communication plays a crucial role in IoT, involving M2M and network domains for data aggregation and transmission to base stations (Shah & Yaqoob, 2016; Romeo et al., 2020). Energy consumption is a significant challenge in M2M interactions, prompting the need for energy-efficient practices such as optimized transmission power management, energy-efficient routing, intelligent task scheduling, and energy harvesting protocols (Xia et al., 2017; Chaudhari et al., 2020; Twayej & Al-Raweshidy, 2017; Dogra et al., 2022). (c) scheduling tasks on machine domain (Ali et al., 2016; Shah & Narmavala, 2018), and (d) banking on energy harvesting protocols (Yang et al., 2017; Zhou et al., 2019).

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4.4. Big Data Analytics

According to Sandhu (2021), the era of big data introduces new challenges, such as rapidly expanding petabyte-scale structured and unstructured datasets with diverse forms. Achieving value optimization for decision-making in big data analytics faces major hurdles in terms of quick data retrieval and accurate search within vast data pools (Ahmed et al., 2017; Wang et al., 2018). Traditional data management systems struggle to store, handle, and analyze big data effectively, leading to the emergence of NoSQL technology to offer tailored solutions for efficient data retrieval and processing (Wang et al., 2018). Given the substantial size of data packets in big data analytics, green and environmentally friendly protocols are essential to compute, scale, and store data efficiently, requiring ample main memory availability and rapid communication mediums accessible through local physical or enterprise cloud servers (Hashem et al., 2016). Thus, ensuring resource efficiency, minimal energy consumption, and scalability of infrastructure is crucial for sustainable green big data analytics (Beneventi et al., 2017; Ganesan et al., 2020).

The application of big data analytics demonstrates its potential to optimize resource processing and storage capabilities, enabling scalability and improved productivity (Dash et al., 2019; Valaskova et al., 2021). Fundamental prerequisites such as high storage availability, technological reliability, and consistency are pivotal for the development and infrastructure of big data technology (Kumari et al., 2018; Benzidia et al., 2021). However, energy conservation and resource optimization aspects, integral to green computing, are often underexplored in recent literature (Vrchota et al., 2020). Cloud computing, a key big data technology, offers outsourced infrastructure that minimizes physical storage space requirements, facilitates multiple user access, and supports efficient storage solutions (Netto et al., 2018; Awaysheh et al., 2021). Cloud-based interfaces reduce reliance on personal computers and promote resource sharing, conservation, and low-energy consumption for high computational processes in big data analytics (Xu et al., 2019; Khashan, 2021). Cloud computing significantly contributes to enabling green big data analytics by enhancing energy efficiency and optimizing resource utilization (Yassine et al., 2019; Lv et al., 2021).

The move towards green big data analytics is evident through innovations like Green-Plum and Green-Hadoop, offering sustainable computing solutions for big data analytics (Miao et al., 2020; Shuja et al., 2017; Wu et al., 2018). Green-Plum, an open-source data warehouse under Apache Inc., facilitates rapid analytics on large-scale datasets through parallel processing and optimized query handling (Jin et al., 2020). Its cost-based query optimization feature ensures efficient data processing, enabling the analysis of extensive datasets with optimal resource utilization (Lyu et al., 2021). Green-Hadoop emphasizes the use of renewable energy sources to balance energy demand and supply for big data analytics (Cheng et al., 2015). This technology integrates solar energy forecasts and grid resources to optimize energy usage by aligning MapReduce jobs accordingly (Shuja et al., 2017). Green-Hadoop supports both batch and interactive processing modes, while real-time energy forecasting is based on historical data center workload trends (Tryfonos et al., 2018).

In sum, green big data analytics leverage cloud computing technology to maximize resource efficiency while minimizing energy consumption (Stergiou et al., 2018). Big data serves critical analytical needs across various sectors such as social networks, healthcare, industry, commerce, and corporate enterprises, facilitating prompt decision-making through data insights (He et al., 2017). Cloud-based data centers and processors play a vital role in storing and processing large volumes of data, offering green analytics solutions (Rehman et al., 2018; Thein et al., 2020). Future projections indicate cloud computing's potential to reduce energy consumption significantly, paving the way for renewable energy technologies to become more cost-effective and efficient energy sources for sustainable big data analytics solutions (Jiang et al., 2020; Karaaslan & Gezen, 2022).

4.5. Networking

Computational networks have played a pivotal role in shaping significant advancements in human civilization over the past few decades (Jarrahi & Sawyer, 2019). With the increasing integration of IT technologies and services across various industries, these networks have become

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more intricate, establishing connections between devices globally (Yang & Gu, 2021). Consequently, these networks and the devices within them consume a substantial portion, nearly 10%, of the total IT energy usage (Popoola & Pranggono, 2018). Essential strategies implemented to enhance energy efficiency in these networks include employing energy-efficient protocols for routing, medium access, and hand-off tasks (Luitel & Moh, 2018; Rathore et al., 2021) as well as Adaptive Link Rate (ALR) techniques aimed at adjusting link rates and utilizing hibernation states for energy-efficient computing (Tuysuz et al., 2017; Assefa & Özkasap, 2019).

Software and virtualization technologies have significantly influenced the advancement of energy efficiency in networking technologies (Hsieh et al., 2018; Montazerolghaem et al., 2020). Software-Defined Networks (SDN) separate data and control functions of network routers using a centralized controller (Prajapati et al., 2018; Abuarqoub, 2020), indirectly impacting energy consumption. The programmable interface of SDN indirectly promotes energy-efficient network operations through resource consolidation methodologies (Hu et al., 2021). Resource optimization techniques can help identify the most energy-efficient subset of network resources and can be implemented through SDN (Son et al., 2017; Kiran et al., 2020). In addition to virtualization and SDN enabling technologies, server and network resource management techniques are also utilized (Afolabi et al., 2018). SDN at the network level can facilitate the implementation of green computing policies on its programmable control plane (Liang et al., 2017). Moreover, the security functions enabled by SDN network devices can contribute to reducing operational costs and energy consumption (Son & Buyya, 2018; Chaudhary et al., 2018).

Another notable technological advancement in telecommunications is Network Function Virtualization (NFV) (Yousaf et al., 2017), which separates network forwarding and routing functions from underlying physical systems (Alam et al., 2021). NFV allows network functions like Firewalls to be executed in software form (virtual network function) on standard servers, enhancing flexibility and cost-efficiency in various IT services, particularly cloud computing services (Taleb et al., 2017). The decoupling of networking functions from physical devices through virtualization enables dynamic resource scheduling, enhancing energy efficiency (Tao et al., 2017; Sun et al., 2020). Several studies have observed energy savings and improved efficiency with NFV-based networking systems in comparison to traditional networks (Ma et al., 2018; Toosi et al., 2019; Chen, 2020). Achieving a balance between network function performance and energy efficiency is essential in the context of virtualization.

While Software Defined Networking (SDN) and Network Function Virtualization (NFV) are still evolving technologies (Yousaf et al., 2017; Kaur et al., 2020), there is a critical need for further research and development in green computing architectures utilizing these technologies, with promising possibilities for integration with other emerging technologies.

4.6. Blockchain Technology

Blockchain, also known as distributed ledger technology, represents an innovative method of data storage in which all data is shared among network participants (Jaradat et al., 2022). These participants are represented by network nodes that store, verify, transfer, and communicate data (Huang et al., 2020). Through these nodes, each participant has access to the ledger, encompassing the full history of network transactions (Dai & Vasarhelyi, 2017; Kewell et al., 2017). Nodes operate under the consensus rules of the blockchain network, establishing consensus among the network nodes when a new transaction complies with network rules and is validated against the ledger history (Bano et al., 2017). In blockchain systems, valid transactions are aggregated into a "block" and cryptographically linked to the existing chronological "chain" of blocks in the ledger (Schletz et al., 2020). This combination of cryptography, timestamping, and hashing ensures the ledger's history is tamper-resistant and highly secure (Andoni et al., 2019; Cong & He, 2019).

The rapid advancements in digital technologies and growing consumer interest in energy efficiency present significant opportunities to transition to a low-carbon energy system. Recently, distributed ledger technologies, particularly blockchain, have gained substantial attention for

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enhancing the security, transparency, and sustainability of the energy sector. Blockchain has been extensively discussed in the context of peer-to-peer (P2P) energy trading, with numerous articles and early product offerings exploring this concept (Andoni et al., 2019; Alam et al., 2020; Zhang et al., 2017). However, our review indicates that blockchain's application to energy efficiency remains largely conceptual and unexplored, with limited literature on the subject. This section aims to highlight key works where the concept has been discussed.

Energy Service Companies (ESCOs) are investigating potential blockchain applications to simplify energy performance contracting (EPC) (Rogers, 2018a). The prevalence of EPC business models has significantly increased in recent years (IEA, 2019), becoming a popular method for improving building energy efficiency. The EPC model involves multiple stakeholders who maintain their own records of energy baseline data, technology implementation costs, project expenses, and energy savings, leading to potential disputes when payments are due. The smart contract feature of blockchain can significantly reduce transaction costs, enabling ESCOs to undertake smaller projects by lowering the time and costs associated with setting up and managing each EPC (Rogers, 2018a). This could increase the number of ESCO projects and the total energy savings achieved. A study by Gürcan et al. developed a prototype where blockchain technology was applied to EPC, eliminating the need for third-party auditors to verify large volumes of baseline and actual consumption data (Gürcan et al., 2018). Ethan (Rogers, 2018b) has discussed how blockchain could enhance the valuation of energy efficiency by encrypting and sharing energy savings over a blockchain platform, thus improving market transparency, information security, and service reliability. The American Council for an Energy-Efficient Economy (ACEEE) is also exploring how blockchain can improve the measurement and verification process and facilitate a more dynamic energy market (Rogers, 2018b). Kawabata (2018) has examined how blockchain technology could enhance supply-side energy efficiency and address energy poverty through a decentralized energy system.

In the realm of energy-related certification schemes, a recent study explored the potential of using blockchain to trade Guarantee of Origin (GoO) certificates, also known as green certificates (Castellanos et al., 2017). These certificates, issued by regulators to renewable energy generators for each megawatt-hour (MWh) of certified renewable energy produced, record details such as when, where, how, and by whom the energy was generated, as well as ownership of the associated green assets. Although the process of transacting these certificates is cumbersome and opaque, the study by Castellanos et al. demonstrated that blockchain can ensure the authenticity of green certificates, enhance system transparency, and reduce transaction costs by eliminating the need for a third-party regulator to manage the scheme (Castellanos et al., 2017).

Energy efficiency holds substantial potential for delivering positive impacts. According to the International Energy Agency's Energy Efficiency 2018 report, improving energy efficiency could reduce consumer energy bills by over $500 billion annually (International Energy Agency, 2018). As blockchain technology evolves, it could enable consumers to trade their excess energy, providing additional incentives for energy savings and home energy efficiency improvements. As the energy efficiency market grows, blockchain technology could significantly enhance administrative processes, transparency, costs, and trust among stakeholders. Key benefits include:

- **Encryption of energy savings:** Encrypting energy savings data and sharing it over a blockchain can secure the energy efficiency market by preventing unauthorized access. Energy baseline and savings data are crucial assets, underpinning various transactions from bank payments to fees for energy service companies and technology providers. Securing this data is critical in today's digitalized world, and blockchain offers a solution for protecting customer energy savings data.
- **Exchange of energy savings:** Beyond P2P energy trading of excess electricity generation, blockchain technology holds potential for trading energy savings within local communities. Energy savings data could be encrypted and stored on a blockchain platform, enabling transactions for balancing energy bills or purchasing additional energy services.

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4.7. Artificial Intelligence

Advances in sensing devices have enabled a shift towards the fourth industrial revolution (Gooneratne et al., 2020). The large volume of data produced by these devices is pushing the technology front of a new generation of AI for IoTs applications (Misra et al., 2022). These applications are expected to make important decisions in the real world instantaneously rather than offloading data to the cloud servers (Javaid et al., 2018; Wu et al., 2019; Zhao et al., 2022). Such a step change in technology requires significant strides in energy efficiency, which continues to be a primary design challenge for IoT hardware designers (Biswas & Chandrakasan, 2018; Neftci, 2018).

Existing AI systems predominantly follow the principle of neural networks (NNs). Originally inspired by Rosenblatt's neural automaton in 1957 (Lei et al., 2020), modern NNs have evolved in complexity across different application domains (Boutaba et al., 2018). Typically, NNs define a learning problem by finding the weighted sum of all inputs in the training phase, organized in multiple layers (Azzouni et al., 2017). The weight updates are defined by a normalized activation function and are performed through rigorous gradient descent exercises. When implemented in hardware, the modular electronic neurons require arithmetic-heavy circuits, such as multiply–accumulate (MAC) units (Yaseen et al., 2019; Lei et al., 2020). The number of these units can quickly grow with more inputs and added complexity of the learning problem (Benini, 2017). Given such a scale of arithmetic complexity, achieving required energy efficiency and performance in NNs can be daunting, which is exacerbated further by the large volume of data generated by IoT devices (Wang et al., 2019; Khan et al., 2020).

Over the last two decades, significant progress has been made in energy-efficient NN hardware research (Ding et al., 2018). A vast majority of the existing work have considered pruning arithmetic complexity to save energy by exploiting the natural resilience of AI applications to minor deviations or error (Li et al., 2019; Armeniakos et al., 2022). Examples include precision scaling (Wang et al., 2019), approximate logic designs (Shafik et al., 2018; Qiqieh et al., 2018), new analogue or mixed-signal circuit designs and hardware/software co-design for NNs (Zhong et al., 2018; Lei et al., 2020). Recently, there have been overwhelming interests in moving away from arithmetics to using binary logic as the core building blocks (Fyrbiak et al., 2018). Binarized neural networks (BNNs) are an example of this development (Nurvitadhi et al., 2016). The key goal is to condense advanced AI workloads with low-energy footprints. However, this can make the learning process (i.e. accuracy and convergence) sensitive to how gradient descent is designed, which is still arithmetic based (Mohammadi et al., 2018; Zhang et al., 2022).

Recently, the Tsetlin machine has been proposed as a promising machine learning (ML) algorithm based on learning automata. The Tsetlin machine simplifies the traditional learning automata by discrete-step action updates through Tsetlin automata, defined as the finite automata with linear tactics. For action updates, each Tsetlin automaton uses rewards for reinforcing an action and penalties for weakening the automaton confidence in performing the action. This discretization with linear step updates allows for formulating the learning problem using powerful propositional logic (Lei et al., 2020); furthermore, it simplifies the learning mechanism, enabling efficient on-chip learning. The input data in a Tsetlin machine are encoded in binarized form as a set of propositional logic variables, called literals. These literals are used to build the logic expressions corresponding to inference classes through ensembles of parallel Tsetlin automata, called clauses, during training (Shafik et al., 2020). When training is completed, the inference outputs are described by binarized classifications.

The logic-based structure of Tsetlin machines provides opportunities for energy-efficient AI hardware design. This will require addressing the major challenges of the systematic architecture allocation of low-level resources as well as parametric tuning and data binarization, which cannot be achieved by using high-level synthesis or hardware-assisted acceleration tools.

5. Research Implications

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This systematic literature review leads us to highlight several key implications for future research for the greening of IT technologies.

5.1. Implications to Theory

This research delves into a comprehensive analysis of energy consumption sources and greenhouse gas emissions stemming from various IT technologies. A significant aspect of this study is to enhance our comprehension of the energy-saving potential inherent in each technology, as well as to explore strategies for cross-technology adoption. By elucidating the intricate interconnections and interdependencies among different IT technologies, this paper sheds light on the significance of informed decision-making in balancing high-performance expectations with the imperative to reduce resource consumption, streamline communication, and simplify computing operations. The foundational discourse on emerging IT technologies and the imperative for sustainability underscores the necessity of strategic trade-offs to optimize environmental outcomes without compromising operational efficiency.

Moreover, as illustrated in the provided theoretical framework in Table 2, a structured approach is delineated to identify key energy-saving imperatives within IT technologies. The framework serves as a foundational guide for categorizing IT technologies into essential components, facilitating a granular exploration of techniques or algorithms aimed at mitigating power consumption within each category. This structured framework offers a roadmap for researchers and practitioners to navigate the complexities of IT technologies, enabling targeted strategies for maximizing energy efficiency across diverse technological domains.

Furthermore, the convergence of cutting-edge technologies necessitates a nuanced understanding of how IT solutions can seamlessly integrate to drive sustainability and energy efficiency. Building upon this foundational framework, future research should explore innovative approaches for leveraging synergies between different IT technologies to achieve holistic greening goals. Acknowledging the evolving landscape of digital transformation and environmental responsibility, a comprehensive framework incorporating a blend of technological solutions, adaptive methodologies, and cross-domain applications is imperative for optimizing greening initiatives in IT ecosystems.

Moreover, the theoretical underpinnings and practical implications of this study extend beyond energy reduction strategies to encompass broader sustainability objectives. Embracing a holistic perspective on IT greening entails not only enhancing energy efficiency but also promoting sustainable practices, minimizing carbon footprints, and fostering eco-friendly technologies. By synthesizing theoretical insights with empirical findings, researchers can inform the design and implementation of tailored greening strategies that resonate with the evolving needs of the digital landscape.

In essence, the theoretical implications outlined in this study serve as a steppingstone for advancing knowledge in IT greening and sustainable technology practices. By fostering a multidisciplinary approach that integrates theoretical frameworks with practical applications, researchers can propel the discourse on greening IT technologies forward, paving the way for transformative solutions that harmonize technological innovation with environmental stewardship.

5.2. Implications to Research

This study underscores the critical need for a SR to synthesize research on emerging IT technologies within consolidated optimization models to enhance environmental sustainability. Existing literature offers a diverse array of theoretical perspectives on optimizing energy efficiency within specific IT technologies and their components, such as software components or communication layers. Many IT-based applications span multiple technological domains, for instance, a smartphone app functioning on a mobile device interconnected to a cloud server, activating various IT technologies like mobile computing, cloud computing, networking, IoT, and WSNs. Notably, current energy estimation techniques often overlook external factors contributing to

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energy consumption. Conventional energy-saving strategies often adopt a segmented approach, inadvertently overlooking the interconnectedness of different technological layers, user demands for high-quality service, and potential trade-offs between efficiency gains in one area leading to added consumption in another. Delving deeper, the intricate interplay of IT technologies, varying software and hardware components, and performance requirements necessitate a holistic approach to energy optimization strategies for sustainable outcomes. Future research should explore comprehensive energy-saving frameworks that account for the synergies and trade-offs among diverse IT technologies.

Expanding on this, another significant research avenue lies in exploring the transformative potential of IT technologies as tools for energy conservation and reducing carbon footprints across various industries. For instance, the strategic deployment of wireless sensors across power grid networks, despite the initial surge in energy consumption, presents substantial benefits. This system equips electricity providers with actionable insights to optimize power generation and distribution, fostering greater energy efficiency and environmental sustainability. It is crucial to consider the holistic impact of greening initiatives in IT technologies on broader industries, recognizing the intricate dynamics between increased energy consumption for data processing and communication demands vis-a-vis overarching environmental benefits. Researchers are encouraged to develop optimization frameworks that encompass the ripple effects of energy usage changes on diverse sectors, ensuring a comprehensive assessment of the overall greening achievements. While achieving greener outcomes may involve transient spikes in energy consumption due to data processing and communication demands, a systemic approach considering the net environmental implications for various industries is vital to attain optimal and sustainable results.

In essence, the academic community is urged to delve deeper into energy-saving frameworks that embrace the complex interactions among diverse IT technologies and industries, elucidating the interconnected dynamics between energy consumption and greening efforts. By exploring these multifaceted interdependencies, researchers can pave the way for innovative and sustainable IT solutions that drive environmental preservation and resource optimization across broader industrial landscapes.

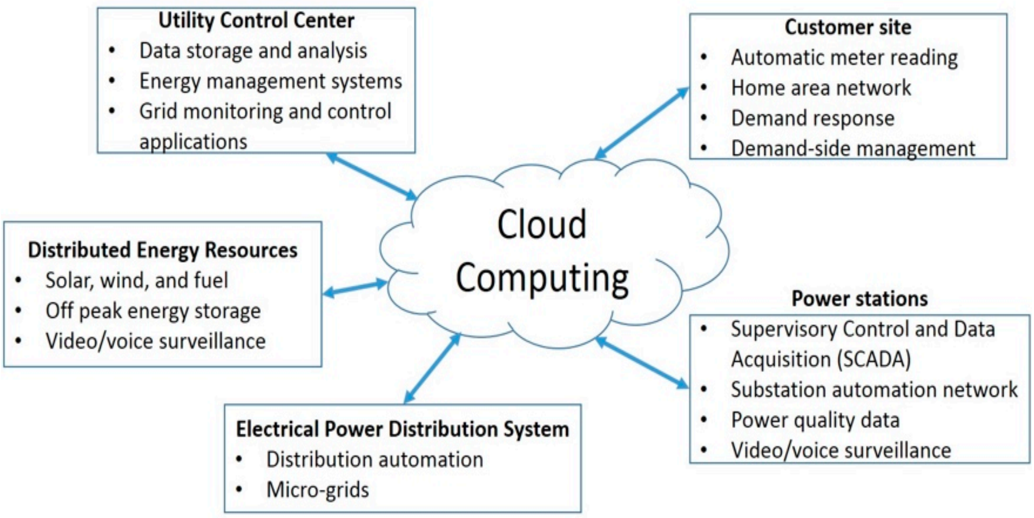

Figure 5. Cloud network – power grid interconnection.

5.3. Implications to Practice

This review study presents crucial practical implications essential for the effective and expedited implementation of greening initiatives within the IT sector. Estimates indicating that the IT industry accounts for approximately 2.4% of global electricity consumption, coupled with its rapid expansion, underscore the significant potential for power savings through the adoption of greening practices

(Koot & Wijnhoven, 2021). The discussion highlights the pivotal role of cloud computing for advancing greening efforts for two primary reasons. Firstly, the expansive scale of the cloud infrastructure makes greening techniques highly impactful (Ali et al., 2020). Secondly, the integration of cloud computing across various IT domains, such as mobile devices leveraging cloud processing capabilities for high-energy operations, underscores its integral role. Technologies like IoT, WSNs, and big data analytics leverage cloud services for data collection, storage, and processing, realizing efficiencies and reducing reliance on personal computers and local servers. Thus, enhancing the sustainability of data centers not only benefits their operations but also cascades into greening other IT technologies.

The integration and widespread adoption of renewable energy sources emerge as a cornerstone in fostering a sustainable environment (Jamal & Khan, 2020). Research indicates that the IT industry has the potential to reduce energy consumption significantly, up to 64%, by embracing renewable energy technologies (Al-Jarrah et al., 2015; Fais et al., 2016). Contemporary research focuses on addressing challenges associated with renewables, such as cost and energy generation unpredictability, offering innovative solutions for wider adoption (Osman et al., 2023). Collaboration among IT companies, organizations, and governmental bodies is imperative in driving the broad deployment of renewable energy sources. Governmental entities and organizations need to establish clear goals, with industry stakeholders working collectively to achieve these targets. Cloud service providers and renewable energy firms stand to benefit from this collaboration, with cloud data centers transitioning to clean energy sources. The symbiotic relationship between renewables and cloud computing facilitates better networking of geographically dispersed renewable energy resources, enabling efficient management, evaluation of performance, maintenance, and expansion plans.

Furthermore, the onus is on software development in driving greening efforts within the IT sector. Simply focusing on providing functionality and rapid response times in software is no longer sufficient. Modern software developers are mandated to possess a deeper understanding of energy consumption patterns and efficiency considerations (Alvi, 2017). Effective software design with energy efficiency as a core objective is pivotal to synergize with energy-aware hardware technologies and advance sustainable IT practices. Incorporating energy analysis models, tools, and energy-aware compilers into the software development process is crucial to optimize energy consumption. Additionally, the development of standardized testing utilities for profiling and benchmarking software applications will enhance the energy efficiency assessment of published software, further aligning software development practices with green IT objectives.

Moreover, the convergence of cloud computing with renewable energy sources presents a prime opportunity to accelerate green initiatives within the IT sector. By leveraging renewable energy and cloud services in tandem, stakeholders can achieve a more sustainable and environmentally conscious ecosystem. This collaborative approach not only enhances the energy efficiency of data centers but also sets a precedent for holistic greening efforts across IT domains. The alignment of cloud technologies with renewable energy sources signifies a pivotal step towards achieving greener IT operations and fostering an eco-friendly digital landscape.

In tandem with the adoption of renewable energy and cloud computing solutions, ongoing advancements in software development practices hold the key to unlocking greater energy efficiency in IT operations. Modern software design must prioritize energy-conscious coding practices, aiming to optimize energy usage and minimize environmental impact. Integrating energy analysis tools and energy-aware compilers into the software development lifecycle empowers developers to infuse energy efficiency considerations into software design, maximizing the sustainability benefits of IT technologies.

In conclusion, a collaborative and multi-faceted approach involving cloud computing, renewable energy sources, and energy-efficient software development practices is pivotal in steering the IT industry toward a greener and more sustainable future. As stakeholders across the IT landscape embrace these practices, they can collectively drive impactful changes towards energy

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efficiency, reduced carbon footprints, and a more environmentally conscious approach to technology innovation. By fostering partnerships, investing in renewable energy technologies, and prioritizing energy-efficient software design, the IT sector can play a pivotal role in advancing environmental sustainability and greener IT practices at a global scale.

6. Research Limitation

This research has two limitations, the first one despite the deployment of a thorough search strategy, some studies on the different advanced technologies that have been presented in this review study were not included, such as gray literature and reports that were not published in the selected databases that were reviewed. The second notable limitation of this systematic review is the scarcity of long-term data and comprehensive assessments of the environmental impact of greening emerging IT technologies. While the literature provides insights into the immediate effects and short-term benefits of adopting green IT practices, there is a gap in understanding the extended, downstream consequences. This limitation arises from the relatively recent adoption of many green IT initiatives, making it challenging to assess their full ecological implications over extended periods. Therefore, the review primarily captures a snapshot of the current state of knowledge, and further research is required to monitor and evaluate the sustainability of green IT solutions over the long term. Longitudinal studies and extended monitoring are essential to gain a more comprehensive understanding of the lasting benefits and potential trade-offs associated with green IT adoption. Additionally, assessing the scalability and applicability of green IT practices across diverse IT ecosystems remains a valuable area for future research. This research limitation highlights the need for more in-depth, long-term studies to fully comprehend the lasting impact of green IT technologies and their scalability in various contexts.

7. Conclusion

The increasing integration and demand for IT technologies are driving higher energy consumption, prompting a global need for more environmentally friendly practices within the industry. In response, researchers and IT professionals have developed various algorithms and protocols to promote sustainability. These strategies include enabling low-power states during idle periods, making energy-conscious decisions, and optimizing resource allocation. However, it's essential to recognize that reducing energy consumption can impact system performance. The extent of energy conservation depends significantly on the specific application's usage, and extremely aggressive energy-saving measures can affect the system's longevity due to frequent power cycling.

Addressing the environmental impact of emerging IT technologies requires a collaborative effort from governments, industries, researchers, and consumers. This endeavor is not solely technological but represents a societal commitment to sustainability. The challenge is substantial, yet the potential for innovation and positive change is immense. By adhering to the key requirements outlined in this review, the IT industry can significantly contribute to a more sustainable and environmentally responsible future. The findings and recommendations presented here are intended to guide further research, fostering the transformation of emerging IT technologies into energy-efficient and sustainable solutions. Through these efforts, the IT sector can play a pivotal role in advancing global environmental sustainability.

References

Gooneratne, C. P., Magana-Mora, A., Contreras Otalvora, W., Affleck, M., Singh, P., Zhan, G. D., & Moellendick, T. E. (2020). Drilling in the Fourth Industrial Revolution—Vision and Challenges. *IEEE Engineering Management Review*, *48*(4), 144–159. https://doi.org/10.1109/emr.2020.2999420

Andri, R., Cavigelli, L., Rossi, D., & Benini, L. (2016). YodaNN: An Ultra-Low Power Convolutional Neural Network Accelerator Based on Binary Weights. *2016 IEEE Computer Society Annual Symposium on VLSI (ISVLSI)*. https://doi.org/10.1109/isvlsi.2016.111

Armeniakos, G., Zervakis, G., Soudris, D., Henkel, J., 2022. Hardware Approximate Techniques for Deep Neural Network Accelerators: A Survey. ACM Comput. Surv. Just Accepted (March 2022). https://doi.org/10.1145/3527156.

Mohammadi, M., Al-Fuqaha, A., Sorour, S., & Guizani, M., (2018). Deep Learning for IoT Big Data and Streaming Analytics: A Survey, in *IEEE Communications Surveys & Tutorials*, vol. 20, no. 4, pp. 2923-2960, 2018.

Zhang, Y., Gu, T., & Zhang, X. (2022), MDLdroid: A ChainSGD-Reduce Approach to Mobile Deep Learning for Personal Mobile Sensing, in *IEEE/ACM Transactions on Networking*, vol. 30, no. 1, pp. 134-147.

Khan, K., Pasricha, S., Kim, RG. (2020), A Survey of Resource Management for Processing-In-Memory and Near-Memory Processing Architectures. *Journal of Low Power Electronics and Applications*. 10(4):30. https://doi.org/10.3390/jlpea10040030

Ding, R., Liu, Z., Blanton, R. D. S., & Marculescu, D. (2018). "Quantized deep neural networks for energy efficient hardware-based inference," *2018 23rd Asia and South Pacific Design Automation Conference (ASP-DAC)*, pp. 1-8.

Azzouni, A., Boutaba, R., & Pujolle, G. (2017). NeuRoute: Predictive dynamic routing for software-defined networks," *2017 13th International Conference on Network and Service Management (CNSM)*, pp. 1-6.

Wang, E., Davis, JJ., Zhao R., Ng, H-C., Niu X., Luk, W., Cheung, PY. & Constantinides GA. (2019) Deep neural network approximation for custom hardware: where we've been, where we're going. *ACM Comput. Surv. (CSUR)* **52**, 40.

Mirjalili, S. (2015) How effective is the Grey Wolf optimizer in training multi-layer perceptrons. Appl Intell **43,** 150–161. https://doi.org/10.1007/s10489-014-0645-7

Z. Li *et al*. (2019). HEIF: Highly Efficient Stochastic Computing-Based Inference Framework for Deep Neural Networks, *IEEE Transactions on Computer-Aided Design of Integrated Circuits and Systems*, vol. 38, no. 8, pp. 1543-1556.

Boutaba, R., Salahuddin, M.A., Limam, N. *et al.* (2018). A comprehensive survey on machine learning for networking: evolution, applications and research opportunities. J Internet Serv Appl **9,** 16. https://doi.org/10.1186/s13174-018-0087-2.

Shafik, R., Yakovlev, A., Das, S. (2018) Real-power computing. IEEE Trans. Comput. **67**, 1445–1461.

Qiqieh, I., Shafik, R., Tarawneh, G., Sokolov, D., Das, S. & Yakovlev, A. (2018) Significance-driven logic compression for energy-efficient multiplier design. *IEEE J. Emerg. Selected Top. Circuits Syst.* **8**, 417–430.

Mrazek, V., Sarwar, SS., Sekanina, L., Vasicek, Z., Roy, K. (2016) Design of power-efficient approximate multipliers for approximate artificial neural networks. In *Proc. IEEE/ACM Int. Conf. on Computer-Aided Design (ICCAD), Austin, TX, 7–10*. pp. 1–7. New York, NY: IEEE.

Lei, J., Wheeldon, A., Shafik, R., Yakovlev, A. & Granmo, O. –C. (2020) From Arithmetic to Logic based AI: A Comparative Analysis of Neural Networks and Tsetlin Machine, *27th IEEE International Conference on Electronics, Circuits and Systems (ICECS)*, pp. 1-4.

Siomau, M. (2014). A quantum model for autonomous learning automata. *Quantum Inf Process* **13,** 1211–1221. https://doi.org/10.1007/s11128-013-0723-5

Chen, Y., Chen, T., Xu, Z., Sun, N., & Temam, O. (2016). DianNao family: energy-efficient hardware accelerators for machine learning. Commun. ACM 59, 11, 105–112. https://doi.org/10.1145/2996864

Zhong, G., Dubey, A., Tan, C., & Mitra, T. (2018) Synergy: an HW/SW framework for high throughput CNNs on embedded heterogeneous SoC. *ACM Trans. Embed. Comput. Syst.* **18**, https://doi:10.1145/3301278.

Misra, N. N., Dixit, Y., Al-Mallahi, A., Bhullar, M. S., Upadhyay, R., & Martynenko, A. (2022). IoT, Big Data, and Artificial Intelligence in Agriculture and Food Industry, *IEEE Internet of Things Journal*, vol. 9, no. 9, pp. 6305-6324.

Li, Bh., Hou, Bc., Yu, Wt. *et al.* (2017) Applications of artificial intelligence in intelligent manufacturing: a review. *Frontiers Inf Technol Electronic Eng* **18,** 86–96. https://doi.org/10.1631/FITEE.1601885.

Benini, L., (2017). Plenty of room at the bottom: micropower deep learning for cognitive cyber physical systems. *Proc. 7th IEEE Int. Workshop on Advances in Sensors and Interfaces (IWASI), Vieste, Italy, 15–16 June 2017*, pp. 165–165. New York, NY

Yaseen, M. U., Anjum, A., Rana, O., & Antonopoulos, N., (2019). Deep Learning Hyper-Parameter Optimization for Video Analytics in Clouds, *IEEE Transactions on Systems, Man, and Cybernetics: Systems*, vol. 49, no. 1, pp. 253-264.

Bogdanov, A., Knezevic, M., Leander, G., Toz, D., Varici, K., & Verbauwhede, I. (2013). SPONGENT: The Design Space of Lightweight Cryptographic Hashing, *IEEE Transactions on Computers*, vol. 62, no. 10, pp. 2041-2053.

Lei, J., Wheeldon, A., Shafik, R., Yakovlev, A., & Granmo, O. -C., (2020). From Arithmetic to Logic based AI: A Comparative Analysis of Neural Networks and Tsetlin Machine," *27th IEEE International Conference on Electronics, Circuits and Systems (ICECS)*, pp. 1-4.

Fyrbiak, M., *et al*. (2019). HAL—The Missing Piece of the Puzzle for Hardware Reverse Engineering, Trojan Detection and Insertion, *IEEE Transactions on Dependable and Secure Computing*, vol. 16, no. 3, pp. 498-510.

Zhao, L., *et al*., (2022). Joint Shareability and Interference for Multiple Edge Application Deployment in Mobile-Edge Computing Environment, *IEEE Internet of Things Journal*, vol. 9, no. 3, pp. 1762-1774.

Wu, C., Peng, Q., Xia, Y., & Lee, J. (2019). Mobility-Aware Tasks Offloading in Mobile Edge Computing Environment, *Seventh International Symposium on Computing and Networking (CANDAR)*, pp. 204-210.

Nurvitadhi, E., Sheffield, D., Sim, J., Mishra, A., Venkatesh, G., & Marr, D., (2016). Accelerating Binarized Neural Networks: Comparison of FPGA, CPU, GPU, and ASIC, *International Conference on Field-Programmable Technology (FPT)*, pp. 77-84.

Javaid, N., Sher, A., Nasir, H., Guizani, N. (2018). Intelligence in IoT-based 5G networks: opportunities and challenges. *IEEE Commun. Mag.* **56**, 94–100.

Biswas, A., Chandrakasan, AP., (2018). Conv-RAM: an energy-efficient SRAM with embedded convolution computation for low-power CNN-based machine learning applications. *Proc. IEEE Int. Solid-State Circuits Conf. (ISSCC)*, San Francisco, CA, 11–18 February 2018, pp. 488–490. New York, NY: IEEE

Neftci, EO., (2018). Data and power efficient intelligence with neuromorphic learning machines. *iScience* **5**, 52–68.

Akadiri, S.S., Adebayo, T.S., Nakorji, M. et al. (2022). Impacts of globalization and energy consumption on environmental degradation: what is the way forward to achieving environmental sustainability targets in Nigeria? Environ Sci Pollut Res. https://doi.org/10.1007/s11356-022-20180-7.

Tao, X., Han, Y., Xu, X. *et al.* (2017). Recent advances and future challenges for mobile network virtualization. *Sci. China Inf. Sci.* **60,** 040301. https://doi.org/10.1007/s11432-017-.

Yousaf, F. Z., Bredel, M., Schaller, S., & Schneider, F., (2017), NFV and SDN—Key Technology Enablers for 5G Networks, *IEEE Journal on Selected Areas in Communications*, vol. 35, no. 11, pp. 2468-2478.

Sun, G., Zhou, R., Sun, J., Yu, H., & Vasilakos, A. V., (2020). Energy-Efficient Provisioning for Service Function Chains to Support Delay-Sensitive Applications in Network Function Virtualization, *IEEE Internet of Things Journal*, vol. 7, no. 7, pp. 6116-6131.

Chen, X., (2020). Energy Efficient NFV Resource Allocation in Edge Computing Environment, *International Conference on Computing, Networking and Communications (ICNC)*, pp. 477-481.

Alam, I., Sharif, K., Li, F., Latif, Z., Karim, M. M., Biswas, S., Nour, B., & Wang, Y., (2020). A Survey of Network Virtualization Techniques for Internet of Things Using SDN and NFV. ACM Comput. Surv. 53, 2, Article 35 (March 2021), 40 pages. https://doi.org/10.1145/3379444.

Prabakaran, S., Ramar, R., Hussain, I., Kavin, BP., Alshamrani. SS., AlGhamdi, AS., Alshehri, A. (2022). Predicting Attack Pattern via Machine Learning by Exploiting Stateful Firewall as Virtual Network Function in an SDN Network. *Sensors*. 22(3):709. https://doi.org/10.3390/s22030709.

Ma, L., Wen, X., Wang, L., Lu, Z., & Knopp, R., (2018). An SDN/NFV based framework for management and deployment of service based 5G core network, *China Communications*, vol. 15, no. 10, pp. 86-98.

Kaur, K., Mangat, V., Kumar, K., (2020). A comprehensive survey of service function chain provisioning approaches in SDN and NFV architecture, Computer Science Review, Volume 38, 100298, https://doi.org/10.1016/j.cosrev.2020.100298.

Taleb, T., Samdanis, K., Mada, B., Flinck, H., Dutta, S., & Sabella, D., (2017). On Multi-Access Edge Computing: A Survey of the Emerging 5G Network Edge Cloud Architecture and Orchestration," in *IEEE Communications Surveys & Tutorials*, vol. 19, no. 3, pp. 1657-1681.

Demirci, S., Demirci, M., & Sagiroglu, S., (2018). Optimal Placement of Virtual Security Functions to Minimize Energy Consumption, *International Symposium on Networks, Computers and Communications (ISNCC)*, pp. 1-6.

Jain, R., & Paul, S., (2013). Network virtualization and software defined networking for cloud computing: a survey, *IEEE Communications Magazine*, vol. 51, no. 11, pp. 24-31.

Toosi, A. N. Son, J., Chi, Q., Buyya, R., (2019). ElasticSFC: Auto-scaling techniques for elastic service function chaining in network functions virtualization-based clouds, Journal of Systems and Software, Volume 152, Pages 108-119, https://doi.org/10.1016/j.jss.2019.02.052.

Soares, J., Dias, M., Carapinha, J., Parreira, B., & Sargento, S., (2014). Cloud4NFV: A platform for Virtual Network Functions, *IEEE 3rd International Conference on Cloud Networking (CloudNet)*, pp. 288-293.

Herrera, J. G., & Botero, J. F., (2016). Resource Allocation in NFV: A Comprehensive Survey, *IEEE Transactions on Network and Service Management*, vol. 13, no. 3, pp. 518-532.

Chaudhary, R., Aujla, G. S., Garg, S., Kumar, N., & Rodrigues, J. J. P. C., (2018). SDN-Enabled Multi-Attribute-Based Secure Communication for Smart Grid in IIoT Environment, *IEEE Transactions on Industrial Informatics*, vol. 14, no. 6, pp. 2629-2640.

Hu, N., Tian, Z., Du, X., Guizani, N., & Zhu, Z., (2021). Deep-Green: A Dispersed Energy-Efficiency Computing Paradigm for Green Industrial IoT, *IEEE Transactions on Green Communications and Networking*, vol. 5, no. 2, pp. 750-764.

Rawat, D. B., & Reddy, S. R., (2017). Software Defined Networking Architecture, Security and Energy Efficiency: A Survey, *IEEE Communications Surveys & Tutorials*, vol. 19, no. 1, pp. 325-346.

Son, J., & Buyya, R., (2018). A Taxonomy of Software-Defined Networking (SDN)-Enabled Cloud Computing. ACM Comput. Surv. 51, 3, Article 59 (May 2019), 36 pages. https://doi.org/10.1145/3190617

Caprolu, M., Raponi, S., & Pietro, R. D., (2019). FORTRESS: An Efficient and Distributed Firewall for Stateful Data Plane SDN, Security and Communication Networks, vol. 2019, Article ID 6874592, 16 pages, https://doi.org/10.1155/2019/6874592.

Liang, K., Zhao, L., Chu, X., & Chen, H., (2017). An Integrated Architecture for Software Defined and Virtualized Radio Access Networks with Fog Computing, *IEEE Network*, vol. 31, no. 1, pp. 80-87.

Yan, Q., & Yu, F. R., (2015). Distributed denial of service attacks in software-defined networking with cloud computing, *IEEE Communications Magazine*, vol. 53, no. 4, pp. 52-59.

Afolabi, I., Taleb, T., Samdanis, K., Ksentini, A., & Flinck, H., (2018). Network Slicing and Softwarization: A Survey on Principles, Enabling Technologies, and Solutions, *IEEE Communications Surveys & Tutorials*, vol. 20, no. 3, pp. 2429-2453.

Kiran, N., Pan, C., Wang, S., & Yin, C., (2020). Joint resource allocation and computation offloading in mobile edge computing for SDN based wireless networks, *Journal of Communications and Networks*, vol. 22, no. 1, pp. 1-11.

Duan, Q., Ansari, N., & Toy, M., (2016). Software-defined network virtualization: an architectural framework for integrating SDN and NFV for service provisioning in future networks, *IEEE Network*, vol. 30, no. 5, pp. 10-16.

Son, J., Dastjerdi, A. V., Calheiros, R. N., & Buyya, R., (2017). SLA-Aware and Energy-Efficient Dynamic Overbooking in SDN-Based Cloud Data Centers, *IEEE Transactions on Sustainable Computing*, vol. 2, no. 2, pp. 76-89.

Haque, I. T., & Abu-Ghazaleh, N., (2016). Wireless Software Defined Networking: A Survey and Taxonomy, *IEEE Communications Surveys & Tutorials*, vol. 18, no. 4, pp. 2713-2737.

Chen, M., Jin, H., Wen, Y., & Leung V. C. M., (2013). Enabling technologies for future data center networking: a primer, *IEEE Network*, vol. 27, no. 4, pp. 8-15.

Yousaf, F. Z., Bredel, M., Schaller, S., & Schneider, F., (2017). NFV and SDN—Key Technology Enablers for 5G Networks, *IEEE Journal on Selected Areas in Communications*, vol. 35, no. 11, pp. 2468-2478.

Hsieh, HC., Lee, CS. & Chen, JL. (2018). Mobile Edge Computing Platform with Container-Based Virtualization Technology for IoT Applications. *Wireless Pers Commun* **102,** 527–542. https://doi.org/10.1007/s11277-018-5856-5.

Zhang, N., & Hämmäinen, H., (2015). Cost efficiency of SDN in LTE-based mobile networks: Case Finland, *International Conference and Workshops on Networked Systems (NetSys)*, pp. 1-5.

Abuarqoub A., (2020). A Review of the Control Plane Scalability Approaches in Software Defined Networking. *Future Internet*. 12(3):49. https://doi.org/10.3390/fi12030049

Prajapati, A., Sakadasariya, A., & Patel, J., (2018). Software defined network: Future of networking, *2nd International Conference on Inventive Systems and Control (ICISC)*, pp. 1351-1354.

Tang, M., & Pan, S., (2015). A Hybrid Genetic Algorithm for the Energy-Efficient Virtual Machine Placement Problem in Data Centers. *Neural Process Lett* 41, 211–221. https://doi.org/10.1007/s11063-014-9339-8

Montazerolghaem, A., Yaghmaee, M. H., & Leon-Garcia, A., (2020). Green Cloud Multimedia Networking: NFV/SDN Based Energy-Efficient Resource Allocation, *IEEE Transactions on Green Communications and Networking*, vol. 4, no. 3, pp. 873-889.

Yang, F., & Gu, S., (2021). Industry 4.0, a revolution that requires technology and national strategies. *Complex Intell. Syst.* **7**, 1311–1325. https://doi.org/10.1007/s40747-020-00267-9.

Assefa, B. G., & Özkasap, Ö., (2019). A survey of energy efficiency in SDN: Software-based methods and optimization models, Journal of Network and Computer Applications, Volume 137, Pages 127-143, https://doi.org/10.1016/j.jnca.2019.04.001.

Bilal, K., Khan, S.U., Madani, S.A. *et al.*, (2013). A survey on Green communications using Adaptive Link Rate. *Cluster Comput* **16,** 575–589. https://doi.org/10.1007/s10586-012-0225-8.

Zeadally, S., Khan, S.U. & Chilamkurti, N., (2012). Energy-efficient networking: past, present, and future. *J Supercomput* **62,** 1093–1118. https://doi.org/10.1007/s11227-011-0632-2.

Luitel, S., & Moh, S., (2018). Energy-Efficient Medium Access Control Protocols for Cognitive Radio Sensor Networks: A Comparative Survey. *Sensors*. 18(11):3781. https://doi.org/10.3390/s18113781.

Rathore, P.S., Chatterjee, J.M., Kumar, A. *et al.* (2021). Energy-efficient cluster head selection through relay approach for WSN. *J Supercomput* **77,** 7649–7675. https://doi.org/10.1007/s11227-020-03593-4.

Tuysuz, M. F., Ankarali, Z. K., & Gözüpek, D., (2017). A survey on energy efficiency in software defined networks, Computer Networks, Volume 113, Pages 188-204, ISSN 1389-1286, https://doi.org/10.1016/j.comnet.2016.12.012.

Wu, J., Zhang, Y., Zukerman, M., & Yung, E. K. -N., (2015). Energy-Efficient Base-Stations Sleep-Mode Techniques in Green Cellular Networks: A Survey, *IEEE Communications Surveys & Tutorials*, vol. 17, no. 2, pp. 803-826.

Popoola, O., & Pranggono, B. (2018). On energy consumption of switch-centric data center networks. *J Supercomput* **74,** 334–369. https://doi.org/10.1007/s11227-017-2132-5

Jarrahi, M. H., & Sawyer, S., (2019). Networks of innovation: the sociotechnical assemblage of tabletop computing, Research Policy, Volume 48, Supplement, 100001, https://doi.org/10.1016/j.repolx.2018.100001.

Khan, A. A., Rehmani, M. H., & Rachedi, A., (2016). When Cognitive Radio meets the Internet of Things? *International Wireless Communications and Mobile Computing Conference (IWCMC)*,pp. 469-474.

Arshad, R., Zahoor, S., Shah, M. A., Wahid, A., & Yu, H., (2017). Green IoT: An Investigation on Energy Saving Practices for 2020 and Beyond, *IEEE Access*, vol. 5, pp. 15667-15681.

Molla, A., Abareshi, A., & Cooper, V., (2014). Green IT beliefs and pro-environmental IT practices among IT professionals, Information Technology & People, Vol. 27 No. 2, pp. 129-154.

Del Giudice, M., Chierici, R., Mazzucchelli, A. and Fiano, F., (2021). "Supply chain management in the era of circular economy: the moderating effect of big data", The International Journal of Logistics Management, Vol. 32 No. 2, pp. 337-356.

Hypolite, J., Sonchack, J., Hershkop, S., Dautenhahn, N., DeHon, A., & Smith, J. M., (2020). DeepMatch: practical deep packet inspection in the data plane using network processors. 16th International Conference on emerging Networking EXperiments and Technologies (CoNEXT '20). Association for Computing Machinery, New York, NY, USA, 336–350. https://doi.org/10.1145/3386367.3431290.

Thein, T., Myo, M. M., Parvin, S., & Gawanmeh, A., Reinforcement learning based methodology for energy-efficient resource allocation in cloud data centers, Journal of King Saud University - Computer and Information Sciences, Volume 32, Issue 10, Pages 1127-1139, https://doi.org/10.1016/j.jksuci.2018.11.005.

Shortall, R., Davidsdottir, B., & Axelsson, G., (2015). Geothermal energy for sustainable development: A review of sustainability impacts and assessment frameworks, Renewable and Sustainable Energy Reviews, Volume 44, Pages 391-406, https://doi.org/10.1016/j.rser.2014.12.020.

Fais, B., Sabio, N., & Strachan, N., (2016). The critical role of the industrial sector in reaching long-term emission reduction, energy efficiency and renewable targets, Applied Energy, Volume 162, Pages 699-712, https://doi.org/10.1016/j.apenergy.2015.10.112.

Bibri, S. E., & Krogstie, J. (2021). A Novel Model for Data-Driven Smart Sustainable Cities of the Future: A Strategic Roadmap to Transformational Change in the Era of Big Data. Future Cities and Environment, 7(1), 3. DOI: http://doi.org/10.5334/fce.116

Mathew, T., Sekaran, K. C., & Jose, J., (2014). Study and analysis of various task scheduling algorithms in the cloud computing environment, *International Conference on Advances in Computing, Communications and Informatics (ICACCI)*, 2014, pp. 658-664.

Del Giudice, M., Chierici, R., Mazzucchelli, A. and Fiano, F. (2021), "Supply chain management in the era of circular economy: the moderating effect of big data", The International Journal of Logistics Management, Vol. 32 No. 2, pp. 337-356.

Çavdar, D., & Alagoz, F., (2012). A survey of research on greening data centers, *IEEE Global Communications Conference (GLOBECOM)*, 2012, pp. 3237-3242.

Rehman, M. H., Ahmed, E., Yaqoob, I., Hashem, I. A. T., Imran, M., & Ahmad, S., (2018). Big Data Analytics in Industrial IoT Using a Concentric Computing Model, *IEEE Communications Magazine*, vol. 56, no. 2, pp. 37-43.

Jiang, D., Wang, Y., Lv, Z., Wang, W., & Wang, H., An Energy-Efficient Networking Approach in Cloud Services for IIoT Networks, *IEEE Journal on Selected Areas in Communications*, vol. 38, no. 5, pp. 928-941.

Karaaslan, A., & Gezen, M., (2022). The evaluation of renewable energy resources in Turkey by integer multi-objective selection problem with interval coefficient, Renewable Energy, Volume 182, Pages 842-854, https://doi.org/10.1016/j.renene.2021.10.053.

Wang, L., Khan, S.U., (2013). Review of performance metrics for green data centers: a taxonomy study. *J Supercomput* **63,** 639–656. https://doi.org/10.1007/s11227-011-0704-3.

He, W., Wang, F.-K. and Akula, V. (2017), "Managing extracted knowledge from big social media data for business decision making", Journal of Knowledge Management, Vol. 21 No. 2, pp. 275-294.

Hashem, I. A. T., Anuar, N. B., Gani, A., Yaqoob, I., Xia, F., & Khan S. U., (2016). Mapreduce: Review and open challenges. Scientometrics. 20161–34.

Awaysheh, F. M., Aladwan, M. N., Alazab, M., Alawadi, S., Cabaleiro, J. C., & Pena, T. F., (2020). Security by Design for Big Data Frameworks Over Cloud Computing, *IEEE Transactions on Engineering Management*, doi: 10.1109/TEM.2020.3045661.

Ahmed, E., Yaqoob, I., Hashem, I. A. T., Khan, I., Ahmed, A. I. A., Imran, M, & Vasilakos, A. V., (2017). The role of big data analytics in Internet of Things Computer Networks, Volume 129, Part 2, Pages 459-471, https://doi.org/10.1016/j.comnet.2017.06.013.

Kumari, A., Tanwar, S., Tyagi, S., & Kumar, N., (2018). Michele Maasberg, Kim-Kwang Raymond Choo, Multimedia big data computing and Internet of Things applications: A taxonomy and process model, Journal of Network and Computer Applications, Volume 124, Pages 169-195, https://doi.org/10.1016/j.jnca.2018.09.014.

Stergiou, C., Psannis, K. E., Gupta, B. B., & Ishibashi, Y., (2018). Security, privacy & efficiency of sustainable Cloud Computing for Big Data & IoT, Sustainable Computing: Informatics and Systems, Volume 19, Pages 174-184, https://doi.org/10.1016/j.suscom.2018.06.003.

Montori, F., Bedogni, L., Di Felice, M., & Bononi, L., (2018). Machine-to-machine wireless communication technologies for the Internet of Things: Taxonomy, comparison and open issues, Pervasive and Mobile Computing, Volume 50, Pages 56-81, https://doi.org/10.1016/j.pmcj.2018.08.002.

Mehmood, A., Natgunanathan, I., Xiang, Y., Hua, G., & Guo, S., (2016). Protection of Big Data Privacy, *IEEE Access*, vol. 4, pp. 1821-1834.

Farhan, L., Kharel, R., Kaiwartya, O., Quiroz-Castellanos, M., Alissa, A., & Abdulsalam, M., (2018). A Concise Review on Internet of Things (IoT) -Problems, Challenges and Opportunities," 11*th International Symposium on Communication Systems, Networks & Digital Signal Processing (CSNDSP)*, pp. 1-6.

Syed, H. J., Gani, A., Ahmad, R. W., Khan, M. K., & Ahmed, A. I. A., (2017). Cloud monitoring: A review, taxonomy, and open research issues, Journal of Network and Computer Applications, Volume 98, Pages 11-26, https://doi.org/10.1016/j.jnca.2017.08.021.

Sandhu, A. K., (2022). Big data with cloud computing: Discussions and challenges, *Big Data Mining and Analytics*, vol. 5, no. 1, pp. 32-40.

Xinhua, E., Han, J., Wang, Y., & Liu, L., Big Data-as-a-Service: Definition and architecture, *15th IEEE International Conference on Communication Technology*, pp. 738-742.

Sundaran, K., Ganapathy, V., & Sudhakara, P., (2017). Fuzzy logic based Unequal Clustering in wireless sensor network for minimizing Energy consumption, *2nd International Conference on Computing and Communications Technologies (ICCCT)*, pp. 304-309, doi: 10.1109/ICCCT2.2017.7972283.

Netto, M. A. S., Calheiros, R. N., Rodrigues, E. R., Cunha, R. L. F., & Buyya, R., (2019). HPC Cloud for Scientific and Business Applications: Taxonomy, Vision, and Research Challenges. ACM Comput. Surv. 51, 1, Article 8, 29 pages. https://doi.org/10.1145/3150224.

Al-Jarrah, OY., Yoo, PD., Muhaidat, S., Karagiannidis GK., & Taha, K., (2015). Efficient machine learning for big data: A review. Big Data Res. ;2(3):87–93.

Miao, K., Li, J., Hong, W., & Chen, M., (2020). A Microservice-Based Big Data Analysis Platform for Online Educational Applications, Scientific Programming, vol. Article ID 6929750, 13 pages, 2020. https://doi.org/10.1155/2020/6929750

Wang, Y., Kung, L., & Byrd, T. A., (2018). Big data analytics: Understanding its capabilities and potential benefits for healthcare organizations, Technological Forecasting and Social Change, Volume 126, Pages 3-13, https://doi.org/10.1016/j.techfore.2015.12.019.

Xu, X., Liu, Q., Luo, Y., Peng, K., Zhang, X., Meng, S., & Qi, L., (2019). A computation offloading method over big data for IoT-enabled cloud-edge computing, Future Generation Computer Systems, Volume 95, Pages 522-533, https://doi.org/10.1016/j.future.2018.12.055.

Wang, J., Cao, J., Sherratt, R.S. *et al.* (2018) An improved ant colony optimization-based approach with mobile sink for wireless sensor networks. *J Supercomput* **74,** 6633–6645. https://doi.org/10.1007/s11227-017-2115-6.

Elgendy, N., Elragal, A. (2014). Big Data Analytics: A Literature Review Paper. In: Perner, P. (eds) Advances in Data Mining. Applications and Theoretical Aspects. ICDM 2014. Lecture Notes in Computer Science, vol 8557. Springer, Cham. https://doi.org/10.1007/978-3-319-08976-8_16

Tanwar, M., Duggal, R., & Khatri, S. K., (2015). Unravelling unstructured data: A wealth of information in big data, *4th International Conference on Reliability, Infocom Technologies and Optimization (ICRITO) (Trends and Future Directions)*, pp. 1-6.

Kumar, A., & Hancke, G. P., (2014). Energy Efficient Environment Monitoring System Based on the IEEE 802.15.4 Standard for Low Cost Requirements, *IEEE Sensors Journal*, vol. 14, no. 8, pp. 2557-2566.

Mathew, P. S., & Pillai, A. S., (2020). Big Data solutions in Healthcare: Problems and perspectives, *International Conference on Innovations in Information, Embedded and Communication Systems (ICIIECS)*, pp. 1-6.

Kantareddy, S. N. R. *et al*., (2020) Perovskite PV-Powered RFID: Enabling Low-Cost Self-Powered IoT Sensors, *Sensors Journal*, vol. 20, no. 1, pp. 471-478.

Jeon, SH., Lee, J., & Choi, JK., (2014). An adaptive reporting frequency control scheme for energy saving on wireless sensor networks. In: Information and Communication Technology Convergence (ICTC), International Conference on. IEEE; p. 39–44.

Duroc, Y., & Kaddour, D., (2012) RFID Potential Impacts and Future Evolution for Green Projects, Energy Procedia, Volume 18, Pages 91-98, https://doi.org/10.1016/j.egypro.2012.05.021.

Wu, C., Chang, R., & Chan, H., (2014). A green energy-efficient scheduling algorithm using the DVFS technique for cloud datacenters, Future Generation Computer Systems, Volume 37, Pages 141-147, https://doi.org/10.1016/j.future.2013.06.009.

Beneventi, F., Bartolini, A., Cavazzoni, C. & Benini, L., (2017). Continuous learning of HPC infrastructure models using big data analytics and in-memory processing tools, *Design, Automation & Test in Europe Conference & Exhibition (DATE)*, pp. 1038-1043.

Li, D., & Halfond, W. G. J., (2014). An investigation into energy-saving programming practices for Android smartphone app development. Proceedings of the 3rd International Workshop on Green and Sustainable Software (GREENS). Association for Computing Machinery, New York, NY, USA, 46–53. https://doi.org/10.1145/2593743.2593750.

Benzidia, S., Makaoui, N., & Bentahar, O., (2021). The impact of big data analytics and artificial intelligence on green supply chain process integration and hospital environmental performance, Technological Forecasting and Social Change, Volume 165, 120557, https://doi.org/10.1016/j.techfore.2020.120557.

Wu, W., Lin, W., Hsu, C., & He, L., (2018). Energy-efficient hadoop for big data analytics and computing: A systematic review and research insights, Future Generation Computer Systems, Volume 86, Pages 1351-1367, https://doi.org/10.1016/j.future.2017.11.010.

Aceto, G., Persico, V., & Pescapé, A., (2020). Industry 4.0 and Health: Internet of Things, Big Data, and Cloud Computing for Healthcare 4.0, Journal of Industrial Information Integration, Volume 18, 100129, https://doi.org/10.1016/j.jii.2020.100129.

Palomba, F., Di Nucci, D., Panichella, A., Zaidman, A., & De Lucia, A., (2019). On the impact of code smells on the energy consumption of mobile applications, Information and Software Technology, Volume 105, Pages 43-55, https://doi.org/10.1016/j.infsof.2018.08.004.

Luvisi, A., (2016). Electronic identification technology for agriculture, plant, and food. A review. *Agron. Sustain. Dev.* **36,** 13. https://doi.org/10.1007/s13593-016-0352-3.

Popli, S., Jha, R. K., & Jain, S., (2022). Green IoT: A Short Survey on Technical Evolution & Techniques. *Wireless Pers Commun* **123,** 525–553. https://doi.org/10.1007/s11277-021-09142-3

Flanagan, J., & McGovern, C., (2022). A qualitative study of improving the operations strategy of logistics using radio frequency identification, Journal of Global Operations and Strategic Sourcing, Vol. ahead-of-print No. ahead-of-print. https://doi.org/10.1108/JGOSS-04-2021-0030.

Ali, A., Shah, G. A., & Arshad, J., (2016). Energy efficient techniques for M2M communication: A survey, Journal of Network and Computer Applications, Volume 68, Pages 42-55, https://doi.org/10.1016/j.jnca.2016.04.002.

Romeo, L., Petitti, A., Marani, R., & Milella, A., (2020) Internet of Robotic Things in Smart Domains: Applications and Challenges. *Sensors;* 20(12):3355. https://doi.org/10.3390/s20123355

Gurusamy, D., & Abas, S., (2020). Modified Clustering Algorithms for Energy Harvesting Wireless Sensor Networks- A Survey, *21st International Arab Conference on Information Technology (ACIT)*, pp. 1-11.

Li, X., Li, D., Wan, J. *et al.* (2017). A review of industrial wireless networks in the context of Industry 4.0. *Wireless Netw* **23,** 23–41. https://doi.org/10.1007/s11276-015-1133-7

Alam, M., Nielsen, R. H., & Prasad, N. R., (2013). The evolution of M2M into IoT, *First International Black Sea Conference on Communications and Networking (BlackSeaCom)*, pp. 112-115.

Valaskova, K., Ward, P., & Svabova, L., (2021). Deep learning-assisted smart process planning, cognitive automation, and industrial big data analytics in sustainable cyber-physical production systems. *Journal of Self-Governance and Management Economics*, *9*(2), 9-20.

Kantareddy, S. N. R., Mathews, I., Bhattacharyya, R., Peters, I. M., Buonassisi, T., & Sarma, S. E., (2019). Long Range Battery-Less PV-Powered RFID Tag Sensors, *IEEE Internet of Things Journal*, vol. 6, no. 4, pp. 6989-6996.

Moraru, A., Helerea, E., Ursachi, C., & Călin, M. D., (2017). RFID system with passive RFID tags for textiles, *10th International Symposium on Advanced Topics in Electrical Engineering (ATEE)*, pp. 410-415.

Escobar, J. J. M., Matamoros, O. M., Padilla, R. T., Reyes, I. L., & Espinosa, H. Q., (2021). A comprehensive review on smart grids: Challenges and opportunities. Sensors, 21(21), 6978.

Khalifa, T., Abdrabou, A., Shaban, K., & Gaouda, A. M. (2018). Heterogeneous wireless networks for smart grid distribution systems: Advantages and limitations. Sensors, 18(5), 1517.

Alvi, H. M., Sahar, H., Bangash, A. A., & Beg, M. O., (2017). EnSights: A tool for energy aware software development, 13th International Conference on Emerging Technologies (ICET), pp. 1-6.

Preprints.org (www.preprints.org) | NOT PEER-REVIEWED | Posted: 6 February 2025 doi:10.20944/preprints202502.0293.v1

Rekik, S., Baccour, N., Jmaiel, M. *et al., (2017).* Wireless Sensor Network Based Smart Grid Communications: Challenges, Protocol Optimizations, and Validation Platforms. *Wireless Pers Commun* **95,** 4025–4047. https://doi.org/10.1007/s11277-017-4038-1.

Huang, Y., CHEN, Z., YU, T., HUANG, X., & GU, X., (2018). Agricultural remote sensing big data: Management and applications, Journal of Integrative Agriculture, Volume 17, Issue 9, Pages 1915-1931, https://doi.org/10.1016/S2095-3119(17)61859-8.

Gomes, T., Salgado, F., Tavares, A., & Cabral, J., (2017). CUTE Mote, A Customizable and Trustable End-Device for the Internet of Things, *IEEE Sensors Journal*, vol. 17, no. 20, pp. 6816-6824, 15 Oct.15.

Pereira, R., Carção, T., Couto, M., Cunha, J., Fernandes, J. P., & Saraiva, J., (2017). Helping Programmers Improve the Energy Efficiency of Source Code, *IEEE/ACM 39th International Conference on Software Engineering Companion (ICSE-C)*, pp. 238-240.

Loganathan, S., & Arumugam, J., (2021). Energy Efficient Clustering Algorithm Based on Particle Swarm Optimization Technique for Wireless Sensor Networks. *Wireless Pers Commun* **119,** 815–843. https://doi.org/10.1007/s11277-021-08239-z.

Yang, F., Tschetter, E., Léauté, X., Ray, N., Merlino, G., & Ganguli, D., (2014).. Druid: a real-time analytical data store. Proceedings of the ACM SIGMOD International Conference on Management of Data (SIGMOD '14). Association for Computing Machinery, New York, NY, USA, 157–168. https://doi.org/10.1145/2588555.2595631

He, L., Lee, Y., Kim, E., & Shin, K. G., (2019). Environment-aware estimation of battery state-of-charge for mobile devices. In Proceedings of the 10th ACM/IEEE International Conference on Cyber-Physical Systems (ICCPS '19). Association for Computing Machinery, New York, NY, USA, 227–236. https://doi.org/10.1145/3302509.3313782.

Dogra, R., Rani, S., Babbar, H., & Krah, D., (2022). Energy-Efficient Routing Protocol for Next-Generation Application in the Internet of Things and Wireless Sensor Networks, Wireless Communications and Mobile Computing, vol. Article ID 8006751, 10 pages, 2022. https://doi.org/10.1155/2022/8006751

Tian, W., (2013). A review of sensitivity analysis methods in building energy analysis, Renewable and Sustainable Energy Reviews, Volume 20, Pages 411-419, https://doi.org/10.1016/j.rser.2012.12.014.

Lyu, Z., Zhang, H. H., Xiong, G., Guo, G., Wang, H., Chen, J., Praveen, A., Yang, Y., Gao, X., Wang, A., Lin, W., Agrawal, A., Yang, J., Wu, H., Li, X., Guo, F., Wu, J., Zhang, J., & Raghavan, V., (2021). Greenplum: A Hybrid Database for Transactional and Analytical Workloads. Proceedings of the 2021 International Conference on Management of Data (SIGMOD '21). Association for Computing Machinery, New York, NY, USA, 2530–2542. https://doi.org/10.1145/3448016.3457562

Ahmed, A., & Sabyasachi, A. S., Cloud computing simulators: A detailed survey and future direction, *IEEE International Advance Computing Conference (IACC)*, pp. 866-872.

Yassine, A., Singh, S., Hossain, M. S., & Muhammad, G., (2019). IoT big data analytics for smart homes with fog and cloud computing, Future Generation Computer Systems, Volume 91, Pages 563-573, https://doi.org/10.1016/j.future.2018.08.040.

Khashan, O. A., (2021). Parallel Proxy Re-Encryption Workload Distribution for Efficient Big Data Sharing in Cloud Computing, *IEEE 11th Annual Computing and Communication Workshop and Conference (CCWC)*, pp. 0554-0559.

Hao, S., Li, D., Halfond, W. G. J., & Govindan, R., (2013). Estimating mobile application energy consumption using program analysis, *35th International Conference on Software Engineering (ICSE)*, pp. 92-101.

Osanaiye, O. A., Alfa, A. S., & Hancke, G. P., (2018). Denial of Service Defence for Resource Availability in Wireless Sensor Networks, *IEEE Access*, vol. 6, pp. 6975-7004.

Shah, K. & Narmavala, Z., (2018). A Survey on Green Internet of Things, *Fourteenth International Conference on Information Processing (ICINPRO)*, pp. 1-4.

Vrchota, J., Pech, M., Rolínek, L., Bednář, J., (2020) Sustainability Outcomes of Green Processes in Relation to Industry 4.0 in Manufacturing: Systematic Review. *Sustainability,* 12(15):5968. https://doi.org/10.3390/su12155968

Shah, S. H., & Yaqoob, I., (2016). A survey: Internet of Things (IOT) technologies, applications and challenges, *IEEE Smart Energy Grid Engineering (SEGE)*, pp. 381-385.

Chaudhari, BS., Zennaro, M., & Borkar, S., (2020). LPWAN Technologies: Emerging Application Characteristics, Requirements, and Design Considerations. *Future Internet*. 12(3):46. https://doi.org/10.3390/fi12030046

Benhamaid, S., Bouabdallah, A., & Lakhlef, H., Recent advances in energy management for Green-IoT: An up-to-date and comprehensive survey, Journal of Network and Computer Applications, Volume 198, 103257, https://doi.org/10.1016/j.jnca.2021.103257.

Fourty, N., Bossche, A., Val, T., (2012). An advanced study of energy consumption in an IEEE 802.15.4 based network: Everything but the truth on 802.15.4 node lifetime, Computer Communications, Volume 35, Issue 14, Pages 1759-1767, https://doi.org/10.1016/j.comcom.2012.05.008.

Qiao, Y., Xing, Z., Fadlullah, Z. M., Yang, J., & Kato, N., (2018). Characterizing Flow, Application, and User Behavior in Mobile Networks: A Framework for Mobile Big Data, *IEEE Wireless Communications*, vol. 25, no. 1, pp. 40-49.

Gu, C., Fan, L., Wu, W., Huang, H., & Jia, X., (2018). Greening cloud data centers in an economical way by energy trading with power grid, Future Generation Computer Systems, Volume 78, Part 1, Pages 89-101, https://doi.org/10.1016/j.future.2016.12.029.

Hoque, M. A., Siekkinen, M., Koo, J., & Tarkoma, S., (2017). Full Charge Capacity and Charging Diagnosis of Smartphone Batteries, in *IEEE Transactions on Mobile Computing*, vol. 16, no. 11, pp. 3042-3055, 1.

Sen, P., Kantareddy, S. N. R., Bhattacharyya, R., Sarma, S. E., & Siegel, J. E., (2020). Low-Cost Diaper Wetness Detection Using Hydrogel-Based RFID Tags, *IEEE Sensors Journal*, vol. 20, no. 6, pp. 3293-3302, 15.

Aldeer, M. M. N., (2013). A summary survey on recent applications of wireless sensor networks, *IEEE Student Conference on Research and Developement*, pp. 485-490.

Catarinucci, L. *et al*., (2015). An IoT-Aware Architecture for Smart Healthcare Systems, *IEEE Internet of Things Journal*, vol. 2, no. 6, pp. 515-526.

Oikonomou, F., *et al*., (2021). Data Driven Fleet Monitoring and Circular Economy, *17th International Conference on Distributed Computing in Sensor Systems (DCOSS)*, pp. 483-488.

Kang, L., Poslad, S., Wang, W., Li, X., Zhang, Y., & Wang, C., (2016). A Public Transport Bus as a Flexible Mobile Smart Environment Sensing Platform for IoT, *12th International Conference on Intelligent Environments (IE)*, pp. 1-8.

Chen, X., Ding, N., Jindal, A., Hu, Y. C., Gupta, M., & Vannithamby, R. (2015). Smartphone Energy Drain in the Wild: Analysis and Implications. SIGMETRICS Perform. Eval. Rev. 43, 1, 151–164.

Lv, Z., Lou, R., Li, J., Singh, A. K., & Song, H., (2021). Big Data Analytics for 6G-Enabled Massive Internet of Things, *IEEE Internet of Things Journal*, vol. 8, no. 7, pp. 5350-5359.

Yousafzai, A., Yaqoob, I., Imran, M., Gani, A., & Noor, R. Md., (2020). Process Migration-Based Computational Offloading Framework for IoT-Supported Mobile Edge/Cloud Computing, *IEEE Internet of Things Journal*, vol. 7, no. 5, pp. 4171-4182.

Shan, H., Peterson, J., Hathorn, S., & Mohammadi, S., (2018). The RFID Connection: RFID Technology for Sensing and the Internet of Things, *IEEE Microwave Magazine*, vol. 19, no. 7, pp. 63-79.

Nowakowski, P., (2018). A novel, cost efficient identification method for disassembly planning of waste electrical and electronic equipment, Journal of Cleaner Production, Volume 172, Pages 2695-2707, https://doi.org/10.1016/j.jclepro.2017.11.142.

Talal, M., Zaidan, A.A., Zaidan, B.B. *et al.,* (2019). Comprehensive review and analysis of anti-malware apps for smartphones. *Telecommun Syst* **72,** 285–337. https://doi.org/10.1007/s11235-019-00575-

Anthony, B., Abdul Majid, M., Romli, A., A generic study on Green IT/IS practice development in collaborative enterprise: Insights from a developing country, Journal of Engineering and Technology Management, Volume 55, 101555, https://doi.org/10.1016/j.jengtecman.2020.101555.

Kong, L., He, L., Gu, Y., Wu, M. -Y., & He, T., (2014). A Parallel Identification Protocol for RFID systems, *IEEE INFOCOM - IEEE Conference on Computer Communications*, pp. 154-162.

LaPre, J. M., Gonsiorowski, E. J., Carothers, C. D., Jenkins, J., Carns, P., & Ross, R., (2015). Time Warp state restoration via delta encoding, *Winter Simulation Conference (WSC)*, pp. 3025-3036.

Liu, Y., Wang, H., Fei, Y., Liu, Y., Shen, L., Zhuang, Z., & Zhang, X., (2021). Research on the Prediction of Green Plum Acidity Based on Improved XGBoost. *Sensors*; 21(3):930. https://doi.org/10.3390/s2103093

Xia, N., Chen, H. -H., & Yang, C. -S., (2018). Radio Resource Management in Machine-to-Machine Communications—A Survey, *IEEE Communications Surveys & Tutorials*, vol. 20, no. 1, pp. 791-828.

Albreem, M. A., Sheikh, A. M., Alsharif, M. H., Jusoh, M. & Mohd, Y. M. N., (2021). Green Internet of Things (GIoT): Applications, Practices, Awareness, and Challenges," *IEEE Access*, vol. 9, pp. 38833-38858.

Tupe, U.L., Babar, S.D., Kadam, S.P. and Mahalle, P.N., (2022), "Research perspective on energy-efficient protocols in IoT: emerging development of green IoT", International Journal of Pervasive Computing and Communications, Vol. 18 No. 2, pp. 145-170. https://doi.org/10.1108/IJPCC-10-2019-0079

Waltho, C., Elhedhli, S., & Gzara, F., (2019). Green supply chain network design: A review focused on policy adoption and emission quantification, International Journal of Production Economics, Volume 208, Pages 305-318, https://doi.org/10.1016/j.ijpe.2018.12.003

Nam, T. M., Thanh, N. H., Hieu, H. T., Manh, N. T., Huynh, N. V., & Tuan, H. D., (2017). Joint network embedding and server consolidation for energy–efficient dynamic data center virtualization, Computer Networks, Volume 125, Pages 76-89, https://doi.org/10.1016/j.comnet.2017.06.007

Zhou, Z. *et al*., (2019). Energy-Efficient Resource Allocation for Energy Harvesting-Based Cognitive Machine-to-Machine Communications, *IEEE Transactions on Cognitive Communications and Networking*, vol. 5, no. 3, pp. 595-607.

Dash, S., Shakyawar, S.K., & Sharma, M. *et al. (2019).* Big data in healthcare: management, analysis and future prospects. *J Big Data* **6,** 54. https://doi.org/10.1186/s40537-019-0217-

Cinquini, L., Crichton, D., Mattmann, C., Harney, J., Shipman, G., Wang, F., Ananthakrishnan, R., Miller, N., Denvil, S., Morgan, M., Pobre, Z., Bell, G. M., Doutriaux, C., Drach, R., Williams, D., Kershaw, P., Pascoe, S., Gonzalez, E., Fiore, S., & Schweitzer, R., (2014). The Earth System Grid Federation: An open infrastructure for access to distributed geospatial data, Future Generation Computer Systems, Volume 36, Pages 400-417, https://doi.org/10.1016/j.future.2013.07.002

Jin, ZH., Shi, H., Hu, YX. *et al.,* (2020). CirroData: Yet Another SQL-on-Hadoop Data Analytics Engine with High Performance. *J. Comput. Sci. Technol.* **35,** 194–208. https://doi.org/10.1007/s11390-020-9536-

Seo, M., Song, Y., Kim, J., Paek, S. W., Kim, G., & Kim, S. W., (2021). Innovative lumped-battery model for state of charge estimation of lithium-ion batteries under various ambient temperatures, Energy, Volume 226, 120301, https://doi.org/10.1016/j.energy.2021.120301

Ganesan, M., Kor, A-L., Pattinson, C., & Rondeau, E., (2020) Green Cloud Software Engineering for Big Data Processing. *Sustainability*. 2020; 12(21):9255. https://doi.org/10.3390/su1221925

Le, H., (2021). Analyzing Energy Leaks of Android Applications Using Event-B. *Mobile Netw Appl* **26,** 1329–1338. https://doi.org/10.1007/s11036-021-01764-y

Asci, C., Wang, W., & Sonkusale, S., (2020). Security Monitoring System Using Magnetically-Activated RFID Tags, *IEEE SENSORS*, pp. 1-4.

Shabtai, A., Kanonov, U., Elovici, Y. *et al.* (2012). "Andromaly": a behavioral malware detection framework for android devices. *J Intell Inf Syst* **38,** 161–190. https://doi.org/10.1007/s10844-010-0148-x

Amutha, J., Sharma, S. & Nagar, J., (2020). WSN Strategies Based on Sensors, Deployment, Sensing Models, Coverage and Energy Efficiency: Review, Approaches and Open Issues. *Wireless Pers Commun* **111,** 1089–1115. https://doi.org/10.1007/s11277-019-06903-

Dong, L., Satpute, M. N., Shan, J., Liu, B., Yu, Y. & Yan, T., (2019). Computation Offloading for Mobile-Edge Computing with Multi-user, *IEEE 39th International Conference on Distributed Computing Systems (ICDCS)*, pp. 841-850.

Xu, J., Xiang, J., & Yang, D., Incentive Mechanisms for Time Window Dependent Tasks in Mobile Crowdsensing, *IEEE Transactions on Wireless Communications*, vol. 14, no. 11, pp. 6353-6364.

Shaikh, F. K., Zeadally, S. & Exposito, E., (2017). Enabling Technologies for Green Internet of Things," *IEEE Systems Journal*, vol. 11, no. 2, pp. 983-994.

Wang, X., Li, X. & Wen, W., (2014). WLCleaner: Reducing Energy Waste Caused by WakeLock Bugs at Runtime, *IEEE 12th International Conference on Dependable, Autonomic and Secure Computing*, pp. 429-434.

Abbasi, A. M. et *al*., (2015). A framework for detecting energy bugs in smartphones, *6th International Conference on the Network of the Future (NOF)*, pp. 1-3.

Pramanik, P. K. D. *et al*., (2019). Power Consumption Analysis, Measurement, Management, and Issues: A State-of-the-Art Review of Smartphone Battery and Energy Usage, *IEEE Access*, vol. 7, pp. 182113-182172.

Cruz, L., & Abreu, R., (2019). Catalog of energy patterns for mobile applications. *Empir Software Eng* **24,** 2209–2235. https://doi.org/10.1007/s10664-019-09682-0

Ha, I., Djuraev, M. & Ahn, B., (2017) An Optimal Data Gathering Method for Mobile Sinks in WSNs. *Wireless Pers Commun* **97,** 1401–1417. https://doi.org/10.1007/s11277-017-4579.

Satyaraj, D., & Bhanumathi, V. (2021). Efficient design of dual controlled stacked SRAM cell. *Analog Integr Circ Sig Process* **107,** 369–376. https://doi.org/10.1007/s10470-020-01761-3

Pedram, M., (2012). Energy-Efficient Datacenters, *IEEE Transactions on Computer-Aided Design of Integrated Circuits and Systems*, vol. 31, no. 10, pp. 1465-1484.

Arshad, R., Zahoor, S., Shah, M. A., Wahid, A. & Yu, H., (2017). Green IoT: An Investigation on Energy Saving Practices for 2020 and Beyond, *IEEE Access*, vol. 5, pp. 15667-15681.

Mao, Y., You, C., Zhang, J., Huang, K. & Letaief, K. B., (2017). A Survey on Mobile Edge Computing: The Communication Perspective, *IEEE Communications Surveys & Tutorials*, vol. 19, no. 4, pp. 2322-2358.

Boukoberine, M. N., Zhou, Z., & Benbouzid, M., (2019). A critical review on unmanned aerial vehicles power supply and energy management: Solutions, strategies, and prospects, Applied Energy, Volume 255, 113823, https://doi.org/10.1016/j.apenergy.2019.113823

Catarinucci, L., Colella, R., Del Fiore, G., et al. (2014). A Cross-Layer Approach to Minimize the Energy Consumption in Wireless Sensor Networks. *International Journal of Distributed Sensor Networks*. doi:10.1155/2014/268284

Gielen, D., Boshell, F., Saygin, D., Bazilian, M. D., Wagner, N., & Gorini, R., (2019) The role of renewable energy in the global energy transformation, Energy Strategy Reviews, Volume 24, Pages 38-50, https://doi.org/10.1016/j.esr.2019.01.

Zhu, C., Leung, V. C. M., Shu, L. & Ngai, E. C., (2017). Green Internet of Things for Smart World, *IEEE Access*, vol. 3, pp. 2151-2162.

Twayej, W., & Al-Raweshidy, H. S., (2017). An energy efficient M2M routing protocol for IoT based on 6LoWPAN with a smart sleep mode, *Computing Conference*, pp. 1317-1322.

Wu, H., Wolter, K., Jiao, P., Deng, Y., Zhao, Y. & Xu, M., (2021). EEDTO: An Energy-Efficient Dynamic Task Offloading Algorithm for Blockchain-Enabled IoT-Edge-Cloud Orchestrated Computing, *IEEE Internet of Things Journal*, vol. 8, no. 4, pp. 2163-2176, 15.

Farooq, M. U., Khan, S. U. R., & Beg, M. O., (2019). MELTA: A Method Level Energy Estimation Technique for Android Development, *International Conference on Innovative Computing (ICIC)*, pp. 1-10.

Owusu, P. A. & Asumadu-Sarkodie, S., (2016). A review of renewable energy sources, sustainability issues and climate change mitigation, Cogent Engineering, 3:1, 1167990.

Tupe, U.L., Babar, S.D., Kadam, S.P. and Mahalle, P.N., (2022). Research perspective on energy-efficient protocols in IoT: emerging development of green IoT, International Journal of Pervasive Computing and Communications, Vol. 18 No. 2, pp. 145-170.

Aslam, W., Soban, M., Akhtar, F., & Zaffar, N. A., (2015). Smart meters for industrial energy conservation and efficiency optimization in Pakistan: Scope, technology and applications, Renewable and Sustainable Energy Reviews, Volume 44, Pages 933-943, https://doi.org/10.1016/j.rser.2015.01.004.

Kamaludin, H., Mahdin, H., & Abawajy, JH. (2018). Clone tag detection in distributed RFID systems. PLoS ONE 13(3): e0193951. https://doi.org/10.1371/journal.pone.0193951

Balasingam, B., Ahmed, M., & Pattipati, K., (2020). Battery Management Systems—Challenges and Some Solutions. *Energies*. 13(11):2825. https://doi.org/10.3390/en13112825.

Singh, M. K., Amin, S. I., Imam, S. A., Sachan, V. K., & Choudhary, A., A Survey of Wireless Sensor Network and its types, *International Conference on Advances in Computing, Communication Control and Networking (ICACCCN)*, pp. 326-330.

Galmés, S., & Escolar, S., (2018) Analytical Model for the Duty Cycle in Solar-Based EH-WSN for Environmental Monitoring. *Sensors*. 18(8):2499. https://doi.org/10.3390/s18082499.

Tryfonos, A., *et al*., (20118). ENEDI: Energy Saving in Datacenters," *2018 IEEE Global Conference on Internet of Things (GCIoT)*, pp. 1-5.

Boukettaya, G., Krichen, L., A dynamic power management strategy of a grid connected hybrid generation system using wind, photovoltaic and Flywheel Energy Storage System in residential applications, Energy, Volume 71, Pages 148-159, https://doi.org/10.1016/j.energy.2014.04.039.

Poongodi, T., Ramya, S.R., Suresh, P., Balusamy, B. (2020). Application of IoT in Green Computing. In: Bhoi, A., Sherpa, K., Kalam, A., Chae, GS. (eds) Advances in Greener Energy Technologies. Green Energy and Technology. Springer, Singapore. https://doi.org/10.1007/978-981-15-4246-6_19

Chen, K., Tan, G., Cao, J., Lu, M., & Fan, X., (2020). Modeling and Improving the Energy Performance of GPS Receivers for Location Services, *IEEE Sensors Journal*, vol. 20, no. 8, pp. 4512-4523, 15.

Aggarwal, C.C., & Abdelzaher, T., (2013). Social Sensing. In: Aggarwal, C. (eds) Managing and Mining Sensor Data. Springer, Boston, MA. https://doi.org/10.1007/978-1-4614-6309-2_9.

Akherfi, K., Gerndt, M., & Harroud, H., (2018). Mobile cloud computing for computation offloading: Issues and challenges, Applied Computing and Informatics, Volume 14, Issue 1, Pages 1-16, https://doi.org/10.1016/j.aci.2016.11.002.

Khune, R. S., & Thangakumar, J., (2012). A cloud-based intrusion detection system for Android smartphones, *International Conference on Radar, Communication and Computing (ICRCC)*, pp. 180-184.

Cruz, L., & Abreu, R., (2017). Performance-Based Guidelines for Energy Efficient Mobile Applications, *IEEE/ACM 4th International Conference on Mobile Software Engineering and Systems (MOBILESoft)*, pp. 46-57.

DeLovato, N., Sundarnath, K., Cvijovic, L., Kota, K., & Kuravi, S., (2019). A review of heat recovery applications for solar and geothermal power plants, Renewable and Sustainable Energy Reviews, Volume 114, 109329, https://doi.org/10.1016/j.rser.2019.109329.

Mohamed, A., Soliman, L. A., Raghavan, V., El-Helw, A., Gu, Z., Shen, E., Caragea, G. C., Garcia-Alvarado, C., Rahman, F., Petropoulos, M., Waas, F., Narayanan, S., Krikellas, K., & Baldwin, R., (2014). Orca: a modular query optimizer architecture for big data. In Proceedings of the 2014 ACM SIGMOD International Conference on Management of Data (SIGMOD '14). Association for Computing Machinery, New York, NY, USA, 337–348. https://doi.org/10.1145/2588555.2595637

Farhan, L., Hameed, RS., Ahmed, AS., Fadel, AH., Gheth, W., Alzubaidi, L., Fadhel, MA., & Al-Amidie, M., (2021) Energy Efficiency for Green Internet of Things (IoT) Networks: A Survey. *Network*. 1(3):279-314. https://doi.org/10.3390/network1030017

Banerjee, A., Chong, L. K., Ballabriga, C., & Roychoudhury, A., (2018). EnergyPatch: Repairing Resource Leaks to Improve Energy-Efficiency of Android Apps, *IEEE Transactions on Software Engineering*, vol. 44, no. 5, pp. 470-490.

Geng, Y., Hu, W., Yang, Y., Gao, W., & Cao, G., (2015). Energy-Efficient Computation Offloading in Cellular Networks, *IEEE 23rd International Conference on Network Protocols (ICNP)*, pp. 145-155.

Maute, J. M., Puebla, V. K. J., Nericua, R. T., Gerasta, O. J. L., & Hora, J. A., (2018). Design Implementation of 10T Static Random Access Memory Cell Using Stacked Transistors for Power Dissipation Reduction, *IEEE 10th International Conference on Humanoid, Nanotechnology, Information Technology,Communication and Control, Environment and Management (HNICEM)*, pp. 1-6.

Gautam, M., & Akashe, S., Transistor gating: Reduction of leakage current and power in full subtractor circuit, *3rd IEEE International Advance Computing Conference (IACC)*, pp. 1514-1518.

Khosravi, L. L., Andrew, H. & Buyya, R., (2017). Dynamic VM Placement Method for Minimizing Energy and Carbon Cost in Geographically Distributed Cloud Data Centers, *IEEE Transactions on Sustainable Computing*, vol. 2, no. 2, pp. 183-196.

Alsamhi, S.H., Ma, O., Ansari, M.S. *et al.* (2019). Greening internet of things for greener and smarter cities: a survey and future prospects. *Telecommun Syst* **72,** 609–632. https://doi.org/10.1007/s11235-019-00597-1.

Ni, J., Lin, X., & Shen, X. S., (2019). Toward Edge-Assisted Internet of Things: From Security and Efficiency Perspectives, *IEEE Network*, vol. 33, no. 2, pp. 50-57.

Ganatra, Y., Ruiz, J., Howarter, J. A., & Marconnet, A., (2018). Experimental investigation of Phase Change Materials for thermal management of handheld devices, International Journal of Thermal Sciences, Volume 129, Pages 358-364, https://doi.org/10.1016/j.ijthermalsci.2018.03.012.

Mikulics, M., & Hardtdegen, H. H., (2020). Fully photon operated transmistor / all-optical switch based on a layered Ge1Sb2Te4 phase change medium, FlatChem, Volume 23, 100186, https://doi.org/10.1016/j.flatc.2020.100186.

Sheng, Z., Yang, S., Yu, Y., Vasilakos, A. V., Mccann, J. A., & Leung, K. K., (2013). A survey on the ietf protocol suite for the internet of things: standards, challenges, and opportunities, *IEEE Wireless Communications*, vol. 20, no. 6, pp. 91-98.

Subbaraj, S., Thiyagarajan, R., & Rengaraj, M., (2021). A smart fog computing based real-time secure resource allocation and scheduling strategy using multi-objective crow search algorithm. J Ambient Intell Human Comput. https://doi.org/10.1007/s12652-021-03354-y.

Ielmini, D., & Wong, HS. P., (2018) In-memory computing with resistive switching devices. *Nat Electron* **1,** 333–343. https://doi.org/10.1038/s41928-018-0092-2

Sarood, O., Miller, P., Totoni, E., & Kalé, L. V., (2012) "Cool" Load Balancing for High Performance Computing Data Centers, *IEEE Transactions on Computers*, vol. 61, no. 12, pp. 1752-1764.

Usman, J., Ismail, A.S., Chizari, H. et al., (2019). Energy-efficient Virtual Machine Allocation Technique Using Flower Pollination Algorithm in Cloud Datacenter: A Panacea to Green Computing. J Bionic Eng 16, 354–366. https://doi.org/10.1007/s42235-019-0030-7.

Yang, Z., Xu, W., Pan, Y., Pan, C., & Chen, M., (2018). Energy Efficient Resource Allocation in Machine-to-Machine Communications With Multiple Access and Energy Harvesting for IoT, *IEEE Internet of Things Journal*, vol. 5, no. 1, pp. 229-245.

Peng, Z., Lin, J., Cui, D. et al. (2020). A multi-objective trade-off framework for cloud resource scheduling based on the Deep Q-network algorithm. Cluster Comput 23, 2753–2767. https://doi.org/10.1007/s10586-019-03042-9.

Zhu, C., Leung, V. C. M., Shu, L., & Ngai, E. C., (2015). Green Internet of Things for Smart World, *IEEE Access*, vol. 3, pp. 2151-2162.

Liu, Y., Xu, C., Cheung, S-C., & Terragni, V., (2016). Understanding and detecting wake lock misuses for Android applications. Proceedings of the 24th ACM SIGSOFT International Symposium on Foundations of Software Engineering (FSE 2016). Association for Computing Machinery, New York, NY, USA, 396–409. https://doi.org/10.1145/2950290.2950297

Mehrotra, D., Srivastava, R., Nagpal, R., & Nagpal, D., (2021). Multiclass classification of mobile applications as per energy consumption, Journal of King Saud University - Computer and Information Sciences, Volume 33, Issue 6, Pages 719-727, https://doi.org/10.1016/j.jksuci.2018.05.007.

Al-Fuqaha, A., Guizani, M., Mohammadi, M., Aledhari, M., & Ayyash, M., (2015). Internet of Things: A Survey on Enabling Technologies, Protocols, and Applications, *IEEE Communications Surveys & Tutorials*, vol. 17, no. 4, pp. 2347-2376.

Rodenas-Herraiz, D., Garcia-Sanchez A-J., Garcia-Sanchez, F., (2013). Garcia-Haro, J., (2013). Current Trends in Wireless Mesh Sensor Networks: A Review of Competing Approaches. *Sensors*. 13(5):5958-5995. https://doi.org/10.3390/s130505958

Ahmed, F., Ali, I., Kousar, S. *et al.* (2022). The environmental impact of industrialization and foreign direct investment: empirical evidence from Asia-Pacific region. *Environ Sci Pollut Res* 29, 29778–29792. https://doi.org/10.1007/s11356-021-17560-w.

Jing, SY., Ali, S., She, K., & Zhong, Y., (2013). State-of-the-art research study for green cloud computing. J Supercomput. 65(1):445–68.

Kortbeek, Vito, Abu Bakar, Cruz, S., Yildirim, K. S., Pawełczak, P., & Hester, J., (2020). BFree: Enabling Battery-free Sensor Prototyping with Python. Proc. ACM Interact. Mob. Wearable Ubiquitous Technol. 4, 4, Article 135, 39 pages. https://doi.org/10.1145/3432191

Sayadnavard, M. H., Haghighat, A. T., & Rahmani, A. M., (2022). A multi-objective approach for energy-efficient and reliable dynamic VM consolidation in cloud data centers, Engineering Science and Technology, an International Journal, Volume 26, 100995, https://doi.org/10.1016/j.jestch.2021.04.014.

Kumar, S., Tiwari, P. & Zymbler, M., (2019). Internet of Things is a revolutionary approach for future technology enhancement: a review. *J Big Data* **6,** 111. https://doi.org/10.1186/s40537-019-0268-2.

Weekly, K., Jin, M., Zou, H., Hsu, C., Soyza, C., Bayen, A., Spanos, C., (2018). Building-in-Briefcase: A Rapidly-Deployable Environmental Sensor Suite for the Smart Building. *Sensors*. 18(5):1381. https://doi.org/10.3390/s18051381.

Giluka, M. K., Rajoria, N., Kulkarni, A. C., Sathya, V. & Tamma, B. R., (2014). Class based dynamic priority scheduling for uplink to support M2M communications in LTE, *IEEE World Forum on Internet of Things (WF-IoT)*, pp. 313-317.

Tamkittikhun, N., Hussain, A., Kraemer, F.A., (2017). Energy Consumption Estimation for Energy-Aware, Adaptive Sensing Applications. In: Bouzefrane, S., Banerjee, S., Sailhan, F., Boumerdassi, S., Renault, E. (eds) Mobile, Secure, and Programmable Networking. MSPN. Lecture Notes in Computer Science, vol 10566. Springer, Cham. https://doi.org/10.1007/978-3-319-67807-8_17

Maray, M., & Shuja, J., (2022). Computation Offloading in Mobile Cloud Computing and Mobile Edge Computing: Survey, Taxonomy, and Open Issues, Mobile Information Systems, vol. 2022, Article ID 1121822, 17 pages.

Gavurova, B., Rigelsky, M., & Ivankova, V. (2021). Greenhouse Gas Emissions and Health in the Countries of the European Union. Front Public Health. 9: 756652. doi: 10.3389/fpubh. 2021.756652.

Chen, M., Zhang, Y., Li, Y., Mao, S., & Leung, V. C. M., (2015). EMC: Emotion-aware mobile cloud computing in 5G, *IEEE Network*, vol. 29, no. 2, pp. 32-38.

Madni, S. H. H., Abd Latiff, M. S., Coulibaly, Y., & Abdulhamid, S. M., (2016). Resource scheduling for infrastructure as a service (IaaS) in cloud computing: Challenges and opportunities, Journal of Network and Computer Applications, Volume 68, Pages 173-200, https://doi.org/10.1016/j.jnca.2016.04.016.

Shuja, J., Ahmad, R.W., Gani, A. *et al.*, (2017). Greening emerging IT technologies: techniques and practices. *J Internet Serv Appl* **8,** 9. https://doi.org/10.1186/s13174-017-0060-5.

Cheng, D., Rao, J., Jiang, C., & Zhou, X., Resource and Deadline-Aware Job Scheduling in Dynamic Hadoop Clusters, *IEEE International Parallel and Distributed Processing Symposium*, pp. 956-965.

Vijayaraghavan, T., et al., (2017). Design and Analysis of an APU for Exascale Computing, *IEEE International Symposium on High Performance Computer Architecture (HPCA)*, pp. 85-96.

Vahedi, E., Ward, R. K., & Blake, I. F., (2014) Performance Analysis of RFID Protocols: CDMA Versus the Standard EPC Gen-2, *IEEE Transactions on Automation Science and Engineering*, vol. 11, no. 4, pp. 1250-1261.

Hossain, M., Haque, M.E., & Arif, M.T., (2022). Kalman filtering techniques for the online model parameters and state of charge estimation of the Li-ion batteries: A comparative analysis, Journal of Energy Storage, Volume 51, 104174, https://doi.org/10.1016/j.est.2022.104174

Guliani, A., & Swift M. M., (2019). Per-Application Power Delivery. Proceedings of the Fourteenth EuroSys Conference (EuroSys '19). Association for Computing Machinery, New York, NY, USA, Article 5, 1–16. https://doi.org/10.1145/3302424.3303981

Shirvani, M. H., Rahmani, A. M., & Sahafi, A., (2020). A survey study on virtual machine migration and server consolidation techniques in DVFS-enabled cloud datacenter: Taxonomy and challenges, Journal of King Saud University - Computer and Information Sciences, Volume 32, Issue 3, Pages 267-286, https://doi.org/10.1016/j.jksuci.2018.07.001.

Samriya, J. K., & Kumar, N., (2020). An optimal SLA based task scheduling aid of hybrid fuzzy TOPSIS-PSO algorithm in cloud environment, Materials Today: Proceedings, https://doi.org/10.1016/j.matpr.2020.10.082.

Angrish, A., Starly, B., Lee, Y-S., & Cohen, P. H., (2017). A flexible data schema and system architecture for the virtualization of manufacturing machines (VMM), Journal of Manufacturing Systems, Volume 45, Pages 236-247, https://doi.org/10.1016/j.jmsy.2017.10.003.

Belkhir, L., & Elmeligi, A., (2018). Assessing ICT global emissions footprint: Trends to 2040 & recommendations, Journal of Cleaner Production, Volume 177, Pages 448-463.

Liu, L., Sun, H., Li, C., Li, T., Xin, J., & Zheng, N., (2021). Exploring Highly Dependable and Efficient Datacenter Power System Using Hybrid and Hierarchical Energy Buffers, *IEEE Transactions on Sustainable Computing*, vol. 6, no. 3, pp. 412-426.

Zhang, L., Gordon, M. S., Dick, R. P., Mao, Z. M., Dinda, P., & Yang, L., (2012). ADEL: an automatic detector of energy leaks for smartphone applications. Proceedings of the eighth IEEE/ACM/IFIP international conference on Hardware/software codesign and system synthesis (CODES+ISSS '12). Association for Computing Machinery, New York, NY, USA, 363–372. https://doi.org/10.1145/2380445.2380503

Torous, J., & Roberts, LW., (2017). Needed Innovation in Digital Health and Smartphone Applications for Mental Health: Transparency and Trust. *JAMA Psychiatry*. 74 (5):437–438. doi:10.1001/jamapsychiatry.2017.0262.

Madhu, J. G. P. & Dhiman, G., (2017). An architecture for energy-efficient hybrid full adder and its CMOS implementation," *2017 Conference on Information and Communication Technology (CICT)*, pp. 1-5.

Lakshmi, S., Raj, C. M., & Krishnadas, D., (2018). Optimization of Hybrid CMOS Designs Using a New Energy Efficient 1 Bit Hybrid Full Adder, *3rd International Conference on Communication and Electronics Systems (ICCES)*, pp. 905-908.

Yuan, J., Wang, Y., Chen, H., Jin, H., & Liu, H., (2021). Eunomia: Efficiently Eliminating Abnormal Results in Distributed Stream Join Systems, *IEEE/ACM 29th International Symposium on Quality of Service (IWQOS)*, pp. 1-11.

Avvari, G.V., Pattipati, B., Balasingam, B., Pattipati, K.R., & Bar-Shalom, Y., (2015). Experimental set-up and procedures to test and validate battery fuel gauge algorithms, Applied Energy, Volume 160, Pages 404-418, https://doi.org/10.1016/j.apenergy.2015.09.048.

Mohammadzadeh, A., Masdari, M., & Gharehchopogh, F.S., (2021). Energy and Cost-Aware Workflow Scheduling in Cloud Computing Data Centers Using a Multi-objective Optimization Algorithm. J Netw Syst Manage 29, 31. https://doi.org/10.1007/s10922-021-09599-

Koronen, C., Åhman, M. & Nilsson, L.J., (2020). Data centres in future European energy systems—energy efficiency, integration and policy. *Energy Efficiency* **13,** 129–144. https://doi.org/10.1007/s12053-019-09833-8.

Freitag, C., Berners-Lee, M., Widdicks, K., Knowles, B., Blair, G. S., Friday, A., (2021). The real climate and transformative impact of ICT: A critique of estimates, trends, and regulations, Patterns, Volume 2, Issue 9, 100340, https://doi.org/10.1016/j.patter.2021.100340.

Tarplee, K. M., Friese, R., Maciejewski, A. A., Siegel, H. J., & Chong, E. K. P., (2016). Energy and Makespan Tradeoffs in Heterogeneous Computing Systems using Efficient Linear Programming Techniques, *IEEE Transactions on Parallel and Distributed Systems*, vol. 27, no. 6, pp. 1633-1646.

Muzamane, HA., & Liu, H-C., (2021). Experimental Results and Performance Analysis of a 1 × 2 × 1 UHF MIMO Passive RFID System. *Sensors*. 21(18):6308. https://doi.org/10.3390/s21186308

Zhuang, H., Ghouchani, B. E. (2021), Virtual machine placement mechanisms in the cloud environments: a systematic review, Kybernetes, Vol. 50 No. 2, pp. 333-368.

Barke, A., Bley, T., Thies, C., Weckenborg, C., & Spengler, T.S., (2022). Are Sustainable Aviation Fuels a Viable Option for Decarbonizing Air Transport in Europe? An Environmental and Economic Sustainability Assessment. *Appl. Sci.*, *12*, 597. https://doi.org/10.3390/app12020597.

Koot, M., & Wijnhoven, F., (2021). Usage impact on data center electricity needs: A system dynamic forecasting model, Applied Energy, Volume 291, 116798, https://doi.org/10.1016/j.apenergy.2021.116798.

Chandra, A., Singh, G. K., & Pant, V., (2021). Protection of AC microgrid integrated with renewable energy sources – A research review and future trends, Electric Power Systems Research, Volume 193, 107036, https://doi.org/10.1016/j.epsr.2021.107036.

Mansour, Y., Hammad, H., Waraga, O. A., & Talib, M. A., Energy Management Systems and Smart Phones: A Systematic Literature Survey, *International Conference on Communications, Computing, Cybersecurity, and Informatics (CCCI)*, pp. 1-7.

Begum, R., Werner, D., Hempstead, M., Prasad, G., & Challen, G., Energy-Performance Trade-offs on Energy-Constrained Devices with Multi-component DVFS, *IEEE International Symposium on Workload Characterization*, pp. 34-43.

Bressler, R.D., (2021). The mortality cost of carbon. *Nat Commun* **12,** 4467. https://doi.org/10.1038/s41467-021-24487-w.

Choudhary, A., Rana, S., & Matahai, K.J., (2016). A Critical Analysis of Energy Efficient Virtual Machine Placement Techniques and its Optimization in a Cloud Computing Environment, Procedia Computer Science, Volume 78, Pages 132-138, https://doi.org/10.1016/j.procs.2016.02.022.

Ahmad, R. W., *et al.*, (2019). Enhancement and Assessment of a Code-Analysis-Based Energy Estimation Framework, *IEEE Systems Journal*, vol. 13, no. 1, pp. 1052-1059.

Lannelongue, L., Grealey, J., & Inouye, M., (2021). Green Algorithms: Quantifying the Carbon Footprint of Computation. Adv Sci (Weinh). 8 (12):2100707.

Nwankwo, W., & Chinedu, P. U., (2020). Green Computing: A Machinery for Sustainable Development in the Post-Covid Era. In (Ed.), Green Computing Technologies and Computing Industry in 2021. IntechOpen. https://doi.org/10.5772/intechopen.95420.

Wu, H., (2018). Multi-Objective Decision-Making for Mobile Cloud Offloading: A Survey, *IEEE Access*, vol. 6, pp. 3962-3976, doi: 10.1109/ACCESS.2018.2791504.

Roelich, K., Knoeri, C., Steinberger, J. K., Varga, L., Blythe, P. T., Butler, D., Gupta, R., Harrison, G. P., Martin, C., & Purnell, P., Towards resource-efficient and service-oriented integrated infrastructure operation, Technological Forecasting and Social Change, Volume 92, Pages 40-52, https://doi.org/10.1016/j.techfore.2014.11.008.

Bharany, S., Sharma, S., Khalaf, O.I., Abdulsahib, G.M., Al Humaimeedy, A.S., Aldhyani, T.H.H., Maashi, M., & Alkahtani, H., (2022). A Systematic Survey on Energy-Efficient Techniques in Sustainable Cloud Computing. *Sustainability*, 14, 6256. https://doi.org/10.3390/su14106256.

Almulhim, A. I., (2022). Household's awareness and participation in sustainable electronic waste management practices in Saudi Arabia, Ain Shams Engineering Journal, Volume 13, Issue 4, 101729, https://doi.org/10.1016/j.asej.2022.101729.

Almobaideen, W., Qatawneh, M., & AbuAlghanam, O., (2019). Virtual Node Schedule for Supporting QoS in Wireless Sensor Network, *IEEE Jordan International Joint Conference on Electrical Engineering and Information Technology (JEEIT)*, pp. 281-285.

Khan, A. A., & Zakarya, M., (2021). Energy, performance and cost efficient cloud datacentres: A survey, Computer Science Review, Volume 40, 100390, https://doi.org/10.1016/j.cosrev.2021.100390.

Peng, C., Goswami, P., & Bai, G., (2020). A literature review of current technologies on health data integration for patient-centered health management. *Health Informatics Journal*. 1926-1951. doi:10.1177/1460458219892387

Benis, A., Tamburis, O., Chronaki, C., & Moen, A., (2021). One Digital Health: A Unified Framework for Future Health Ecosystems
J Med Internet Res; 23 (2):e22189.

Keeler, L. W., & Bernstein, M. J., (2021). The future of aging in smart environments: Four scenarios of the United States in 2050, Futures, Volume 133, 102830, https://doi.org/10.1016/j.futures.2021.102830.

Zhang, X., Manogaran, G., & Muthu, B., (2021). IoT enabled integrated system for green energy into smart cities, Sustainable Energy Technologies and Assessments, Volume 46, 101208, https://doi.org/10.1016/j.seta.2021.101208.

Sarrafan, K., Muttaqi, K. M., & Sutanto, D., (2020). Real-Time State-of-Charge Tracking Embedded in the Advanced Driver Assistance System of Electric Vehicles, *IEEE Transactions on Intelligent Vehicles*, vol. 5, no. 3, pp. 497-507.

Calza, F., Parmentola, A., & Tutore, I., (2020). Big data and natural environment. How does different data support different green strategies? Sustainable Futures, Volume 2, 100029, https://doi.org/10.1016/j.sftr.2020.100029.

Toosi, A. N., Qu, C., Assunção, M. D., & Buyya, R., (2017). Renewable-aware geographical load balancing of web applications for sustainable data centers, Journal of Network and Computer Applications, Volume 83, Pages 155-168, https://doi.org/10.1016/j.jnca.2017.01.036.

Georgiou, S., Rizou, S., & Spinellis, D., (2020). Software Development Lifecycle for Energy Efficiency: Techniques and Tools. ACM Comput. Surv. 52, 4, Article 81, 33 pages. https://doi.org/10.1145/3337773

Prakash, S., Köhler, A., Liu, R., Stobbe, L., Proske, M., & Schischke, K., (2016). Paradigm shift in Green IT - extending the life-times of computers in the public authorities in Germany, *Electronics Goes Green 2016+ (EGG)*, pp. 1-7.

Qureshi, K. N., Hussain, R., & Jeon, G., (2020). A Distributed Software Defined Networking Model to Improve the Scalability and Quality of Services for Flexible Green Energy Internet for Smart Grid Systems, Computers & Electrical Engineering, Volume 84, 106634, https://doi.org/10.1016/j.compeleceng.2020.106634.

Cao, Z., Zhou, X., Hu, H., Wang, Z., & Wen, Y., (2022). Toward a Systematic Survey for Carbon Neutral Data Centers," in *IEEE Communications Surveys & Tutorials*, vol. 24, no. 2, pp. 895-936.

Diniz, E. H., Yamaguchi, J. A., Santos, T. R., Carvalho, A. P., Alégo, A. S., & Carvalho, M., Greening inventories: Blockchain to improve the GHG Protocol Program in scope 2, Journal of Cleaner Production, Volume 291, 125900, https://doi.org/10.1016/j.jclepro.2021.125900.

Lumbreras, M., Diarce, G., Martin-Escudero, K., Campos-Celador, A., Larrinaga, P., (2022). Design of district heating networks in built environments using GIS: A case study in Vitoria-Gasteiz, Spain, Journal of Cleaner Production, Volume 349, 131491, https://doi.org/10.1016/j.jclepro.2022.131491.

Ahmad, R. W., Gani, A., Hamid, S. H., Xia, F., & Shiraz, M., (2015). A Review on mobile application energy profiling: Taxonomy, state-of-the-art, and open research issues, Journal of Network and Computer Applications, Volume 58, Pages 42-59, https://doi.org/10.1016/j.jnca.2015.09.002.

Dauvergne, P., (2022). Is artificial intelligence greening global supply chains? Exposing the political economy of environmental costs, Review of International Political Economy, 29:3, 696-718.

Tso, F., Jouet, S., Pezaros, & D. P., (2016). Network and server resource management strategies for data centre infrastructures: A survey, Computer Networks, Volume 106, Pages 209-225, https://doi.org/10.1016/j.comnet.2016.07.002.

Biran, O., Corradi, A., Fanelli, M., Foschini, L., Nus, A., Raz, D., Silvera, E., (2012). A stable network-aware VM placement for cloud systems. Proceedings of IEEE/ACM International Symposium on Cluster, Cloud and Grid Computing (CCGRID '12), pp. 498-506.

Mann, V., Gupta, A., Dutta, P., Vishnoi, A., Bhattacharya, P., Poddar, R., Iyer, A., (2012). Remedy: network-aware steady state VM management for data centers Proceedings of IFIP TC 6 Networking Conference, LNCS, vol. 7289, pp. 190-204.

Gutierrez-Estevez, D.M., Luo, M., (2015). Multi-resource schedulable unit for adaptive application-driven unified resource management in data centers. Proceedings of 2015 International Telecommunication Networks and Applications Conference (ITNAC), pp. 261-268.

Manvi, S. S., & Shyam, G. K., (2014). Resource management for Infrastructure as a Service (IaaS) in cloud computing: A survey, Journal of Network and Computer Applications, Volume 41, Pages 424-440, https://doi.org/10.1016/j.jnca.2013.10.004.

Tso, F.P., Oikonomou, K., Kavvadia, E., & Pezaros, D.P. (2014). Scalable traffic-aware virtual machine management for cloud data centers. Proceedings of the 34th International Conference on Distributed Computing Systems (ICDCS), IEEE, pp. 238-247

Shuja, J., Bilal, K., Madani, SA., Othman, M., Ranjan, R., Balaji, P., & Khan, SU. (2016). Survey of techniques and architectures for designing energy-efficient data centers. IEEE Syst J.10 (2):507–19.

Koot, M., & Wijnhoven, F., (2021). Usage impact on data center electricity needs: A system dynamic forecasting model, Applied Energy, Volume 291, 116798, https://doi.org/10.1016/j.apenergy.2021.116798.

Wierman, A., Liu, Z., Liu, I. & Mohsenian-Rad, H., (2014). Opportunities and challenges for data center demand response, *International Green Computing Conference*, pp. 1-10.

Moazamigoodarzi, H., Pal, S., Down, D., Esmalifalak, M., & Puri, I. K., (2020). Performance of a rack mountable cooling unit in an IT server enclosure, Thermal Science and Engineering Progress, Volume 17, 100395, https://doi.org/10.1016/j.tsep.2019.100395.

Pathak, A., Jindal, A., Hu, Y. C., & Midkiff, S. P., (2012). What is keeping my phone awake? Characterizing and detecting no-sleep energy bugs in smartphone apps. Proceedings of the 10th international conference on Mobile systems, applications, and services (MobiSys '12). Association for Computing Machinery, New York, NY, USA, 267–280. https://doi.org/10.1145/2307636.2307661

Carvalho, S. A. L., Cunha, D. C., Silva-Filho, A. G., (2019). Autonomous power management in mobile devices using dynamic frequency scaling and reinforcement learning for energy minimization, Microprocessors and Microsystems, Volume 64, Pages 205-220, https://doi.org/10.1016/j.micpro.2018.09.008.

Ebrahimi, K., Jones, GF., &Fleischer, AS. (2014). A review of data center cooling technology, operating conditions and the corresponding low-grade waste heat recovery opportunities. Renew Sust Energ Rev. 31: 622–38.

Shuja, J., Gani, A., Shamshirband, S., Ahmad, R. W., & Bilal, K., (2016). Sustainable Cloud Data Centers: A survey of enabling techniques and technologies, Renewable and Sustainable Energy Reviews, Volume 62, Pages 195-214, https://doi.org/10.1016/j.rser.2016.04.034.

Tiwary, M., Puthal, D., Sahoo, K. S., Sahoo, B., & Yang, L. T., (2018). Response time optimization for cloudlets in Mobile Edge Computing, Journal of Parallel and Distributed Computing, Volume 119, Pages 81-91, https://doi.org/10.1016/j.jpdc.2018.04.004.

Jin, C., Bai, X., Yang, C., Mao, W., & Xu, X., (2020). A review of power consumption models of servers in data centers, Applied Energy, Volume 265, 114806, https://doi.org/10.1016/j.apenergy.2020.114806.

Mosaad, M. I., Elkalashy, N. I., & Ashmawy, M. G., (2018). Integrating adaptive control of renewable distributed Switched Reluctance Generation and feeder protection coordination, Electric Power Systems Research, Volume 154, Pages 452-462, https://doi.org/10.1016/j.epsr.2017.09.017.

Jacquet, D., *et al*., (2014). A 3 GHz Dual Core Processor ARM Cortex TM -A9 in 28 nm UTBB FD-SOI CMOS With Ultra-Wide Voltage Range and Energy Efficiency Optimization, *IEEE Journal of Solid-State Circuits*, vol. 49, no. 4, pp. 812-826.

Lin, W., Wu, W., Wang, H., Wang, J. Z., & Hsu, C., (2018). Experimental and quantitative analysis of server power model for cloud data centers, Future Generation Computer Systems, Volume 86, Pages 940-950, https://doi.org/10.1016/j.future.2016.11.034.

Xiao, P., Hu, Z., Liu, D., Yan, G., & Qu, X., (2013). Virtual machine power measuring technique with bounded error in cloud environments, Journal of Network and Computer Applications, Volume 36, Issue 2, Pages 818-828, https://doi.org/10.1016/j.jnca.2012.12.002.

Arroba, P., Risco-Martín, J. L., Zapater, M., Moya, J. M., Ayala, J. L., Olcoz, K., (2014). Server Power Modeling for Run-time Energy Optimization of Cloud Computing Facilities, Energy Procedia, Volume 62, Pages 401-410, https://doi.org/10.1016/j.egypro.2014.12.402.

Kumar, C. & Naik, K. (2021). Smartphone processor architecture, operations, and functions: current state-of-the-art and future outlook: energy performance trade-off. *J Supercomput* **77,** 1377–1454. https://doi.org/10.1007/s11227-020-03312-z

Strazzabosco, A., Gruenhagen, J.H., & Cox, S., (2022). A review of renewable energy practices in the Australian mining industry, Renewable Energy, Volume 187, Pages 135-143, https://doi.org/10.1016/j.renene.2022.01.021.

Wan, J., Gui, X., Kasahara, S., Zhang, Y., & Zhang, R., (2018). Air Flow Measurement and Management for Improving Cooling and Energy Efficiency in Raised-Floor Data Centers: A Survey, *IEEE Access*, vol. 6, pp. 48867-48901, doi: 10.1109/ACCESS.2018.2866840.

Tarafdar, A., Debnath, M., Khatua, S. *et al.*, (2020). Energy and quality of service-aware virtual machine consolidation in a cloud data center. *J Supercomput* **76,** 9095–9126. https://doi.org/10.1007/s11227-020-03203-3

Iranmanesh, A., & Naji, H.R., (2021). DCHG-TS: a deadline-constrained and cost-effective hybrid genetic algorithm for scientific workflow scheduling in cloud computing. *Cluster Comput* **24,** 667–681. https://doi.org/10.1007/s10586-020-03145-8

Huang, J., Wu, K., & Moh, M., (2014). Dynamic Virtual Machine migration algorithms using enhanced energy consumption model for green cloud data centers, *International Conference on High Performance Computing & Simulation (HPCS)*, pp. 902-910.

Bhuiyan, M. N., Rahman, M. M., Billah, M. M. & Saha, D., (2021). Internet of Things (IoT): A Review of Its Enabling Technologies in Healthcare Applications, Standards Protocols, Security, and Market Opportunities, *IEEE Internet of Things Journal*, vol. 8, no. 13, pp. 10474-10498.

Altamimi, M., Abdrabou, A., Naik, K., & Nayak, A., (2015). Energy Cost Models of Smartphones for Task Offloading to the Cloud, *IEEE Transactions on Emerging Topics in Computing*, vol. 3, no. 3, pp. 384-398, doi: 10.1109/TETC.2014.2387752.

Jing, SY., Ali, S., She, K., & Zhong, Y., (2013). State-of-the-art research study for green cloud computing. J Supercomput. 65(1):445–68.

Reuben, J., *et al*., (2017). Memristive logic: A framework for evaluation and comparison, *27th International Symposium on Power and Timing Modeling, Optimization and Simulation (PATMOS)*, pp. 1-8.

Al-Tarazi, M. & Chang, J. M., (2019). Performance-Aware Energy Saving for Data Center Networks, *IEEE Transactions on Network and Service Management*, vol. 16, no. 1, pp. 206-219.

Roy, K., Jung, B., Peroulis, D., & Raghunathan, A., (2016). Integrated Systems in the More-Than-Moore Era: Designing Low-Cost Energy-Efficient Systems Using Heterogeneous Components, *IEEE Design & Test*, vol. 33, no. 3, pp. 56-65.

Varasteh, A., & Goudarzi, M., (2017). Server Consolidation Techniques in Virtualized Data Centers: A Survey, *IEEE Systems Journal*, vol. 11, no. 2, pp. 772-783.

Watson, B., & Venkiteswaran, V. K., Universal Cooling of Data Centres: A CFD Analysis, Energy Procedia, Volume 142, Pages 2711-2720, https://doi.org/10.1016/j.egypro.2017.12.215.

Ebrahimi, K., Jones, G. F., & Fleischer, A. S., (2014). A review of data center cooling technology, operating conditions and the corresponding low-grade waste heat recovery opportunities, Renewable and Sustainable Energy Reviews, Volume 31, Pages 622-638, https://doi.org/10.1016/j.rser.2013.12.007.

Jangiti, S., & Sriram, V. S. S., (2018). Scalable and direct vector bin-packing heuristic based on residual resource ratios for virtual machine placement in cloud data centers, Computers & Electrical Engineering, Volume 68, Pages 44-61, https://doi.org/10.1016/j.compeleceng.2018.03.029.

Meena, J., Kumar, M. & Vardhan, M., (2016). Cost Effective Genetic Algorithm for Workflow Scheduling in Cloud Under Deadline Constraint," in *IEEE Access*, vol. 4, pp. 5065-5082.

Alsamhi, S. H., Almalki, F. A., Al-Dois, H., Ben Othman, S., Hassan, J., Hawbani, A., Sahal, R., Lee, B., & Saleh, H., (2021). Machine Learning for Smart Environments in B5G Networks: Connectivity and QoS", Computational Intelligence and Neuroscience, vol. 2021, Article ID 6805151, 23 pages, https://doi.org/10.1155/2021/6805151.

Davies, G. F., Maidment, G. G., & Tozer, R. M., (2016). Using data centres for combined heating and cooling: An investigation for London, Applied Thermal Engineering, Volume 94, Pages 296-304, https://doi.org/10.1016/j.applthermaleng.2015.09.111.

Khalaj, A. H., & Halgamuge, S. K., (2017). A Review on efficient thermal management of air- and liquid-cooled data centers: From chip to the cooling system, Applied Energy, Volume 205, Pages 1165-1188, https://doi.org/10.1016/j.apenergy.2017.08.037.

Patel, Y. S., Mehrotra, N., & Soner, S., (2015). Green cloud computing: A review on Green IT areas for cloud computing environment, *International Conference on Futuristic Trends on Computational Analysis and Knowledge Management (ABLAZE)*, pp. 327-332.

Jorge-Martinez, D., Butt, S.A., Onyema, E.M. et al., (2021). Artificial intelligence-based Kubernetes container for scheduling nodes of energy composition. Int J Syst Assur Eng Manag. https://doi.org/10.1007/s13198-021-01195-8.

Zhang, F., Cao, J., Li, K., Khan, S. U., Hwang, K., (2014). Multi-objective scheduling of many tasks in cloud platforms, Future Generation Computer Systems, Volume 37, Pages 309-320, https://doi.org/10.1016/j.future.2013.09.006.

Zheng, J., Chien, A. A., Suh, S., (2020). Mitigating Curtailment and Carbon Emissions through Load Migration between Data Centers, Joule, Volume 4, Issue 10, Pages 2208-2222, https://doi.org/10.1016/j.joule.2020.08.001

Usmani, Z., & Singh, S., (2016). A Survey of Virtual Machine Placement Techniques in a Cloud Data Center, Procedia Computer Science, Volume 78, Pages 491-498, https://doi.org/10.1016/j.procs.2016.02.093.

Askarizade Haghighi, M., Maeen, M. & Haghparast, M. (2019). An Energy-Efficient Dynamic Resource Management Approach Based on Clustering and Meta-Heuristic Algorithms in Cloud Computing IaaS Platforms. *Wireless Pers Commun* 104, 1367–1391. https://doi.org/10.1007/s11277-018-6089-3.

Antal, M., Cioara, T., Anghel, I., Pop, C., & Salomie, I. (2018). Transforming Data Centers in Active Thermal Energy Players in Nearby Neighborhoods. *Sustainability*. 10(4):939. https://doi.org/10.3390/su10040939.

Kołodziej, J., Khan, SU., Wang, L., & Byrski, A., Min-Allah, N., Madani, SA. (2013). Hierarchical genetic-based grid scheduling with energy optimization. Clust Comput. 16 (3):591–609.

Srichandan, S., Kumar, T. A., & Bibhudatta, S., (2018). Task scheduling for cloud computing using multi-objective hybrid bacteria foraging algorithm, Future Computing and Informatics Journal, Volume 3, Issue 2, Pages 210-230, https://doi.org/10.1016/j.fcij.2018.03.004.

Oró, E., Depoorter, V., Garcia, A., & Salom, J., (2015). Energy efficiency and renewable energy integration in data centres. Strategies and modelling review, Renewable and Sustainable Energy Reviews, Volume 42, Pages 429-445, https://doi.org/10.1016/j.rser.2014.10.035.

Xiao, Z., Song, W., & Chen, Q., (2013). Dynamic Resource Allocation Using Virtual Machines for Cloud Computing Environment, *IEEE Transactions on Parallel and Distributed Systems*, vol. 24, no. 6, pp. 1107-1117.

Dvorak, V., Zavrel, V., Torrens Galdiz, J.I. *et al.*, (2020). Simulation-based assessment of data center waste heat utilization using aquifer thermal energy storage of a university campus. *Build. Simul.* 13, 823–836. https://doi.org/10.1007/s12273-020-0629-y

Woodruff, J. Z., Brenner, P., Buccellato, A. P. C., David, B., (2014). Go, Environmentally opportunistic computing: A distributed waste heat reutilization approach to energy-efficient buildings and data centers, Energy and Buildings, Volume 69, Pages 41-50, https://doi.org/10.1016/j.enbuild.2013.09.036.

Ljungdahl, V., Jradi, M., Veje, C., (2022). A decision support model for waste heat recovery systems design in Data Center and High-Performance Computing clusters utilizing liquid cooling and Phase Change Materials, Applied Thermal Engineering, Volume 201, Part A, 117671, https://doi.org/10.1016/j.applthermaleng.2021.117671.

Lykou, G., Mentzelioti, D., & Gritzalis, D., (2018). A new methodology toward effectively assessing data center sustainability, Computers & Security, Volume 76, Pages 327-340, https://doi.org/10.1016/j.cose.2017.12.008.

Xiao, Z., Song, W., & Chen, Q., (2013). Dynamic resource allocation using virtual machines for cloud computing environment. IEEE Trans Parallel Distrib Syst. 24 (6):1107–17.

Aranzazu-Suescun, C., & Cardei, M. (2019). Anchor-based routing protocol with dynamic clustering for Internet of Things WSNs. *J Wireless Com Network*, 130. https://doi.org/10.1186/s13638-019-1447-8

Shuja, J., Bilal, K., Madani, SA., Othman, M., Ranjan, R., Balaji, P., & Khan, SU. (2016). Survey of techniques and architectures for designing energy-efficient data centers. IEEE Syst J. 10 (2):507–19.

Deng, W., Liu, F., Jin, H., Li, B., & Li, D., (2014). "Harnessing renewable energy in cloud datacenters: opportunities and challenges, *IEEE Network*, vol. 28, no. 1, pp. 48-55.

Mazumdar, S., & Pranzo, M., (2017). Power efficient server consolidation for Cloud data center, Future Generation Computer Systems, Volume 70, Pages 4-16, https://doi.org/10.1016/j.future.2016.12.022.

Iwai, H., (2015). Future of nano CMOS technology, Solid-State Electronics, Volume 112, Pages 56-67, https://doi.org/10.1016/j.sse.2015.02.005.

Liu, H., Jin, H., Xu, CZ., & Liao, X., (2013). Performance and energy modeling for live migration of virtual machines. Clust Comput. 16(2):249–64.

Masdari, M., Nabavi, S. S., & Ahmadi, V., (2016). An overview of virtual machine placement schemes in cloud computing, Journal of Network and Computer Applications, Volume 66, Pages 106-127, https://doi.org/10.1016/j.jnca.2016.01.011.

Zhang, F., Liu, G., Fu, X. & Yahyapour, R., (2018) A Survey on Virtual Machine Migration: Challenges, Techniques, and Open Issues, *IEEE Communications Surveys & Tutorials*, vol. 20, no. 2, pp. 1206-1243, doi: 10.1109/COMST.2018.2794881.

Tso, FP., Hamilton, G., Oikonomou, K., & Pezaros, DP., (2013). Implementing scalable, network-aware virtual machine migration for cloud data centers. In: IEEE CLOUD. p. 557–564.

Yang, T., Zhao, Y., Pen, H., & Wang, Z., (2018). Data center holistic demand response algorithm to smooth microgrid tie-line power fluctuation, Applied Energy, Volume 231, Pages 277-287, https://doi.org/10.1016/j.apenergy.2018.09.093.

Yu, C., Hou, W., Guo, L., Zong, Y., (2016). Parallel virtual machine migration in WDM optical data center networks, Optical Switching and Networking, Volume 20, Pages 46-54, https://doi.org/10.1016/j.osn.2015.11.002.

Baccarelli, E., Cordeschi, N., Mei, A., Panella, M., Shojafar, M., & Stefa, J., (2016). Energy-efficient dynamic traffic offloading and reconfiguration of networked data centers for big data stream mobile computing: review, challenges, and a case study, *IEEE Network*, vol. 30, no. 2, pp. 54-61.

Gove, R.J., (2014). 7 - Complementary metal-oxide-semiconductor (CMOS) image sensors for mobile devices, Editor(s): Daniel Durini, High Performance Silicon Imaging, Woodhead Publishing, Pages 191-234, https://doi.org/10.1533/9780857097521.2.191.

Vallejos, R., Olavarría, J., & Jara, N., (2016). Blocking evaluation and analysis of dynamic WDM networks under heterogeneous ON/OFF traffic, Optical Switching and Networking, Volume 20, Pages 35-45, https://doi.org/10.1016/j.osn.2015.11.001.

Hasan, M. S., Kouki, Y., Ledoux, T., & Pazat, J., (2017). Exploiting Renewable Sources: When Green SLA Becomes a Possible Reality in Cloud Computing, *IEEE Transactions on Cloud Computing*, vol. 5, no. 2, pp. 249-262.

Nada, S.A., Elfeky, K.E., Attia, A.M.A. et al. (2017). Experimental parametric study of servers cooling management in data centers buildings. Heat Mass Transfer 53, 2083–2097. https://doi.org/10.1007/s00231-017-1966-y.

Hoque, M. A., Siekkinen, M., Khan, K. N., Xiao, Y., & Tarkoma, S. (2016). Modeling, Profiling, and Debugging the Energy Consumption of Mobile Devices. ACM Comput. Surv. 48, 3, Article 39, 40 pages. https://doi.org/10.1145/2840723.

Huang, F., Lu, J., Zheng, J., & Baleynaud, J., (2015). Feasibility of heat recovery for district heating based on cloud computing industrial park. International Conference on Renewable Energy Research and Applications (ICRERA). IEEE. p. 287–291.

Kang, X., Jia, S., Xu, R., Liu, S., Peng, J., Yu, H., & Zhou, X., (2021). Highly efficient pyroelectric generator for waste heat recovery without auxiliary device, Nano Energy, Volume 88, 106245, https://doi.org/10.1016/j.nanoen.2021.106245.

Luporini, F., Varbanescu, AL., Rathgeber, F., Bercea, GT., Ramanujam, J., Ham, DA., & Kelly, PH., (2015). Cross-loop optimization of arithmetic intensity for finite element local assembly. ACM Trans Archit Code Optim (TACO). 11(4):57.

Shuja, J., Gani, A., Shamshirband, S., Ahmad, RW., & Bilal, K., (2016). Sustainable cloud data centers: A survey of enabling techniques and technologies. Renew Sust Energ Rev. 62:195–214.

Wang, X., Vasilakos, AV., Chen, M., Liu, Y., & Kwon, TT., (2012). A survey of green mobile networks: Opportunities and challenges. Mob Netw Appl.17(1):4–20.

Abbasi, Z., Jonas, M., Banerjee, A., Gupta, S., & Varsamopoulos, G., (2013). Evolutionary Green Computing Solutions for Distributed Cyber Physical Systems. Berlin, Heidelberg: Springer Berlin Heidelberg; pp. 1–28.

Deng, W., Liu, F., Jin, H., Li, B., & Li, D., (2014). Harnessing renewable energy in cloud datacenters: opportunities and challenges. IEEE Networks. 28(1):48–55.

Zhou, J., Sun, J., Athukorala, K., Wijekoon, D., & Ylianttila, M., (2012). Pervasive social computing: augmenting five facets of human intelligence. J Ambient Intell Humanized Comput. 3(2):153–66.

Ahmed, E., Yaqoob, I., Gani, A., Imran, M., & Guizani, M., (2016) Internet-of-things-based smart environments: state of the art, taxonomy, and open research challenges. IEEE Wirel Commun. 23(5):10–6.

Sharma, R., (2013). A Review on Cloud Computing-An Emerging Technology. *International Journal of Scientific & Engineering Research*, 4 (6), 2120-2124.

Banger, N., Pallavi, K., & Shetty, S.J., (2022). A Review Paper on Cloud Computing Architecture, Types, Advantages and Disadvantages. *International Journal of Advanced Research in Science, Communication and Technology (IJARSCT), 2 (2), 14-22.*

Grace, J. S., & Gandhi, G. M., (2022). Study of varied Scheduling Algorithms for a Green Cloud IT Infrastructures. *International Journal of Mechanical Engineering*, 7 (1), 5841-5846.

Ogala, E., Akoh, R. O., & Agbata, A. A. B., (2022). Green cloud-based computing architecture with integrated green infrastructure. East African Scholars Journal of Engineering and Computer Sciences, 5(1), 1-5.

Jamal, F., & Khan, R. Z., (2020). Emerging technologies and developments in cloud computing: A systematic review. International Journal of Emerging Trends in Engineering Research, 8(3), 894-905.

Elazhary, H. (2019). Internet of Things (IoT), mobile cloud, cloudlet, mobile IoT, IoT cloud, fog, mobile edge, and edge emerging computing paradigms: Disambiguation and research directions. Journal of Network and Computer Applications, 128, 105-140.

Nazir, S., Ali, Y., Ullah, N., & García-Magariño, I. (2019). Internet of things for healthcare using effects of mobile computing: a systematic literature review. *Wireless Communications and Mobile Computing*, 2019.

Ma, X., Wang, Z., Zhou, S., Wen, H., & Zhang, Y. (2018). Intelligent healthcare systems assisted by data analytics and mobile computing. 14th International Wireless Communications & Mobile Computing Conference (IWCMC), IEEE, pp. 1317-1322.

Zaidi, S.F.H., Osmanaj, V., Ali, O. and Zaidi, S.A.H. (2021), "Adoption of mobile technology for mobile learning by university students during COVID-19", International Journal of Information and Learning Technology, 38 (4), pp. 329-343. https://doi.org/10.1108/IJILT-02-2021-0033

Ramasamy, L. K., & Kadry, S. (2021). Blockchain in the Industrial Internet of Things. IOP publishing.

Liao, B., Ali, Y., Nazir, S., He, L., & Khan, H. U. (2020). Security analysis of IoT devices by using mobile computing: a systematic literature review. IEEE Access, 8, 120331-120350.

Ma, X., Wang, Z., Zhou, S., Wen, H., & Zhang, Y. (2018). Intelligent healthcare systems assisted by data analytics and mobile computing. In 14th International Wireless Communications & Mobile Computing Conference (IWCMC) (pp. 1317-1322).

Alzoubi, Y. I., Al-Ahmad, A., & Jaradat, A., (2021). Fog computing security and privacy issues, open challenges, and blockchain solution: An overview. International Journal of Electrical & Computer Engineering (2088-8708), 11(6), 5081-5088.

Haoxiang, W., & Smys, S., (2021). Big data analysis and perturbation using data mining algorithm. Journal of Soft Computing Paradigm (JSCP), 3(01), 19-28.

Ageed, Z. S., Zeebaree, S. R., Sadeeq, M. M., Kak, S. F., Yahia, H. S., Mahmood, M. R., & Ibrahim, I. M., (2021). Comprehensive survey of big data mining approaches in cloud systems. Qubahan Academic Journal, 1(2), 29-38.

Awan, J.M., Mohd-Rahim, M. S., Nobanee, H., Yasin, A., & Khalaf, O. I., (2021). A big data approach to black friday sales. MJ Awan, M. Shafry, H. Nobanee, A. Yasin, OI Khalaf et al.," A big data approach to black friday sales," Intelligent Automation & Soft Computing, 27(3), 785-797.

Giri, K. J., & Lone, T. A., (2014). Big Data-overview and challenges. International Journal of Advanced Research in Computer Science and Software Engineering, 4(6).

Giri, K. J., & Lone, T. A., (2014). Big Data-overview and challenges. International Journal of Advanced Research in Computer Science and Software Engineering, 4(6).

Günther, W. A., Mehrizi, M. H. R., Huysman, M., & Feldberg, F., (2017). Debating big data: A literature review on realizing value from big data. The Journal of Strategic Information Systems, 26(3), 191-209.

Oussous, A., Benjelloun, F. Z., Lahcen, A. A., & Belfkih, S. (2018)., Big Data technologies: A survey. Journal of King Saud University-Computer and Information Sciences, 30(4), 431-448.

Wang, J., Xu, C., Zhang, J., & Zhong, R., (2021). Big data analytics for intelligent manufacturing systems: A review. Journal of Manufacturing Systems.

Issaoui, Y., Khiat, A., Bahnasse, A., & Ouajji, H., (2019). Smart logistics: Study of the application of blockchain technology. Procedia Computer Science, 160, 266-271.

Ali, O., Jaradat, A., Kulakli, A., & Abuhalimeh, A., (2021). A comparative study: Blockchain technology utilization benefits, challenges and functionalities. IEEE Access, 9, 12730-12749.

Riđić, O., Jukić, T., Riđić, G., Mangafić, J., Bušatlić, S., & Karamehić, J., (2022). Implementation of Blockchain Technologies in Smart Cities, Opportunities and Challenges. Blockchain Technologies for Sustainability, 71-89.

Casino, F., Dasaklis, T. K., & Patsakis, C., (2019). A systematic literature review of blockchain-based applications: current status, classification and open issues. Telematics and Informatics, 36, pp. 55-81.

Jaoude, J. A. & Saade, R. G., (2019). Blockchain applications–usage in different domains. IEEE Access, 7, pp. 45360-45381.

McGhin, T., Kim-Kwang, R. C., Charles Z. L. & Debiao H., (2019). Blockchain in healthcare applications: Research challenges and opportunities. Journal of Network and Computer Applications (2019)

Katuwal, G. J., Sandip P., Mark, H. & Bishal, L., (2018). Applications of blockchain in healthcare: Current landscape & challenges. arXiv preprint arXiv: 1812. 02776.

Zhang, P., Schmidt, D. C., White, J., & Lenz, G., (2018). Blockchain technology use cases in healthcare. In Advances in computers, 111, pp. 1-41

Beck, R., Müller-Bloch, C. and King, J.L., (2018). Governance in the Blockchain Economy: A Framework and Research Agenda. Journal of the Association for Information Systems, 19 (10), pp. 1020-1034. https://doi.org/10.17705/1jais.00518

Nærland, K., Müller-Bloch, C., Beck, R. and Palmund, S., (2017). Blockchain to rule the waves: Nascent design principles for reducing risk and uncertainty in decentralized environments. The 38th International Conference on Information Systems, Seoul, South Korea, pp. 1-16.

Clemons E. K., Dewan, R. M., Kauffman, R. J., & Weber, T. A., (2017). Understanding the information-based transformation of strategy and society. Journal of Management Information Systems, 34 (2), pp. 425-456.

Iansiti, M. and Lakhani, K.R., (2017). The truth about blockchain. Harvard Business Review, 95 (1), 118-127.

Francisco Luis, BM., Pedro Víctor, NCU., Valentín, MM., Esteban, RF., (2022). Blockchain as a Service: A Holistic Approach to Traceability in the Circular Economy. In: Muthu, S.S. (eds) Blockchain Technologies for Sustainability. Environmental Footprints and Eco-design of Products and Processes. Springer, Singapore, pp. 119-133. https://doi.org/10.1007/978-981-16-6301-7_6

Androutsopoulou, A., Karacapilidis, N., Loukis, E., & Charalabidis, Y., (2019). Transforming the communication between citizens and government through AI-guided chatbots. *Government information quarterly*, 36(2), 358-367.

Vesnic-Alujevic, L., Nascimento, S., & Polvora, A., (2020). Societal and ethical impacts of artificial intelligence: Critical notes on European policy frameworks. Telecommunications Policy, 44(6), 101961.

Dwivedi, Y. K., Hughes, L., Ismagilova, E., Aarts, G., Coombs, C., Crick, T., ... & Williams, M. D., (2021). Artificial Intelligence (AI): Multidisciplinary perspectives on emerging challenges, opportunities, and agenda for research, practice and policy. International Journal of Information Management, 57, 101994.

Alshahrani, A., Dennehy, D., & Mäntymäki, M., (2022). An attention-based view of AI assimilation in public sector organizations: The case of Saudi Arabia. Government Information Quarterly, 39(4), 101617.

Sousa, W. G.d., Melo, E. R. P.d., Bermejo, P. H. D. S., Farias, R. A. S., & Gomes, A. O., (2019). How and where is artificial intelligence in the public sector going? A literature review and research agenda. *Government Information Quarterly*, 36(4), 101392. https://doi.org/10.1016/j.giq.2019.07.004

Zuiderwijk, A., Chen, Y. C., & Salem, F., (2021). Implications of the use of artificial intelligence in public governance: A systematic literature review and a research agenda. Government Information Quarterly, 38(3), 101577.

Huang, L.; Cai, J.; Lee, T.; Weng, M. A. (2020). Study on the development trends of the energy system with blockchain technology using patent analysis. *Sustainability*, 12, 2005.

Dai, J.; Vasarhelyi, M.A. (2017). Toward blockchain-based accounting and assurance. *Journal of Information Systems*, 31, 5-21.

Kewell, B.; Adams, R.; Parry, G. (2017). Blockchain for good? Strateg. Chang, 26, 429-437.

Bano, S.; Sonnino, A.; Al-bassam, M.; Azouvi, S.; Mccorry, P. (2017) SoK: Consensus in the age of blockchains. arXiv 2017, arXiv:arXivabs/1711.03936v2. Available online: https://arxiv.org/abs/1711.03936v2.

Schletz, M.; Nassiry, D.; Lee, M.K. (2020). Blockchain and tokenized securities: The potential for green finance; ADBI Working Papers; ADBI Institute: Tokyo, Japan, 2020. Available online: https://www.adb.org/publications/ blockchain-tokenized-securities-potential-green-finance.

Cong, L.W.; He, Z. (2019). Blockchain disruption and smart contracts. *Review of Finance Studies*, 32, 1754–1797.

Andoni, M.; Robu, V.; Flynn, D.; Abram, S.; Geach, D.; Jenkins, D.; Mccallum, P.; Peacock, A. (2019). Blockchain technology in the energy sector: A systematic review of challenges and opportunities. *Renew. Sustain. Energy Rev.*,100, 143–174.

Alam, M.R.; St-Hilaire, M.; Kunz, T. (2019). Peer-to-peer energy trading among smart homes. *Applied Energy*, 238, 1434-1443.

Zhang, C.; Wu, J.; Long, C.; Cheng, M. (2017). Review of existing Peer-to-Peer energy trading projects. *Energy Procedia*, 105, 2563–2568.

Rogers, E. (2018). *How Can Blockchain Save Energy? Here Are Three Possible Ways*; American Council for Energy Efficient Economy: Washington, DC, USA, 2018.

IEA, (2019). *Energy Service Companies at the Heart of Innovative Financing Models for Efficiency*; International Energy Agency: Paris, France.

 doi:10.20944/preprints202502.0293.v1

Gürcan, Ö.; Agenis-Nevers, M.; Batany, Y.V.; Elmtiri, M.; le Fevre, F.; Tucc, S. (2018). An industrial prototype of trusted energy performance contracts using blockchain technologies. *The IEEE 20th International Conference on High Performance Computing and Communications*; Exeter, UK, 28–30.

Rogers, E. (2018). Blockchain and energy efficiency: A Match Made in Heaven; American Council for an Energy Efficient Economy: Washington, DC, USA. Energies 2019, 12, 3317 14 of 14.

Kawabata, T. (2018). Blockchain technology brings innovative ways to achieve energy efficiency. *International Partnership for Energy Efficient Cooperation*: Paris, France.

Castellanos, J.A.F.; Coll-Mayor, D.; Notholt, J.A. (2017). Cryptocurrency as guarantees of origin: Simulating a green certificate market with the Ethereum Blockchain. *The IEEE International Conference on Smart Energy Grid Enegineering*, Oshawa, ON, Canada, 14-17.

International Energy Agency, (2018). *Energy Efficiency 2018 Analysis and Outlooks to 2040*; OECD/IEA: Paris, France, 2018.

Shafik R, Wheeldon A, Yakovlev A. (2020). Explainability and dependability analysis of learning automata-based AI hardware. *The 26th IEEE Int. Symp. on On-line Testing and Robust System Design* (IOLTS 2020), 1st virtual edition, 13 July 2020. New York, NY: IEEE.

Osman, A.I., Chen, L., Yang, M. (2023). Cost, environmental impact, and resilience of renewable energy under a changing climate: A review. Environmental Chemical Letter, 21, 741-764. https://doi.org/10.1007/s10311-022-01532-8.