Industry IoT Consortium

Green IT: A 360-Degree Scan of Current Research, Projects and Initiatives

2023-04-26

Author:

Yannic Schlimpen, M.Sc.
Fraunhofer Institute for Communication,
Information Processing and Ergonomics (FKIE)
yannic.schlimpen@fkie.fraunhofer.de

CONTENTS

FIGURES

TABLES

1 Introduction

Climate change is currently arguably the greatest threat to our existence, and the role of IT cannot be neglected. The topic of Green IT deals with sustainable and energy-efficient IT solutions that affect both hardware and software. Like IT itself, Green IT is an extremely broad subject area that needs to be surveyed.

1.1 Purpose

The aim of this article is to provide an overview of the current state of Green IT research and thus make it easier for interested parties and newcomers to get started in Green IT.

1.2 Scope

This article intends to provide a rough overview of current Green IT topics in research as well as initiatives and organizations working on the topic. It presents tools for estimating the emissions of IT systems, guidelines that provide suggestions, best practices for the sustainable and energy-efficient design, and labels that distinguish particularly efficient and sustainable systems.

1.3 Structure

The document is organized as follows:

- Chapter 1. Introduction
- Chapter 2. Motivation
- Chapter 3. Current Research Topics
- Chapter 4. Conclusion

1.4 Audience

The reader should gain a greater basic understanding of Green IT through this article. Different Green IT aspects and areas such as green data centers or green artificial intelligence are described. It also shows how the use of IT, such as IoT or AI, can help to reduce energy consumption.

1.5 Use

This article is intended as a guide to the current state of research in the field of Green IT and what aspects are relevant. The lists are by no means exhaustive but attempt to provide a rough overview of the broad subject area.

1.6 Terms and Definitions

The following terms and definitions are key to understanding this document:

- IT – Information Technology
- ICT – Information and Communications Technology
- CO2e – Greenhouse gases
- AI – Artificial Intelligence
- IoT – Internet of Things

1.7 CONVENTIONS

Given that the document is non-normative, all 'must', 'may' and 'should' statements are to be interpreted as English language.

1.7.1 TYPOGRAPHICAL AND LINGUISTIC CONVENTIONS AND STYLE

Terms that require definition are rendered in *italics*. (As the usage immediately preceding demonstrates, italics may also be used as example, or for emphasis.)

Generally, only the first use of the term is italicized. However, when a term can be read in its usual English language mode, the first use of the term may be italicized as the discussion becomes technical. In the first example below, "safety" and "security" are used informally. In the second, it introduces a definition.

Example

> "Among the key system characteristics that must be considered, safety is perhaps the most important, followed by security."
>
> "*Safety* is the condition of the system operating without causing unacceptable risk of physical injury or damage to the health of people, either directly or indirectly, as a result of damage to property or to the environment."

2 MOTIVATION

Climate change is probably the greatest threat to our existence at present. Among the many social and industrial sectors affected, one area must not be neglected: IT / ICT. According to Capgemini[1], data centers were responsible for 1% of the global energy demand in 2019, while 55.5 million tons of e-waste were generated in 2020 alone - an increase of 20% in the last 5 years. Globally, only 43% of executives are aware of their company's IT footprint.

Green IT (also *Green Computing* or *Green ICT*) is the term used to describe environmentally friendly and sustainable IT solutions that include aspects such as the entire sustainable life cycle of an IT solution, from production to disposal, the perception of the general public, energy-efficient software or even the energy supply of IT solutions. While seals of approval such as Energy Star already exist for hardware, there is still a need for universally valid seals of approval

[1] Capgemini: Sustainable IT – "Why it's time for a Green revolution for your organization's IT," 2021. Available: (*https://www.capgemini.com/)*

and benchmarks in the area of software. Energy savings and reduced emissions using IT can be called *Green by IT.* In particular, current technology trends such as the Internet of Things or Artificial Intelligence can be used to make processes in industry more efficient. “

2.1 MOTIVATION: RESEARCH GOALS

Energy-efficient hardware and software not only ensure lower greenhouse gas emissions, but also a longer useful life of the equipment. The goal of this research was to identify current research topics and relevant aspects of Green IT and to obtain a broad overview of the entire subject area.

To achieve this, the available scientific literature and ongoing research activities on energy-efficient software development and use were reviewed, and Green IT initiatives and existing Green IT labels were identified.

2.2 MOTIVATION: GREEN IT

Green IT is a combination of two buzzwords that are more important than ever in an era of digitization and advancing climate change and stands for environmentally friendly and sustainable ICT solutions. In addition to the entire lifecycle of an ICT solution, from production to disposal, the software that runs on an ICT device and the energy supply of the devices also play an important role. Green IT first came to public attention in 1992 when the US Environmental Protection Agency launched Energy Star, a program to identify consumer electronics that meet energy efficiency standards.

Another event that boosted the popularity of Green IT was in 2007/2008, when Green IT was the main theme of the Cebit trade fair. The main aspects at that time were: recycling, green by IT, energy efficiency and less toxic substances in the production of hardware.

IT can be used as an effective tool against climate change, but the carbon footprint caused by IT itself must not be forgotten. According to a study by "the Shift Project,"[2] digital technologies are responsible for 4% of greenhouse gas emissions worldwide. At the same time, energy consumption is increasing by almost 9% annually. However, according to the study, this growth can be reduced to only 1.5% per year through adapted digital practices. The energy intensity, a measure of the energy inefficiency of an economy, of the ICT sector is growing by 4% annually, which contrasts with the trend of the energy intensity of the global gross domestic product, which is decreasing by 1.8% annually.

But what exactly does green IT deal with? The most important aspects include[3]:

[2] The Shift Project, “Lean ICT - Towards Digital Sobriety”, 2019. *Lean-ICT-Report_The-Shift-Project_2019.pdf (theshiftproject.org)*

[3] S. Murugesan, “Harnessing Green IT: Principles and Practices,” IT Professional, February 2008.

- design for environmental sustainability
- energy-efficient computing
- power management
- data center design, layout, and location
- server virtualization
- responsible disposal and recycling
- regulatory compliance
- green metrics, assessment tools, and methodology
- environment-related risk mitigation
- use of renewable energy sources
- eco-labeling of IT products.

Although the aspects mentioned beforehand were published in 2008, the aspects and topics addressed are still current and important. Data centers in particular are a major topic, but with increasing technological progress, new areas have also emerged having also green IT potential.

Trending technologies that have become increasingly important in recent years, such as the Internet of Things, cloud/edge computing or artificial intelligence, are responsible for a significant progress with an impact on everyday life, but the emissions caused by those technologies and their power consumption must not be disregarded.

The following chapter will take a closer look at the specific aspects of green IT nowadays.

3 Current Research Topics

In this chapter, current topics from research are examined in more detail.

3.1 Research Methodology: Keyword Analysis

For this purpose, scientific publications (papers) from recent years were analyzed for recurring keywords.

Papers from the last six years (January 2016- August 2022) were examined. These were taken from the scientific literature database Scopus. The search terms used were:

- Green IT
- Green ICT
- Green Computing

Other possible search terms such as "Green Internet of Things" or "Green AI" were omitted to prevent a bias towards these topics. In the period under review, 12,551 papers on the above terms were found. The papers were analyzed using the software environment R.

In addition to the findings from the paper analysis, projects or initiatives were identified that address various aspects of Green IT.

3.2 Research Results: Keyword Analysis

Bibliographic information of the papers was read in by Scopus and processed using various R packages. In particular, the keywords specified in the papers were extracted and processed in R, so that subject areas could be identified on the basis of the frequency of certain keywords. Previously, duplicate papers were removed from the dataset, leaving 12,539 papers.

Keyword	Frequency
green computing	12586
energy efficiency	6523
energy utilization	5381
cloud computing	3269
internet of things	2702
data centers*	2270
edge computing	1516
electric power utilization	1311
virtual machine	1068
scheduling	1046
resource allocation	1036
artificial intelligence + machine learning	940

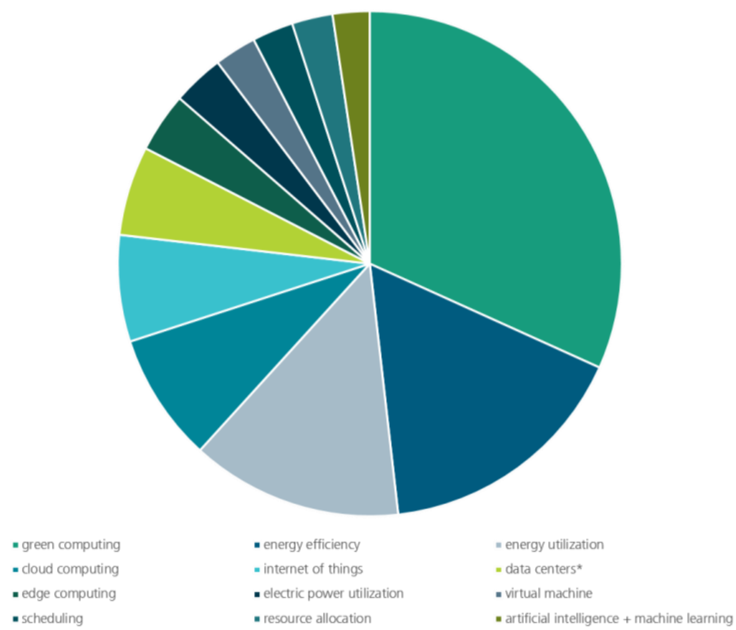

Figure 3-1: IT/OT convergence and trustworthiness.

Figure 3-1 shows the distribution of keywords that occurred at least 1000 times in the data set. The most frequently occurring keyword is, as expected, one of the search terms, "Green Computing." Here it is noticeable that scientific papers are not marked with the keywords "Green IT" or "Green ICT," which occurred less than 1000 times, but predominantly with "Green Computing."

In addition to general aspects of green IT such as "energy efficiency" and "energy utilization," the most frequent keywords that appear in the same articles with one of the search terms as a keyword also include current technology trends such as "cloud computing," "edge computing" and the "Internet of Things." Green IT is therefore definitely concerned with current technologies.

Upon further examination, it is also noticeable that two topics are missing that should supposedly play a greater role: "Data Centers," which was only used 905 times as a keyword, and "Artificial

Intelligence," which was used a total of 383 times. In the case of data centers, however, it should be noted that various spellings and special cases were used.

For example, in addition to the aforementioned keyword "Data Centers," the thematically related terms "Data Center" (493 times), "Cloud Data Centers" (419 times), "Datacenter" (344 times) and "Green Data Centers" (109 times) also appeared, so that the topic area of data centers is represented overall at a similar level to the technology trends mentioned.

In the following, the individual key topics are analyzed in more detail. For this purpose, those papers that match the respective keyword/aspect are filtered out of the previously selected papers. The following topics are examined in more detail based on their frequency:

- Cloud Computing
- Edge Computing
- Virtual Machine
- Data Center
- Internet of Things
- Artificial Intelligence

The search query on Scopus was extended accordingly by a search term with the corresponding keywords, as well as related terms and other spellings. The results were also again limited to the period 2016-2022 (key date: October 11th, 2022) to maintain a certain topicality.

3.3 RESEARCH RESULTS: A CLOSER LOOK

Keyword	Search Term	Frequency
Cloud Computing	{Cloud}	4674
Internet of Things	{Internet of Things} OR {IoT}	2671
Edge Computing	{Edge}	2002
Virtual Machine	{Virtual Machine} OR {VM}	1242
Data Centers	{Data Centers} OR {Data Center}	2617
Artificial Intelligence	{Artificial Intelligence} OR {AI} OR {Machine Learning}	1205

Table 3-1: Frequency of papers with specific keywords.

Table 3-1 shows the number of papers for each keyword, while **Error! Reference source not found.**Figure 3-2 shows word clouds containing the most important keywords for each of the topics listed in Table 3-1. The larger a word appears in the cloud, the more frequently it appears as a keyword found in the papers. Thus, general aspects such as energy efficiency or consumption play an important role for many of the topic areas. However, a closer look also reveals aspects that are more technical. For Cloud and Edge Computing, for example, mechanisms such as virtualization or computation offloading are important.

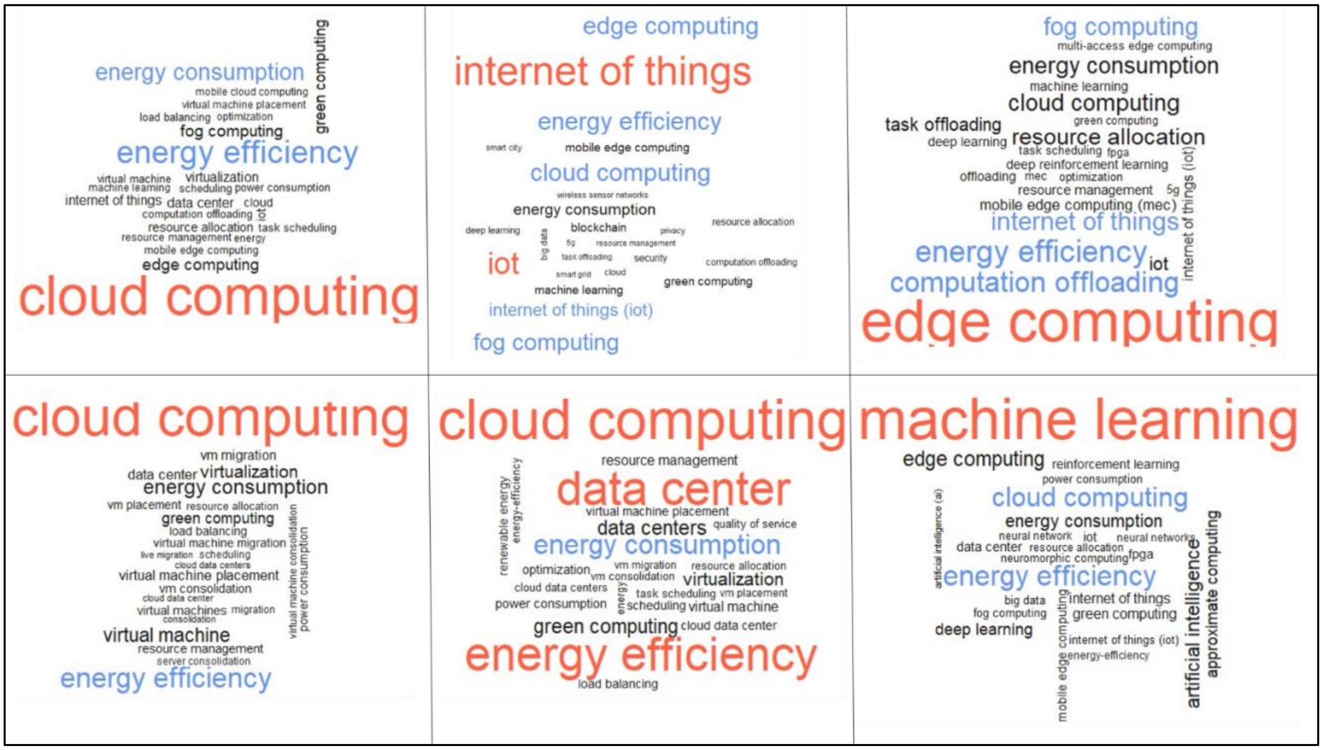

Figure 3-2: Word clouds, from top left to bottom right: Cloud Computing, Internet of Things, Edge Computing, Virtual Machine, Data Centers, and Artificial Intelligence.

3.3.1 GREEN CLOUD COMPUTING

Concrete trends in Green Cloud Computing are mainly solution approaches in which virtualization can be used by cloud computing to reduce the energy consumption and emissions of physical data centers. The main Green Cloud Computing characteristics include[4]:

[4] A. Singha, S. J. Sarkar, S. Nayak and R. Patgiri, "Green Cloud Computing-To Build A Sustainable Tomorrow," 2022 International Conference for Advancement in Technology (ICONAT), Goa, India, 2022. pp. 1-6, doi: 10.1109/ICONAT53423.2022.9726052.

Characteristic	Short Description	Challenges
Virtualization	Reduction of hardware by abstracting multiple virtual computers on a single physical machine.	- General optimization of virtualization process methods. - Automated development of optimal VMs with significant resources, complex resource allocation and communication capabilities without impacting cloud performance.
Energy efficiency	Performance is an important factor of a "green" cloud. Use of effective energy control methods to minimize energy consumption on individual cloud objects (servers, computing centers, processors, etc.).	- In data centers, data storage and data processing software consume large amounts of energy. To achieve energy efficiency, the cloud needs an efficient energy monitoring system, a complex energy distribution system, and a smart energy supply decision system. - Intelligent mechanisms for energy optimization of the entire cloud infrastructure.
Multi-Tenancy	Cloud instance serves multiple tenants of the same category instead of establishing one cloud instance per tenant.	- Privacy and protection issues. - Design of a secure multi-locator infrastructure and secure access to the corresponding modules.
Consolidation	Method of installing data processing applications connected to different data centers on a single virtualization server.	-Potential issues related to multi-aspect thresholding, core resource utilization, and server downtime management.
Eco-friendly	Economic growth and environmental friendliness are not always compatible. Green Cloud Computing aims to close the gap through sustainable clouds.	Developing software with a focus on the environment, such as CO2 calculator software that can quantify the impact of a cloud on nature.

Table 3-2: Green Cloud Computing characteristics.

3.3.2 Green Edge Computing

In general, the challenges and requirements for green edge computing are very similar to those for green cloud computing. Perhaps the most important difference lies in the benefits of each technology. In edge computing, data is processed de-centrally at the edge of a network, rather than being collected and analyzed by a central server or in the cloud.

One advantage of edge computing over cloud computing in terms of Green IT is that the decentralized storage and processing of data at the network edge means that large data packets do not need to be sent over a global network and consume bandwidth. In particular, much smaller data that is measured or calculated at short intervals does not need to be stored and processed in larger cloud server facilities. In addition, smaller edge computing devices can be more easily tailored to individual user needs than data centers and servers. This allows organizations to pay more attention to the recyclability and energy efficiency of individual devices, and thus fit into a possible corporate sustainability strategy.

3.3.3 Green Virtual Machine

According to Figure 3-1, the main aspects of a Green Virtual Machine include "cloud computing" and "virtualization." The topics and research aspects thus essentially coincide with the aspects already mentioned in 3.3.13.3.1 and 3.3.2.

When it comes to data centers, Figure 3-2 shows that the most important topics are cloud computing and energy efficiency, but also virtualization and renewable energy for data center power. The overall topic of 'data centers’ is also likely to be one of the most important Green IT topics, partly because optimizing data centers involves other important topics such as cloud and edge computing, and partly because the volume of data, the associated computing load and, ultimately, energy requirements will continue to increase in the coming years as global digitization continues. The challenge for data center operators will not only be how to store and process the data, but also how to supply the various components with sufficient energy - a major hurdle in the face of rising electricity prices.

Data centers are therefore a significant factor and there is clearly a great deal of potential for optimization. One problem that arises in this context is how to measure the energy efficiency of a data center. One possible indicator is Power Usage Effectiveness (PUE), which is the quotient of the total energy demand of a data center and the separate energy demand of IT. This metric was introduced by The Green Grid in 2006 and is now one of the most widely used metrics for measuring data center energy efficiency.

However, the PUE must be critically analyzed, as it can only be calculated in very general terms and thus ignores specific requirements. For example, it does not take into account the location of the data center or the external climatic conditions. A data center that is located in a very hot place and requires more energy for cooling systems, but is otherwise extremely efficient, could have a lower PUE than a data center that is not particularly efficient but requires less powerful cooling systems because it is located in a cold place, so the overall PUE is lower. Another problem is that PUE only makes sense if the entire IT is running at full capacity, to get a true value for the maximum energy consumption of the IT. In addition, there is no clear definition of which energy sources are included in total data center consumption. Perhaps the biggest criticism of PUE is that it does not take into account IT performance. Only the power consumption is relevant to the PUE, which does not allow any conclusions to be drawn about the actual performance of the data center's IT. The PUE is therefore relatively easy to calculate but should also be treated with caution.

An alternative way of measuring the energy efficiency of data centers is the KPI4DCE (Key Performance Indicators for Data Center Efficiency)[5] system developed by the German Federal Environment Agency. The aim of the development was to create a performance indicator system that covers all areas of a data center and considers IT performance. The main tasks of KPI4DCE were the collection and evaluation of existing key figures, indicators and methods, the development of a key figure system in the sense of the objective, the evaluation of the system on the basis of practical use cases, the incorporation of the results into harmonization and standardization activities and the further development of the ecolabel Blue Angel for data centers with the help of the key figures.

3.3.4 Green Internet of Things

According to the word cloud from Figure 3-2, the most important topics are cloud and edge computing. From a technical perspective, blockchain and machine learning are also relevant.

The main goal of the Green Internet of Things is to reduce emissions, toxic components and the general energy consumption of IoT devices. The reduction of emissions generated by other systems through the use of IoT applications is called Green by IoT and will be discussed later in this article. Green IoT is primarily about the "greening" of the Internet of Things itself and the associated devices. Important characteristics include[6]:

- Energy-efficient hardware and software design techniques to reduce energy consumption in IoT-based applications.
- Application of enhanced encryption and decryption techniques.
- Reframing to avoid data redundancy.
- Environmentally friendly manufacturing of IoT devices.
- Powering the IoT network through renewable energy sources.

Specific technologies that can help implement these characteristics are[7]:

---

[5] B. Schödwell, R. Zarnekow, R. Liu, J. Gröger, M. Wilkens, "Kennzahlen und Indikatoren für die Beurteilung der Ressourceneffizienz von Rechenzentren und Prüfung der praktischen Anwendbarkeit", 2018. *Kennzahlen und Indikatoren für die Beurteilung der Ressourceneffizienz von Rechenzentren und Prüfung der praktischen Anwendbarkeit | Umweltbundesamt*r

[6] M. A. Albreem, A. M. Sheikh, M. H. Alsharif, M. Jusoh and M. N. Mohd Yasin, "Green Internet of Things (GIoT): Applications, Practices, Awareness, and Challenges," in IEEE Access, vol. 9, pp. 38833-38858, 2021. doi: 10.1109/ACCESS.2021.3061697.

[7] M. A. Albreem, A. M. Sheikh, M. H. Alsharif, M. Jusoh and M. N. Mohd Yasin, "Green Internet of Things (GIoT): Applications, Practices, Awareness, and Challenges," in IEEE Access, vol. 9, pp. 38833-38858, 2021. doi: 10.1109/ACCESS.2021.3061697.

Technology	Short Description
Machine-to-Machine (M2M)	Direct communication capability between wired and wirelessly connected IoT devices without human intervention.
Wireless Sensor Network (WSN)	Network of sensor nodes. Uses scheduling, interference reduction, resource allocation and routing to be energy efficient and acts as a gateway to a local area network.
RFID	Electronic tag that can answer an identification request from a reader.
Microcontroller Unit	Low cost processor unit.
Energy Harvesting	Energy generation for batteries of e.g. IoT network sensors by mechanical, thermal, radiative or biochemical sources. High-frequency signals have advantages over low-frequency signals, as they can produce energy and process information at the same time.

Table 3-3: Green IoT technologies.

3.3.5 Green Artificial Intelligence

According to Figure 3-2, the most important keywords in the field of Green AI are "machine learning," "cloud computing" and "energy efficiency," but technical aspects such as "approximate computing" also appear. In addition to data centers, the energy consumption of training and using artificial intelligence should not be underestimated. According to forecasts, deep learning processes will consume almost 300,000 times more computing power in 2019 than in 2013[8].

In general, the energy consumption of AI should not be neglected. A single large speech transformer model can generate nearly 300 tons of CO_2 during training from scratch. To put this in perspective, an average human is responsible for just under 5 tons of CO_2 over the course of a year[9]. However, as methods for greening AI itself currently need more research, greening other processes with the help of AI, Green by AI, can have a direct impact on the combat against climate change.

The potential for savings through artificial intelligence, i.e. "green by AI," exists and relates to energy consumption, resource conservation and CO_2 emissions. According to a study by the

[8] R. Schwartz, J. Dodge, N. A. Smith und O. Etzioni, “Green AI,” in *Communications of the ACM,* pp. 54-63, December 2020.

[9] E. Strubell, A. Ganesh, A. McCallum, “Energy and Policy Considerations for Deep Learning in NLP,” 2019.

Boston Consulting Group (BCG)[10], which surveyed private and public sector executives involved in climate and AI issues, 87% of respondents believe that artificial intelligence can be a helpful tool in the fight against climate change, but only just under 40% of organizations have a concrete idea of how they can use artificial intelligence to achieve their own climate goals.

Thus, AI can be used for mitigation, adaptation and resilience, and fundamentals such as strengthening climate research and modeling. Concrete use cases are therefore:

- Gather, complete, and process data
  - E.g. satellite and IoT data
  - Filling gaps in sparse data
- Strengthen planning and decision making
  - Policy and climate-risk analytics
  - Modeling higher-order effects
  - Bionic management
- Optimize processes
  - Supply chain
  - Simulation environments
- Support collaborative ecosystems
  - Vertical data sharing
  - Enhanced communication tools
- Encourage climate-positive behaviors
  - Climate-weighted suggestions

More recommendations on the use of artificial intelligence in the fight against climate change can be found in a paper[11] by members of Climate Change AI.

[10] H. Maher, H. Meinecke, D. Gromier, M. Garcia-Novelli, R. Fortmann, "How AI Can Be a Powerful Tool in the Fight Against Climate Change," 2022. *ai-for-the-planet-bcg-report-july-2022.pdf*

[11] David Rolnick et al., "Tackling Climate Change with Machine Learning", in ACM Comput. Surv. 55, 2023. *https://doi.org/10.1145/3485128*

		Causal inference	Computer vision	Interpretable models	NLP	RL & Control	Time-series analysis	Transfer learning	Uncertainty quantification	Unsupervised learning
Mitigation	**Electricity systems**									
	Enabling low-carbon electricity		•	•		•	•		•	•
	Reducing current-system impacts		•				•		•	•
	Ensuring global impact		•					•		•
	Transportation									
	Reducing transport activity		•				•		•	•
	Improving vehicle efficiency		•			•				
	Alternative fuels & electrification					•				•
	Modal shift	•	•				•		•	
	Buildings and cities									
	Optimizing buildings	•				•	•	•		
	Urban planning		•				•	•		•
	The future of cities				•			•	•	•
	Industry									
	Optimizing supply chains		•			•	•			
	Improving materials									•
	Production & energy		•	•		•				
	Farms & forests									
	Remote sensing of emissions		•							
	Precision agriculture		•			•	•			
	Monitoring peatlands		•							
	Managing forests		•			•	•			
	Carbon dioxide removal									
	Direct air capture									•
	Sequestering CO_2		•						•	•
Adaptation	**Climate prediction**									
	Uniting data, ML & climate science		•	•			•		•	
	Forecasting extreme events		•	•			•		•	
	Societal impacts									
	Ecology		•					•		
	Infrastructure					•	•		•	
	Social systems		•				•			•
	Crisis		•		•					
	Solar geoengineering									
	Understanding & improving aerosols						•		•	
	Engineering a control system					•			•	
	Modeling impacts						•		•	
Tools for Action	**Individual action**									
	Understanding personal footprint	•			•	•	•			
	Facilitating behavior change				•					•
	Collective decisions									
	Modeling social interactions			•		•				
	Informing policy	•	•		•				•	•
	Designing markets					•	•			•
	Education				•	•				
	Finance				•		•		•	

Figure 3-3: Climate change solution domains.[12]

[12] David Rolnick et al., "Tackling Climate Change with Machine Learning," in ACM Comput. Surv. 55, 2023. *Tackling Climate Change with Machine Learning | ACM Computing Surveys*

Figure 3-3 shows various application areas of artificial intelligence combined with relevant areas of machine learning. The individual proposals are not intended to be, and cannot be, a single solution to climate change, and will require collaboration across multiple thematic areas to implement.

Looking at the specifics of AI and how it can have an impact in the context of climate change, key areas where AI can facilitate climate action include[13]:

- Distilling raw data into actionable information: AI identifies important information among large amounts of unstructured data. E.g., AI can analyze satellite images to identify areas of cities vulnerable to coastal inundation, or areas that are prone to forest fires.
- Improving Predictions: Based on historic data AI can make predictions on the future. E.g., AI can make minute-level predictions on solar power generation helping to balance the electrical grid.
- Optimizing complex systems: With the help of AI methods, complex systems with many variables that can be controlled simultaneously can be optimized. E.g., AI methods can be used to reduce the energy needed for heating or cooling a building.
- Accelerating scientific modeling and discovery: AI can accelerate the process of scientific discovery by blending known constraints with data-driven approximations. E.g., AI can simulate portions of climate and weather models to make them more computationally tractable.

Regarding industrial settings, AI can be used to optimize the following aspects[14]:

- Supply chains: AI can help to reduce emissions in supply chains by predicting supply and demand based on past data, identifying lower-carbon products and optimizing shipping routes. Overproduction and food waste can be reduced this way.
- Improving Materials: AI can help to minimize the emissions produced by carbon-intensive materials like cement and steel by transforming industrial processes to run on low-carbon energy or even by redesigning the chemistry of structural materials.
- Production and energy: AI can help to reduce the overall electricity consumption by streamlining factories' HVAC systems and the development of models for industrial processes to run them on low-carbon energy instead of fossil-fueled energy.

However, despite all the possible positive effects, the damage caused by AI in the form of emissions needs to be kept in mind. Therefore, any use of AI must carefully consider the extent to which the benefits to climate change outweigh the potential harms of AI.

---

[13] Peter Clutton-Brock et al., "Climate Change and AI – Recommendations for Government Action," 2021. *climate-change-and-ai.pdf (gpai.ai)*

[14] David Rolnick et al., "Tackling Climate Change with Machine Learning," in ACM Comput. Surv. 55, 2023. *Tackling Climate Change with Machine Learning | ACM Computing Surveys*

3.4 CURRENT INITIATIVES AND LABELS

This section highlights several international initiatives and organizations working on Green IT as well as labels created for awarding highly efficient and/or sustainable hardware or software. The selection is not exhaustive and does not intend to undermine the work of other initiatives or organizations not listed here.

In general, the focus of all initiatives and organizations is to raise awareness of Green IT. This is achieved primarily through the provision of guidelines, best practices, tools and a community. Bringing together a number of stakeholders in an initiative also generates greater interest in Green IT.

Table 3-4 provides a brief overview of some organizations involved in Green IT.

Organization	Short Description	Website
Climate Change AI	Focus on the role of artificial intelligence and machine learning in tackling climate change.	*https://www.climatechange.ai/*
The Green Web Foundation	Focus on a fossil-free Internet	*https://www.thegreenwebfoundation.org/*
ClimateAction.tech	Association of tech workers who want to share their knowledge and skills in the fight against climate change in companies, organizations and industry through a self-organized community.	*https://climateaction.tech/*
The Green Grid	Member of the Information Technology Industry Council (ITI) dedicated to creating tools, technical expertise and optimizing the energy and resource efficiency of data center ecosystems.	*https://www.thegreengrid.org/*
Sustainable Digital Infrastructure Alliance	Independent alliance of stakeholders from the digital sector aiming at a sustainable digital infrastructure by 2030.	*https://sdialliance.org/*
International Telecommunications Union	United Nations specialized agency for ICT. Working Group 5 "Environment, Climate Change and the Circular Economy" deals with Green IT. Under "Green ICT Standards and Supplements," various recommendations are listed, including data centers, but also smart cities and smart homes.	*https://www.itu.int/en/Pages/default.aspx*
Green Software Foundation	A non-profit foundation that aims to build an ecosystem of people, standards, tools and practices for the creation and development of sustainable software, thereby shifting the culture of the software development industry towards a greater focus on software sustainability.	*https://greensoftware.foundation/*

Table 3-4: Organizations with focus on Green IT aspects.

While initiatives and associations are important to further stimulate interest and work on Green IT, some labels already exist to identify particularly efficient IT products. Table 3-5 provides a brief overview of some already existing Green IT labels.

Label	Short Description	Website
Energy Star	Certification for high efficiency products. Available for: Audio/Visual, Computers, Data Center Storage, Displays, Imaging Equipment, Servers, Small Network Equipment, Televisions, Uninterruptible Power Supplies.	*https://www.energystar.gov/*
EPEAT	Eco-label for a range of IT products. Available for computers and displays, imaging equipment, mobile phones, networking equipment and servers.	*https://www.epeat.net/*
TCO Certified	Sustainability certification for IT products. Criteria include product and sustainability information, green manufacturing and reduction of hazardous substances.	*https://tcocertified.com/*
Green Web Check	Labels environmentally friendly websites.	*https://www.thegreenwebfoundation.org/green-web-check/*
Blue Angel: Resources and Energy-Efficient Software Products	Label for reduced energy and resource consumption in software products.	*https://www.blauer-engel.de/en/productworld/resources-and-energy-efficient-software-products*
Blue Angel: Server and Data Storage Products	Label for servers, data storage products and power supplies that are particularly energy efficient, durable and environmentally friendly.	*https://www.blauer-engel.de/en/productworld/server-and-data-storage-products*
Blue Angel: Data Centers	Label for data centers that are operated in a particularly energy-efficient and resource-conserving manner.	*https://www.blauer-engel.de/en/productworld/data-centers*
Software Carbon Intensity Specification	Specification for the rate of carbon emissions for a software system. Work still in progress.	*https://github.com/Green-Software-Foundation/software_carbon_intensity*

Table 3-5: Green IT labels.

4 CONCLUSION

To summarize, the focus of Green IT in the future will be on data centers, software in general, and especially current technology trends such as the Internet of Things or Artificial Intelligence.

For some aspects, labels already exist, such as the Blue Angel for data centers or software products, or the Energy Star label and TCO Certified for IT hardware. However, in the course of digitization and the associated increase in data volume and computing load, which is often ultimately processed in a data center, it is now necessary to apply these labels in practice and to implement specific measures.

The focus does not necessarily have to be on new technologies or processes: The energy savings potential from higher server utilization alone can bring significantly higher efficiency. Similarly, underperforming servers should be turned off. Combined with efficient air-conditioning technology and an uninterruptible power supply that is tailored to actual consumption, as well as waste heat recovery, data centers can be designed to be sustainable.

There is still a lack of standards and benchmarks for green software. Approaches and tools are available to measure the energy consumption of software and estimate the associated emissions, but there is a lack of common metrics that can be used for classification. Initiatives such as the Green Software Foundation and the Sustainable Digital Infrastructure Alliance are addressing this issue. Results are still in progress. Such initiatives also raise awareness and enable collaboration among different stakeholders with the goal of making green software more attractive and tangible to a broader spectrum.

Artificial Intelligence and the Internet of Things can play a key role in the combat against climate change. Due to their wide range of applications, there are numerous opportunities to make industrial processes in particular more sustainable and efficient. However, it is important not to overlook the emissions generated by AI and IoT itself, which particularly remain an area of concern in the case of AI.

5 Acknowledgements

The views expressed in the *IIC Journal of Innovation* are the contributing authors' views and do not necessarily represent the views of their respective employers nor those of the Industry IoT Consortium.

➢ Return to *IIC Journal of Innovation landing page* for more articles and past editions.