Green AI: A Study on Carbon Footprint and Water Consumption of Artificial Intelligence Systems

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***Abstract*—Developments in machine learning, cloud computing, and artificial intelligence (AI) techniques have led to the development of AI technologies in recent times. Despite the positive effects AI has on automation, productivity, and decision-making, AI has raised concerns regarding its environmental impacts such as carbon emissions, energy consumption, and water usage. AI systems require large models that should be trained using complex and intensive computation capabilities provided by high-powered computers that require energy to function effectively. This paper explores the environmental impacts of Artificial Intelligence systems, particularly carbon emissions and water consumption. The paper will analyze how AI training, AI inference processes and cloud computing impact environmental degradation. In addition, this paper explains how data centers, GPUs, and cooling systems contribute to the increase in energy consumption. Moreover, this paper looks at the concept of green AI, which promotes sustainability in AI technology. Some of the ways suggested include model optimization, utilization of renewable energy sources, efficient use of hardware and effective data center management.**

***Index Terms*—Green AI, Carbon Footprint, Water Consumption, Artificial Intelligence, Sustainable Computing, Data Centers, Energy Efficiency, Generative AI, Environmental Impact.**

I. INTRODUCTION

Artificial Intelligence is one of the fastest-growing technologies emerging in today's world. Various fields such as healthcare, finance, education, transportation, cybersecurity, and manufacturing make use of AI technology. The emergence of advanced AI models such as Large Language Models (LLMs) and generative AI systems has resulted in increasing computation demands. The demands of an advanced AI system involve high-performance computing and massive data processing.

Training these advanced AI models involves using many GPUs and servers for long hours. This process is energy-intensive and leads to significant greenhouse gas emissions. In addition to being highly power-demanding, AI systems also require a cooling system to ensure that the temperatures in data centers remain in an optimum range.

This paper will explore the environmental issues and considerations of AI systems and discuss the potential for sustainable solutions via Green AI practices.

There are the following major contributions in this work:

I. Analysis of carbon emissions generated by AI systems.
II. Study of water consumption in AI data centers.
III. Understanding the environmental impact of large AI models.
IV. Exploration of sustainable and energy-efficient AI solutions.
V. Discussion on the future scope of Green AI technologies.

II. LITERATURE REVIEW

Artificial Intelligence (AI) technologies have experienced significant development and research discussions about their environmental footprint. A few researchers have explored the correlation between the use of AI systems, energy consumption, and carbon emissions.

The computational power needed to train large machine learning models has been previously pointed out as a large electricity consumption and high greenhouse gas emissions [1], [2]. It was noted that the energy efficiency of AI models is much lower than that

of traditional computing systems, which is attributed to the growing complexity of AI neural networks.

Another field of study is cloud computing, and data center infrastructure. Scholars studied the temperature regulation of data centers supporting the operation of artificial intelligence, which requires considerable cooling mechanisms and water sources [3], [4]. These studies showed that cloud-based AI services make a significant contribution to environmental stress.

Green AI-related research explored sustainable approaches that could minimize the environmental footprint created through the development of artificial intelligence. To save energy, researchers have suggested various ways including model compression, efficient algorithms, use of renewable energy sources, and optimized hardware use [5], [6]. Another important topic that received attention in recent times is the ethical concerns and sustainability challenges of generative AI models.

With the advent of chatbots and image generation AI tools, AI computing consumes a significant amount of energy, which results in increased energy demands [7], [8]. Despite the advancements made in the understanding of sustainability in AI, most of the current literature focuses solely on the energy demand of AI or the hardware used for processing [5], [6]. There exists no research study that considers the carbon footprint along with water consumption analysis simultaneously.

Therefore, there is a need for a comprehensive investigation of the environmental footprint created by AI systems.

III. METHODOLOGY

In the suggested research study, the chosen approach will be a research-based method, which aims to analyze the environmental effect of AI systems using literature review, comparison, and case evaluation approaches.

A. System Overview

This study consists of three broad themes:

1. Carbon Footprint Analysis
2. Water Consumption Analysis
3. Solutions for Sustainable Green AI.

This analysis is conducted based on published research papers, sustainability reports, industrial case studies and environmental statistics related to AI systems and data centers.

B. Working Principle

The research method is as follows:

1. Research paper/case studies data collection
2. Analysis of AI energy usage patterns.
3. Research on water consumption in AI data centers.
4. The traditional computing system and the AI system are evaluated.
5. Identify sustainable AI practices
6. Conclusion based on environmental analysis.

C. Main Modules

1) Carbon Emission Analysis Module

This module analyzes electricity consumption caused by AI model training and inference operations. The effects of GPU clusters and cloud infrastructure on carbon emissions are examined.

2) Water Consumption Analysis Module

This module is dedicated to the analysis of water usage in AI data centers. This research investigates the significant water usage of cooling systems in HPC systems for AI applications.

3) Sustainable AI Module

This module explores Green AI techniques such as:

1. Energy-efficient algorithms
2. Renewable energy usage
3. Model optimization
4. Efficient hardware systems

4) Comparative Study Module

This module compares traditional computing systems with AI-based systems based on:

1. Energy Consumption
2. Carbon Emissions
3. Environmental Sustainability

C. Mathematical Formulas Used

FORMULA 1 — Carbon Emission Formula

$CO_2 = E \times CI$

Where:

CO_2 = Carbon emissions (kg CO_2)

E = Energy consumed (kWh)

CI= Carbon intensity factor (kg CO_2/kWh)

Purpose:

Used to estimate carbon emissions generated by AI systems.

FORMULA 2 — POWER CONSUMPTION FORMULA
$P = V \times I$
Where:
P= Power consumed (Watts)
V = Voltage
I = Current
Purpose:
Used to calculate electrical power consumed by AI hardware.

FORMULA 3 — ENERGY CONSUMPTION FORMULA
$E = P \times t$
Where:
E = Energy consumed (kWh)
P = Power consumption (kW)
t = Time duration (hours)
Purpose:
Used to calculate total energy used during AI model training.

FORMULA 4 — WATER USAGE EFFECTIVENESS

$$WUE = \frac{Annual\ Water\ Usage\ (L)}{IT\ Equipment\ Energy\ (kWh)}$$

Where:
WUE = Water Usage Effectiveness.
Annual Water Usage (L)= Total water consumed by the data center in liters.
IT Equipment Energy=Energy consumed by IT equipment in kWh
Purpose:
Measures cooling efficiency of AI data centers.

IV. RESULT AND DISCUSSION

A. Analysis of Environmental Impacts:
The estimated energy consumption, carbon emissions and water usage during AI operations were used to analyze the environmental impact of Artificial Intelligence systems. The AI systems are very power-intensive, particularly as they are trained using large-scale AI models, which run on high-performance GPUs and cloud-based systems.
The effects of AI operations on the environment escalate as operations get more complex, as indicated in TABLE I. Data centers consume substantial amounts of electricity to power the Large Language Models (LLMs) and employ sophisticated cooling infrastructure to maintain the LLM servers, leading to additional water usage in the centers.

Operation	Estimated Energy Used	Carbon Emission
Small ML Model Training	50 kWh	20 kg CO_2
Medium AI Model	500 kWh	200 kg CO_2
Large Language Model	10000 + kWh	Very High
AI Inference Operations	Moderate	Moderate

Table I. Estimated Environmental Impact of Ai Operations

From Table I, it can be observed that AI systems consume significantly higher computational resources compared to traditional computing systems. The continuous computation of Large Language Models (LLMs) on GPUs and the corresponding usage of a large cloud infrastructure contributes to high electricity consumption, carbon emissions, and water use.

B. Comparative Analysis
A comparison was made between the traditional computing system and an AI-based system to determine the differences in the computational requirements, cooling requirements and environmental footprint.
Compared to traditional computing systems, AI systems consume a great deal more energy and computational power, as shown in TABLE II.

Parameter	Traditional Computing	AI System
Energy Consumption	Moderate	Very High
Carbon Emission	Moderate	High
Water Usage	Low	High
Computational Requirement	Moderate	Very High
Infrastructure Cost	Medium	High
Environmental Impact	Medium	Severe

Table Ii. Traditional Computing Vs Ai Systems

TABLE II., shows that high-performance GPUs, large scale data centers and cooling systems are essential to

the success of an AI system. These requirements add a substantial demand for electricity and water. Traditional computing systems generally use simpler architectures and consume less energy. By contrast, AI systems ingest huge amounts of data when they are trained and tested, and when they are used to make predictions, causing significant environmental damage. This comparison vividly shows how critical Green AI techniques are for sustainable development of AI.

C. Graphical Analysis

1) AI Energy Consumption Growth

In recent years, the use of Artificial Intelligence technologies has grown quickly, contributing to the rise in global energy consumption. The widespread adoption of generative AI systems, cloud computing and Large Language Models is driving electricity consumption of AI infrastructure.

Year	Estimated AI Energy Consumption
2020	100 Units
2021	180 Units
2022	320 Units
2023	500 Units
2024	800 Units

Fig. 3. Growth Of AI Energy Consumption Between 2020 and 2024.

In Fig. 3, it can be observed that the use of AI has grown significantly over the years. AI has played a significant role in driving up global energy consumption with its deployment in various industries. Companies need to use a large amount of electricity to run AI models, especially when training them on large-scale cloud infrastructure. The figure illustrates the critical importance of energy-efficient AI systems and sustainable computing practices.

2) Water Usage Comparison

In order to maintain the stable temperature of the servers during intensive computing, advanced cooling systems are required for AI data centers. A lot of water is needed for cooling mechanisms, especially in AI related applications using GPUs.

System Type	Water Usage
Traditional Servers	Low
Cloud Computing	Moderate
AI Data Centers	Very High

Fig. 4. Water Usage Comparison

Compared to the traditional computing system, the water usage of AI data centers is much larger, as can be observed in Fig. 4. This increase is mainly due to cooling requirements for GPU clusters and high-performance servers.

As AI continues to be adopted globally, the amount of water consumed for AI infrastructure is expected to increase even further. The use of sustainable cooling technologies and renewable-energy-powered data centers can help to reduce this impact on the environment.

D. Discussion

The findings suggest that although Artificial Intelligence offers substantial technological advancements, it also brings environmental challenges which need to be addressed. The increasing demand for generative AI systems is expected to increase electricity consumption and water usage in the future. Through enhanced algorithm design, energy generation from renewable sources, and hardware design, Green AI could play a role in lowering the ecological footprint. But creating sustainable AI technology will hinge on a combination of scientists, business and governments.

V. EXISTING VS PROPOSED GREEN AI APPROACH

Traditional AI infrastructure primarily focuses on performance and computational efficiency, but not on sustainability. Current AI systems rely on a massive amount of electricity for the continuous GPU processing and cooling operations.

To mitigate these challenges, Green AI focuses on sustainable computing practices like the use of renewable energy, optimization of algorithms, efficient hardware systems, and eco-friendly cooling methods. The goal of traditional AI infrastructure is to

deliver performance and computational efficiency, rather than being sustainable. The electric consumption required for the large volume of GPUs processing and cooling data is a key issue with current AI systems.

Green AI aims to address these challenges by implementing sustainable computing practices, such as renewable energy sources, algorithm optimization, efficient hardware systems, and environmentally friendly cooling solutions.

System Type	Water Usage
Traditional Servers	Low
Cloud Computing	Moderate
AI Data Centers	Very High

Fig. 5. Existing vs Proposed Green AI System

As illustrated in Fig. 5, the proposed Green AI approach can lead to considerable energy savings and environmental friendliness. Renewable energy sources, maximum use of hardware, and sustainable cooling can reduce carbon emissions and water usage. This comparison highlights how sustainable AI practices can enhance sustainability without compromising computational performance.

VI. LIMITATIONS

The research paper will be based primarily on secondary sources which are publicly available. Environmental factors might be different across regions, infrastructure, and type of AI model deployed. Furthermore, the dynamics of AI technology may create new trends environmentally in the future. In addition, the lack of transparency in the industrial AI infrastructure makes it challenging to accurately estimate the impact on the environment.

VII. CONCLUSION

This paper presents a research study of the carbon footprint and water usage of Artificial Intelligence (AI) systems. The results show that Artificial Intelligence technologies require massive amounts of computing power, which results in energy use, CO_2 emissions and water use.

Overall, the findings highlight the importance of green AI practices in developing sustainable and eco-friendly AI systems. AI technologies can impact the environment, but with smart design, renewable energy usage, and sustainable management of data centers, the ecological footprint can be reduced. Further development is essential to develop more energy-efficient architectures for AI and improve the sustainability guidelines for the use of AI on a larger scale.

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