



Green Artificial Intelligence: Reducing Energy Consumption in AI Systems

Neetu Anand ¹, Harshita Pandey ², Harshita Gulati ³

¹Associate Professor, Maharaja Surajmal Institute, Affiliated to GGSIPU, New Delhi, India

^{2,3}Research Scholar, Maharaja Surajmal Institute, Affiliated to GGSIPU, New Delhi, India

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Abstract - Artificial Intelligence (AI) has become one of the most powerful technologies in modern society, transforming industries such as healthcare, education, finance, and transportation. However, the rapid growth of AI systems, especially large-scale machine learning and deep learning models, has significantly increased energy consumption and carbon emissions due to their heavy computational requirements. This growing environmental impact has raised concerns about the sustainability of AI development. Green Artificial Intelligence (Green

AI) focuses on reducing the energy consumption of AI systems while maintaining their performance and efficiency. It promotes sustainable practices such as energy-efficient algorithms, model optimization, hardware improvements, and the use of renewable energy-powered data centers. This research paper explores the environmental challenges associated with traditional AI systems, examines key Green AI techniques, and highlights the benefits, limitations, and future potential of sustainable AI practices. The study emphasizes that adopting Green AI is essential for balancing technological innovation with environmental responsibility.

Keywords - Green AI, Sustainable Computing, Energy Efficiency, Artificial Intelligence, Carbon Footprint, Machine Learning

I. Introduction

Artificial Intelligence (AI) has rapidly become a major part of modern technological advancement. From virtual assistants and recommendation systems to healthcare diagnostics and autonomous vehicles, AI is now widely used across multiple sectors. Its ability to process large amounts of data and perform complex tasks has made it an essential tool for innovation and economic growth.

Despite its numerous benefits, the development and deployment of advanced AI systems require substantial computational power. Training large machine learning models, especially deep learning and large language models, often depends on high-performance processors such as GPUs and large-scale data centers. These systems consume significant amounts of electricity, leading to increased operational costs and considerable carbon emissions.



As AI adoption continues to grow globally, concerns regarding its environmental sustainability have also increased. The energy-intensive nature of traditional AI systems contributes to climate change and resource depletion, creating a need for more responsible technological practices. This challenge has led to the emergence of Green Artificial Intelligence (Green AI), which focuses on developing AI systems that prioritize energy efficiency, reduced carbon footprints, and sustainable resource utilization.

Green AI emphasizes designing models and infrastructures that achieve strong performance while minimizing environmental impact. Techniques such as model optimization, energy-efficient hardware, renewable-powered data centres, and sustainable computing frameworks are becoming increasingly important.

This research paper aims to explore the environmental impact of conventional AI systems, analyse the principles and techniques of Green AI, and discuss its role in building a more sustainable future for artificial intelligence. By understanding the importance of energy-efficient AI, this study highlights how innovation can be balanced with environmental responsibility.

II. Literature Review

The concept of Green Artificial Intelligence has gained significant attention in recent years as researchers have begun to examine the environmental costs associated with AI development. Traditional AI systems, particularly deep learning models, require extensive computational resources for training and deployment. Several studies have highlighted that the energy consumption of large AI models can generate substantial carbon emissions, making sustainability an important concern in modern computing.

Schwartz et al. (2019) [1] introduced the concept of Green AI by emphasizing that AI research should not focus solely on performance improvements but also consider computational efficiency and environmental costs. Their work encouraged the research community to evaluate AI systems based on both accuracy and energy consumption.

Strubell et al. (2019) [2] further examined the financial and environmental impact of training large natural language processing models. Their study demonstrated that large-scale model training can consume enormous amounts of electricity, producing carbon emissions comparable to those of multiple vehicles over their lifetimes.

Recent systematic reviews have explored multiple strategies for reducing AI's environmental impact. These include model compression, efficient neural network architectures, transfer learning, and renewable energy-powered data centres. Researchers have also highlighted the role of hardware optimization, such as energy-efficient processors and specialized AI accelerators, in promoting sustainable AI development[3,4].

Green computing practices, which focus on reducing energy use in broader computing systems, have also contributed to Green AI research. Sustainable cloud infrastructure, carbon-aware scheduling, and resource-efficient data management are increasingly recognized as essential components of environmentally responsible AI systems[5].

Although Green AI is still an emerging field, existing literature consistently emphasizes the urgent need for balancing technological advancement with ecological sustainability.[6] Previous studies provide a strong foundation for understanding the environmental challenges of AI while offering practical solutions to improve energy efficiency.

This research builds upon these existing studies by examining both the challenges of traditional AI systems and the sustainable approaches proposed under Green AI.

III. Problem Statement: Environmental Impact of Traditional AI Systems

The rapid expansion of Artificial Intelligence technologies has led to significant advancements across various industries, but it has also introduced serious environmental concerns. Traditional AI systems, particularly large-scale machine learning and deep learning models, require enormous computational power during training, testing, and deployment. These processes often depend on energy-intensive hardware such as Graphics Processing Units (GPUs), Tensor Processing Units (TPUs), and large cloud-based data centres.

Training advanced AI models can consume substantial amounts of electricity over extended periods, sometimes lasting weeks or even months. This high energy demand contributes directly to increased carbon emissions, especially when data centres rely on non-renewable energy sources. As AI applications continue to expand globally, the cumulative environmental burden of these systems is becoming increasingly difficult to ignore.



In addition to energy consumption, traditional AI infrastructure also requires significant hardware resources, leading to increased electronic waste, cooling demands, and resource depletion. The growing dependence on large computational systems creates sustainability challenges that conflict with global efforts to reduce carbon footprints and promote environmentally responsible technological development.

Another major concern is that AI research has historically prioritized performance metrics such as accuracy, speed, and model complexity, often overlooking the environmental cost associated with these improvements. As a result, larger and more complex models continue to be developed without sufficient consideration for energy efficiency.

This situation highlights the urgent need for sustainable AI practices that reduce energy consumption while maintaining acceptable performance levels. Without adopting environmentally conscious approaches, the future growth of AI may contribute significantly to global energy challenges and climate-related issues.

Therefore, addressing the environmental impact of traditional AI systems has become a critical priority, making Green AI an essential direction for future technological innovation.

IV. Green AI Techniques and Sustainable Solutions

Green Artificial Intelligence focuses on reducing the environmental impact of AI systems by improving energy efficiency, minimizing resource consumption, and promoting sustainable technological practices. Several techniques and strategies have been developed to make AI systems more environmentally responsible while maintaining acceptable performance levels[7,8].

1. Model Compression

Model compression involves reducing the size and complexity of AI models without significantly affecting their accuracy. Techniques such as pruning, quantization, and knowledge distillation help eliminate unnecessary parameters, lower computational requirements, and decrease energy consumption during training and deployment.

2. Efficient Algorithm Design

Developing lightweight and optimized algorithms is another key Green AI strategy. Energy-efficient neural

network architectures, such as smaller deep learning models, require fewer computational resources while still delivering competitive performance. Efficient algorithm design helps reduce both electricity usage and operational costs.

3. Transfer Learning

Transfer learning allows AI systems to reuse pre-trained models instead of training new models from scratch. This significantly reduces training time, computational power, and energy consumption. By leveraging existing knowledge, transfer learning supports sustainable AI development.

4. Hardware Optimization

Specialized energy-efficient hardware, such as AI accelerators, optimized processors, and low-power chips, can improve computational performance while reducing electricity consumption. Hardware advancements play a crucial role in achieving sustainable AI systems.

5. Renewable Energy-Powered Data Centres

Data centres are among the largest contributors to AI-related energy consumption. Using renewable energy sources such as solar, wind, or hydroelectric power for data centre operations can significantly reduce carbon emissions and environmental impact.

6. Edge Computing

Edge computing processes data closer to the source rather than relying entirely on centralized cloud systems. This reduces data transmission energy costs, decreases latency, and lowers the overall power consumption of AI applications.

7. Carbon-Aware Scheduling

Carbon-aware computing schedules computational tasks during periods when renewable energy availability is high or electricity demand is lower. This approach further reduces the carbon footprint of AI operations.

Together, these Green AI techniques provide practical solutions for building more sustainable AI systems. By integrating these methods, organizations can balance technological innovation with environmental responsibility, ensuring that AI continues to evolve without causing excessive ecological harm.



V. Benefits of Green AI

1. Reduced Energy Consumption

One of the major advantages of Green AI is its ability to lower electricity usage during AI training and deployment. Energy-efficient algorithms, optimized hardware, and lightweight models help reduce computational requirements and overall power consumption[9].

2. Lower Carbon Emissions

Since many AI systems rely heavily on data centres and high-performance computing resources, reducing energy usage directly contributes to lower carbon emissions. Green AI helps organizations minimize their environmental footprint and supports global efforts to combat climate change.

3. Cost Efficiency

Reducing energy consumption also decreases operational costs. Organizations can save money on electricity, cooling systems, and hardware maintenance by implementing sustainable AI practices. Efficient AI systems can therefore provide both environmental and financial benefits.

4. Sustainable Technological Development

Green AI encourages the development of technologies that prioritize long-term sustainability. It promotes responsible innovation by ensuring that technological progress does not come at the expense of environmental health.

5. Improved Resource Utilization

Efficient AI systems make better use of computational resources such as processors, storage, and memory. This reduces unnecessary hardware usage and helps extend the lifespan of computing infrastructure.

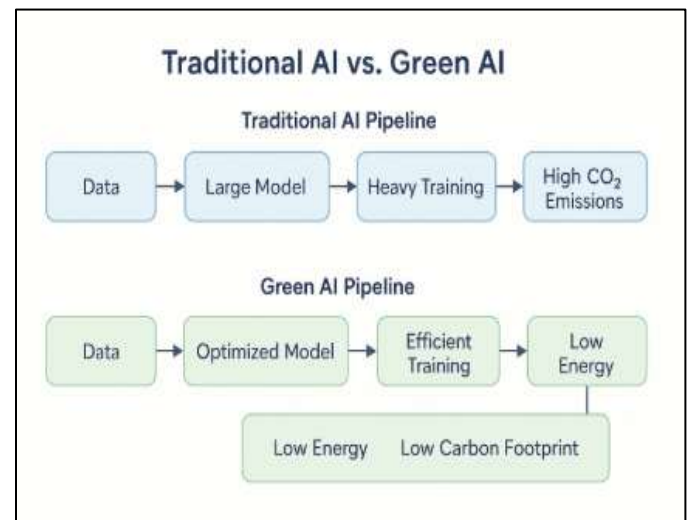
6. Support for Ethical AI Practices

Green AI aligns with ethical and socially responsible technology development. It highlights the importance of balancing performance improvements with environmental responsibility and encourages organizations to consider the broader impact of AI systems.

7. Enhanced Public and Organizational Awareness

The growing focus on Green AI increases awareness regarding the environmental effects of digital technologies. It motivates researchers, industries, and governments to invest in sustainable computing solutions and environmentally friendly infrastructure.

Overall, Green AI provides a pathway toward more sustainable and responsible artificial intelligence systems. Its benefits extend beyond energy savings by supporting environmental protection, economic efficiency, and ethical technological advancement.



VI. Challenges and Limitations of Green AI

Although Green Artificial Intelligence offers promising solutions for reducing the environmental impact of AI systems, several challenges and limitations still exist. Implementing sustainable AI practices requires technological, financial, and organizational changes that may not always be easy to achieve[10,11].

1. Performance and Efficiency Trade-Off

One of the major challenges of Green AI is maintaining high performance while reducing energy consumption. In some cases, highly optimized or compressed AI models may experience reduced accuracy or limited functionality compared to larger traditional models. Balancing efficiency and performance remain a significant concern for researchers and developers.



2. High Initial Infrastructure Costs

Developing energy-efficient infrastructure often requires substantial investment. Renewable energy-powered data centres, advanced cooling systems, and specialized low-power hardware can be expensive to implement, especially for smaller organizations and developing regions.

3. Lack of Standard Measurement Metrics

Currently, there is no universally accepted standard for measuring the energy efficiency or carbon footprint of AI systems. Different organizations use different evaluation methods, making it difficult to compare the sustainability of various AI models and technologies.

4. Limited Awareness and Adoption

Many industries and developers still prioritize model accuracy and computational power over sustainability. As a result, awareness regarding the environmental impact of AI remains limited, slowing the adoption of Green AI practices.

5. Dependence on Large Data Centres

Modern AI systems continue to rely heavily on cloud-based infrastructures and large-scale data centres. Even with optimization techniques, these facilities still consume large amounts of electricity and require extensive cooling systems, contributing to environmental concerns.

6. Rapid Growth of AI Technologies

The increasing demand for more advanced AI applications, including large language models and deep learning systems, continues to increase computational requirements. As AI technologies expand rapidly, achieving sustainability becomes more challenging[12].

7. Limited Availability of Sustainable Hardware

Although energy-efficient processors and AI accelerators are being developed, they are not yet widely available or affordable for all organizations. Many existing systems still depend on conventional hardware with high power consumption[13,14,15].

Despite these limitations, Green AI remains an essential approach for the future of sustainable computing. Continuous research, technological innovation, and global awareness can help overcome

these challenges and promote environmentally responsible AI development.

VII. Future Scope of Green AI

The future of Green Artificial Intelligence is highly promising as the demand for sustainable and energy-efficient technologies continues to grow worldwide. With increasing awareness of climate change and environmental sustainability, researchers and technology companies are expected to invest more heavily in developing eco-friendly AI systems.

One important future direction is the development of highly energy-efficient AI models that can deliver strong performance while consuming minimal computational resources. Researchers are continuously working on lightweight neural networks, optimized training methods, and advanced model compression techniques to reduce energy consumption.

Another significant area of future growth is the use of renewable energy-powered data centres. Technology companies are increasingly adopting solar, wind, and hydroelectric energy sources to operate large computing infrastructures more sustainably. In the future, more organizations are expected to transition toward carbon-neutral AI operations.

The advancement of specialized low-power AI hardware is also expected to improve the sustainability of AI systems. Energy-efficient processors, AI accelerators, and edge computing devices will help reduce dependence on high-power cloud infrastructures while supporting faster and greener AI applications.

Government regulations and environmental policies may also play an important role in encouraging sustainable AI practices. Future AI development may include mandatory reporting of energy consumption and carbon emissions, motivating organizations to adopt environmentally responsible computing strategies.

In addition, Green AI can contribute significantly to achieving global sustainability goals by supporting smart energy management, climate prediction systems, sustainable agriculture, and resource optimization. AI itself can become a tool for solving environmental problems when developed responsibly.

As Artificial Intelligence continues to evolve, integrating sustainability into AI research and deployment will become increasingly necessary. The future of AI is expected to focus not only on higher



performance and automation but also on environmental responsibility, ethical innovation, and long-term sustainability.

VIII. Conclusion

Artificial Intelligence has become one of the most influential technologies of the modern era, driving innovation across multiple industries and transforming the way organizations operate. However, the rapid growth of AI systems has also resulted in increasing energy consumption, high computational demands, and significant environmental concerns. Traditional AI models, especially large-scale deep learning systems, require extensive computational resources that contribute to carbon emissions and sustainability challenges.

This research paper examined the concept of Green Artificial Intelligence, which focuses on reducing the environmental impact of AI systems through energy-efficient techniques and sustainable computing practices. Various Green AI strategies such as model compression, transfer learning, hardware optimization, renewable energy-powered data centres, and edge computing were discussed as practical approaches for minimizing energy consumption while maintaining acceptable performance levels.

The paper also explored real-world case studies and practical applications that demonstrate how organizations are beginning to adopt sustainable AI solutions. In addition, the benefits, challenges, and future potential of Green AI were analysed to provide a balanced understanding of the topic.

The findings of this study highlight that Green AI is not only a technological requirement but also an environmental responsibility. As AI continues to expand globally, integrating sustainability into AI development will become increasingly important for reducing ecological impact and supporting long-term technological growth.

In conclusion, Green Artificial Intelligence represents a crucial step toward building responsible, energy-efficient, and sustainable AI systems. By balancing innovation with environmental awareness, Green AI can help create a future where technological advancement and sustainability coexist effectively.

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