JETIR.ORG ISSN: 2349-5162 | ESTD Year : 2014 | Monthly Issue
JOURNAL OF EMERGING TECHNOLOGIES AND INNOVATIVE RESEARCH (JETIR)
An International Scholarly Open Access, Peer-reviewed, Refereed Journal

AI ENERGY CONSUMPTION AND ITS IMPACT ON ENVIRONMENTAL SUSTAINABILITY

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Abstract- Artificial Intelligence (AI) and Generative AI (GenAI) have become important technologies in the modern world and are widely used in areas such as healthcare, education, banking, transportation, and business. GenAI systems can perform complex tasks such as generating text, images, and other content. However, the growing use of AI and GenAI requires significant computing resources, which can increase electricity consumption and create environmental challenges. Data centres require energy for processing, storage, networking, and cooling, while water may also be used for cooling. These activities can contribute to carbon emissions and other environmental impacts.

This paper explores the relationship between AI energy consumption and environmental sustainability. The study focuses on electricity consumption, carbon emissions, water use, and cooling requirements associated with AI systems. It also examines GenAI models, particularly Transformer-based models and Diffusion Models, to understand their role in energy consumption. The research uses Linear Regression, Decision Tree, KMeans, and Random Forest techniques to analyse energy consumption data, identify patterns, make predictions, and support sustainable decision-making. Based on the findings, the paper proposes sustainable approaches such as renewable energy, energy-efficient AI models, energy-aware scheduling, and smart cooling systems to reduce the environmental impact of AI. The study concludes that AI and GenAI can become more sustainable when energy efficiency and environmental considerations are included in their development and use.

Keywords: Artificial Intelligence, Generative AI, Energy Consumption, Environmental Sustainability, Carbon Emissions, Renewable Energy, Smart Cooling, Green Computing, Machine Learning.

INTRODUCTION

Artificial Intelligence (AI) has become an important technology in modern society and is widely used in healthcare, education, banking, transportation, agriculture, and business. The development of Generative AI (GenAI) has further expanded its applications by enabling systems to generate text, images, code, and other forms of content.

Despite its benefits, the rapid growth of AI has increased the demand for computational resources and electricity. AI systems consume energy during model training and inference, while data centres require additional power for servers, storage, networking, and cooling.

Large GenAI models, including Transformer-based models and Diffusion Models, can require considerable computational resources due to their size and complexity [1].
The environmental impact of AI includes high electricity consumption, carbon emissions, water consumption, and increasing cooling requirements [1],[2]. The use of fossil-fuel-based electricity can increase CO_2 emissions, while water-based cooling systems may increase water consumption. As AI models and workloads continue to grow, their computational and energy requirements also increase.

However, AI can also support environmental sustainability by optimising energy use, predicting electricity demand, improving cooling efficiency, and supporting renewable energy management. Therefore, sustainable AI requires a balance between AI performance and the efficient use of environmental resources [3].

This research examines AI Energy Consumption and Its Impact on Environmental Sustainability by studying electricity consumption, carbon emissions, water use, cooling requirements, and energy sources. The study also explores sustainable approaches such as renewable energy, energy-efficient AI models, energy-aware scheduling, and smart cooling systems to reduce the environmental impact of AI and GenAI.

AI AND ENVIRONMENTAL CHALLENGES

AI systems require computational resources for training and inference, resulting in electricity consumption. The amount of energy required depends on factors such as model size, workload, processing time, and number of requests. AI data centres consume additional energy for computing, storage, networking, and cooling.

The major environmental challenges associated with AI are:

2.1 High Electricity Consumption:

Training and operating large AI models require substantial computational power and electricity [1],[3].

2.2 Data-Centre Energy Consumption:

AI data centres consume energy for servers, storage, networking, and cooling [4],[6].

2.3 Water Consumption for Cooling:

Some data centres use water-based cooling systems, which may increase water consumption as AI workloads grow [2].

2.4 Carbon Dioxide Emissions:

AI operations can contribute to CO_2 emissions when the electricity used is generated from fossil fuels [1],[3].

2.5 Dependence on Fossil Fuels:

Electricity generated from coal, natural gas, and other fossil fuels can increase the carbon footprint of AI systems [1],[3].

2.6 Increasing Computational Workloads:

Larger and more complex AI models require greater computational resources and energy [1],[3].

2.7 Need for Sustainable AI:

AI development should balance performance with the efficient use of energy, water, and other environmental resources [3].

LITERATURE REVIEW

Previous studies have examined the energy and environmental impact of AI and data centres. Strubell et al. reported that large AI models require high computational power, increasing energy use and carbon emissions [1], while Li et al. highlighted water consumption for cooling AI and data-centre infrastructure [2]. Schwartz et al. promoted energy-efficient AI and consideration of environmental costs [3]. Buyya, Beloglazov and Abawajy focused on energyefficient data-centre resource management [4], while Buyya and Gill discussed sustainable cloud computing and reducing energy and carbon impact [5]. Further work by Buyya and collaborators supported energy-efficient resource management and sustainable data-centre operations [6].

RESEARCH GAP

Existing studies have mainly examined AI energy consumption, carbon emissions, water usage, or sustainable computing separately [1]-[6]. Energy studies often focus on specific AI models, while carbon emissions and water consumption are generally analysed as individual environmental factors. Although energy-efficient and sustainable computing approaches have been proposed, limited research combines energy consumption, carbon emissions, water consumption, and cooling requirements into a broader assessment of AI's environmental impact. This indicates a need for a more integrated approach to understanding AI energy consumption and environmental sustainability.

RESEARCH GAP QUESTIONS

1. How does AI energy consumption affect environmental sustainability?
2. What is the relationship between AI energy consumption and carbon emissions?
3. How do water consumption and cooling requirements contribute to the environmental impact of AI?
4. What sustainable approaches can reduce the energy and environmental impact of AI systems?

PROBLEM STATEMENT

The rapid growth of Artificial Intelligence (AI) and Generative AI (GenAI) has increased the demand for computational resources and electricity. Large AI models and data centres consume significant energy for processing, storage, networking, and cooling, which can contribute to carbon emissions and water consumption [1],[2],[4],[6]. As AI workloads continue to increase, these environmental impacts may become more significant. However, energy consumption, carbon emissions, water use, and cooling requirements are often studied separately. Therefore, there is a need to better understand the overall environmental impact of AI and identify sustainable approaches that can reduce energy consumption and environmental impact without affecting AI performance.

RESEARCH METHODOLOGY

This study uses a quantitative and analytical research approach to examine the relationship between AI energy consumption and environmental sustainability. The research utilizes both primary and secondary sources of data. Primary data is collected through a survey questionnaire to understand public awareness of AI and its environmental impact. Secondary data is collected from existing research papers, reports, and publicly available datasets related to AI energy consumption, carbon emissions, water consumption, and data centre operations. The collected data is analysed using descriptive analysis, Chi-Square testing, and Machine Learning techniques such as Linear Regression, Decision Tree, Random Forest, and KMeans Clustering. A comparative analysis is also conducted to compare different AI systems or workloads based on energy consumption and environmental impact.

PUBLIC SURVEY

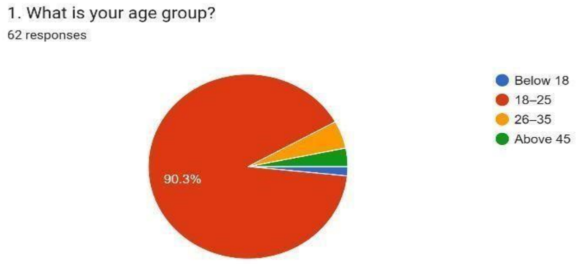
The survey was conducted to collect primary data for the study AI Energy Consumption and Its Impact on Environmental Sustainability. It aimed to understand public awareness and opinions about the environmental impact of AI and smart technology. A total of 62 respondents participated. The questionnaire covered AI electricity and water consumption, carbon emissions, Sustainable AI, renewable energy, energy-efficient models, energy-aware scheduling, and other sustainable practices. The collected responses were analysed using percentage-based descriptive methods.

Questionnaire

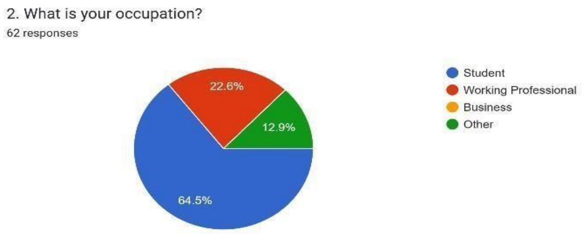
1. What is your age group?
2. What is your occupation?
3. How familiar are you with Artificial Intelligence (AI) and smart technology?
4. How often do you use AI tools such as ChatGPT, Gemini, Copilot, or other AI applications?
5. Were you aware that AI systems require significant electricity for training and operation?
6. Were you aware that data centres may consume water for cooling computing equipment?
7. Were you aware that electricity consumption by AI can contribute to CO_2 emissions?
8. Have you heard of “Green AI” or “Sustainable AI”?
9. Do you think the increasing use of AI and smart technology can negatively affect the environment?
10. Should technology companies be responsible for reducing the environmental impact of AI?
11. Should AI data centres use renewable energy such as solar, wind, or hydroelectric power?
12. Should companies disclose the energy consumption and carbon footprint of their AI systems?
13. Which environmental impact of AI concerns you the most?
14. Would you support an AI system that takes slightly longer to complete a task if it significantly reduces energy consumption?
15. Should AI tasks be scheduled according to electricity and renewable-energy availability?
16. If renewable energy is unavailable, should low-priority AI tasks be delayed until cleaner energy becomes available?
17. Can selecting servers with lower power consumption reduce the environmental impact of AI?
18. Which solution would be most effective in reducing the environmental impact of AI?
19. Do you believe AI and smart technology can become environmentally sustainable?
20. Do you think AI companies should invest more in developing energy-efficient AI models and technologies?
21. What suggestions do you have for reducing the energy consumption and environmental impact of AI and smart technology?

RESULTS

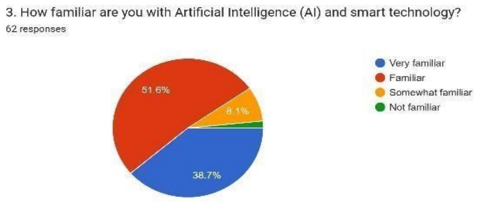
1. Out of 62 respondents, 56 (90.3%) belonged to the 18–25 age group, showing that the survey was mainly answered by young respondents.



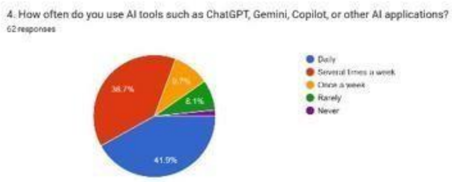
2. 40 respondents (64.5%) were students, while 14 (22.6%) were working professionals.



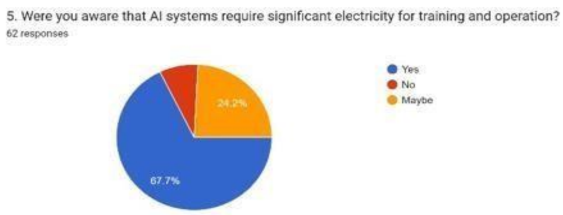
3. 56 respondents (90.3%) were either familiar or very familiar with AI and smart technology.



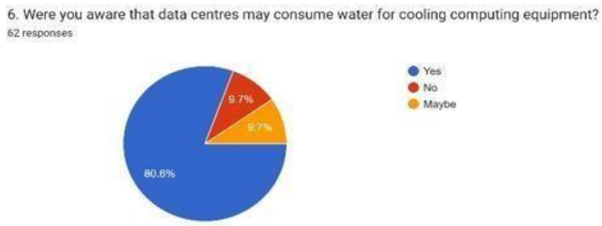
4. 50 respondents (80.6%) used AI tools either daily or several times a week.



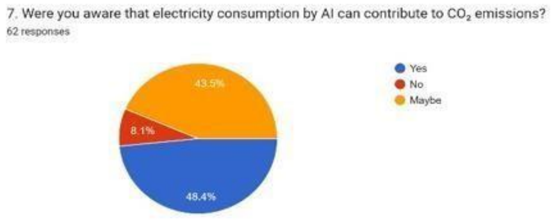
5. 42 respondents (67.7%) were aware that AI systems require significant electricity.



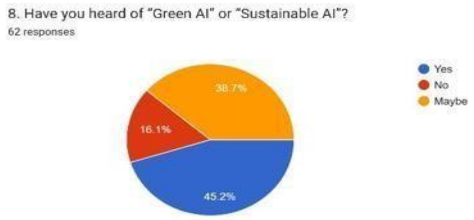
6. 50 respondents (80.6%) were aware that data centres may consume water for cooling.



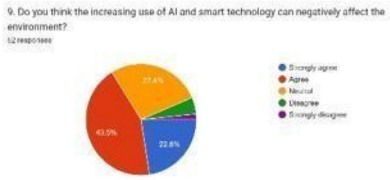
7. 30 respondents (48.4%) were aware that AI electricity consumption can contribute to CO_2 emissions.



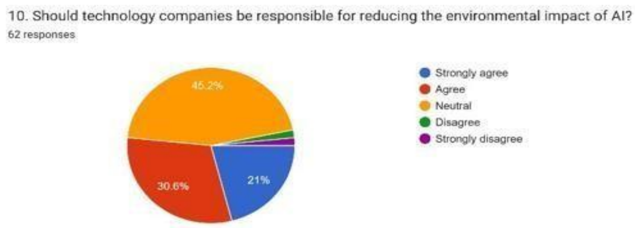
8. 28 respondents (45.2%) had heard of Green AI or Sustainable AI.



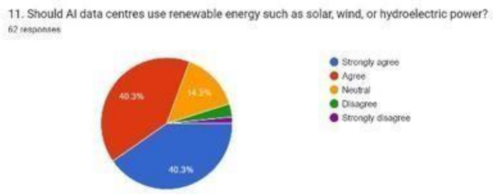
9. 41 respondents (66.1%) agreed or strongly agreed that increasing AI use can negatively affect the environment.



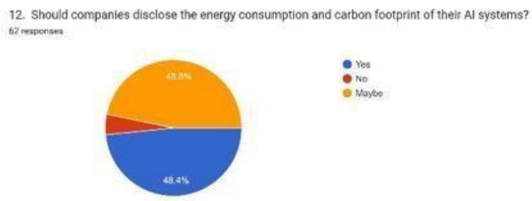
10. 32 respondents (51.6%) agreed or strongly agreed that technology companies should be responsible for reducing AI's environmental impact.



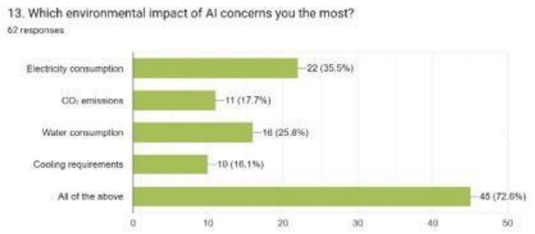
11. 50 respondents (80.6%) agreed or strongly agreed that AI data centres should use renewable energy.



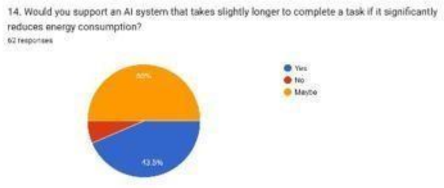
12. 30 respondents (48.4%) selected Yes, while 29 (46.8%) selected Maybe.



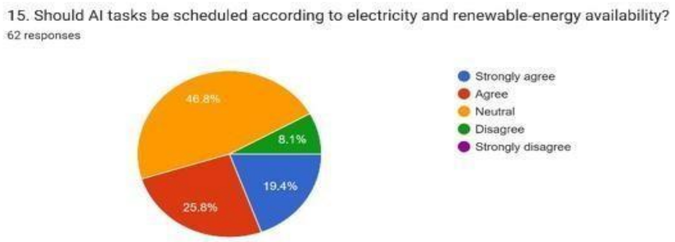
13. 34 respondents (54.8%) selected “All of the above,” indicating concern about multiple environmental impacts.



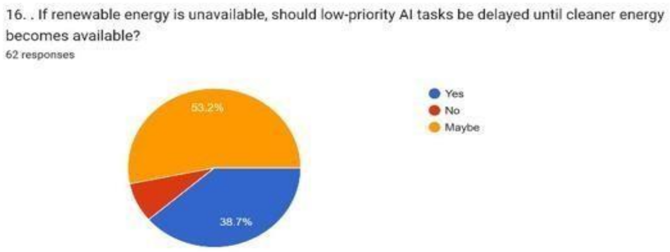
14. 27 respondents (43.5%) selected Yes, while 31 (50.0%) selected Maybe.



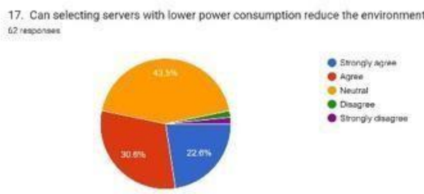
15. 28 respondents (45.2%) agreed or strongly agreed that AI tasks should be scheduled according to electricity and renewable-energy availability.



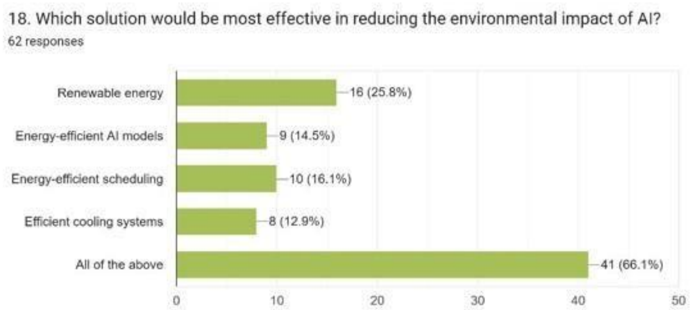
16. 24 respondents (38.7%) selected Yes, while 33 (53.2%) selected Maybe.



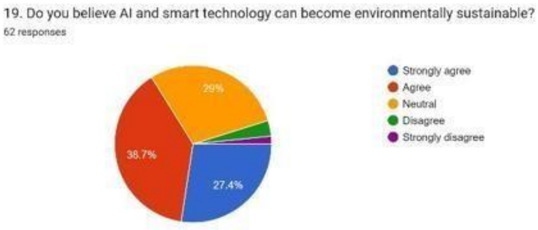
17. 33 respondents (53.2%) agreed or strongly agreed that selecting lower-power servers can reduce AI's environmental impact.



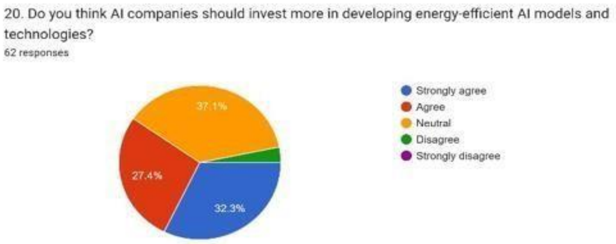
18. 39 respondents (62.9%) selected “All of the above,” showing support for a combined sustainability approach.



19. 41 respondents (66.1%) agreed or strongly agreed that AI and smart technology can become environmentally sustainable.



20. 37 respondents (59.7%) agreed or strongly agreed that AI companies should invest more in energy efficient AI models and technologies.



21. What suggestions do you have for reducing the energy consumption and environmental impact of AI and smart technology?

- I think companies should focus on using renewable energy and making AI systems more energy efficient. They can also improve cooling systems in data centres and avoid wasting energy on unnecessary tasks.
- Reducing the energy consumption and environmental impact of AI and smart technology requires a multi pronged approach focused on hardware efficiency, software optimisation and sustainable infrastructure.
- Reduce unnecessary AI processing.
- Use energy-efficient AI models and algorithms.
- Changes in hardware, software design, data center operations, and daily user habits. optimizing both how models are built and how users interact with them daily.
- Require companies to measure and disclose AI systems' energy use and carbon emissions.
- Use smaller, on-device models and run them in low precision, and turn off always-on cloud features when a simple rule will do.
- Develop energy-efficient AI models.
- Use renewable energy and efficient AI.
- Power data centers with renewable energy sources like solar and wind, and upgrade to closedloop liquid cooling systems reduce carbon emissions and maximize energy efficiency.
- Run AI systems using renewable energy sources.
- Use energy - efficient AI tools use renewable energy.
- To lower the energy use and environmental impact of artificial intelligence and smart technology, developers can optimize model sizes and utilize green data centers, while individuals can practice mindful prompting and limit unnecessary digital workloads.

HYPOTHESIS TESTING

Null Hypothesis (H_0): There is no significant relationship between awareness of AI electricity consumption and the perception that increasing AI use can negatively affect the environment.
Alternative Hypothesis (H_1): There is a significant relationship between awareness of AI electricity consumption and the perception that increasing AI use can negatively affect the environment.
The **Chi-Square Test of Independence** was used to examine the relationship between the two categorical variables at a **5% significance level ($\alpha = 0.05$)**. Survey responses were grouped into a **2×2 contingency table**.

Table 1. Contingency Table for Q5 and Q9

Awareness of AI electricity consumption (Q5)	**Agree/Strongly Agree**	**Neutral/Disagree/Strongly Disagree**	**Total**
Yes	33	9	42
Maybe/No	8	12	20
Total	41	21	**62**

The calculated Chi-Square value was **$\chi^2 = 9.00$**, with **1 degree of freedom (df = 1)** and a **p-value = 0.0027**.

Since **p-value (0.0027) < α (0.05)**, the null hypothesis is **rejected**.

Conclusion: There is a statistically significant relationship between awareness of AI electricity consumption and the perception that increasing AI use can negatively affect the environment. Respondents who were aware of AI's electricity consumption were more likely to recognize its potential negative environmental impact.

FINDINGS

The survey of 62 respondents showed high AI awareness, with 90.3% aged 18–25, 64.5% students, and 80.6% frequently using AI tools. Awareness of AI electricity consumption was 67.7%, water use for cooling 80.6%, and CO_2 emissions 48.4%, while 45.2% had heard of Green AI. Most supported renewable energy (80.6%), energy-efficient AI, low-power servers, and sustainable practices, with 66.1% believing AI can become environmentally sustainable.
The Chi-Square test found a significant relationship between electricity-consumption awareness and perceived environmental impact ($\chi^2 = 9.00$, $p = 0.0027$). Overall, respondents showed considerable environmental awareness and support for sustainable AI.

CONCLUSION

AI and Generative AI offer significant benefits but also increase electricity use and environmental impacts through computing, cooling, and water consumption. The survey shows awareness of these challenges and strong support for renewable energy, energy-efficient AI, and responsible data-centre practices. The Chi-Square test found a significant relationship between electricity-consumption awareness and perceived environmental impact. Therefore, sustainable AI requires energy efficiency, renewable energy, efficient cooling, and responsible infrastructure management.

FUTURE SCOPE

- Monitor AI’s real-time energy and carbon impact.
- Increase renewable energy and energy-efficient AI.
- Improve data-centre cooling to reduce energy and water use.
- Study AI’s environmental impact across regions and workloads.
- Conduct larger, more diverse surveys.
- Promote sustainable AI practices and environmental awareness.

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