

Environmental Impacts and Energy Demands of AI



An AI Generated Overview of the Environmental Impacts and Energy Demands of AI - - - (WARNING - Hallucinations are possible)

ChatGPT 4o - 12/15/2024 ... AI, Environmental Impacts and Energy Consumption

(Prompt - Please provide an overview that considers the possible impact of AI on both the environment and the demand for energy. Please make your response roughly 800-1000 words in length and appropriate for a college audience.)

Artificial intelligence (AI) has become an integral part of technological advancements, revolutionizing industries and enabling groundbreaking innovations. However, alongside its potential benefits, AI also carries significant implications for the environment and energy demand. As the adoption of AI technologies grows, understanding these impacts becomes critical for developing sustainable practices and policies. This overview examines the environmental and energy-related effects of AI, highlighting both challenges and opportunities.

Energy Demand and AI

The increasing application of AI technologies, particularly machine learning (ML) and deep learning (DL), has led to a surge in computational requirements. Training state-of-the-art AI models, such as large language models (LLMs) or generative adversarial networks (GANs), often demands immense computational power. For instance, training GPT-3, a widely recognized LLM, consumed an estimated 1,287 megawatt-hours of electricity, producing roughly 552 metric tons of CO₂ emissions. This energy-intensive nature of AI raises concerns about the scalability and sustainability of such technologies.

Several factors contribute to the high energy demands of AI:

1. **Data Processing:** AI systems require vast amounts of data for training, necessitating the use of large-scale data centers. These facilities consume substantial amounts of electricity for both computation and cooling.

2. **Inference Workloads:** Beyond training, deploying AI models in real-world applications also consumes energy. For instance, running AI-powered recommendation systems or voice assistants on millions of devices worldwide involves significant ongoing energy expenditure.
3. **Hardware Infrastructure:** Specialized hardware, such as graphics processing units (GPUs) and tensor processing units (TPUs), enhances computational efficiency but requires high power inputs, contributing to overall energy consumption.

Environmental Impact of AI

The environmental impact of AI is intrinsically linked to its energy consumption. As AI-driven systems proliferate, their carbon footprint has become a pressing concern. Key environmental challenges include:

1. **Carbon Emissions:** The reliance on fossil fuels for electricity generation in many regions exacerbates the carbon footprint of AI operations. Unless addressed, the growing demand for AI could undermine global efforts to combat climate change.
2. **Electronic Waste:** The rapid evolution of AI hardware necessitates frequent upgrades, contributing to the generation of electronic waste (e-waste). Disposing of outdated components often involves harmful environmental practices.
3. **Resource Depletion:** The production of high-performance computing hardware depends on rare earth elements and other finite resources. Mining and refining these materials have significant ecological and social costs.
4. **Water Usage:** Data centers also require vast amounts of water for cooling systems, raising concerns about water resource depletion, particularly in regions already facing scarcity.

Mitigating the Negative Effects of AI

Despite these challenges, several strategies can mitigate the environmental and energy-related impacts of AI:

1. **Energy-Efficient Algorithms:** Researchers are developing more efficient algorithms that require fewer computations without compromising performance. Techniques such as model pruning, quantization, and knowledge distillation help reduce energy consumption during both training and inference.
2. **Renewable Energy Integration:** Transitioning data centers to renewable energy sources, such as solar and wind, can significantly lower the carbon footprint of AI systems. Companies like Google and Microsoft have already committed to powering their AI operations with 100% renewable energy.
3. **Optimized Hardware Design:** Innovations in hardware, such as application-specific integrated circuits (ASICs), aim to maximize computational efficiency while minimizing energy use. AI hardware designed for specific tasks, such as vision or natural language processing, can achieve higher performance-per-watt ratios.

4. **Regulatory Policies:** Governments and international organizations can enforce regulations that promote sustainable AI practices. For example, mandating energy efficiency standards for data centers or incentivizing renewable energy adoption can drive systemic change.
5. **Lifecycle Management:** Developing strategies for the sustainable lifecycle management of AI hardware, including recycling and refurbishing components, can reduce e-waste and resource depletion.

Opportunities for Environmental Benefits

While AI poses challenges, it also holds the potential to drive positive environmental outcomes. Leveraging AI for sustainability efforts can help mitigate its negative impacts and create additional benefits:

1. **Climate Modeling and Mitigation:** AI systems can analyze complex climate data to predict weather patterns, track deforestation, and monitor greenhouse gas emissions. These insights support informed decision-making for climate change mitigation.
2. **Energy Optimization:** AI can optimize energy usage in various sectors, from smart grids and industrial processes to building management systems. For instance, AI-driven demand response systems can balance energy loads, reducing overall consumption and reliance on fossil fuels.
3. **Biodiversity Conservation:** By analyzing satellite imagery and other environmental data, AI tools can help track endangered species, combat illegal poaching, and manage protected areas more effectively.
4. **Agricultural Efficiency:** AI-powered systems enable precision agriculture, reducing resource wastage and increasing crop yields. Technologies like drone-based monitoring and AI-driven irrigation systems conserve water and minimize environmental strain.
5. **Circular Economy Support:** AI can enhance recycling processes by improving material sorting and identifying components suitable for reuse. Automated systems can also assess the condition of products, extending their lifecycle.

Balancing AI Growth with Sustainability

As AI continues to evolve, striking a balance between technological growth and environmental sustainability is imperative. This requires collaborative efforts across academia, industry, and government. Key considerations include:

1. **Transparency and Accountability:** Organizations developing and deploying AI systems should disclose their energy usage and carbon emissions. Transparent reporting enables stakeholders to assess environmental impacts and drive improvements.
2. **Research Funding:** Governments and private entities should invest in research focused on sustainable AI practices. This includes funding for energy-efficient algorithms, hardware innovation, and renewable energy integration.

3. **Public Awareness:** Educating the public about the environmental implications of AI can foster greater demand for sustainable solutions. Consumers and businesses alike must advocate for greener technologies.
4. **Global Collaboration:** Addressing the environmental impact of AI is a global challenge that requires international cooperation. Collaborative initiatives can establish standards and share best practices for sustainable AI development.

Conclusion

AI's transformative potential is undeniable, offering immense opportunities for innovation and problem-solving. However, its environmental and energy-related challenges cannot be overlooked. By adopting energy-efficient practices, leveraging renewable resources, and promoting policies that prioritize sustainability, society can ensure that AI advances align with global environmental goals. Through collective action and innovative solutions, the dual objectives of technological progress and environmental stewardship can be achieved, paving the way for a sustainable AI-driven future.

Human Views on the Environmental Impacts and Energy Demands of AI - - -
(WARNING - Humans are fallible)

Definitions and Reference Articles

[UNI only] Frana, P. L. (2021). **AI and Climate Crisis**. In Philip L. Frana, & Michael J. Klein. *Encyclopedia of Artificial Intelligence: The Past, Present, and Future of AI* (pp. 75-79). ABC-CLIO.
https://login.proxy.lib.uni.edu/login?url=https://search.ebscohost.com/login.aspx?direct=true&db=e000xna&AN=2895727&site=ehost-live&ebv=EB&ppid=pp_76

Shorter Podcasts and Videos

AI and the energy required to power it fuel new climate concerns

PBS News Hour (7:52)

(July 4, 2024) [Video]

https://www.youtube.com/watch?v=VOezW-b_mD8

AI drives energy consumption

CNBC (2:48)

(July 3, 2024) [Video]

<https://www.youtube.com/watch?v=AmbYUofQOpQ>

AI's hidden climate costs

CBC (14:08)

(June 13, 2023) [Video]

https://www.youtube.com/watch?v=RT8-GIA_rkM

Amazon Joins Google and Microsoft in AI Nuclear Buildout

The A.I. Daily Brief - Nathaniel Whitemore (6:21)

(October 17, 2024) [Video]

https://www.youtube.com/watch?v=ke_b5gMqFzg

Can AI help solve the climate crisis?

TED - Sims Witherspoon (12:16)

(July, 2023) [Video]

https://www.ted.com/talks/sims_witherspoon_can_ai_help_solve_the_climate_crisis

How AI can help and hurt the environment

Wall Street Journal - WSJ Tech News Briefing - Zoe Thomas (6:07)

(October 2, 2023) [Video]

https://www.youtube.com/watch?v=JIYRf_K56b4

A 'thirsty' AI boom could deepen Big Tech's water crisis

CNBC International (7:51)

(December 6, 2023) [Video]

<https://www.youtube.com/watch?v=SGHk3zE5xh4>

Why AI Companies Are Looking To The Nuclear Option

Forbes (4:49)

(June 15, 2024) [Video]

<https://www.youtube.com/watch?v=GQA0xfkWpqw>

Longer Videos and Podcasts

Generative AI is a climate disaster w/ Sasha Luccioni

Tech Won't Save Us - Paris Marx and Sasha Luccioni (1:00:00)

(July 18, 2024) [Podcast]

<https://podcasts.apple.com/us/podcast/tech-wont-save-us/id1507621076>

Powering tomorrow: Innovations at the intersection of AI and energy

Center for Strategic & International Studies - Joseph Majkut and Joshua Parker (35:17)

(September 26, 2024) [Video]

<https://www.csis.org/events/powering-tomorrow-innovations-intersection-ai-and-energy>

Magazine and Newspaper Articles

Calma, Justine. (2024, May 2). **Microsoft made the biggest renewable energy agreement ever to fuel its AI ambitions.** *The Verge*.

<https://www.theverge.com/2024/5/2/24147153/microsoft-ai-data-center-record-renewable-energy-purchase>

[UNI only] Cooper, Sean Patrick. (2024, September 15). **Noisy, Hungry Data Centers Are Catching Communities by Surprise.** *New York Times*.

<https://www.nytimes.com/2024/09/15/opinion/data-centers-ai-amazon-google-microsoft.html>

[UNI only] Erdenesanaa, Delger. (2023, October 10). **A.I. could soon need as much electricity as an entire country.** *New York Times*.

<https://www.nytimes.com/2023/10/10/climate/ai-could-soon-need-as-much-electricity-as-an-entire-country.html>

[UNI only] Gelles, David. (2024, July 11). **A.I.'s insatiable appetite for energy.** *New York Times*.

<https://www.nytimes.com/2024/07/11/climate/artificial-intelligence-energy-usage.html>

[UNI only] Lohr, Steve. (2024, August 26). **Will A.I. Ruin the Planet or Save the Planet?**

It's a notorious energy hog. But artificial intelligence can also foster innovation and discovery, and it could speed the global transition to cleaner power. *New York Times*.

<https://www.nytimes.com/2024/08/26/climate/ai-planet-climate-change.html>

[UNI only] Sommer, Jeff. (2024, September 7). **Nuclear Power Is the new A.I. trade. What could possibly go wrong? Artificial intelligence's hunger for energy has set off a boom in utility stocks and may lead to the reopening of the Three Mile Island nuclear plant, our columnist says.** *New York Times*.

<https://www.nytimes.com/2024/09/27/business/ai-nuclear-power-stocks.html>

[UNI only] Sorkin, A. S., Mattu, R., Warner, B., Kessler, S., de la Merced, M. J., Hirsch, L., & Livni, E. (2024, May 6). **How bad is A.I. for the climate?** *New York Times*.

<https://www.nytimes.com/2024/05/06/business/dealbook/ai-power-energy-climate.html>

Vincent, James. (2024, February 16). **How much electricity does AI consume?** *The Verge*.

<https://www.theverge.com/24066646/ai-electricity-energy-watts-generative-consumption>

[UNI only] Wong, Matteo. (2023, August 23). **The internet's next great power suck.** *Atlantic Online*. (1870 words)

<https://advance.lexis.com/api/permalink/3f7fbb25-2cc6-405c-b991-3bc6fad72d39/?context=1516831>

Scholarly Journal Articles

Kaack, L. H., Donti, P. L., Strubell, E., Kamiya, G., Creutzig, F., & Rolnick, D. (2022). **Aligning artificial intelligence with climate change mitigation.** *Nature Climate Change*, 12(6), 518-527.

<https://par.nsf.gov/servlets/purl/10469824>

There is great interest in how the growth of artificial intelligence and machine learning may affect global GHG emissions. However, such emissions impacts remain uncertain, owing in part to the diverse mechanisms through which they occur, posing difficulties for measurement and forecasting. Here we introduce a systematic framework for describing the effects of machine learning (ML) on GHG emissions, encompassing three categories: computing-related impacts, immediate impacts of applying ML and system-level impacts. Using this framework, we identify priorities for impact assessment and scenario analysis, and suggest policy levers for better understanding and shaping the effects of ML on climate change mitigation.

Luers, A., Koomey, J., Masanet, E., Gaffney, O., Creutzig, F., Lavista Ferres, J., & Horvitz, E. (2024). **Will AI accelerate or delay the race to net-zero emissions?** *Nature*, 628(8009), 718-720.
<https://www.nature.com/articles/d41586-024-01137-x.pdf>

Abstract: "As artificial intelligence transforms the global economy, researchers need to explore scenarios to assess how it can help, rather than harm, the climate."

Rillig, M. C., Ågerstrand, M., Bi, M., Gould, K. A., & Sauerland, U. (2023). **Risks and benefits of large language models for the environment.** *Environmental Science & Technology*, 57(9), 3464-3466.
<https://pubs.acs.org/doi/pdf/10.1021/acs.est.3c01106>

Abstract: Large language models (LLMs) are artificial intelligence (AI) models with complex architecture and a large number of parameters that have been trained on very large amounts of text (billions of words). These models, arising from the field of natural language processing, can generate natural, human-like writing and have been designed to react to user input, enabling conversations and customized output according to prompts. The release of the chatbot ChatGPT by OpenAI in late 2022 has rapidly spread this technology to a wide range of users (GPT means generative pretrained transformer and denotes the type of large language model used in this chatbot). Other companies are offering their own apps featuring different kinds of LLMs, and this technology is also being rapidly integrated into existing apps and online tools. Because LLMs will likely become extremely common, the potentially transformative nature of these models has already sparked a lively debate about their use. This discussion focuses on academic integrity and the future of research and teaching, the meaning of authorship, potential consequences for the general workforce, and unresolved copyright issues. However, the debate has so far largely missed the potential implications of current and future LLM tools for the environment. We see the possibility of direct and indirect environmental impacts and effects, and opportunities and risks for researchers in the environmental sciences

Policy Papers

Ammanath, Beena. (2024, April 25). **How to manage AI's energy demand — today, tomorrow and in the future.** *World Economic Forum*.
<https://www.weforum.org/stories/2024/04/how-to-manage-ais-energy-demand-today-tomorrow-and-in-the-future/>

Abstract: The computational power required for sustaining AI's rise is doubling roughly every 100 days. It is imperative that we balance the progression of AI with the imperatives of sustainability. There are steps we can take immediately — and foundations that we can lay today that will pay

dividends in the future — to manage AI and the green transition.

Castro, Daniel. (2024, January 29). **Rethinking concerns about AI's energy use.** *ITIF - Information Technology and Innovation Foundation*.

<https://itif.org/publications/2024/01/29/rethinking-concerns-about-ai-energy-use/>

Abstract: Concerns about the energy used by digital technologies are not new. Near the peak of the dot-com boom in the 1990s, a Forbes article lamented, “Somewhere in America, a lump of coal is burned every time a book is ordered online.” The authors of the article, which became widely cited in subsequent years in debates about energy policy, estimated that “half of the electric grid will be powering the digital-Internet economy within the next decade.” However, the estimate was wrong, with errors in both its facts and methodology. In hindsight, there is no longer any dispute, as the International Energy Agency (IEA) estimates that today’s data centers and data transmission networks “each account for about 1–1.5% of global electricity use.”

This mistake was not an isolated event. Numerous headlines have appeared over the years predicting that the digital economy’s energy footprint will balloon out of control. For example, as the streaming wars kicked off in 2019—with Apple, Disney, HBO, and others announcing video streaming subscription services to compete with Netflix, Amazon, and YouTube—multiple media outlets repeated claims from a French think tank that “the emissions generated by watching 30 minutes of Netflix is the same as driving almost 4 miles.” But again, the estimate was completely wrong (it is more like driving between 10 and 100 yards), resulting from a mix of flawed assumptions and conversion errors, which the think tank eventually corrected a year later.

With the recent surge in interest in artificial intelligence (AI), people are once again raising questions about the energy use of an emerging technology. In this case, critics speculate that the rapid adoption of AI combined with an increase in the size of deep learning models will lead to a massive increase in energy use with a potentially devastating environmental impact.

However, as with past technologies, many of the early claims about the consumption of energy by AI have proven to be inflated and misleading. This report provides an overview of the debate, including some of the early missteps and how they have already shaped the policy conversation, and sets the record straight about AI’s energy footprint and how it will likely evolve in the coming years.

Das, Tanya. (2024, September 2024). **Accelerating AI sustainability and innovation at the Department of Energy**. *Bipartisan Policy Center*.
<https://bipartisanpolicy.org/report/accelerating-ai-sustainability-and-innovation-at-doe/>

Abstract: The U.S. government has played a key role in nurturing artificial intelligence and the technologies that enable AI systems. Several agencies are contributing to federal AI efforts. Within the many policy positions proposed by policymakers and thought leaders to advance national AI policy, the role of the Department of Energy (DOE) is understudied. To address this gap, this report examines the ways that DOE has contributed to U.S. leadership on AI and explores ways that DOE should remain engaged with AI going forward. Within the federal government, DOE has unique expertise in AI as a department that studies, uses, and develops AI applications and spans several critical areas:

- Meeting the energy demands of the growing AI industry.
- Applying AI to a host of public policy challenges.
- Developing next-generation AI capabilities in collaboration with the private sector.
- Operating the world's most powerful supercomputers.

This report begins by providing some background on AI and by describing DOE's AI-related activities and contributions to date. Subsequent sections focus on the department's efforts to improve the energy efficiency of AI technologies and operations, and on ways that AI tools are being deployed to advance energy technologies, national security, and scientific discovery. The report concludes with recommendations for the future of DOE's contributions to AI.

Kemene, E., Valkhof, B., & Tladi, Thapelo. (2024, July 22). **AI and energy: Will AI help reduce emissions or increase demand? Here's what to know**. *World Economic Forum*.
<https://www.weforum.org/stories/2024/07/generative-ai-energy-emissions/>

Abstract: Tech companies are reporting increased emissions due to running the data centres that power AI. But AI tools can also help facilitate the energy transition. A multistakeholder approach, like The World Economic Forum's Artificial Intelligence Governance Alliance, is vital to help balance AI's resource use and benefits.

Kitchen, Klon. (2024, April 1). **Feeding the beast: AI's energy demand may double by 2026**. *American Enterprise Institute*.
<https://www.aei.org/op-eds/feeding-the-beast-ais-energy-demand-may-double-by-2026/>

What's New: Global electricity demand, which saw a moderate increase in 2023, is expected to rise more sharply through 2026, driven by emerging economies and, reportedly, will be met

entirely by clean energy, according to a new study by the International Energy Agency.

Why This Matters: The intersection of rising electricity demand and the pivot towards clean energy sources underscores a pivotal era for both the global energy landscape and technological advancement. With data centers, artificial intelligence, and cryptocurrency mining poised to significantly contribute to this demand, the importance of energy efficiency and renewable energy sources becomes ever more critical. This shift not only impacts the environment and energy markets but also influences geopolitical, economic, and technological paradigms.

Kumar, Claire, & Meredith, Dora. (2024, November 7). **The environmental risks of generative AI: why better global governance is urgently needed.** *ODI - Overseas Development Institute*.
<https://odi.org/en/insights/the-environmental-risks-of-generative-ai-why-better-global-governance-is-urgently-needed/>

Abstract: The International Energy Agency (IEA) predicts that between 2022 and 2026 the electricity consumption of data centres could more than double. These growing energy demands are linked to the complexity of AI programmes and specifically the computational resources used by generative AI in training and running large AI models.

Sexton, Mike. (2024, May 1). **How AI uses energy.** *Third Way*.
<https://www.thirdway.org/memo/how-ai-uses-energy>

Abstract: When ChatGPT was unveiled to the public in 2022, energy usage was probably not on most people's list of top things to wonder about. But the AI era will use a lot of power. Already, the energy usage of AI is increasing exponentially and by some estimates will surpass the energy used by Bitcoin by 2027. And Bitcoin already consumes more energy than The Netherlands over the course of a year.

van Soest, H., Rueda, I. A., Park, H. M., Spurling, B., Wyatt, A., Fine, H., Steier, J., & Lebreton, M. (2024, June 21). **The use of AI for improving energy security. Exploring the risks and opportunities of the deployment of AI applications in the electricity system.** *RAND*.

Abstract: Electricity systems around the world are under pressure due to aging infrastructure, rising demand for electricity and the need to decarbonise our energy supplies at pace. Artificial intelligence (AI) applications have potential to help address these pressures and increase overall energy security. For example, AI applications can reduce peak demand through demand response, improve the efficiency of wind farms and facilitate the integration of large numbers of electric vehicles into the power grid. However, the widespread deployment of AI applications could also come with heightened cybersecurity risks, the risk of unexplained or unexpected

actions, or supplier dependency and vendor lock-in. The speed at which AI is developing means many of these opportunities and risks are not yet well understood.

The aim of the study was to provide insight into the state of the art of AI applications for the power grid and the associated risks and opportunities. We conducted a focused scan of the scientific literature to find examples of relevant AI applications to determine the state of the art in the United States, the European Union, China and the UK. We then used a Python-based power system model called PyPSA to explore the extent to which different AI applications can improve energy security. For mapping the risks, we first created a risk taxonomy. We also invited external stakeholders from policymaking and research organisations to participate in a backcasting exercise, where we discussed the key enablers that would contribute to certain positive and negative outcomes out to 2050.

Websites and Blogs

Aschenbrenner, Leopold. (2024, June). **Racing to the Trillion-Dollar Cluster. Situational Awareness: The Decade Ahead.** <https://situational-awareness.ai/racing-to-the-trillion-dollar-cluster/>

Overview: The most extraordinary techno-capital acceleration has been set in motion. As AI revenue grows rapidly, many trillions of dollars will go into GPU, datacenter, and power buildout before the end of the decade. The industrial mobilization, including growing US electricity production by 10s of percent, will be intense.