BEST 402

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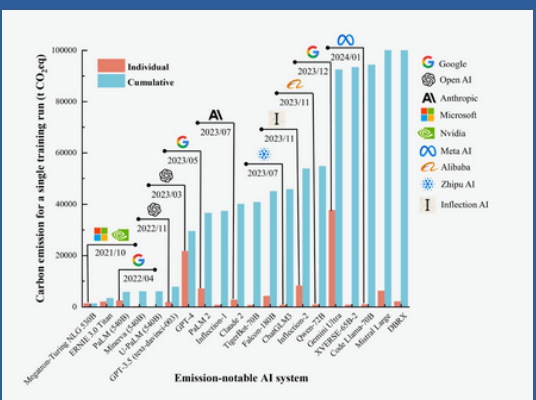
WHEN INNOVATION EMITS: AI's Carbon Footprint

Introduction

AI has emerged as a transformative technology that will continue to shape society. While advancements in technology enhance our daily lives, it is equally important to acknowledge the environmental externalities associated with these systems. A comprehensive analysis highlights key areas requiring improvement to ensure alignment with sustainable development.

TRENDS



Yu et al. (2024)

AI training now exceeds 100,000 t CO_2-eq per run

The figure above provides the visual for the rapid growth in carbon emissions as AI development progresses and user number increases. The literature also reflects this pattern, as well as shows a shift from narrow carbon only views toward broader, system level, and long-term assessments that capture both operational use and embodied impacts.

METHODS

To address the challenges, researchers employ diverse methods:

Life Cycle Asesement

Life Cycle Assessments have been used as a quantitative measurement across research articles. Service-based LCAs expand analysis beyond energy use, allowing for a more comprehensive understanding of environmental impacts. (Berthelot, 2024)

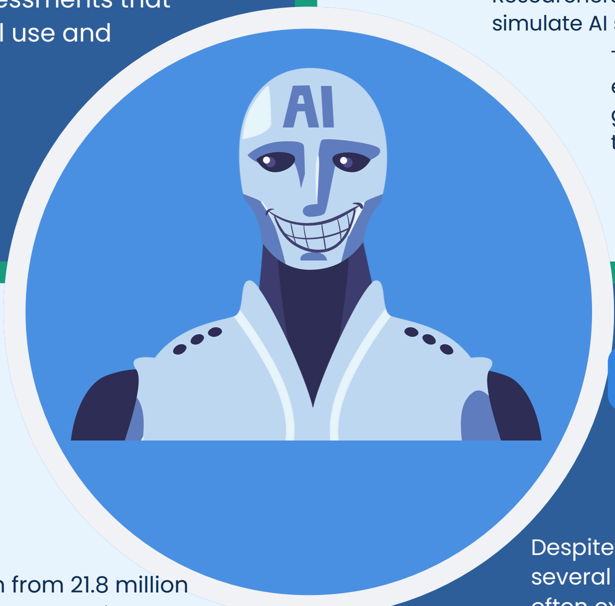
Carbon Calculator

Lacoste (2019) used carbon calculators as both an educational device and a quantitative tool, turning complex energy + hardware data into understandable emissions estimates for AI researcher

Workload Modeling

Researchers use workload modeling to simulate AI services, such as ChatGPT. This approach projects future emissions based on expected growth in demand and technological change.

(Chien et al., 2023)



METRICS

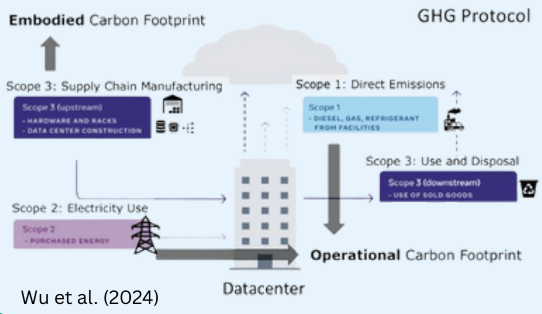
102.6 Mt of CO2-eq per year
(Yu et al., 2024)

Emission from 21.8 million human consumption

0.00000784 t of CO2-eq
(Berthelot, 2024)

Emission from Single-User Sessions

While the per-use footprint appears negligible, the annualized service perspective reveals substantial cumulative impacts, especially for energy use and emissions. This contrast underscores the importance of evaluating Gen-AI both at the micro level (individual users) and the macro level (system-wide operation), as small actions can compound into large environmental costs. The figure below represents the scope of how the system is currently being measured on an operational scale.



Wu et al. (2024)

CHALLENGES

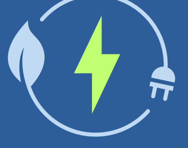
Despite advances in quantification, several obstacles remain. Current LCAs often exclude the emissions from data center construction or material extraction, creating blind spots in reporting (Ligozat, 2022).

In addition, limited transparency from major AI providers makes accurate comparisons difficult. Finally, questions of accountability persist: who bears responsibility—the scientists, the providers, or the energy suppliers? (Tamburrini, 2022).

- **Missing Phases in LCA**
- **Lack of Transparency**
- **Unclear accountability**

RECOMMENDATIONS

The literature emphasizes proactive strategies for reducing AI's environmental footprint. Incentives, such as prize systems for energy-efficient AI, could encourage innovation while eco-conscious consumer behavior and industry alliances reinforce systemic change.
(Tamburrini, 2022; Wang, Ji, & Xie, 2023)



Transitioning to renewable-powered data centers
Mitu & Mitu, 2022

Improving Hardware Efficiency
Wu et al., 2024

Greater transparency and cross-sector collaboration

REFERENCES

Berthelot, A., Caron, E., Jay, M., & Lefèvre, L. (2024). Estimating the environmental impact of Generative-AI services using an LCA-based methodology. Procedia CIRP, 122, 707–712. https://doi.org/10.1016/j.procir.2024.01.098

Chien, A. A., Lin, L., Nguyen, H., Rao, V., Sharma, T., & Wijayawardana, R. (2023). Reducing the Carbon Impact of Generative AI Inference (today and in 2035). Proceedings of the 2nd Workshop on Sustainable Computer Systems, 1–7. https://doi.org/10.1145/3604930.3605705

Lacoste, A., Luccioni, A., Schmidt, V., & Dandres, T. (2019). Quantifying the Carbon Emissions of Machine Learning (No. arXiv:1910.09700). arXiv. https://doi.org/10.48550/arXiv.1910.09700

Ligozat, A.-L., Lefevre, J., Bugeau, A., & Combaz, J. (2022). Unraveling the Hidden Environmental Impacts of AI Solutions for Environment Life Cycle Assessment of AI Solutions. Sustainability, 14(9), 5172. https://doi.org/10.3390/su14095172

Mitu, N. E., & Mitu, G. T. (2024, September 1). The Hidden Cost of AI: Carbon Footprint and Mitigation Strategies. SSRN. https://doi.org/10.2139/ssrn.5036344

Tamburrini, G. (2022). The AI Carbon Footprint and Responsibilities of AI Scientists. Philosophies, 7(1), 4. https://doi.org/10.3390/philosophies7010004

Wu, C., Acun, B., Raghavendra, R., & Hazelwood, K. (2024). Beyond efficiency: Scaling AI sustainably. Ieee Micro, 44(5), 37-46. https://doi.org/10.1109/MM.2024.3409275

Yu, Y., Wang, J., Liu, Y., Yu, P., Wang, D., Zheng, P., & Zhang, M. (2024). Revisit the environmental impact of artificial intelligence: The overlooked carbon emission source? Frontiers of Environmental Science & Engineering, 18(12), 158–158. https://doi.org/10.1007/s11783-024-1918-y