CROSSING THE RUBICON

CONSUMPTION COSTS OF ARTIFICIAL INTELLIGENCE AND ENVIRONMENTAL SECURITY

ERMAN AKILLI, GLORIA SHKURTI ÖZDEMİR

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SETA | SİYASET, EKONOMİ VE TOPLUM ARAŞTIRMALARI VAKFI
Nenehatun Cd. No: 66 GOP Çankaya 06700 Ankara TÜRKİYE
Tel: +90 312 551 21 00 | Faks: +90 312 551 21 90
www.setav.org | info@setav.org | @setavakfi

SETA | İstanbul
Defterdar Mh. Savaklar Cd. Ayvansaray Kavşağı No: 41-43
Eyüpsultan İstanbul TÜRKİYE
Tel: +90 212 395 11 00 | Faks: +90 212 395 11 11

SETA | Washington D.C.
1025 Connecticut Avenue, N.W., Suite 1106
Washington D.C., 20036 USA
Tel: 202-223-9885 | Faks: 202-223-6099
www.setadc.org | info@setadc.org | @setadc

SETA | Berlin
Kronenstraße 1, 10117 Berlin GERMANY
berlin@setav.org

SETA | Brussels
Avenue des Arts 27, 1000 Brussels BELGIUM
Tel: +3226520486

CONTENTS

Erman Akıllı
Assoc. Prof. Dr. Erman Akıllı is currently serving as a faculty member in the Department of International Relations at Ankara Hacı Bayram Veli University. His areas of expertise include artificial intelligence in foreign policy, digital diplomacy, the Central Asia region, the Organization of Turkish States, soft power, and its sub-branches. Throughout his academic career, he has published articles in peer-reviewed journals indexed in SSCI and WOS; and has contributed as an author and editor to books published by prestigious publishing houses such as Routledge, Palgrave MacMillan, and Springer Nature. Additionally, he served as the chief editor at the OSCE Academy in Bishkek between 2023-2024 and continues his work as an assistant editor for the Insight Turkey journal published by SETA.

Gloria Shkurti Özdemir
Dr. Gloria Shkurti Özdemir holds a BA in Political Science and International Relations from Albania. She completed her master's studies at Sakarya University, presenting a thesis titled "A Lethal Weapon that Became the Cure-all for Terrorism: Discursive Construction of the U.S. Dronified Warfare." Her doctorate was obtained at Ankara Yıldırım Beyazıt University, where her research focused on the application of artificial intelligence in the military, specifically examining the U.S.-China rivalry.
Her primary research interests revolve around emerging technologies, particularly artificial intelligence, and their implications for international relations, U.S. foreign policy, and drone warfare. Currently, Gloria is a researcher in the Foreign Policy Directorate at the SETA Foundation. Additionally, she serves as the Assistant Editor of Insight Turkey, a journal published by the SETA Foundation.

SUMMARY

> This analysis delves into the intricate relationship between AI, its energy consumption, and environmental security. By examining current research and integrating new analytical insights, this analysis seeks to underscore the urgent need for sustainable AI development and the establishment of international regulatory frameworks to mitigate its environmental impact.

In recent years, the world has grappled with the far-reaching effects of climate change, disproportionately impacting developing and undeveloped nations. Historically, industrialized countries have benefited from progress while significantly contributing to environmental degradation. With major CO2 emitters like the US, China, and European nations leading the AI revolution, particularly in Large Language Model (LLM) development, concerns about the environmental impact of these advancements are growing. Instead of assigning blame, the focus should be on determining necessary actions. The technological revolution offers opportunities for many countries to develop their technologies in ways that serve their interests, but the environmental impact of these technologies must be addressed promptly. The AI sector has already crossed a critical threshold with substantial environmental consequences. The challenge now is to chart a sustainable path forward.

It is crucial for all states and stakeholders, including governments and big tech companies, to take proactive measures by establishing necessary legislation and regulations to maximize AI's environmental benefits and mitigate its negative impacts on climate change. By fostering a collaborative approach and prioritizing sustainable development, the AI revolution can contribute positively to our global future rather than exacerbating the climate crisis. The urgency to address AI's environmental implications cannot be overstated, as the path chosen now will determine whether AI becomes a tool for sustainable progress or a catalyst for further environmental degradation. International cooperation and a shared commitment to sustainability are essential to harness the power of AI while safeguarding our planet.

INTRODUCTION

As the saying goes, Rome wasn't built in a day, but through a series of actions. In 49 B.C., Julius Caesar crossed the Rubicon River with his army, defying the Roman Senate's explicit orders and declaring war on Rome. This decisive act marked the point of no return for Caesar, setting into motion a series of events that ultimately led to the fall of the Roman Republic and the rise of the Roman Empire. Thus, "crossing the Rubicon" has come to symbolize a decisive, irreversible step that commits one to a specific course of action, often with far-reaching, significant consequences.

Similarly, the development and deployment of Artificial Intelligence (AI) have crossed their own Rubicon, particularly regarding their impact on the carbon footprint. The irreversible integration of AI into various sectors signifies a commitment to a path with profound and lasting implications for the environment and society. Just as Rome wasn't built in a day, the ongoing advancements in AI technology represent a series of cumulative actions that will shape our future. AI has emerged as a transformative technology with significant implications across various sectors. As highlighted in numerous studies, AI's exponential development extends its influence from security, health care, and education to diplomacy, continually reshaping these fields. While it is essential to acknowledge and celebrate the positive outcomes of AI, such as improved efficiency, enhanced decision-making, and innovative solutions to complex problems, this perspective aims to shed light on a less-discussed aspect of AI technology: its environmental impact.

The rapid development and deployment of AI systems have raised significant concerns regarding their environmental footprint, particularly in terms of energy consumption and carbon emissions. AI technologies, especially those involving deep learning models, demand substantial computational resources, leading to high energy usage and considerable carbon footprints. This analysis delves into the intricate relationship between AI, its energy consumption, and environmental security. By examining current research and integrating new analytical insights, this analysis seeks to underscore the urgent need for sustainable AI development and the establishment of international regulatory frameworks to mitigate its environmental impact.

AI AND ENERGY CONSUMPTION

At the World Economic Forum's annual meeting in Davos, Switzerland, OpenAI's chief executive, Sam Altman, said that the AI industry is on the brink of an energy crisis.[1] Altman also underlined

1 "Davos 2024: Sam Altman on the Future of AI," *World Economic Forum*, (January 18, 2024), retrieved June 3, 2024, from https://www.weforum.org/agenda/2024/01/davos-2024-sam-altman-on-the-future-of-ai/.

that the upcoming wave of generative AI systems will demand significantly more power than anticipated, posing a serious challenge for existing energy infrastructures. "There's no way to get there without a breakthrough," he stated.[2]

It is important to note that data centers, which are crucial for training AI models and are major consumers of energy, have experienced significant growth in both number and capacity in recent years due to the rising demand for AI model training. As illustrated in Graph 1, there are currently over 11,000 data centers worldwide, with approximately half located in the US, reflecting the country's advancements in AI and large language models (LLMs). In terms of power consumption, the impact of these data centers is paramount. Specifically, focusing only on the U.S. data centers, according to a report by McKinsey & Company the power consumption is expected to increase by 10% annually until 2030. Consumption is expected to reach 35 gigawatts (GW) by 2030, up from 7 GW in 2014, 17 GW in 2022, and approximately 20 GW in 2024.[3] Additionally, it is important to note that the global greenhouse gas emissions from these data centers are estimated to be around 1% to 1.5% of total emissions, indicating that their environmental impact is significant and growing.[4]

Moving away from the general impact of the data centers and focusing especially on the LLMs, one assessment suggests that ChatGPT, an LLM created by OpenAI in San Francisco, California, already consumes as much energy as 33,000 homes.[5] Considering that ChatGPT currently has over 180 million users[6] and OpenAI.com receives approximately 1.6 billion visits per month, the seriousness of this situation becomes evident. It's estimated that a search driven by generative AI uses four to five times the energy of a conventional web search. In the coming years, large AI systems may require as much energy as entire nations.[7]

> The development and deployment of AI have crossed their own Rubicon, particularly regarding their impact on the carbon footprint. The irreversible integration of AI into various sectors signifies a commitment to a path with profound and lasting implications for the environment and society.

However, the concern isn't limited to energy alone. Generative AI systems also require vast amounts of fresh water to cool processors and generate electricity (Figure 1).[8] Thus, AI is directly addressing one of the most critical challenges of the 21st century: the management and allocation of increasingly scarce global fresh-

2 "OpenAI CEO Altman Says at Davos Future AI Depends on Energy Breakthrough," *Reuters*, (January 16, 2024), retrieved June 3, 2024, from https://www.reuters.com/technology/openai-ceo-altman-says-davos-future-ai-depends-energy-breakthrough-2024-01-16/.

3 "Investing in the Rising Data Center Economy," McKinsey & Company, (January 17, 2023), retrieved June 5, 2024, from https://www.mckinsey.com/industries/technology-media-and-telecommunications/our-insights/investing-in-the-rising-data-center-economy .

4 "How Data Centres and New Power Semiconductor Technologies Can Support Decarbonization," *World Economic Forum*, (November 2, 2023), retrieved June 5, 2024, from https://www.weforum.org/agenda/2023/11/data-centres-power-semiconductor-technologies-decarbonization/; "Data Centres and Data Transmission Networks," IEA, retrieved June 5, 2024, from https://www.iea.org/energy-system/buildings/data-centres-and-data-transmission-networks.

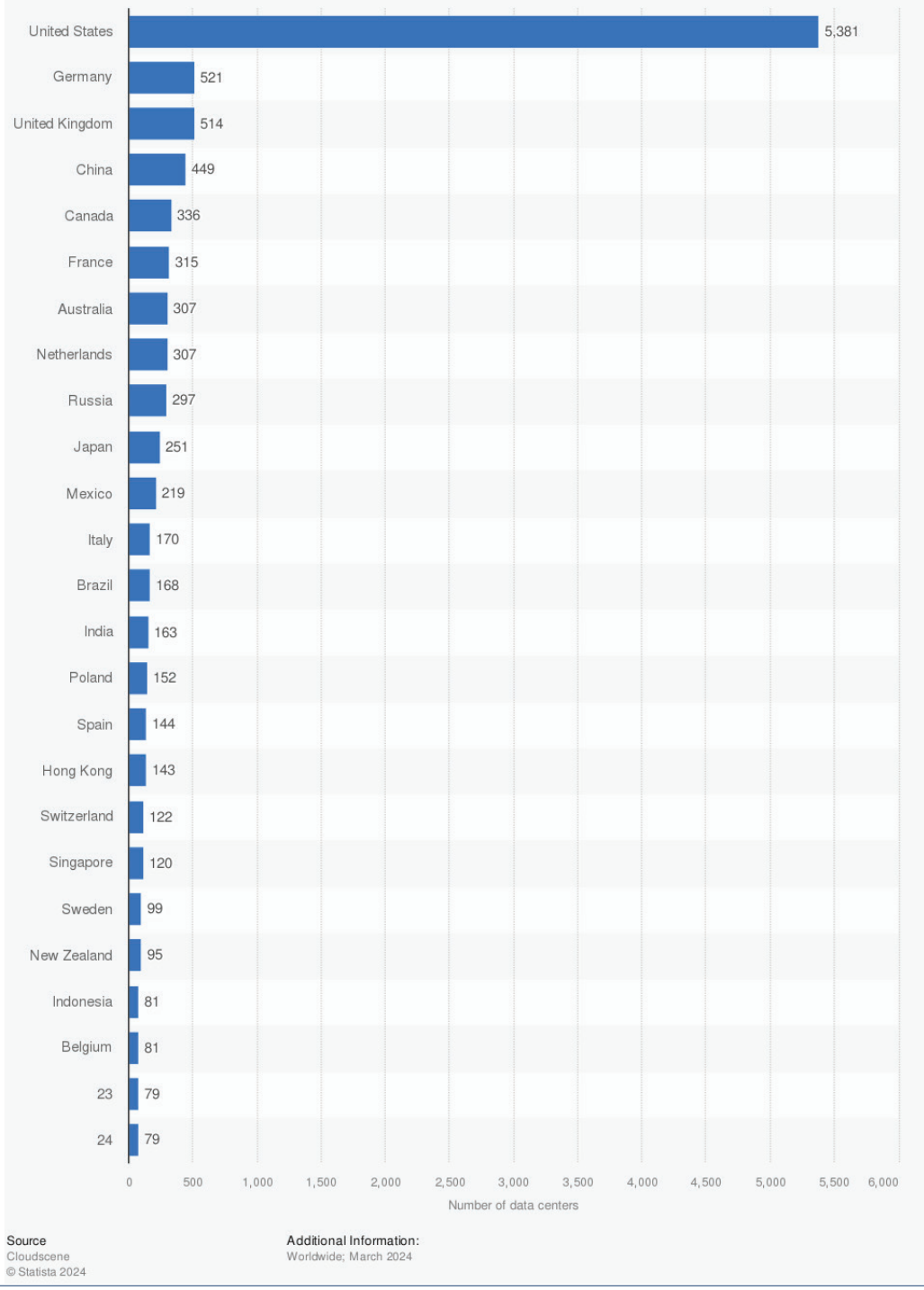
5 "The Shocking Truth of AI Energy Consumption," *Integrity Energy*, retrieved June 3, 2024, from https://www.integrityenergy.com/blog/the-shocking-truth-of-ai-energy-consumption/.

6 "ChatGPT Users," *Exploding Topics*, (June 6, 2024), retrieved June 6, 2024, from https://explodingtopics.com/blog/chatgpt-users.

7 "The Generative AI Search Race Has a Dirty Secret," *Wired*, (February 10, 3023), retrieved June 3, 2024, from https://www.wired.com/story/the-generative-ai-search-race-has-a-dirty-secret/.

8 Kate Crawford, "Generative AI's Environmental Costs Are Soaring — and Mostly Secret," Nature, Vol. 626, (2024), p. 693, retrieved from https://www.nature.com/articles/d41586-024-00478-x.

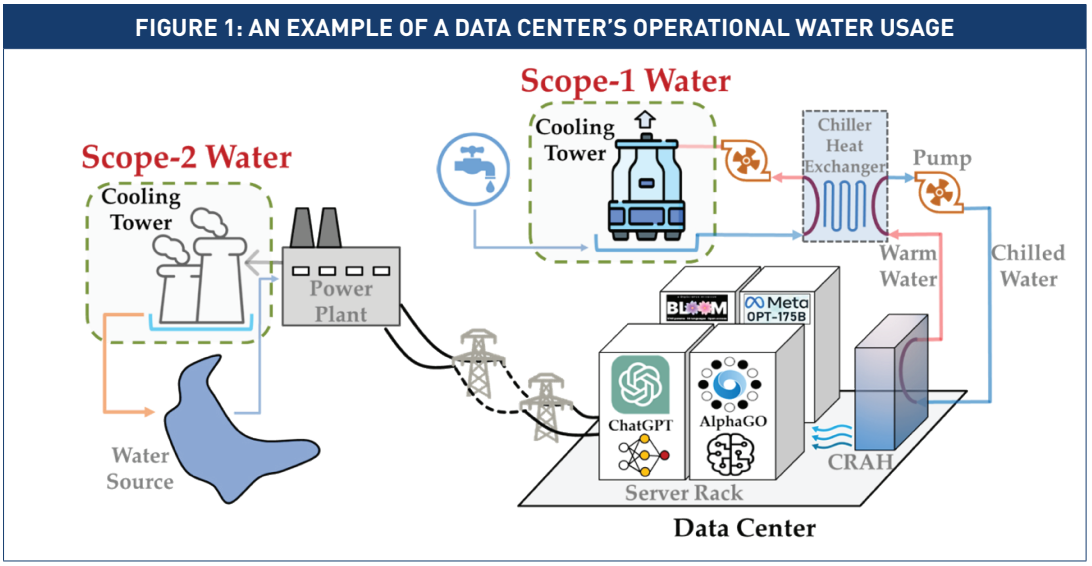
GRAPH 1: LEADING COUNTRIES BY NUMBER OF DATA CENTERS AS OF MARCH 2024



Source: Statista*

* "Leading Countries by Number of Data Centers as of March 2024," *Statista*, (March 2024), retrieved June 5, 2024, from https://www.statista.com/statistics/1228433/data-centers-worldwide-by-country/.

FIGURE 1: AN EXAMPLE OF A DATA CENTER'S OPERATIONAL WATER USAGE



Source: OECD*
*https://oecd.ai/en/wonk/how-much-water-does-ai-consume

water resources.[9] In West Des Moines, Iowa, a massive data center cluster supports OpenAI's most advanced model, GPT-4. In July 2022, the month before OpenAI completed training the model, the cluster reportedly used about 6% of the district's water.[10] As Google and Microsoft prepared their Bard and Bing large language models, both companies saw significant spikes in water usage – increases of 20% and 34%, respectively, in one year, according to their environmental reports.[11] To put this into perspective, a study estimates that global AI demand could account for 4.2 to 6.6 billion cubic meters of water withdrawal in 2027 – four to six times more than the total annual water withdrawal of Denmark or half of the United Kingdom.[12] In another study, Facebook AI researchers[13] described the environmental effects of the industry's pursuit of scale as the "elephant in the room."

As stated above, AI technologies, particularly deep learning models, demand substantial computational resources for both the training and inference phases. Training large models like GPT-3, for instance, is associated with significant carbon footprints, estimated at 502 metric tons of CO2 equivalents.[14] This level of carbon emission

9 Ayşegül Kibarpoğlu, "Türkiye's Water Security Policy: Energy, Agriculture, and Transboundary Issues," in Muhittin Ataman and Gloria Shkurti Özdemir (eds.), *Different Dimensions of Environmental Security in Turkiye and Beyond,* (İstanbul: SETA Publications, 2023), p. 179.

10 Matt O'Brien and Hannah Fingerhutt, "Artificial Intelligence Technology Behind ChatGPT Was Built in Iowa — with a Lot of Water," *Des Moines Register*, (2023), retrieved June 2, 2024, from https://www.desmoinesregister.com/story/money/business/2023/09/10/chatgpt-was-built-in-iowa-using-artificial-intelligence-microsoft-west-des-moines/70819093007/.

11 Matt O'Brien and Hannah Fingerhutt, "A.I. Tools Fueled a 34% Spike in Microsoft's Water Consumption, and One City with Its Data Centers Is Concerned About the Effect on Residential Supply," *Fortune*, (September 9, 2023), retrieved June 3, 2024, from https://fortune.com/2023/09/09/ai-chatgpt-usage-fuels-spike-in-microsoft-water-consumption/.

12 Pengfei Li, Jianyi Yang, Mohammad Islam, and Shaolei Ren, "Making AI Less "Thirsty": Uncovering and Addressing the Secret Water Footprint of AI Models," *arXiv*. (2023), retrieved from https://arxiv.org/abs/2304.03271.

13 Carole-Jean Wu, et al., "Energy-Efficient Practices in Deep Learning Training: Preliminary Steps Towards." *arXiv*, (2022), retrieved from https://arxiv.org/abs/2111.00364.

14 Renée Cho, "AI's Growing Carbon Footprint." Columbia Climate School, *Columbia Climate School*, (2023), retrieved June 3, 2024 from https://news.climate.columbia.edu/2023/06/09/ais-growing-carbon-footprint/

is comparable to the annual emissions of dozens of cars. The energy consumption during the inference phase is even more pronounced. Once these models are deployed, they handle millions of queries, leading to continuous and extensive use of computational power. This creates a persistent and growing demand for energy, exacerbating the environmental impact. The widespread adoption of AI-driven applications in various industries, from health care and finance to entertainment, further amplifies this energy consumption.[15] For instance, data centers often rely on large-scale cooling systems that consume vast amounts of fresh water and electricity. In regions where water is scarce, this can create additional environmental and societal challenges.[16]

REGULATORY AND ETHICAL CONSIDERATIONS

In recent months, we have witnessed tremendous advancements in AI, particularly in LLMs. These models have become integral to our daily lives and are widely used by companies and institutions, significantly impacting various sectors, including the economy. Moreover, from this perspective, the substantial energy required to train AI models contributes to climate change. As we face the severe effects of climate change today, it is crucial to take decisive and effective measures to mitigate AI's environmental impact before it is too late. As awareness of the environmental impact of AI grows, various states and actors are actively working to mitigate these negative effects as they focus on supporting the development of sustainable AI solutions.

One of the first steps taken within this perspective was slowing down or halting new data center construction. For example, Singapore stopped building new data centers in 2019 to meet its net-zero emissions target by 2050 (however, work resumed in 2023). Ireland followed suit and delayed new constructions until 2028.[17] In the case of the US, at the federal level, the government has also started to play a more significant role in incentivizing data center activities through tax policy. Even if not directly focusing on data centers per se, the Inflation Reduction Act, for example, includes provisions that provide financial rewards for data centers that prioritize sustainability and energy efficiency.[18]

However, at the beginning of 2024, a significant new initiative was launched: the Artificial Intelligence Environmental Impacts Act of 2024 was introduced separately in both the Senate and the House of Representatives. While the bill has a long journey before it can become law, it is notable for directly addressing the environmental impacts of AI. The bill specifically states that the rapid growth of data center infrastructure, including cooling systems and backup power equipment supporting AI and other computing-intensive technologies, contributes to pollution, water consumption, and land-use changes.

To tackle these issues, the bill mandates that the administrator of the Environmental Protection Agency, in collaboration with the secretary of energy, the director of the National Institute

15 Crawford, "Generative AI's Environmental Costs Are Soaring — and Mostly Secret."

16 "AI and Energy Consumption Challenge Data Centers to Innovate Amid Growing Demand," JLL, (2024), retrieved June 3, 2024, from https://www.jll.com.br/en/trends-and-insights/investor/ai-energy-consumption-challenge-data-centers-innovate.

17 "Data centres Improved Greatly in Energy Efficiency as They Grew Massively Larger," *The Economist*, (January 29, 2024), retrieved June 5, from https://www.economist.com/technology-quarterly/2024/01/29/data-centres-improved-greatly-in-energy-efficiency-as-they-grew-massively-larger.

18 Christopher Tozzi, "The State of Data Center Tax Incentives and Legislation in 2023," *Data Center Knowledge*, (March 15, 2023), retrieved June 5, 2024 from https://www.datacenterknowledge.com/regulations/the-state-of-data-center-tax-incentives-and-legislation-in-2023.

of Standards and Technology, and the director of the Office of Science and Technology Policy, conduct a comprehensive study on the environmental impacts of AI. The results of this study must be submitted to Congress and made publicly available. Additionally, the bill calls for creating a consortium to identify future measurements, methodologies, standards, and other necessary tools to accurately measure and report the full range of AI's environmental impacts.[19]

At the state level, Virginia, a major hub for data centers, has been contemplating stricter zoning laws to regulate data center construction. One of the last proposed bills in Virginia has been HB 338, which allows localities to conduct site assessments to determine a data center's potential impact on water usage and carbon emissions. While the bill passed the House, the Senate has decided to postpone further consideration or action on the bill until the next legislative session in 2025.[20]

On the international level, there is still a lack of comprehensive legislation addressing the environmental impact of data centers or how AI impacts the environment in general. Given the often-slow pace of global governance in enacting new laws, such legislation is unlikely to materialize soon. However, existing regulations can help mitigate the environmental impact of data centers. For example, COP28's discussions on sustainability and climate action[21] will have wide-reaching effects on various industries, including the data center sector. Businesses will need to adapt to ambitious goals and evolving standards focused on sustainability. Supporting this argument, COP28 President and the United Arab Emirates (UAE) Minister of Industry and Advanced Technology Sultan Ahmed Al-Jaber emphasized the growth of AI as a major future trend during the opening of Baku Energy Week. He said that data center expansions for AI growth will need renewable energy supplemented by natural gas.[22]

On the international level, there is still a lack of comprehensive legislation addressing the environmental impact of data centers or how AI impacts the environment in general. Given the often-slow pace of global governance in enacting new laws, such legislation is unlikely to materialize soon.

Lastly, another legislation addressing the environmental impact of AI is the EU AI Act, which was approved at the beginning of this year. The regulation explicitly states that it aims to ensure that fundamental rights, democracy, the rule of law, and environmental sustainability are protected from high-risk AI.[23] The legislation further classifies AI systems that harm the environment, among other criteria, as high-risk systems. Delving into more detail, Article 40

19 "S.3732 - Artificial Intelligence Environmental Impacts Act of 2024," *US Congress*, (2024) retrieved June 5, 2024 from https://www.congress.gov/bill/118th-congress/senate-bill/3732/text.

20 "VA HB33," *Bill Track*, retrieved June 5, 2024, from https://www.billtrack50.com/billdetail/1661111.

21 "Summary of Global Climate Action at COP 28," UNFCCC, retrieved June 5, 2024, from https://unfccc.int/sites/default/files/resource/Summary_GCA_COP28.pdf.

22 "COP28 Presidency Calls for Global Effort to Leverage the Rise of AI, the Energy Transition and the Growth of the Global South to Accelerate Sustainable Development for All," *COP28*, (June 4, 2024), retrieved June 5, 2024, from https://www.cop28.com/en/news/2024/06/COP28-Presidency-calls-for-global-effort-to-leverage-the-rise-of-AI.

23 "Artificial Intelligence Act: Deal on Comprehensive Rules for Trustworthy AI," *European Parliament*, (December 9, 2023), retrieved June 5, 2024, from https://www.europarl.europa.eu/news/en/press-room/20231206IPR15699/artificial-intelligence-act-deal-on-comprehensive-rules-for-trustworthy-ai.

of the AI Act states: *"The Commission shall issue standardization requests … The standardization request shall also ask for deliverables on reporting and documentation processes to improve AI systems' resource performance,* ***such as reducing the high-risk AI system's consumption of energy and other resources consumption during its lifecycle, and on the energy-efficient development of general-purpose AI models****."*[24]

In addition, the legislation specifically targets general-purpose AI (GPAI) systems, which include generative models like ChatGPT, as outlined in Annex XI. It mandates that providers of general-purpose AI models must supply detailed technical documentation, including information on energy consumption.[25]

WHAT NEEDS TO BE DONE?

The AI industry must explore and invest in sustainable practices to address these issues. Innovations in energy-efficient algorithms, the use of renewable energy sources for data centers, and advancements in hardware that reduce power consumption are crucial steps toward mitigating the environmental impact of AI technologies. Collaboration between AI developers, environmental scientists, and policymakers will be essential in ensuring that the growth of AI does not come at the expense of our planet's health.[26] The growing energy demands of AI highlight the need for developing more energy-efficient algorithms and hardware. Current practices often result in substantial energy wastage, emphasizing the necessity for optimized neural network architectures that reduce energy consumption both during training and inference.

To address these challenges, several strategies can be implemented. Firstly, improving the efficiency of neural network designs can significantly reduce the energy required for training. This involves developing models that achieve similar performance levels with fewer parameters and less computational complexity.[27] Technics like model pruning, quantization, and knowledge distillation are being explored to create leaner and more efficient models without compromising accuracy.[28]

Secondly, advancements in hardware are also crucial. Designing specialized AI processors, such as application-specific integrated circuits (ASICs) and field-programmable gate arrays (FPGAs), can enhance the efficiency of AI computations.[29] These chips are tailored to perform specific AI tasks more efficiently than general-purpose processors, leading to significant energy savings.

Additionally, adopting renewable energy sources for data centers is essential. By utilizing solar, wind, or hydroelectric power, the AI industry can reduce its reliance on fossil fuels and decrease its overall carbon footprint. Companies like Google and Microsoft have already committed to powering their data centers with renewable energy, setting a precedent for the industry.[30]

24 "Artificial Intelligence Act," *European Parliament*, (2024) retrieved June 5, 2024, from https://www.europarl.europa.eu/doceo/document/TA-9-2024-0138_EN.pdf, emphasize added.

25 "Annex XI: Technical Documentation Referred to in Article 53(1a)," *EU AI Act*, retrieved June 5, 2024 from https://artificialintelligenceact.eu/annex/11/.

26 David B. Olawade, et al., "Artificial Intelligence Potential for Net Zero Sustainability: Current Evidence and Prospects," *Next Sustainability*, (2024), Vol. 4, retrieved from https://doi.org/10.1016/j.nxsust.2024.100041.

27 Tim Yarally, Luis Cruz, Daniel Feitosa, June Sallou, and Arie van Deursen, "Uncovering Energy-Efficient Practices in Deep Learning Training: Preliminary Steps Towards," *arXiv*, (2023), retrieved June 3, from https://arxiv.org/pdf/2303.13972.

28 R. Dhiman, S. Miteff, Y. Wang, S.-C Ma, R. Amirikas, and B. Fabian, "Artificial Intelligence and Sustainability-A Review," *Analytics*, Vol. 3, (2024), pp. 140-164.

29 Saif M Khan, "AI Chips: What They Are and Why They Matter," *CSET*, (2020), retrieved June 3, from https://cset.georgetown.edu/publication/ai-chips-what-they-are-and-why-they-matter/.

30 Michael Studer," The Energy Challenge of Powering AI Chips," *Robeco*, (2023), retrieved from https://www.robeco.com/en-me/insights/2023/11/the-energy-challenge-of-powering-ai-chips.

Furthermore, implementing energy-efficient data center designs, such as improved cooling systems[31] and better thermal management,[32] can minimize the energy required to maintain optimal operating conditions. Innovations in liquid cooling and advanced airflow management can significantly reduce the electricity needed for cooling. Collaborative efforts between AI developers, environmental scientists, and policymakers will be key in driving these changes. By prioritizing sustainability in AI research and development, the industry can continue to advance technological capabilities while mitigating its environmental impact.[33]

DISCUSSION AND CONCLUSION

In recent years, the world has been grappling with the far-reaching effects of climate change, a crisis that has disproportionately affected developing and undeveloped nations. Historically, industrialized countries have reaped the benefits of progress while contributing significantly to environmental degradation, a pattern that raises pressing questions as AI technology becomes increasingly central. With major CO2 emitters like the US, China, and the European nations spearheading the AI revolution, especially in Large Language Model (LLM) development, there are growing concerns about the environmental impact of these advancements. Nevertheless, instead of assigning blame, the primary focus should be on determining the necessary actions. The technological revolution we are witnessing offers opportunities for many countries to develop their technologies, in ways that best serve their interests. Consequently, the environmental impact of these technologies will be even greater if not addressed promptly.

> The AI industry must explore and invest in sustainable practices to address these issues. Innovations in energy-efficient algorithms, the use of renewable energy sources for data centers, and advancements in hardware that reduce power consumption are crucial steps toward mitigating the environmental impact of AI technologies.

Reflecting on the Rubicon metaphor, the AI sector has already crossed a critical threshold, committing to a trajectory with substantial environmental consequences. The current challenge is not assigning blame but charting a sustainable path forward. The technological revolution presents a unique opportunity for countries to develop AI, in a manner that aligns with their interests while considering environmental stewardship. Therefore, it is crucial for all states and stakeholders, including governments and big tech companies, to take proactive measures. They must establish the necessary legislation and regulations to maximize AI's environmental benefits while mitigating its negative impacts on climate change at the same time.

31 "Data Center Cooling Innovations: Towards Energy Efficiency," *Data Bank*, (2024), retrieved June 3, 2024, from https://www.databank.com/resources/blogs/data-center-cooling-innovations-towards-energy-efficiency/.

32 Yogesh Fulpagare and Atul Bhargav, "Advances in Data Center Thermal Management," *Renewable and Sustainable Energy Reviews*, Vol. 43, (2015), pp. 981-996, retrieved from https://doi.org/10.1016/j.rser.2014.11.056.

33 Tshilidzi Marwala, "Artificial Intelligence and Sustainable Development" *Medium*, (2024), retrieved June 3, 2024, from https://medium.com/@tshilidzimarwala/artificial-intelligence-and-sustainable-development-d19b2bdaaf56.

By fostering a collaborative approach and prioritizing sustainable development, we can ensure that the AI revolution contributes positively to our global future, rather than exacerbating the climate crisis.

As AI continues to evolve and integrate into every facet of society, the urgency to address its environmental implications cannot be overstated. The path we choose now will determine whether AI will become a tool for sustainable progress or a catalyst for further environmental degradation. International cooperation and a shared commitment to sustainability are essential to harness the power of AI while safeguarding our planet.

The lessons from history, particularly the irreversible step by Julius Caesar when he crossed the Rubicon, serve as a powerful reminder of the importance of decisive action. Just as Caesar's decision set the course for Rome's future, our current decisions on AI and its environmental impact will shape our planet's future. It is a call to action for policymakers, industry leaders, and society as a whole to embrace sustainable practices and ensure that the benefits of AI are realized without compromising the health of our environment.

In conclusion, AI's integration into our lives represents a significant turning point, much like the crossing of the Rubicon. The stakes are high, and the potential consequences are profound. By acknowledging the environmental challenges posed by AI and committing to sustainable development, we can navigate this transformative era with foresight and responsibility, ensuring a future where technology and nature coexist harmoniously.

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Within this context, this analysis delves into the intricate relationship between AI, its energy consumption, and environmental security. By examining current research and integrating new analytical insights, this analysis seeks to underscore the urgent need for sustainable AI development and the establishment of international regulatory frameworks to mitigate its environmental impact.

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