Ethical Considerations of Applying AI to Sustainability: An Analysis of the Environmental Impact of Data Centers in Northern Virginia

A Research Paper submitted to the Department of Engineering and Society

Presented to the Faculty of the School of Engineering and Applied Science

University of Virginia • Charlottesville, Virginia

In Partial Fulfillment of the Requirements for the Degree

Bachelor of Science, School of Engineering

Emily Huber

Spring 2025

On my honor as a University Student, I have neither given nor received unauthorized aid on this assignment as defined by the Honor Guidelines for Thesis-Related Assignments

Advisor

Pedro A. P. Francisco, Department of Engineering and Society

STS Research Paper

Introduction

Climate change is one of our generation's most pressing issues. Acknowledging that climate change will affect nearly every aspect of life, the 2015 Paris Agreement set goals to limit global warming below 1.5 degrees Celsius by the end of this century (Nations, n.d.). To achieve global sustainability goals, high emitting industries must decrease greenhouse gas usage to reduce environmental footprints. Growing consumer dependence on artificial intelligence (AI) based services and applications have pushed companies to rely heavily on data centers needed to train AI models. Colloquially known as "Data Center Alley", Northern Virginia (NOVA) hosts the largest concentration of data centers in the world (*Clicking Clean Virginia*). 70% of global internet traffic passes through Data Center Alley ("Virginia," 2023)**.** Northern Virginia has a large technology industry specializing in government contracting and resource-intensive server farms (Rosati et al., 2023). Tax exemptions, cheap energy from Dominion Energy, proximity to Washington, DC and relationships with the US federal government draws large companies and government agencies to place data centers in Northern Virginia ("Virginia," 2023)**.**

I will explore the environmental impact of data centers in Northern Virginia to find out how data centers impact climate change and local communities. As climate change worsens, we must find ways to reduce the environmental impact of the technology sector. Data centers have advanced the artificial intelligence landscape, however they negatively contribute to environmental issues through high greenhouse gas emissions and water consumption.

Advocates of AI and data centers include technology companies that profit from AI and consumers who want access to AI-based services and applications. Advocates of data centers in Northern Virginia state that the economic benefits outweigh environmental impacts (Mullin,

2023)**.** Critics of data centers may include local governments, communities, and environmental agencies. Large AI systems require intensive data center resources for model training. Data centers consume tons of water and energy for maintenance and cooling. Energy consumption puts pressure on local energy grids and potentially raises energy costs. The large consumption of water can stress dry ecosystems and cause environmental harm. Additionally, large-scale data centers can be loud and ugly (*Clicking Clean Virginia)*.

Through my STS research paper, I will discuss the environmental impact of data centers required to train AI systems. I will analyze the case study of the environmental impact of Northern Virginia's Data Center Alley through the lens of utilitarian ethics. I will explore and comment on the potentially paradoxical nature of using AI for sustainability, given that in order to train AI models, large data centers must devour natural resources. I conclude that applying AI for sustainability is ethical if the environmental and economic benefits outweigh the environmental harm caused by production and operation.

Background/Significance/Motivation

As data centers continue to dominate the Northern Virginia landscape, their sociotechnical impact must be studied to understand and prevent environmental and community damage. Data centers have material impacts on environmental health and require lots of electricity that often comes from local power grids reliant on fossil fuels. Thousands of gallons of water per day are needed to cool servers (Ipsen, n.d.). When evaluating the environmental impacts of data centers, it is important to take a holistic approach, including both energy and water footprints into consideration.

Data centers are designed for information technology (IT) equipment, not people. Filled with rows of IT equipment racks containing servers, storage devices, and networking equipment, these buildings often have no windows and low air circulation. IT devices generate heat that must be extracted from the building to maintain operation. Air conditioning circulating within the building cools IT equipment (U.S. Environmental Protection Agency, 2007). The International Energy Association (IEA) estimates that 1-1.5% of global electricity use comes from data center energy demand (Chakraborty, 2024). Data centers can use over 40 times more energy than conventional office buildings. In 2019, data centers in Virginia demanded 4.5 gigawatts of energy, roughly the same power output as nine large coal power plants (*Clicking Clean Virginia The Dirty Energy Powering Data Center Alley*, n.d.). Energy is used for operation of the IT equipment, cooling of the IT equipment, and power delivery. Usually the people responsible for purchasing and operating IT equipment are not the same people responsible for paying utility bills and facilitating power & cooling. This split incentive means those who control the IT equipment energy use have little incentive to reduce power consumption (U.S. Environmental Protection Agency, 2007).

Growth in the data center sector has led to increased energy consumption from the power and cooling infrastructure that supports the servers. Increased energy use has led to higher energy costs for business and government, increased greenhouse gas emissions, higher strain on local power grids to meet increased demand, and increased capital costs for data center expansion and construction (U.S. Environmental Protection Agency, 2007).

Water footprint is the industry standard for quantifying water use, measuring the amount of freshwater consumed and polluted (Ristic et al., 2015). Water is used for cooling onsite as well

as off-site electricity generation (Chakraborty, 2024). The amount of cooling needed to maintain IT equipment can be 5-10 times the cooling used in office or meeting spaces (Ristic et al., 2015).

Though many tech companies have stated corporate sustainability goals related to energy consumption, most of the renewable energy progress to the data center industry is not happening in Virginia. Some argue that this is because data centers have few options for buying renewable energy. Two thirds of Virginia's energy market is controlled by Dominion Energy, which actively lobbies for increased natural gas and coal usage (*Clicking Clean Virginia*). In 2023, only 5% of Dominion Energy's energy came from renewable resources (Dominion Energy, 2023). The rise of Data Center Alley has proved incredibly profitable for Dominion Energy, which derives a large portion of its long-term business strategy from data center electricity sales (*Clicking Clean Virginia*). Growth in data centers and AI has and will continue to increase global electricity demand. The need for power will outpace the efficiency improvements to the energy grid. As such, it is imperative that we source energy for data centers from renewable and scalable sources (Ermakov, 2024). The dire need to transition away from fossil fuels and the sheer scale of data center electricity use in Northern Virginia puts global importance on the energy operations of Dominion Energy (*Clicking Clean Virginia*).

Artificial intelligence can be applied to detect and solve complex environmental issues. However, the very existence of AI has negative environmental impacts, due to the high resource consumption of data centers required for model training. With the rise of artificial intelligence, it is important to apply AI for societal good, such as fighting the most pressing environmental challenges. However, it is also crucial to understand AI's environmental impacts. After all, if an AI application meant for sustainable purposes actually causes more harm than benefit to the

environment it claims to protect, is the system truly ethical? In my paper, I will explore the ethical dilemma of using AI for sustainability given its negative environmental footprint.

Methodology

In this paper, I will analyze the morality of using artificial intelligence for sustainability through the lens of utilitarianism. Utilitarianism is a form of consequentialism, holding that the most morally just choice is the one that maximizes the greatest good. By utilitarian ethics, the greater population's happiness outweighs the potential suffering of a small number of people (*Utilitarianism*, n.d.).

Utilitarianism has limitations. Firstly, utilitarianism's focus on outcomes places considerable importance on the future, which is often uncertain. It is often difficult to know with 100% certainty what the consequences of an action will be. The utilitarian method of making decisions based on whether the consequences of an action are good or bad is thus based on inherent uncertainty. Utilitarianism struggles to account for human values like individual rights and justice. When prioritizing the greatest good for the greatest number of people, utilitarianism neglects the value of the individual. As such, utilitarianism has been used to justify war, spreading messages that individual sacrifice will bring benefit to the masses (*Utilitarianism*, n.d.).

Acknowledging its limitations, I hold that utilitarianism is the best ethical framework to help understand my sociotechnical problem. Utilitarianism will allow me to approach the issue of applying AI for sustainability as a matter of maximizing the overall benefit to society. I will analyze the case study of Northern Virginia data centers' environmental impact through utilitarianism. The lens of utilitarianism will allow me to acknowledge and weigh the benefits

and drawbacks of data centers and artificial intelligence. The case study of Data Center Alley will reveal the negative environmental impact of data centers in the Northern Virginia region. As I perform the case study of the environmental impact of Northern Virginia data centers, I aim to draw conclusions about whether the negative environmental impacts of said data centers outweigh the environmental benefits of using AI to advance challenging sustainability problems, or vice versa. Applying utilitarianism to the Northern Virginia (NOVA) case study will help me discuss whether the benefit to society that AI for sustainability brings outweighs its environmental impact.

To answer my research question, I will use a combination of a case study and a literature review. I will conduct a case study on the environmental impact of data centers in Northern Virginia. Analyzing the NOVA region will help me make broader conclusions about the environmental impact of data centers across the country. Given that large data centers are needed to train AI models, understanding the environmental impact of data centers will help to elucidate the environmental impact of artificial intelligence. Once the environmental impact of AI has been discussed, I will analyze the morality of using AI for sustainability through the lens of utilitarianism. Through this utilitarian analysis, I will weigh the benefit of using AI to solve sustainability issues considering the environmental drawbacks of the data centers needed to train AI models.

Within this case study, the environmental impact of data centers in Northern Virginia will be analyzed with a literature review. Evidence on the environmental footprint, characterized by energy and water consumption, will be collected. The environmental impact of data centers outside of Northern Virginia will be interpreted to apply to Northern Virginia-specific data centers. Evidence specific to Northern Virginia data centers will also be collected. Northern

Virginia power grid and energy use will be analyzed to determine how data center energy use fits into the larger energy economic status in Virginia. All of this evidence will be analyzed to provide a comprehensive overview of the environmental impacts of data centers in Northern Virginia.

Literature Review / Results / Discussion

AI's unique capabilities make it a desirable option for dealing with climate change. Models trained on environmental datasets can improve predictions of extreme weather, process data on endangered species, track deforestation, and much more. Many environmental issues previously unsolvable due to available technology or computing resources can now be tackled. However, it is important to understand that AI itself has negative impacts on the environment. Data centers used to train AI systems consume enormous amounts of water and energy, releasing greenhouse gases and contributing to climate change (Coeckelbergh, 2021). Through the case study of the environmental impacts of data centers in NOVA, I explore how the rise of AI and Data Center Alley has affected the region. In doing so, I discuss the ethical implications of using AI for sustainability through the lens of utilitarianism. When considering the ethics of using artificial intelligence for sustainable development, it is important to examine both environmental and economic impacts. I have concluded that through utilitarianism, AI for climate is ethical as long as the environmental and economic benefits outweigh the environmental harm caused by data centers needed for model training.

According to recent assessments of AI's environmental impact, increased growth of AI may strain natural resources and undermine sustainability goals (Chakraborty). In Northern Virginia, data centers have massive water, carbon, and physical footprints. However, large tech

companies in the region often obfuscate environmental impact data. Throughout the region, water is consumed at enormous rates both directly in HVAC systems and indirectly from power grid use. Carbon is released into the atmosphere from the manufacturing of IT equipment in data centers needed for AI training. Data centers occupy thousands of acres of land, leaving a large physical footprint on local communities. Analyzing the environmental impact of data centers in the NOVA region helps to make broader conclusions about the environmental impact of data centers across the country (*Clicking Clean Virginia)*.

In *Clicking Clean Virginia, The Dirty Energy Powering Data Center Alley*, Greenpeace outlines the energy use by large cloud computing companies with data centers in Northern Virginia. Data Center Alley has rapidly expanded its importance in cloud computing, now hosting the largest concentration of data centers in the world. Greenpeace criticizes big tech companies like AWS for lack of transparency on emissions. The report aims to hold large companies accountable by publicly tracking and publishing their data centers' energy footprint and comparing said footprints to corporate sustainability promises.

Greenpeace critiques Dominion Energy, Virginia's largest energy provider, for hypocriticism related to public statements on renewable energy intentions. Dominion Energy's 15 year plan includes an increased reliance on natural gas, which is hypercritical to public statements about a focus on renewable energy. Greenpeace notes how most of the renewable energy progress to the tech industry is not happening in Virginia. The paper claims that this is because data centers have few options for buying renewable energy. Virginia's energy market is largely controlled by Dominion Energy, which actively lobbies for increased natural gas and coal usage. A section of the paper consists of attacks on Dominion Energy and their control over Virginia's energy grid. Only 4% of Dominion Energy's energy comes from renewable sources.

Yet Dominion controls two thirds of Virginia's electricity. The rise of Data Center Alley has proved incredibly profitable for Dominion Energy. A large part of Dominion's long-term strategy to drive electricity sales comes from Virginia data centers. According to Greenpeace, Dominion Energy has cited increased energy demands from data centers to support their lobbying for the Atlantic Coast Pipeline, a proposed natural gas pipeline through West Virginia, Virginia, and North Carolina that would increase greenhouse gas emissions and destroy forests (*Clicking Clean Virginia)*.

While examining the environmental impact of data centers in Northern Virginia, it is important to take a holistic approach, examining multiple parts of the environmental footprint. *Clicking Clean Virginia* examines the energy consumption of NOVA data centers in depth. In addition to energy consumption, it is important to consider the water footprint to provide a full assessment of the environmental footprint. Water footprint is the industry standard for measuring water use. Water footprints are divided into blue, green, and grey water footprints, representing the volume of freshwater, rainwater, and water needed to assimilate pollutants. Energy efficiency of data centers has been extensively researched but little research has been done on the water footprint. In *The Water Footprint of Data Centers*, Ristic et. al. calculates a water footprint based on cooling and energy consumption in data centers. According to their calculations, outbound data traffic generates a water footprint of between 1 - 205 liters per gigabyte. The largest fraction of the water footprint comes from energy consumption. Energy consumption is used directly for HVAC systems to cool IT equipment and indirectly as electricity needed to power IT equipment. The amount of energy needed to cool IT equipment can be 5-10 times the cooling used in an office of similar size (Ristic).

If used irresponsibly, ‘AI for climate’ systems can cause more harm than good to the environment. Training neural networks used for deep learning systems consume significant amounts of energy and water. According to Coeckelbergh, the training process of a natural language processing (NLP) model can emit nearly 300,000kg of carbon dioxide equivalent, nearing five times the amount of carbon dioxide emitted by an average car over its lifetime (Coeckelbergh, 2021). Though not all AI models consume this much energy, the training of large AI systems is key to understanding the scope of AI’s environmental impact.

Through the lens of utilitarianism, in order for an AI system to be ethical, the benefits must outweigh the harm brought about by the application. There is disagreement in the AI ethics community about what constitutes a worthwhile benefit of AI. Proponents of data centers cite economic growth as a reason to continue growing the data center industry in NOVA. In his 2023 paper, Mullin outlines the economic benefit of data centers to the Northern Virginia region. Data centers in NOVA provide economic growth opportunities such as high paying jobs. The growth of AI and its reliance on NOVA data centers has stimulated Virginia’s economy. The article cites a Mangum Economics study that estimates that data centers in Virginia supported 45,460 jobs and $15.3 billion in economic output in 2021 (which is 1% of Virginia’s jobs and 2.5% of its economic output). Though data center companies often receive tax breaks, local governments still receive some tax money, also contributing to economic growth. Data center companies are often drawn to Virginia through tax incentives, making NOVA a major player in the data center industry. Jobs created through the rise of Data Center Alley have contributed to the economic boom of the NOVA region. The author refutes environmental issues discussed in studies of data centers as too pessimistic, saying that the economic benefits outweigh the environmental harm (Mullin, 2023).

According to Mullin (2023), the economic benefits of AI outweigh the environmental turmoil. In my opinion, underneath this claim lies the belief that the economic prosperity of humans is more important than global environmental health. To provide a comprehensive cost-benefit analysis of using AI for sustainability, I believe it is important to consider economic gain as a driving factor. However, I level my analysis with the belief that environmental protection is innately valuable, even without direct economic benefit.

I agree with Mullin's argument to some extent. While I agree that the rise of Data Center Alley and increased importance of AI has stimulated the Northern Virginia economy, I think this take is short-sighted. The article fails to consider the long-term economic turmoil caused by climate change. According to Tol's 2018 analysis of the economic effects of climate change, a global mean temperature increase of 2.5 degrees Celsius will make the average person feel as if they had lost 1.3% of their income. It is also important to consider that the economic and environmental impacts of AI are not uniformly distributed. Wealthier countries tend to benefit more from AI systems and are better equipped to handle environmental turmoil that ensues. In contrast, poorer nations may bear the brunt of extreme weather patterns and environmental distress caused by climate change. Climate change disproportionately affects the most vulnerable (Tol, 2018).

So, in the utilitarian analysis of whether or not AI for sustainability is ethical, it is important to establish what timeline one considers important for analysis. Short-term and long-term economic impacts conflict when performing a utilitarian analysis. Those who prioritize long term health, economic prosperity, and environmental safety would emphasize responsible AI development. Those who prioritize short term economic benefit would argue that growth in Data Center Alley and increased use of AI is more beneficial than any potential issues

in the future. To me, to ensure the greatest benefit to the most people, one should prioritize long-term economic stability. Prioritizing long-term economics means prioritizing fighting climate change over current economic benefit.

To conclude, I believe that applications that employ AI for climate change reduction are ethical, as long as they are created responsibly. Based on the discussed literature, it is clear that data centers, and thus AI, negatively impact the environment. However, if the environmental benefit of an AI for climate application outweighs the resource use required for its creation, then by utilitarianism, the system is ethical. As AI for climate becomes more prevalent and Data Center Alley continues to grow, if growth is irresponsible, then any positive benefits to fighting climate change will be overpowered by the environmental impact of the applications themselves. Of course, quantifying whether an AI application will bring more benefit to the environment than harm is difficult. I believe that due to AI's large environmental footprint, AI for climate should only be developed when it is abundantly clear that lower-footprint systems are not sufficient.

Conclusion

Through the lens of utilitarianism, applying AI for sustainability is ethical and beneficial if the environmental and economic benefit from the application is greater than its environmental degradation. AI for climate can help advance sustainability initiatives, but data center use for training also contributes significantly to climate change, the very cause it hopes to solve. A case study of the environmental and economic effects of data centers in Northern Virginia exemplified a balance between economic and environmental priorities. To successfully accomplish goals of reducing the effects of climate change, it is imperative that AI for climate systems are developed responsibly and natural resource use is efficient. To ensure responsible development, it is critical

that infrastructure in Data Center Alley and beyond employ renewable energy sources. Widespread awareness of the environmental impact of AI and data centers is needed to ensure ethical and beneficial uses of AI in the future.

References

Chakraborty, S. (2024). *Towards A Comprehensive Assessment of AI's Environmental Impact* (arXiv:2405.14004). arXiv. http://arxiv.org/abs/2405.14004

Clicking Clean Virginia The Dirty Energy Powering Data Center Alley. (n.d.). OurEnergyPolicy. Retrieved October 6, 2024, from https://www.ourenergypolicy.org/resources/clicking-clean-virginia-the-dirty-energy-powering-data-center-alley/

Coeckelbergh, M. (2021). AI for climate: Freedom, justice, and other ethical and political challenges. *AI and Ethics*, *1*(1), 67–72. https://doi.org/10.1007/s43681-020-00007-2

Dominion Energy. (2023). *2023 annual report and annual report on form 10-K*. https://s2.q4cdn.com/510812146/files/doc_downloads/2024/2024/03/20/20/Dominion-Energy-2023-Annual-Report-and-Annual-Report-on-Form-10-K.pdf

Ermakov, A. *(2024). Electricity Demand Growth for Data Centres and AI and Implications for Natural-Gas Fired Power Generation.*

Ipsen, H. A. (n.d.). *Catching the Cloud and Pinning It Down: The Social and Environmental Impacts of Data Centers* [M.A., Syracuse University]. Retrieved October 14, 2024, from https://www.proquest.com/docview/2066820596/abstract/F94D5BCDD6A54884PQ/1

Mullin, J. (2023). Virginia's Data Centers and Economic Development: The state's fast-growing data center industry continues to build on its early advantages. *Econ Focus*, *28*(2), 14–17.

Nations, U. (n.d.). *The Paris Agreement*. United Nations; United Nations. Retrieved October 30, 2024, from https://www.un.org/en/climatechange/paris-agreement

Ristic, B., Madani, K., & Makuch, Z. (2015). The Water Footprint of Data Centers. *Sustainability*, *7*(8), 11260–11284. https://doi.org/10.3390/su70811260

Rosati, C., James, A., & Metcalf, K. (2023). Data plantation: Northern Virginia and the territorialization of digital civilization in "the Internet Capital of the World." *Online Media and Global Communication*, *2*(2), 199–227. https://doi.org/10.1515/omgc-2023-0017

Tol, R. S. J. (2018). The Economic Impacts of Climate Change. *Review of Environmental Economics and Policy*, *12*(1), 4–25. https://doi.org/10.1093/reep/rex027

U.S. Environmental Protection Agency. (2007). *Report to Congress on server and data center energy efficiency: Public Law 109-431*. Washington, DC: U.S. Environmental Protection Agency. https://www.energystar.gov/ia/partners/prod_development/downloads/EPA_Datacenter_Report_Congress_Final1.pdf

Utilitarianism. (n.d.). Ethics Unwrapped. Retrieved February 26, 2025, from https://ethicsunwrapped.utexas.edu/glossary/utilitarianism

Virginia: The Data Center Capital of the World. (2023). *Site Selection*, *68*(2), 36–36.