

International Journal of Computer Science and Mobile Computing

A Monthly Journal of Computer Science and Information Technology



ISSN 2320-088X
IMPACT FACTOR: 7.056

IJCSMC, Vol. 14, Issue. 9, September 2025, pg.124 – 128

Sustainable AI: Developing Carbon-Conscious Azure Machine Learning Pipelines for US Healthcare Uses

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DOI: <https://doi.org/10.47760/ijcsmc.2025.v14i09.017>

Abstract: As artificial intelligence (AI) becomes more and more a part of American healthcare; it has a far bigger effect on the environment. AI enables genomics, medical imaging, patient monitoring, and predictive diagnostics. Healthcare businesses who care about the environment and want to be more sustainable shouldn't utilize a lot of processing power for large-scale model training because it releases more carbon dioxide into the air. This study proposes a machine learning (ML) pipeline that takes carbon emissions into account and uses Microsoft Azure's range of sustainable technologies.

The design includes Azure Batch with green scheduling, the Carbon Aware SDK, Azure Machine Learning, and Power BI for reporting on sustainability. A real-world case study from a nonprofit hospital system in the US found that carbon-aware model training lowered emissions by 48% without hurting model performance. This article connects AI innovation and environmental responsibility in healthcare cloud computing so that HIPAA compliance, clinical performance requirements, and environmental impact goals can all be met at the same time.

Keywords: Responsible ML, Environmental Stewardship in Hospitals, ESG in Healthcare, Carbon Optimization, Power BI for Sustainability, U.S. Healthcare IT, Green Cloud Computing, HIPAA-compliant AI, Carbon-Aware SDK, Azure Batch Scheduling, Sustainable AI, Carbon-Aware Computing, Azure Machine Learning, and Energy-Aware ML Infrastructure.

1. Overview

A quick look AI has changed clinical diagnosis, hospital operations, and how patients interact with healthcare. Artificial intelligence (AI) models are used these days to improve operations by predicting things like bed occupancy, readmissions, missed appointments, and diagnostic imaging (for example, finding malignancies with radiology scans). But the expense of training big models, especially deep neural networks, has gone substantially, which has led to more energy use and carbon emissions.

The healthcare business in the US uses a lot of energy and is responsible for around 10% of the country's greenhouse gas (GHG) emissions (Chung & Meltzer, 2009). As hospitals switch to digital infrastructures that incorporate AI, their cloud platforms must meet sustainability criteria including the Federal Sustainability Plan, Environmental Sustainability Certification, and optional ESG goals. Microsoft Azure is a one-of-a-kind platform for creating AI that is good for the environment. It is fantastic for developing ML pipelines that are beneficial for the environment because it contains carbon-aware scheduling, ML lifecycle tools, and a goal of 100% renewable energy by 2025.

This article presents a sustainable AI framework for US healthcare that is based on a detailed case study of a real healthcare system that used Azure ML and the Carbon Aware SDK to reduce carbon emissions without affecting performance.

2. Review of Literature

Policy and academic circles are paying more and more attention to how AI affects the environment. Strubell et al.'s (2019) well-known estimate says that training only one NLP model, like BERT, can cause more than 626,000 pounds of CO₂ emissions throughout its lifetime. That's the same amount as five American cars. The healthcare business makes this footprint worse by employing longitudinal EHR datasets or high-resolution medical imaging data to train AI models, which takes a lot of computing power.

Code Carbon (Lacoste et al., 2021), the Carbon Aware SDK (Microsoft, 2023), and green cloud resource managers are all technologies that have been developed to assist in monitoring and reducing emissions. Individuals are aware that Azure cares about the environment. It is common knowledge that Azure cares about the environment. Microsoft ceased reliance on carbon in 2012. Today they offer ML performance-vs-emissions dashboards, renewable-aware task scheduling, and APIs for reporting emissions.

Few studies thoroughly examine Azure ML's impact in the highly regulated, mission-critical U.S. healthcare sector, despite recent studies (Bannour et al., 2023) validating its integration with green infrastructure in sectors like banking and transportation. This study fills that gap by showing how to use a carbon-aware machine learning pipeline for predictive analytics in a US nonprofit hospital network.

3. Approach: Making the Azure Carbon-Aware ML Pipeline

3.1 Overview of the Architecture

The suggested pipeline links four key Azure services with tools for long-term use:

- Azure Machine Learning (Azure ML) is in charge of using models, keeping track of them, and training them.
- The Carbon Aware SDK sets up training for datacenters that have the least amount of carbon.

- Azure Batch does a lot of model training with virtual machines (VMs) that can be used again or removed.
- Power BI shows how performance, cost, training effectiveness, and emissions are all connected. **Security Layer:** Using Azure Private Link, HIPAA compliant storage, and Key Vault the system keeps information secure and private.

3.2 Steps for optimizing carbon

Retrieving Carbon Data: When using the Carbon Aware SDK, this will retrieve real time carbon intensity from other Azure regions energy grids (i.e. East US 2 and West US).

Job Scheduling: Azure ML has a custom pipeline component that will move or take into account the scheduling of jobs, if the carbon emissions are considered low.

Resource Matching: Azure Batch trained the Spot virtual machines that are considered to make the least consistent pollution.

Performance Monitoring: Power BI will continuously monitor the model accuracy, model training time, and emissions.

4. A case study of using carbon-aware AI to predict readmissions at Healthcare

4.1 Background

One of the Healthcare in Georgia is a major nonprofit academic health system in the US. It wanted to reduce its impact on the environment while also pursuing AI-driven innovation. They look at medications, vital signs, and discharge instructions in the EHR to see how likely it is that a person will need to go back to the hospital within 30 days.

They were worried that training LSTM-based models on 1.2 million patient records from different times would let out a lot of carbon dioxide. The data science team wanted to keep the quality of their models in line with environmental goals and the Health Care Without Harm sustainability framework.

4.2 Deployment Strategy Data:

- Five hospitals' worth of pseudonymized records that follow HIPAA rules from 2018 to 2023.
- Model: LSTM model for predicting sequences in Azure ML pipelines.
- Baseline: Free training in the eastern US.

Sustainable Configuration:

- With the Carbon Aware SDK, you can keep an eye on emissions in a certain area.
- Azure Batch arranged training from 2 AM to 6 AM when there was a lot of demand for renewable energy.
- Compute VMs with $\leq 30\%$ idle buffer and a limit of 20 vCPUs.

4.3 Baseline Setup: Results Metric for Carbon-Aware Setup

Metric	Setting Up the Baseline	Set Up for Carbon Awareness
Average CO ₂ Emissions per Job	43.8 kg	22.7 kg
Time for Training	4.5 hours	5.2 hours
AUC for Model Accuracy	0.91	0.91
Price per Training Job	\$86.10	\$64.35
Risk of not following the law (HIPAA breach)	Low	Low

Key Findings:

- There were 48.2% less emissions without sacrificing accuracy.
- The cost of computing went reduced by 25.3% because virtual machines (VMs) got cheaper. However, the time it took to train went increased by 16%.
- Key Vault, Role-Based Access Control, and TLS encryption are all Azure-native compliance tools that made sure the whole pipeline was HIPAA-compliant.

5. Discussion

5.1 Benefits of Carbon-Aware ML in U.S. Healthcare

- **Cost-Efficiency:** Green scheduling and spot VMs lower expenses and emissions.
- **Public Reputation:** Promises to be good for the environment suit patients' needs and make them feel more confident.
- **Regulatory Readiness:** Helps you meet the Joint Commission's environmental and SEC, CMS, and ESG reporting requirements.

5.2 Solutions and Tradeoffs

Delays in Training: Production SLAs could not function for occupations that need to switch shifts. When developing and training, use the Carbon Aware SDK instead of inference.

Complexity: To include carbon-aware logic, you only need to make a few small changes to DevOps. Microsoft includes sample templates that can help you get things done faster.

5.3 Alignment of HIPAA and Compliance

- There was never any personally identifiable information shared during any cloud transfer.
- We used Managed Identity and Azure Security Center rules to limit who could see logs and models.
- You can only get to Power BI dashboards in safe parts of the hospital's intrane.

6. Conclusion

For the future of healthcare, sustainable AI is not a nice-to-have; it's a must-have. This article talks about how U.S. healthcare organizations can use Microsoft Azure to create predictive models that are carbon-aware, fully secure, compliant, and optimized for performance.

By using the Carbon Aware SDK, Azure Machine Learning, and smart scheduling methods together, hospitals can cut down on their emissions by a lot without lowering the quality of care or their ability to analyze data.

This method can help clinical NLP, imaging (radiology AI), and even federated research collaborations in places where HIPAA rules apply. Cloud-native, carbon-aware machine learning will be crucial in forming sustainable digital health as carbon accounting becomes required in both healthcare and AI development.

References

- [1] Miao, Z., Liu, L., Nan, H., Li, W., Pan, X., Yang, X., Yu, M., Chen, H., & Zhao, Y. (2024, October 15). *Energy and carbon-aware distributed machine learning tasks scheduling scheme for the multi-renewable energy-based Edge-Cloud Continuum*. Science and Technology for Energy Transition. <https://www.stet-review.org/articles/stet/abs/2024/01/stet20240197/stet20240197.html#:~:text=Additionally%2C%20considering%20the%20dynamic%20differences,task%20failure%20rate%20of%201.25%25.&text=This%20is%20an%20Open%20Access,original%20work%20is%20properly%20cited.>
- [2] Bannour, H., Feriani, A., & Ghrab, R. (2023). Sustainable AI: Carbon-aware training on the cloud. *Journal of Cloud Computing*.
- [3] Patel, D., Raut, G., Cheetirala, S. N., Nadkarni, G. N., Freeman, R., Glicksberg, B. S., Klang, E., & Timsina, P. (2024, December 8). *Cloud platforms for developing generative AI Solutions: A scoping review of tools and services*. arXiv.org. <https://arxiv.org/abs/2412.06044>
- [4] Tyagi, V., Tyagi, P., Tyagi, G., & Goel, P. K. (1970, January 1). *Cloud computing for Carbon Monitoring and Analytics*. IGI Global Scientific Publishing. <https://www.igi-global.com/chapter/cloud-computing-for-carbon-monitoring-and-analytics/376132>
- [5] (PDF) measuring the effectiveness of carbon-aware AI training strategies in cloud instances: A confirmation study. (n.d.-d). https://www.researchgate.net/publication/384030895_Measuring_the_Effectiveness_of_Carbon-Aware_AI_Training_Strategies_in_Cloud_Instances_A_Confirmation_Study
- [6] Chung, J. W., & Meltzer, D. O. (2009). Estimate of the carbon footprint of the US health care sector.
- [7] Lacoste, A., Luccioni, A., Schmidt, V., & Dandres, T. (2021). Quantifying the carbon emissions of machine learning. *Journal of Machine Learning Research*, 21(248), 1–29. <http://jmlr.org/papers/v21/20-812.html>
- [8] Microsoft. (2023). *Azure Carbon Aware SDK documentation*. <https://github.com/microsoft/carbon-aware-sdk>
- [9] Microsoft. (2024). *Azure Machine Learning documentation*. <https://learn.microsoft.com/en-us/azure/machine-learning>
- [10] The White House. (2022). *Federal Sustainability Plan*. <https://www.sustainability.gov/>
- [11] *Climate-smart health care*. Climate-smart Health Care | Health Care Without Harm - US & Canada. (n.d.). <https://us.noharm.org/climate-smart-health-care>