AI Emissions & Data Centers: Regional Analysis and Strategic Shifts

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1. Introduction & Dataset Overview

Executive Summary

This analysis evaluates global AI workload to forecast AI emissions through 2035 and the impact of strategic Cloud region selection on carbon footprints. Using IEA Energy and AI projections combined with regional carbon intensity data, **emission growth scenarios** are projected and mitigation strategies are formed. **Demonstration of regional workload shifting** to potentially reduce **up to 6 $MtCO_2$ annually** under realistic scenarios.

Dataset Sources

- **International Energy Agency (IEA) - Energy and AI datafile :**
  World as well as Regional Electricity consumption (TWh) across four scenarios (Base, High Efficiency, Headwinds and Lift-Off)
- **Our World In Data (OWID) - OWID Energy Data :**
  Historical and current Carbon Intensity measurements (gCO_2/kWh) by Country and Regions (2020-2023)
- **Methodology:**
  Combined regional AI electricity consumption (TWh) with carbon intensities (gCO_2/kWh) to calculate Emissions in $MtCO_2$ (actual formula in Appendix)

Key Research Questions

1. How will global AI workload emissions evolve over the next decade ?
2. What role does cloud region selection play in reducing carbon intensity?
3. Which Sustainable IT strategies offer the highest leverage for emissions reduction?

Key variables: data center TWh electricity consumption, worldwide and regional carbon intensities in gCO_2/kWh and the resulting Carbon dioxide emissions in $MtCO_2$

2. Analysis & Visualizations

Q1: AI Emissions Growth Trajectory (2020-2035)

Key Finding: AI workload emissions could grow from 122 $MtCO_2$ (2020) to 300-729 $MtCO_2$ by 2035, representing 145-496% growth depending on efficiency improvements and adoption rates.

Evidence:

- Historical acceleration already evident: 44% growth by 2024 (176 $MtCO_2$)
- Technology efficiency scenarios show dramatic impact: High Efficiency (412 $MtCO_2$) vs Lift-off (729 $MtCO_2$) in 2035
- Even constrained growth (Headwinds) results in doubling of emissions

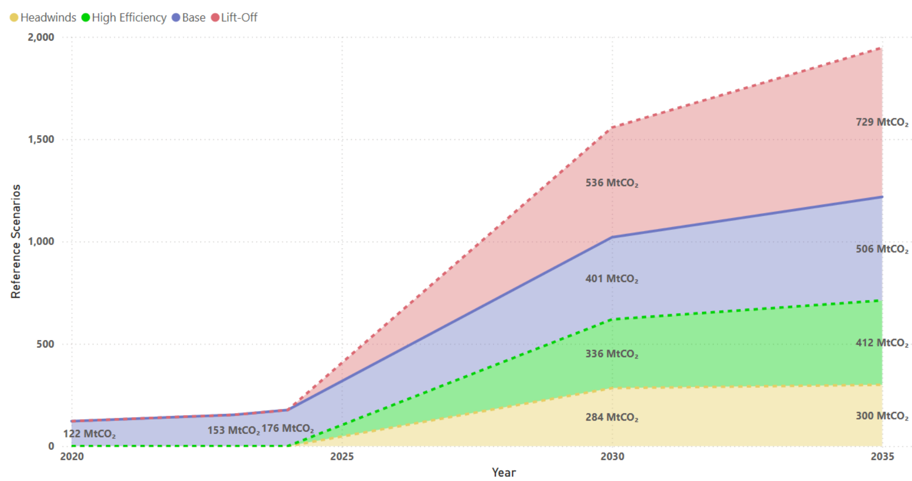

Figure 1: Stacked Area Chart of Projected Global Emissions

Figure 1 shows a stacked area chart of global AI emissions from 2020-2035 under three reference scenarios (Headwinds, High-Efficiency and Lift-Off) along with Base projections of 2030-2035.

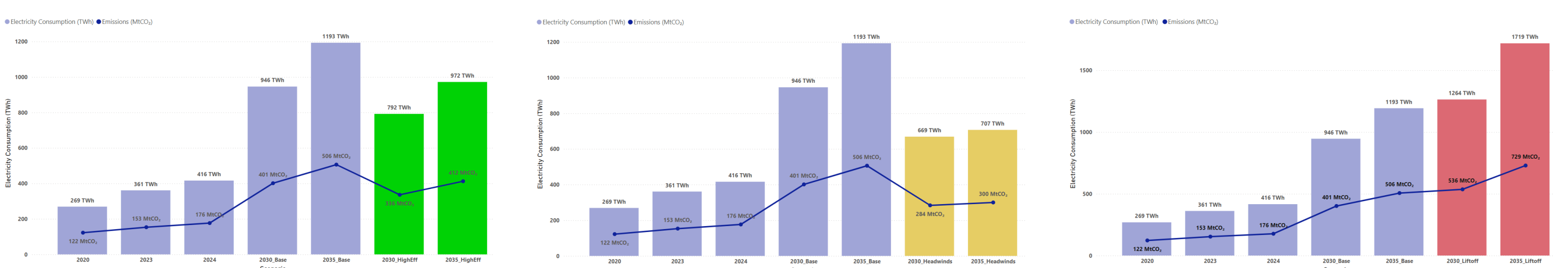

Figure 2: Column Charts of Electricity Consumption (TWh) with Emission line ($MtCO_2$) for all Scenarios

Q2: Regional Cloud Selection Impact

Key Finding: Strategic cloud region selection can reduce emissions by **4-6%** in **realistic scenarios** for equivalent workloads**,** with theoretical maximum reductions up to 71% between extreme regional carbon intensities. Carbon intensity varying 3.4x across major regions (186-641 gCO_2/kWh).

Regional Analysis (2023 Data):

- **Highest Impact Regions:** Asia Pacific (69.45 $MtCO_2$), North America (57.4 $MtCO_2$)
- **Cleanest Grids:** Central/South America (186 gCO_2/kWh), Europe (300 gCO_2/kWh)
- **Highest Carbon Intensity:** Middle East (641 gCO_2/kWh), Africa (541 gCO_2/kWh)

Workload Shift Scenario: Moving 20% of Asia Pacific AI workloads to Europe reduces total emissions by **6 $MtCO_2$ (4% global reduction)** while maintaining operational feasibility.

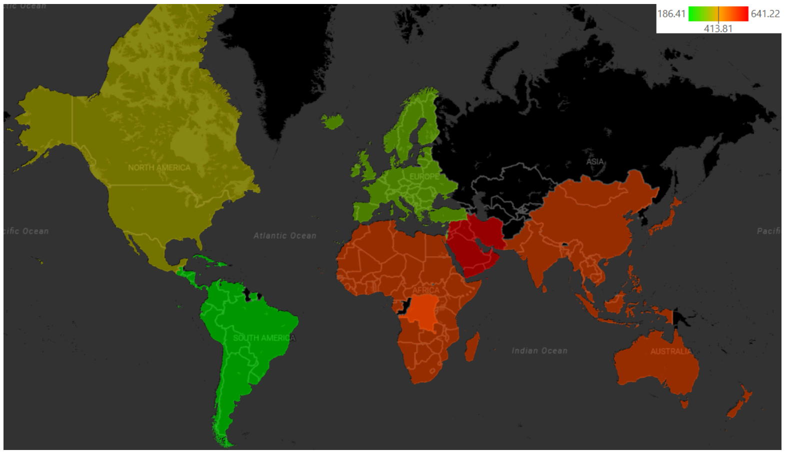

Figure 3: Carbon Intensity (gCO_2/kWh) by Region

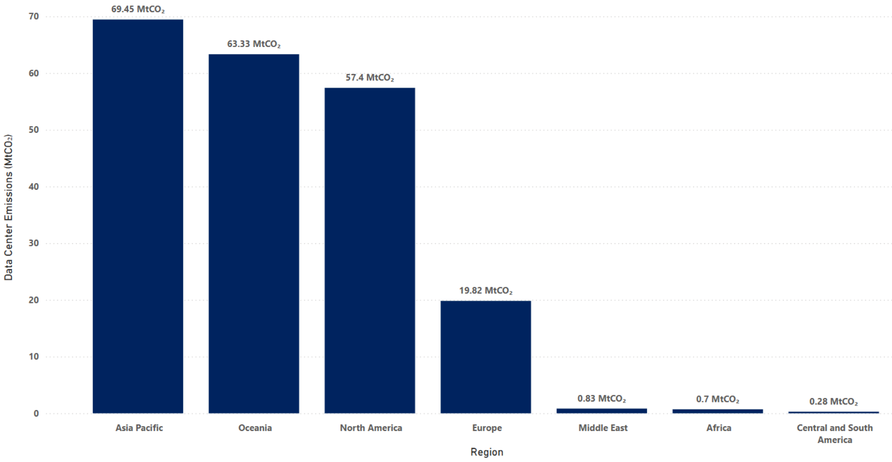

Figure 4: Data Center Emissions ($MtCO_2$) by Region

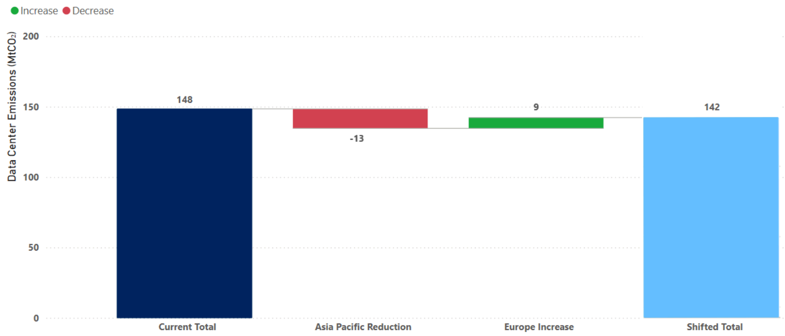

Figure 5: Reduction in Global Emissions due to Workload Shift (Asia Pacific → Europe)

Q3: Strategic Recommendations

Priority 1: Workload Shifting to Low-Carbon Regions (most immediate, evidence-backed)

- The workload shift scenario demonstrated above saved **6 MtCO_2** by shifting 20% of Asia-Pacific workloads to Europe.
- Prioritize **Europe** for training workloads because we can't use Central and South America due to lack of AI datacenters and infrastructure, even though this region has the cleanest carbon grid.

Priority 2: Technology Efficiency Acceleration

- **43% emissions reduction** by 2035, **Evidence:** High Efficiency vs Lift-Off scenario comparison.
- Hardware: Latest-generation AI chip deployment
- Software: Model optimization and quantization
- Infrastructure: Advanced cooling, PUE target <1.2

Priority 3: Enhanced Carbon Tracking

- Enables optimization of all other strategies.
- Real-time emissions monitoring dashboards (antarctica.io home page)
- Integration with cloud provider carbon APIs (AWS, Google, etc.)
- Enhanced Scope 3 reporting frameworks

ESG Framework Evolution Recommended:

- **Granular AI Emissions Tracking:** Move beyond aggregate electricity consumption to model-specific, region-specific reporting
- **Standardized Metrics:** Require reporting of compute location, electricity intensity, and hardware refresh cycles.
- **Scope 3 Enhancement:** Better methodologies for cloud-based AI emissions attribution. When using cloud services like AWS for AI, those emissions should count toward your company's carbon footprint.
- **Real-time Reporting:** Shift from annual to continuous carbon intensity monitoring
- **Digital Emissions Scope:** Treat AI workloads as a distinct line item in Scope 2 emissions. AI should get its own separate category in environmental reports, not lumped together with regular office electricity use.
- **Benchmarking:** Compare per-job carbon emissions to sector standards

Appendix

References

- **Our World In Data (OWID) - OWID Energy Data** (https://github.com/owid/energy-data/blob/master/owid-energy-data.csv)
- **International Energy Agency (IEA) - Energy and AI datafile** (https://www.iea.org/data-and-statistics/data-product/energy-and-ai#data-sets)
- **PUE Wikipedia Article:** https://en.wikipedia.org/wiki/Power_usage_effectiveness

Formulae and Code Snippets

- **Jupyter Notebook** for data cleaning, modifying, analysis and creating dataframes: https://drive.google.com/drive/folders/1hDXFLrw3Upwk7sLnBs-72faon63uOTHP?usp=drive_link
- **Power BI** for visualization:
  - pbix file: https://drive.google.com/file/d/10qXmFfTECz0srzF8QKbaBEow145ZNefX/view?usp=drive_link
  - Visualization folder: https://drive.google.com/drive/folders/13bpHE-LQPtDt3CqTaSmQFSDDPCO4fPDn?usp=sharing
- **Excel** data files: https://drive.google.com/file/d/1NGAKsV9M2ZP39YnIEKpzvpLikw5lMujK/view?usp=sharing
- $\mathbf{MtCO_2 = TWh} \times (10^9) \times \mathbf{gCO_2/kWh} \times 10^{(-12)}$

Remaining Figure:

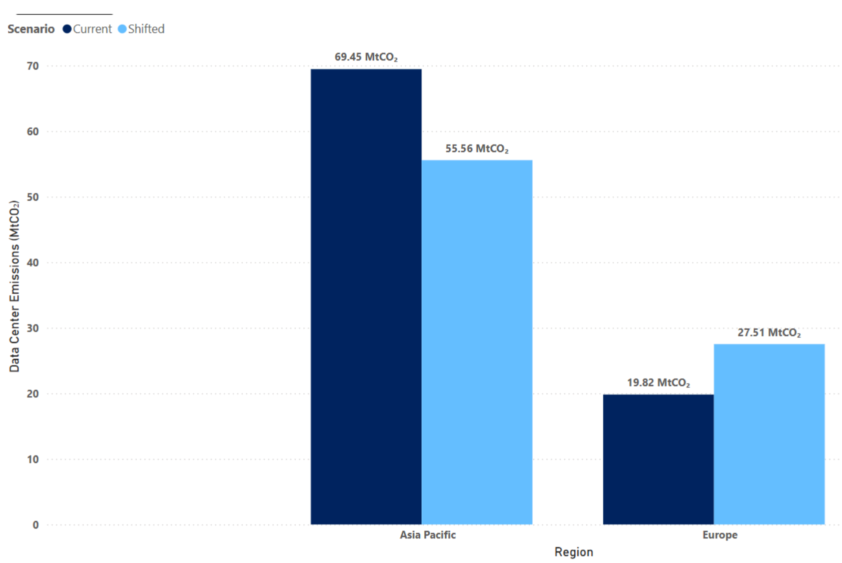

Figure 5: Grouped Bar Chart of emissions Before and After workload shift (Asia-Pacific to Europe)