# AI's Carbon Shadow: An Exploration of the Energy Dilemma and Earth's Future

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# Overview

- As artificial intelligence continues to advance, more processing power and energy usage are required.
- AI's growing energy consumption can have severe negative impacts on global climate, biodiversity, sustainability, as well as marginalized communities and developing countries.
- Technological innovation can foster increased efficiency and greater knowledge and understanding; *however*, measures must be put in place to protect our planet.

# Importance & Relevance

1) Becoming widespread – and expanding rapidly
2) Energy-intensive
3) Potential to cause extensive damage to the environment

# Research Proposal Questions

1) How will AI's current and projected energy consumption contribute to global energy demand and carbon emissions?
2) What are the environmental impacts of AI on developing countries versus developed countries?
3) What sustainable practices can be implemented in the development of AI to reduce energy usage while allowing for advancement?

# Carbon Impact: Training LLMs

The carbon footprint of training a single large learning model (LLM) is estimated to contribute **300,000 kilograms of carbon emissions** to the Earth's atmosphere (Dhar, 2020, p. 423).

This is compared to the carbon emissions of **125 round-trip flights from New York to Beijing, China** (Dhar, 2020, p. 423).

# AI’s Computational Growth

“The computations required for deep learning research **have been doubling every few months**, resulting **in an estimated 300,000x increase [in computations] from 2012 to 2018**.

These computations have a surprisingly large carbon footprint”

(Schwartz et al., 2020, p. 54).

# GPT-3: Energy Usage & Emissions

After calculating the energy usage and carbon footprint of several LLMs , it was determined that training GPT -3 required 552 metric tons of a $CO_2$ equivalent ($tCO_2e$) and consumed 1,287 Megawatt - hours (MWh) (Patterson et al., 2021, p. 7) .

*This is the equivalent of 123 gasoline -powered passenger vehicles driven for one year (Scientific American, 2023, para. 5).*

# Potential Environmental Impact

- **Strained water resources** (Berreby, 2024)
  "***Google's data centers consumed about 5 billion gallons (nearly 20 billion liters) of fresh water for cooling."***
- **Intensified habitat loss** (Cowls et al., 2023)
  ***This surge in carbon emissions can cause increased ocean acidification and land degradation, leading to the destruction of marine and land ecosystems.***
- **Decreased quality of life** (Ritchie et al., 2023)
  ***Assuming AI's development continues at this rate, humans can anticipate worsened air quality, more frequent natural disasters, lower quality crop yields, higher overall temperatures, and increased disease.***

# Proposed Methodology

## 1) Gather secondary data from “AI Report.”

- The Artificial Intelligence Index Report, published by Stanford University in 2023

## 2) Run a simple linear regression on the data.

- Look at factors including Talent, Infrastructure, Research, & Development
- Determine which factors are more pronounced throughout different countries

## 3) Split data into four subsets based on UN Development Index.

- The four subsets are **Developed**, **Developing**, **Least Developed Countries**, and **Land Locked Developing Countries**

***Hypothesis – ROI for AI is generally higher in developed and developing countries.***

# Anticipated Results

- Exacerbation of inequalities between developed and developing countries
- Land degradation within developing regions due to extraction of critical minerals
- Direct negative environmental impacts to developed nations based on frequent usage of AI and more rapid AI development

**SOURCE: (Kyriakopoulou, 2023)**

# Bottomline

- Artificial intelligence development will have advantages and disadvantages for both developed and developing nations.
- AI’s development (if unmanaged) is likely to have a greater adverse impact on developing nations.

# Discussion

## What can we do to reduce energy usage while allowing for advancement in artificial intelligence?

**1)** Use power-capping hardware to limit the energy consumption of AI training and inference (Castro, 2024).

**2)** Optimize AI software and models by using techniques such as model pruning and sparsity (Castro, 2024).

**3)** Leverage AI to improve the energy efficiency of data centers that power AI systems, e.g., Google DeepMind's work on reducing data center cooling energy (Evans & Gao, 2016).

# Future Research Directions

- The environmental and social impacts of mining raw materials used in the development of AI
- AI’s impact on human rights issues
- The impact of e-waste from AI development on the environment
- How energy usage from AI development influences the frequency of natural disasters

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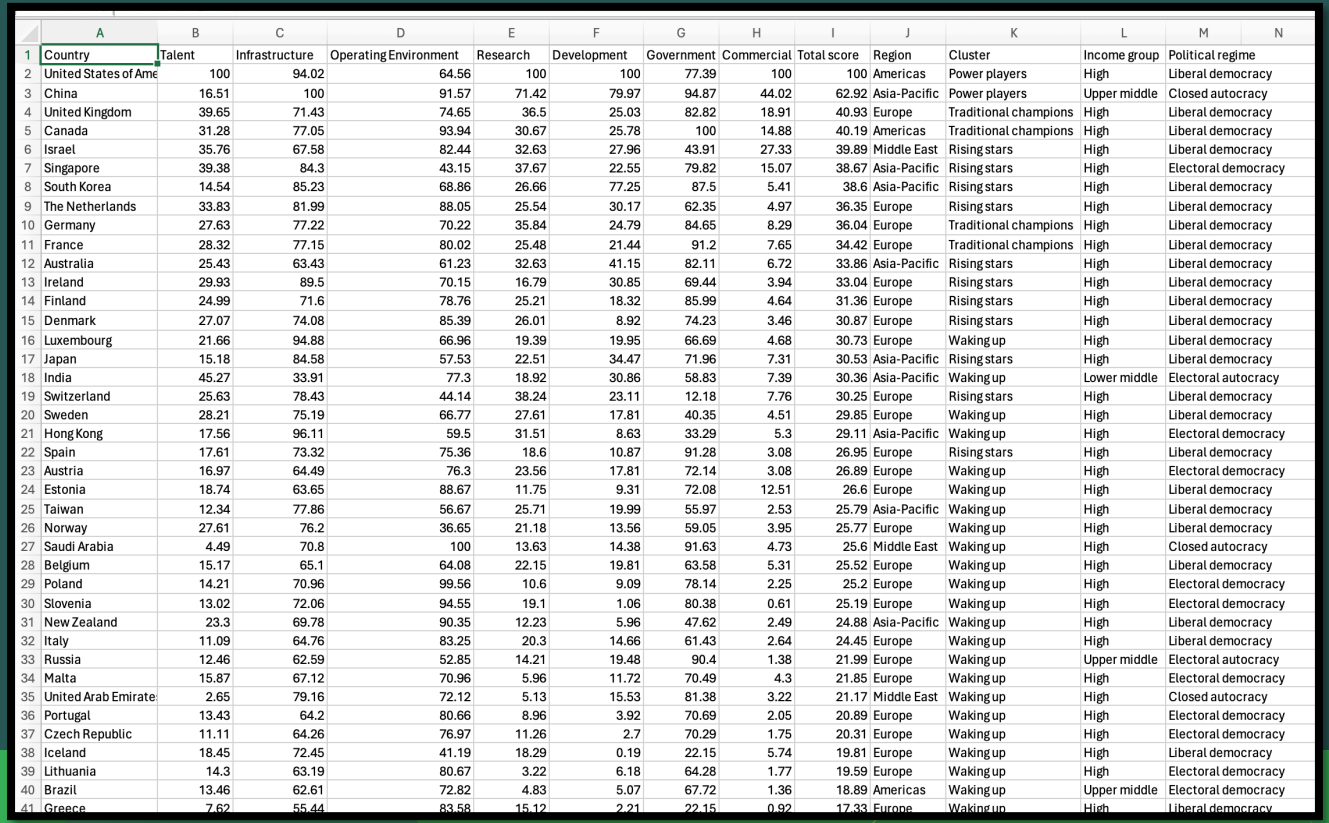
# Appendix

**SOURCE: (Meleshenko, 2023)**



| | A | B | C | D | E | F | G | H | I | J | K | L | M | N |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Country | Talent | Infrastructure | Operating Environment | Research | Development | Government | Commercial | Total score | Region | Cluster | Income group | Political regime | |
| 2 | United States of Ame | 100 | 94.02 | 64.56 | 100 | 100 | 77.39 | 100 | 100 | Americas | Power players | High | Liberal democracy | |
| 3 | China | 16.51 | 100 | 91.57 | 71.42 | 79.97 | 94.87 | 44.02 | 62.92 | Asia-Pacific | Power players | Upper middle | Closed autocracy | |
| 4 | United Kingdom | 39.65 | 71.43 | 74.65 | 36.5 | 25.03 | 82.82 | 18.91 | 40.93 | Europe | Traditional champions | High | Liberal democracy | |
| 5 | Canada | 31.28 | 77.05 | 93.94 | 30.67 | 25.78 | 100 | 14.88 | 40.19 | Americas | Traditional champions | High | Liberal democracy | |
| 6 | Israel | 35.76 | 67.58 | 82.44 | 32.63 | 27.96 | 43.91 | 27.33 | 39.89 | Middle East | Rising stars | High | Liberal democracy | |
| 7 | Singapore | 39.38 | 84.3 | 43.15 | 37.67 | 22.55 | 79.82 | 15.07 | 38.67 | Asia-Pacific | Rising stars | High | Electoral democracy | |
| 8 | South Korea | 14.54 | 85.23 | 68.86 | 26.66 | 77.25 | 87.5 | 5.41 | 38.6 | Asia-Pacific | Rising stars | High | Liberal democracy | |
| 9 | The Netherlands | 33.83 | 81.99 | 88.05 | 25.54 | 30.17 | 62.35 | 4.97 | 36.35 | Europe | Rising stars | High | Liberal democracy | |
| 10 | Germany | 27.63 | 77.22 | 70.22 | 35.84 | 24.79 | 84.65 | 8.29 | 36.04 | Europe | Traditional champions | High | Liberal democracy | |
| 11 | France | 28.32 | 77.15 | 80.02 | 25.48 | 21.44 | 91.2 | 7.65 | 34.42 | Europe | Traditional champions | High | Liberal democracy | |
| 12 | Australia | 25.43 | 63.43 | 61.23 | 32.63 | 41.15 | 82.11 | 6.72 | 33.86 | Asia-Pacific | Rising stars | High | Liberal democracy | |
| 13 | Ireland | 29.93 | 89.5 | 70.15 | 16.79 | 30.85 | 69.44 | 3.94 | 33.04 | Europe | Rising stars | High | Liberal democracy | |
| 14 | Finland | 24.99 | 71.6 | 78.76 | 25.21 | 18.32 | 85.99 | 4.64 | 31.36 | Europe | Rising stars | High | Liberal democracy | |
| 15 | Denmark | 27.07 | 74.08 | 85.39 | 26.01 | 8.92 | 74.23 | 3.46 | 30.87 | Europe | Rising stars | High | Liberal democracy | |
| 16 | Luxembourg | 21.66 | 94.88 | 66.96 | 19.39 | 19.95 | 66.69 | 4.68 | 30.73 | Europe | Waking up | High | Liberal democracy | |
| 17 | Japan | 15.18 | 84.58 | 57.53 | 22.51 | 34.47 | 71.96 | 7.31 | 30.53 | Asia-Pacific | Rising stars | High | Liberal democracy | |
| 18 | India | 45.27 | 33.91 | 77.3 | 18.92 | 30.86 | 58.83 | 7.39 | 30.36 | Asia-Pacific | Waking up | Lower middle | Electoral autocracy | |
| 19 | Switzerland | 25.63 | 78.43 | 44.14 | 38.24 | 23.11 | 12.18 | 7.76 | 30.25 | Europe | Rising stars | High | Liberal democracy | |
| 20 | Sweden | 28.21 | 75.19 | 66.77 | 27.61 | 17.81 | 40.35 | 4.51 | 29.85 | Europe | Waking up | High | Liberal democracy | |
| 21 | Hong Kong | 17.56 | 96.11 | 59.5 | 31.51 | 8.63 | 33.29 | 5.3 | 29.11 | Asia-Pacific | Waking up | High | Electoral democracy | |
| 22 | Spain | 17.61 | 73.32 | 75.36 | 18.6 | 10.87 | 91.28 | 3.08 | 26.95 | Europe | Rising stars | High | Liberal democracy | |
| 23 | Austria | 16.97 | 64.49 | 76.3 | 23.56 | 17.81 | 72.14 | 3.08 | 26.89 | Europe | Waking up | High | Electoral democracy | |
| 24 | Estonia | 18.74 | 63.65 | 88.67 | 11.75 | 9.31 | 72.08 | 12.51 | 26.6 | Europe | Waking up | High | Liberal democracy | |
| 25 | Taiwan | 12.34 | 77.86 | 56.67 | 25.71 | 19.99 | 55.97 | 2.53 | 25.79 | Asia-Pacific | Waking up | High | Liberal democracy | |
| 26 | Norway | 27.61 | 76.2 | 36.65 | 21.18 | 13.56 | 59.05 | 3.95 | 25.77 | Europe | Waking up | High | Liberal democracy | |
| 27 | Saudi Arabia | 4.49 | 70.8 | 100 | 13.63 | 14.38 | 91.63 | 4.73 | 25.6 | Middle East | Waking up | High | Closed autocracy | |
| 28 | Belgium | 15.17 | 65.1 | 64.08 | 22.15 | 19.81 | 63.58 | 5.31 | 25.52 | Europe | Waking up | High | Liberal democracy | |
| 29 | Poland | 14.21 | 70.96 | 99.56 | 10.6 | 9.09 | 78.14 | 2.25 | 25.2 | Europe | Waking up | High | Electoral democracy | |
| 30 | Slovenia | 13.02 | 72.06 | 94.55 | 19.1 | 1.06 | 80.38 | 0.61 | 25.19 | Europe | Waking up | High | Electoral democracy | |
| 31 | New Zealand | 23.3 | 69.78 | 90.35 | 12.23 | 5.96 | 47.62 | 2.49 | 24.88 | Asia-Pacific | Waking up | High | Liberal democracy | |
| 32 | Italy | 11.09 | 64.76 | 83.25 | 20.3 | 14.66 | 61.43 | 2.64 | 24.45 | Europe | Waking up | High | Liberal democracy | |
| 33 | Russia | 12.46 | 62.59 | 52.85 | 14.21 | 19.48 | 90.4 | 1.38 | 21.99 | Europe | Waking up | Upper middle | Electoral autocracy | |
| 34 | Malta | 15.87 | 67.12 | 70.96 | 5.96 | 11.72 | 70.49 | 4.3 | 21.85 | Europe | Waking up | High | Electoral democracy | |
| 35 | United Arab Emirate | 2.65 | 79.16 | 72.12 | 5.13 | 15.53 | 81.38 | 3.22 | 21.17 | Middle East | Waking up | High | Closed autocracy | |
| 36 | Portugal | 13.43 | 64.2 | 80.66 | 8.96 | 3.92 | 70.69 | 2.05 | 20.89 | Europe | Waking up | High | Electoral democracy | |
| 37 | Czech Republic | 11.11 | 64.26 | 76.97 | 11.26 | 2.7 | 70.29 | 1.75 | 20.31 | Europe | Waking up | High | Electoral democracy | |
| 38 | Iceland | 18.45 | 72.45 | 41.19 | 18.29 | 0.19 | 22.15 | 5.74 | 19.81 | Europe | Waking up | High | Liberal democracy | |
| 39 | Lithuania | 14.3 | 63.19 | 80.67 | 3.22 | 6.18 | 64.28 | 1.77 | 19.59 | Europe | Waking up | High | Electoral democracy | |
| 40 | Brazil | 13.46 | 62.61 | 72.82 | 4.83 | 5.07 | 67.72 | 1.36 | 18.89 | Americas | Waking up | Upper middle | Electoral democracy | |
| 41 | Greece | 7.62 | 55.44 | 83.58 | 15.12 | 2.21 | 22.15 | 0.92 | 17.33 | Europe | Waking up | High | Liberal democracy | |