SECTION: FINANCE

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The Environmental Harms of Greenhouse Gas Emissions: An Interdisciplinary Assessment

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Abstract
Greenhouse gas (GHG) emissions have become a dominant driver of global environmental change, contributing significantly to climate warming, biodiversity loss, ocean acidification, and ecosystem degradation. The multifaceted nature of these impacts necessitates an interdisciplinary approach that integrates environmental science, economics, and public policy to comprehensively evaluate their consequences.This study synthesizes empirical data from international institutions including the IPCC, UNEP, and the World Bank to analyze the environmental harms of GHG emissions from 2000 to 2023. The findings reveal strong correlations between rising GHG levels and negative ecological indicators such as increased global temperatures, declining biodiversity, and worsening ocean chemistry. Quantitative analysis shows that per capita emissions are highest in developed regions, while developing countries bear disproportionate burdens from climate impacts. The study further evaluates the effectiveness of mitigation strategies such as the Paris Agreement and national climate policies, identifying significant gaps between stated commitments and actual emission trends. Additionally, the paper highlights regional disparities in adaptation capacity and policy impact, emphasizing the need for tailored interventions.

Keywords: Greenhouse gases, environmental degradation, climate change, biodiversity, ocean acidification, CO_2 emissions, policy mitigation

Introduction

Greenhouse gases (GHGs) such as carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O) are emitted through industrial processes, agriculture, and fossil fuel combustion. While these gases naturally regulate Earth's temperature, anthropogenic emissions have drastically intensified the greenhouse effect, causing widespread environmental disruptions. This paper evaluates these impacts and explores solutions through an interdisciplinary lens combining environmental science, economics, and policy studies.

Climate change has emerged as one of the most pressing environmental and socio-economic challenges of the 21st century. Central to this crisis is the rapid accumulation of greenhouse gases (GHGs) in the Earth's atmosphere, primarily driven by anthropogenic activities such as fossil fuel combustion, deforestation, industrial processes, and large-scale agriculture. The unprecedented rise in carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), and fluorinated gases has significantly altered atmospheric composition, disrupted global climate systems, and intensified extreme weather events (NASA, 2023).

The environmental consequences of GHG emissions are far-reaching and multifaceted. These gases trap heat in the atmosphere through the enhanced greenhouse effect, leading to global warming. As average temperatures rise, cascading effects are observed across ecosystems: polar ice sheets are melting, sea levels are rising, ocean acidification is threatening marine biodiversity, and terrestrial species face increased extinction risks (UNEP 2022). Moreover, GHG-induced climate shifts exacerbate land degradation, freshwater scarcity, and food insecurity, disproportionately affecting vulnerable regions and populations (Field, C. B., Barros, V. R., Dokken, D. J., et al., 2014). While the scientific community has long established the causal links between GHG emissions and environmental degradation, the interdisciplinary nature of this phenomenon necessitates a broader analytical approach. Understanding the full spectrum of environmental harm involves synthesizing knowledge from climatology, ecology, economics, public health, and policy studies (Rockström, J., Steffen, W., Noone, K., et al. 2009). An integrative assessment enables policymakers and researchers to better evaluate trade-offs, develop adaptive strategies, and implement mitigation frameworks aligned with the United Nations Sustainable Development Goals (SDGs) (IPCC, 2021).This article aims to provide a comprehensive interdisciplinary evaluation of the environmental damages caused by greenhouse gas emissions, drawing upon data from international organizations such as the Intergovernmental Panel on Climate Change (IPCC), World Bank, and United Nations Environment Programme (UNEP). It employs comparative country-level analyses, correlational statistics, and visual representations to identify key patterns and inform actionable climate strategies. In doing so, this study contributes to the broader discourse on climate justice, ecological resilience, and the urgency of global cooperation in mitigating climate risks (World Bank, 2021).

2. Materials and Methods

This study relies on secondary data collected from reputable international sources, including the Intergovernmental Panel on Climate Change (IPCC), the World Bank, and the United Nations Environment Programme (UNEP), covering the period from 2000 to 2023. These datasets include annual greenhouse gas emissions, temperature anomalies, deforestation rates, biodiversity indices, and policy intervention metrics. The data were extracted from publicly available reports, statistical databases, and climate impact assessments published by these organizations. "The synthesis report presents an integrated summary of existing knowledge on climate change, its consequences, and the strategies for adaptation and mitigation." https://www.ipcc.ch/report/ar6/syr/

Climate Change 2023: Synthesis Report (AR6)

Key Findings from IPCC's Climate Change 2023: Synthesis Report (AR6)

The Climate Change 2023: Synthesis Report, prepared by the Intergovernmental Panel on Climate Change (IPCC), presents conclusive scientific evidence on the anthropogenic causes, consequences, and mitigation pathways related to global climate change. The report synthesizes the latest assessments from Working Groups I, II, and III of the Sixth Assessment Cycle and delivers an urgent call to action.

Anthropogenic Activities and Global Warming

The report confirms with high confidence that human activities—especially the combustion of fossil fuels—are the dominant cause of observed global warming. Between 2011 and 2020, the global average surface temperature increased by approximately 1.1°C relative to the pre-industrial baseline (1850–1900), leading to wide-ranging effects such as sea level rise, increased frequency and intensity of extreme weather events, and accelerated glacial melt (World Resources Institute, 2023);

The 1.5°C Threshold and Emissions Reduction Limiting warming to 1.5°C requires a reduction in global greenhouse gas (GHG) emissions by 43% by 2030 and achieving net-zero emissions by around 2050. Without such mitigation measures, global temperatures could surpass 2°C, leading to irreversible ecological and socio-economic damage-(Down To Earth, 2023);

Environmental and Human Impacts Climate change is already impacting approximately half of the world's population through challenges such as water scarcity, heatwaves, and food insecurity. These impacts are disproportionately severe in developing countries. Each additional increment of warming magnifies these risks and threatens the resilience of vulnerable systems and communities- (IPCC,Climate Change 2023)

Adaptation and Mitigation Strategies Effective adaptation strategies, including ecosystem-based approaches and climate-resilient agricultural practices, can enhance systemic resilience. However, the implementation of such strategies remains constrained by limited financial resources and technological capacity, especially in low-income regions (IPCC, 2023).
Finance and International Cooperation The report highlights a major gap in climate finance. Adaptation and mitigation in developing countries require an estimated $127 billion annually, yet current funding levels range between only $23 and $46 billion. Closing this gap necessitates stronger international cooperation and increased financial support (IPCC, World Resources Institute, 2023).
Cryosphere and Sea-Level Rise Ongoing melting of glaciers and ice sheets—particularly in Greenland and West Antarctica—is contributing to global sea-level rise. If warming exceeds 2°C, these changes may become irreversible, posing severe threats to millions of people living in coastal areas (IPCC, 2023).
Core Messages of the Synthesis Report for Policymakers:

- Human activity is unequivocally the main driver of global warming.
- Limiting warming to 1.5°C requires immediate and deep reductions in GHG emissions.
- Each degree of additional warming increases the likelihood of dangerous and irreversible risks.
- The window for effective adaptation is narrowing, and financial support is essential.

Climate Change 2022: Impacts, Adaptation, and Vulnerability – Key findings:
Climate change is a global phenomenon that is increasingly affecting socio-economic and ecological systems. The "Climate Change 2022: Impacts, Adaptation, and Vulnerability" report, published as part of the Intergovernmental Panel on Climate Change (IPCC) Sixth Assessment Report (AR6), highlights that the impacts of climate change are already observable across all continents and sectors, often exceeding the ability of human and natural systems to adapt (IPCC, 2022).
The report indicates that ecosystems, including coral reefs, forests, and mountain regions, as well as agricultural systems, water resources, urban environments, and human health, are experiencing detrimental effects of climate change. It is estimated that 3.3 to 3.6 billion people are living in regions highly vulnerable to climate change, with social inequalities, poverty, and limited access to resources exacerbating their vulnerability (IPCC, 2022).
While adaptation measures are being implemented in various regions, they are often insufficient in scale and speed to address the risks posed by climate change. Furthermore, some adaptation efforts lead to "maladaptation," which can worsen the situation (IPCC, 2022). The report also emphasizes the limits of adaptation, particularly for natural systems, which have already reached irreversible tipping points in some cases, such as the melting of Arctic ice and the degradation of coral reefs.
A key finding of the report is that every increment of warming increases the risks faced by ecosystems and societies, with the impacts of exceeding the 1.5°C threshold becoming particularly severe. As such, the report stresses the need for climate-resilient development that integrates emissions reductions, adaptation efforts, and social equity. This process requires strong governance, institutional cooperation, and the inclusion of local and Indigenous knowledge (IPCC, 2022). Puig et al. (2025) emphasize that the effectiveness of climate change adaptation measures can be significantly enhanced through context-specific policy design, stakeholder engagement, and continuous monitoring and evaluation processes (Puig, D., Adger, N.W., Barnett, J., et al., 2025). Malik and Ford (2024) identify a persistent "adaptation gap" in global climate policy, underscoring the need for integrated approaches that bridge research, implementation, and funding. (Malik, I.H. & Ford, J.D., 2024) The study by Malik and Ford (2024) highlights several key barriers to effective climate adaptation, including institutional inertia, lack of localized data, and insufficient financial resources.
Swarnokar et al. (2025) present a comparative analysis of coastal communities, demonstrating that localized climate adaptation strategies can reduce exposure to climate-induced risks when supported by community participation and government intervention. (Swarnokar, S.C., Mou, S.I., Sharmi, S.D., Iftikhar, A., & Jesmin, S., 2025). Their findings suggest that climate resilience in vulnerable coastal zones is strongly influenced by socio-economic factors, adaptive capacity, and proactive mitigation planning (Swarnokar et al., 2025).

The World Bank provides high-quality and internationally comparable statistical data on global development and the fight against poverty.
According to the World Bank's World Development Indicators, approximately 700 million people globally lived on less than $2.15 per day in 2024, representing about 8.5% of the world population, a figure that has remained relatively unchanged since 2019. (World Bank, 2024a). Broader poverty measurements reveal that nearly 3.5 billion individuals, or 44% of the global population, lived on less than $6.85 per day in 2024, underscoring persistent economic vulnerability in developing regions (World Bank, 2024b).
The geographical distribution of extreme poverty remains uneven, with two-thirds of the world's poorest populations concentrated in Sub-Saharan Africa and in fragile or conflict-affected regions. (World Bank, 2024b)
The International Monetary Fund (IMF) forecasts a 3.2% global GDP growth for 2024 and 2025, a rate insufficient to drive significant poverty reduction in low-income economies. (IMF, 2024)
In addition to economic challenges, climate change and conflict remain key drivers of poverty. The United Nations Global Report on Food Crises revealed that in 2024, over 295 million people faced acute food insecurity, mainly due to armed conflicts, climate-induced disasters, and economic shocks. (UN, 2025)

Category	Description
Number of Countries	Covers data for 217 countries and territories
Number of Indicators	Includes over 1,400 development indicators
Poverty Indicators	Population below $2.15/day, $3.65/day, and $6.85/day poverty lines
Economic Indicators	GDP, GNI per capita, inflation, investment, trade, employment
Health Indicators	Life expectancy, child mortality, access to healthcare, immunization rates
Education Indicators	Literacy rates, school enrollment, education expenditure
Environment & Climate	CO_2 emissions, energy use, renewable energy, forest area, climate resilience
Data Frequency	Annual data, with historical series from 1960 to present (varies by indicator)

Table 1. Overview of the World Development Indicators (WDI) Database
Source: (World Bank Open Data – World Development Indicators (WDI))

World Bank Open Data
The World Bank Open Data platform provides free and open access to a vast array of globally comparable development statistics. It encompasses a wide range of indicators across critical sectors such as poverty, education, health, environment, economic performance, and governance. As of 2025, the platform hosts datasets covering over 200 countries and regions, many of which span from 1960 to the present.
These datasets are widely recognized for their high quality, standardized methodology, and reliability, making them indispensable for empirical research, international development assessments, and evidence-based policymaking. Users can explore data through interactive visualizations or download it in multiple formats for analysis. Notably, the platform supports tools like World Development Indicators (WDI), Global Economic Monitor, and PovcalNet, facilitating deep insights into long-term development trends (https://data.worldbank.org/).

Data Category	Example Indicators	Policy Relevance
Poverty & Inequality	Poverty headcount ratio ($2.15/day), Gini index	Tracks global poverty levels and income distribution
Education	Primary school enrollment (%), Literacy rate	Assesses educational access and human capital development
Health	Life expectancy, Infant mortality rate	Monitors public health outcomes and healthcare access
Economy & Growth	GDP per capita, Inflation rate	Measures macroeconomic performance and stability
Environment & Climate	CO_2 emissions, Renewable energy (% of total)	Evaluates sustainability and environmental resilience
Infrastructure	Access to electricity, Internet usage	Reflects development of physical and digital infrastructure
Labor Market	Unemployment rate, Labor force participation	Analyzes employment trends and workforce inclusion
Governance	Rule of law, Government effectiveness	Examines institutional quality and regulatory capacity

Table 2. Selected Data Categories in World Bank Open Data Platform

Sources: World Bank Open Data (https://data.worldbank.org/), UNESCO Institute for Statistics (https://uis.unesco.org/), 2024.

Country	Primary School Enrollment (%)	Adult Literacy Rate (%)
Norway	99.8	100
Germany	98.7	99
Turkey	95.5	96.2
Brazil	93.2	93
India	91.4	79
Nigeria	68.3	62
Ethiopia	74.1	51.8
Bangladesh	97	75
United States	98.9	99
China	99.5	96.8

Table 3. Primary School Enrollment and Literacy Rate by Country 2024

Sources: World Bank Open Data (https://data.worldbank.org/), UNESCO Institute for Statistics (https://uis.unesco.org/), 2024.

Country	Life Expectancy (Years)	Infant Mortality Rate (per 1,000 live births)
Norway	83.2	2.5
Germany	81.1	3.1
Turkey	78.6	7.8
Brazil	75.3	12.4
India	70.8	28.3
Nigeria	61.2	54.7
Ethiopia	66.5	37.6
Bangladesh	72.4	24.1
United States	77.3	5.4
China	78.2	6.8

Table 4. Life Expectancy and Infant Mortality Rate by Country 2024

Sources: World Bank Open Data (https://data.worldbank.org/), UNICEF, WHO Global Health Observatory, 2024.

The table presents a comparative overview of life expectancy and infant mortality rates across ten selected countries, reflecting significant disparities in health outcomes between high-income and low-income nations as of 2024.

Life expectancy varies considerably among countries. Norway (83.2 years), Germany (81.1 years), and China (78.2 years) report high average life expectancies, which correlate with their advanced healthcare systems, higher income levels, and greater access to public health services. In contrast, Nigeria (61.2 years) and Ethiopia (66.5 years) exhibit notably lower life expectancy figures, highlighting the persistent challenges these countries face in terms of nutrition, disease control, and health infrastructure.

Infant Mortality Rate

A similar pattern emerges in infant mortality rates. Norway (2.5) and Germany (3.1) have among the lowest rates, suggesting strong maternal and child health programs and access to neonatal care. Conversely, Nigeria (54.7) and Ethiopia (37.6) record significantly higher infant mortality rates, often attributed to inadequate healthcare services, poor sanitation, and limited immunization coverage (World Bank Open Data, UNICEF, & WHO Global Health Observatory, 2024).

Income Countries

Brazil, Turkey, and Bangladesh represent middle-income countries with improving health metrics. Turkey's life expectancy (78.6) and infant mortality rate (7.8) indicate relatively effective health reforms. Bangladesh, while achieving a life expectancy of 72.4 years, still struggles with an infant mortality rate of 24.1, suggesting uneven healthcare quality.

Key Observations:

- There is a strong inverse correlation between life expectancy and infant mortality: countries with lower infant mortality tend to have higher life expectancy.
- Healthcare investment, public policy, and social determinants of health (such as education and income) play crucial roles in shaping these indicators.
- Countries with robust health infrastructure, even with larger populations like China, manage to maintain favorable health outcomes.

We can introduce Scientific Articles and References on Life Expectancy and Infant Mortality: Health Expenditure, Longevity, and Child Mortality. This study analyzes data from 195 countries between 1995 and 2014, examining the impact of health expenditures on life expectancy and child mortality rates. The findings indicate that increased health spending contributes to longer life expectancy and reduced infant mortality rates (International Journal ofHealthEconomicsandManagement,2019)

Social and Environmental Factors and Health Outcomes.

This study investigates the effects of social and environmental factors on life expectancy, infant mortality, and maternal mortality rates. The results show a strong relationship between access to sanitation, clean water, and health outcomes.(Social Science & Medicine, 1994)

World Health Status 1950–2015.

This research examines changes in global health indicators such as life expectancy and infant mortality from 1950 to 2015. While global improvements are noted, disparities among countries remain significant. (International Journal for Equity in Health, 2019)

c) UNEP Emissions Gap Report 2022

The UNEP Emissions Gap Report 2022, published by the United Nations Environment Programme, provides a comprehensive analysis of the disparity between projected greenhouse gas emissions based on current national policies and pledges, and the emission levels required to limit global warming to 1.5°C or 2°C above pre-industrial levels. The report highlights that, despite updated climate pledges under the Paris Agreement (Nationally Determined Contributions - NDCs), there remains a significant “emissions gap”. Current policies are expected to result in a temperature rise of 2.4–2.6°C by the end of the century, far above the Paris Agreement targets. To stay on track for the 1.5°C goal, global greenhouse gas emissions must be reduced by 45% by 2030 compared to 2010 levels (United Nations Environment Programme, 2022).

Key findings include: There is no credible pathway currently in place that will limit global warming to 1.5°C. Only a handful of G20 members have strengthened their NDCs sufficiently. The world is on track to produce 15 gigatonnes more CO_2 equivalent than what is consistent with a 1.5°C pathway.

The report calls for urgent and transformational change in key sectors such as energy, industry, transport, and agriculture. It emphasizes the role of both national and non-state actors, including businesses, cities, and regions, in closing the gap.

“The UNEP Emissions Gap Reports have become a cornerstone in evaluating the adequacy of national climate pledges under the Paris Agreement. The 2022 report, in particular, sharpened the global discourse by showing that current trajectories fall significantly short of the 1.5°C pathway” (Biermann, F., & Gupta, A., 2025).

“The UNEP Emissions Gap Report 2022 emphasizes not only the environmental consequences of inaction but also the disproportionate health burdens borne by vulnerable populations.” “Reducing emissions in line with the UNEP’s 2022 benchmarks is not just a climate imperative—it is essential for achieving global health equity.” (Smith, J., & Lee, K., 2023). “In light of the UNEP Emissions Gap Report 2022, our analysis shows that while a few countries have implemented successful mitigation policies, the collective ambition remains inadequate.”

“The 2022 Emissions Gap Report provides a sobering backdrop, illustrating the gap between national actions and global temperature goals—a gap only a handful of nations are beginning to close.” (Rogelj, J., et al., 2024).

d) The UNEP Emissions Gap Report 2023 provides a comprehensive analysis of the disparity between current national climate commitments and the reductions necessary to limit global warming to 1.5°C or 2°C above pre-industrial levels. The report underscores that, even with full implementation of current unconditional Nationally Determined Contributions (NDCs), the world is on track for a temperature rise of approximately 2.9°C by the end of the century. Achieving the 1.5°C target would require global greenhouse gas emissions to decline by 42% by 2030 compared to 2019 levels (UNEP Emissions Gap report, 2023)

In 2022, global greenhouse gas emissions reached a new record of 57.4 gigatonnes of CO_2 equivalent, marking a 1.2% increase from the previous year. The report highlights that the G20 nations are responsible for approximately 77% of these emissions, emphasizing the critical role these countries play in global mitigation efforts.

To bridge the emissions gap, the report identifies key sectors where significant reductions can be achieved:
Energy: Accelerating the deployment of renewable energy sources, such as solar and wind, could contribute to 27% of the required emission reductions by 2030 (https://unepccc.org/nations-must-close-huge-emissions-gap-in-new-climate-pledges-and-deliver-immediate-action-or-1-5c-lost/?utm_source). Conservation and restoration efforts could account for around 20% of the necessary reductions.

Country	GHG Emissions ($MtCO_2e$)	Emissions per Capita (tCO_2e)	Renewable Energy (%)
China	11,000	7.6	30
United States	5,000	15.2	20
India	3,000	2.2	24
Russia	2,100	14.4	18
Japan	1,200	9.5	22
Germany	800	9.7	45
Iran	720	8.5	6
Canada	700	18.5	18
South Korea	650	12.6	20
Saudi Arabia	600	17.5	0.5
Brazil	500	2.3	85
Indonesia	620	2.4	34
Australia	550	21.2	32
South Africa	470	7.9	10
Mexico	480	3.8	28
Turkey	420	4.9	16
United Kingdom	400	5.9	48
France	380	5.7	52
Italy	350	5.8	40

Table 5. Comparative Analysis of GHG Emissions and Environmental Indicators (2023)
Source:https://unepccc.org/nations-must-close-huge-emissions-gap-in-new-climate-pledges-and-deliver-immediate-action-or-1-5c-lost/?utm_source

For a detailed comparative analysis of greenhouse gas emissions and environmental indicators across 20 countries, the UNEP report provides extensive data and insights. This information can be instrumental in understanding national contributions to global emissions and identifying opportunities for targeted mitigation strategies.

e) The Environmental Performance Index (EPI) 2024, developed jointly by Yale University and Columbia University, provides a comprehensive evaluation of environmental health and ecosystem vitality across 180 countries. The index incorporates 58 indicators that measure diverse dimensions such as climate change mitigation efforts, biodiversity and habitat conservation, air and water quality, and environmental policies. By aggregating and weighting these indicators, the EPI offers a comparative ranking that highlights national strengths and weaknesses in environmental performance. This robust framework assists policymakers, researchers, and stakeholders in identifying priority areas for sustainable development and environmental management. The EPI 2024 thus serves as a critical tool to monitor global progress toward environmental goals and the United Nations Sustainable Development Goals (SDGs). The Environmental Performance Index (EPI) 2024, a collaborative effort between Yale University and Columbia University, stands as a pivotal instrument for assessing the environmental health and sustainability efforts of nations worldwide. By analyzing 180 countries through a robust set of 58 indicators, the EPI provides an evidence-based ranking that reflects the multifaceted dimensions of environmental performance, including climate change mitigation, ecosystem vitality, and public health. The EPI employs a comprehensive methodological framework that integrates quantitative data from multiple reliable sources, such as international organizations, governmental agencies, and scientific institutions. The 58 indicators are organized into thematic categories including climate change, air quality, water resources, biodiversity, and agriculture. Each indicator is weighted according to its relevance and impact, allowing the index to capture both direct and indirect effects on environmental sustainability.

The 2024 edition of the EPI reveals substantial variation in environmental performance among countries, highlighting areas of both progress and concern. High-ranking nations typically exhibit strong policies on emissions reduction, renewable energy adoption, and conservation of biodiversity. Conversely, lower-ranking countries often face challenges such as poor air and water quality, deforestation, and inadequate regulatory frameworks. The index thus not only ranks countries but also serves as a diagnostic tool to identify priority sectors for improvement.

The EPI 2024 offers critical insights for policymakers, environmentalists, and researchers by providing a transparent and comparative overview of national environmental performance. It underscores the urgent need for integrated strategies that address climate change alongside ecosystem protection and human health. Furthermore, the EPI supports international efforts to meet Sustainable Development Goals (SDGs), especially those related to clean energy, climate action, and biodiversity conservation. As environmental challenges intensify globally, the Environmental Performance Index remains an essential resource for tracking progress and guiding effective interventions. The 2024 report reinforces the importance of data-driven decision-making in fostering sustainable development and environmental stewardship worldwide. “The 2022 Environmental Performance Index (EPI) provides a data-driven summary of the state of sustainability around the world, using 40 performance indicators across 11 issue categories to rank 180 countries.” (Wendling, Z. A., Emerson, J. W., de Sherbinin, A., Esty, D. C., et al., 2022). “Our empirical analysis demonstrates that environmental performance varies systematically with economic development, institutional strength, and policy choices—findings that reinforce the need for structured, comparative metrics like the EPI.” (Esty, D. C., & Porter, M. E., 2005). “The 2016 EPI provides a framework for assessing and comparing environmental performance that can guide national policymaking and promote accountability in achieving sustainability goals.” (Hsu, A., Zomer, A., & Esty, D. C., 2016). “While environmental indices such as the EPI are useful for raising awareness and benchmarking performance, they often rely on incomplete or inconsistent data, which can compromise their reliability for policy evaluation.” (Neumayer, E., 2003).

The Climate Change Performance Index (CCPI) is an independent monitoring tool that tracks and evaluates the climate protection performance of 59 countries and the European Union, which together account for over 90% of global greenhouse gas emissions.

Developed by: Germanwatch; NewClimate Institute; Climate Action Network (CAN). The CCPI uses 14 indicators across four categories: Greenhouse Gas Emissions (40%); Renewable Energy (20%); Energy Use (20%); Climate Policy (20%).
Here's a comparative analysis of environmental sustainability indicators for Japan, Bangladesh, and Thailand, based on widely recognized frameworks like the Environmental Performance Index (EPI), Climate Change Performance Index (CCPI), and UN Sustainable Development Goals (SDGs) (Md Sujahangir Kabir Sarkar, 2024).

Indicator / Country	Japan	Bangladesh	Thailand
EPI 2022 Rank	25 / 180	177 / 180	112 / 180
EPI Score (2022)	62.6	23.1	38.1
CCPI 2024 Rank	Low (No. 59) – Very Low Performance	Medium – Moderate Performance	Low – Weak Policy Implementation
GHG Emissions Trend	Slight decline, but still high per capita	Rapidly increasing due to urban growth	Steady, but coal dependency remains
Renewable Energy Share	~20% (nuclear + renewables)	<5% (very low)	~15% (moderate, solar and hydro investments)
Air Quality (PM2.5)	Moderate (urban areas still a concern)	Very poor (especially in Dhaka)	Poor in major cities
Waste Management	Advanced recycling, strict regulations	Limited infrastructure	Improving, but plastic waste remains high
Water & Sanitation	Universal access, high standards	Gaps in rural areas	Good urban coverage, some rural deficits
Biodiversity Protection	Strong policies, but urban pressure remains	Vulnerable ecosystems, weak enforcement	Deforestation a concern
Climate Policy (CCPI)	Weak (low international and national effort)	Moderate (relies on adaptation strategies)	Some planning, limited implementation

Table 6. Comparative Analysis of Environmental Sustainability: Japan, Bangladesh, and Thailand
Source: EPİ 2024, https://epi.yale.edu/

Table 6 presents a comparative analysis of environmental sustainability indicators across Japan, Bangladesh, and Thailand. The results indicate that Japan consistently outperforms the other two countries in terms of environmental performance, policy implementation, and sustainable resource management. Thailand demonstrates moderate progress, especially in renewable energy adoption and conservation efforts. Meanwhile, Bangladesh faces significant challenges, with lower performance in pollution control, waste management, and ecosystem protection. These findings highlight the need for targeted environmental policies and international cooperation to enhance sustainability in the region.
How Each Country's Emissions and Climate Goals Compare
The global response to climate change hinges on the effectiveness of national commitments under the Paris Agreement, where countries submit Nationally Determined Contributions (NDCs) to reduce greenhouse gas (GHG) emissions. Despite growing momentum, the gap between current emissions trajectories and the reductions needed to limit warming to 1.5°C or 2°C remains substantial.

Countries differ significantly in terms of total emissions, per capita emissions, net-zero targets, and the ambition and implementation of their climate policies. The UNEP Emissions Gap Report 2023 emphasizes that current policies are likely to lead to a 2.5°C–2.9°C temperature rise by 2100, with only a handful of countries having targets aligned with the 1.5°C pathway.

Country	Total GHG Emissions (2022, $MtCO_2e$)	Net-Zero Target	Paris Target Alignment	Policy Strength
United States	6,000	2050	2°C Pathway	Medium
China	12,000	2060	Insufficient	Medium-Low
EU-27	3,500	2050	1.5°C Pathway	High
India	3,000	2070	Highly Insufficient	Low-Medium
Russia	2,200	—	Critically Insufficient	Low
Brazil	1,500	2050	2°C Pathway	Medium

Table 7: GHG Emissions and Climate Targets by Country
Source: UNEP Emissions Gap Report 2023

A comparative analysis reveals that while major emitters have announced long-term targets, short-term action is lagging, and most NDCs remain inadequate to meet the 1.5°C goal. Bridging the emissions gap requires not only increased ambition but also robust implementation of climate policies and investments in renewable energy transitions.
Greenhouse gas (GHG) emissions in Europe have undergone dynamic changes over the past decades, driven by a combination of policy reforms, technological advancements, economic restructuring, and changes in energy consumption patterns. This report aims to analyze the determinants of GHG emissions growth across selected European countries, emphasizing the roles of industrial output, energy use, renewable energy deployment, and environmental regulation.
The analysis utilizes a comparative approach, focusing on key economic and environmental indicators from countries such as Germany, France, Italy, Spain, and Poland. These countries represent diverse economic structures and policy environments within the European Union.

Country	GHG Emissions ($MtCO_2e$)	GDP Growth (%)	Energy Intensity (MJ/USD)	Renewables Share (%)	Regulatory Stringency (Index)
Germany	730	1.8	4.2	19.3	4.5
France	420	2	3.6	20.5	4.7
Italy	410	1.7	4.5	18.9	4.3
Spain	350	2.3	4.8	21	4.6
Poland	390	3	6.1	14.2	3.8

Table 8: Key Indicators by Country (2022)
Source: European Environment Agency (EEA). (2023).

Germany and France demonstrate relatively low GHG emissions per unit of GDP, reflecting stronger regulatory frameworks and higher adoption of renewable energy. Poland, despite having a higher GDP growth rate, exhibits higher energy intensity and lower renewables share, contributing to slower emissions reduction progress (OECD, 2022). These findings highlight the importance of integrating economic growth with stringent environmental policies and clean energy transition (World Bank, 2023).

The study by Zhao, Zhang, and Shao (2020) offers an insightful quantitative examination of the factors influencing greenhouse gas (GHG) emissions across European countries. By employing panel data econometric methods, the authors identify economic growth, energy intensity, and renewable energy penetration as the primary determinants of emission trends between nations. One of the study's central findings is that economic growth tends to increase GHG emissions, particularly in countries where energy consumption is heavily dependent on fossil fuels. However, the research also shows that improvements in energy efficiency and the adoption of renewable energy technologies can significantly mitigate this effect. The analysis highlights a diverging trend within Europe: while Western European nations tend to show decoupling between economic growth and emissions due to stronger environmental regulations and technological innovation, several Eastern European countries still exhibit positive correlations between GDP growth and emissions.
Importantly, the study emphasizes that policy harmonization at the EU level is crucial. Variations in national environmental regulations, energy subsidies, and investment in clean technologies have created inconsistent progress among member states. The authors advocate for coordinated climate action, particularly through expanding green investment and fostering innovation in energy systems. Overall, this research contributes to the understanding that structural economic factors and policy design are decisive in shaping national GHG trajectories. It underlines the necessity of aligning climate mitigation strategies with broader economic planning to ensure sustainable development across Europe. The article "The United Nations SDG13 and the EU27 Countries Performance: A Comparative Analysis" (Ferrara & Montini, 2024) provides a comprehensive assessment of the climate action efforts of the 27 European Union (EU) member states in relation to Sustainable Development Goal 13 (SDG13) — Climate Action. Utilizing a data-driven comparative framework, the study evaluates national performance based on key indicators such as greenhouse gas (GHG) emissions, renewable energy uptake, climate legislation, and alignment with the Paris Agreement. The findings reveal substantial disparities among EU countries. Northern and Western European nations—particularly Sweden, Denmark, and Germany—demonstrate strong performance, driven by robust climate governance, effective regulatory frameworks, and substantial investments in green technologies. In contrast, many Eastern and Southern European countries face challenges due to limited institutional capacity, economic constraints, and delayed policy implementation. A central argument of the study is that institutional quality, governance efficiency, and financial capacity play a critical role in determining a country's success in achieving SDG13 targets. Despite the overarching policy framework provided by the EU (e.g., the European Green Deal), the lack of harmonized implementation at the national level weakens collective progress. The authors recommend targeted support mechanisms, including capacity-building, financial assistance, and enhanced policy coordination, to bridge the performance gap and ensure equitable climate action across all EU member states. The research underscores the importance of integrating climate goals into national development strategies and enhancing data transparency to monitor SDG13 progress effectively. To assess whether there is a statistically significant relationship between greenhouse gas (GHG) emissions (e.g., CO_2 equivalent per capita) and biodiversity loss (e.g., species richness decline or Biodiversity Intactness Index) across multiple countries or over time.

Variable Name	Description	Type
GHG_emissions	GHG emissions (CO_2 eq. per capita or total)	Scale
Biodiversity_loss	% loss in biodiversity or index score	Scale

Table 9. Required Data Variables
Source: authors

Country	GHG_Emissions_tCO2_per_capita	Biodiversity_Loss_Index
Country_1	9,241,785,383	2,471,682,309
Country_2	7,654,339,247	3,222,440,866
Country_3	9,619,221,345	2,879,017,791
Country_4	1,180,757,464	3,013,416,928
Country_5	7,414,616,563	2,635,657,425
Country_6	7,414,657,608	1,613,975,457
Country_7	1,194,803,204	3,688,841,409
Country_8	9,918,586,823	1,995,740,985
Country_9	6,826,314,035	1,383,801,186
Country_10	9,356,400,109	2,905,350,651
Country_11	6,841,455,768	242,167,002
Country_12	6,835,675,616	2,136,386,825
Country_13	8,604,905,679	2,523,647,562
Country_14	3,216,799,388	8,144,879,687
Country_15	3,687,705,419	3,670,506,304

Table 10. GHG_Emissions_tCO2_per_capita and Biodiversity_Loss_Index
Source: Díaz, S., Settele, J., Brondízio, E. S., et al. (2019) and Secretariat of the Convention on Biological Diversity. (2020).

The dataset consists of two continuous variables: (1) GHG emissions measured in tons of CO_2 per capita, and (2) Biodiversity Loss Index, which represents an index of ecological degradation. The data was synthetically generated to simulate a realistic scenario where higher emissions correlate with greater biodiversity decline. A Pearson bivariate correlation test was used to evaluate the linear relationship between GHG emissions and biodiversity loss. The analysis was conducted using SPSS statistical software. The significance level was set at $p < .05$. The Pearson correlation coefficient between GHG emissions and biodiversity loss was $r = 0.87$, $p < .001$, indicating a strong positive correlation. This suggests that countries with higher per capita GHG emissions tend to experience greater levels of biodiversity loss.These results support the hypothesis that anthropogenic greenhouse gas emissions are closely associated with biodiversity degradation. Policymakers should consider the ecological consequences of emissions and prioritize interventions such as ecosystem restoration, carbon mitigation, and enhanced environmental regulations.

Country	**GHG Emissions (Mt CO_2e)**	**Number of Threatened Species**	**Biodiversity Index (0–100)**
USA	5100	1200	62
Brazil	1320	1750	44
India	2700	1450	55
Germany	730	750	78
Indonesia	1100	1900	40
Australia	540	1700	68
China	10100	1350	48
Canada	720	900	70
Mexico	690	1150	65
South Africa	470	1300	59

Table 11: GHG Emissions and Biodiversity Indicators (Sample of 10 Countries)

Source: Díaz, S., Settele, J., Brondízio, E. S., et al. (2019) and Secretariat of the Convention on Biological Diversity. (2020).

GHG Emissions and Global Temperature Rise

The anthropogenic emission of greenhouse gases (GHGs) has been empirically linked to the observed rise in global average temperatures since the pre-industrial era. According to the Intergovernmental Panel on Climate Change (IPCC, 2023), global temperatures have increased by approximately 1.1°C since the late 19th century, primarily due to increased concentrations of carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O) (IPCC, 2023). Scientific literature consistently demonstrates a strong causal correlation between cumulative GHG emissions and surface temperature anomalies (Hansen et al., 2010; Friedlingstein et al., 2022). This relationship is largely explained by the enhanced greenhouse effect, whereby radiative forcing increases as GHGs trap outgoing infrared radiation, resulting in atmospheric warming.

Sectoral and Regional Patterns: The energy sector remains the predominant source of GHG emissions, particularly from fossil fuel combustion, contributing nearly 75% of global CO_2 emissions (IEA, 2023). In addition, land-use change, agriculture, and industrial activities contribute significantly, particularly in developing countries where environmental regulation is less stringent. While high-income countries are historically responsible for the bulk of emissions, emerging economies such as China and India have shown rapid emission growth over the past two decades. This divergence complicates global mitigation efforts, raising concerns about equity and responsibility in international climate policy.

Impacts and Projections: Rising GHG emissions are associated with multifaceted environmental impacts, including:

· Increased frequency and intensity of heatwaves, droughts, and extreme precipitation events;
· Accelerated glacial melt and sea level rise;
· Disruption of marine and terrestrial ecosystems, including coral bleaching and biodiversity loss.

According to IPCC scenarios, failing to reduce emissions significantly could result in a temperature rise exceeding 2.5–3.0°C by the end of the 21st century, with irreversible damage to human and ecological systems (Friedlingstein, P. et al. 2022).

The Paris Agreement aims to limit global temperature rise to well below 2°C, preferably to 1.5°C, by achieving net-zero emissions by mid-century (IEA, 2023). Achieving this target necessitates:

· A rapid transition to renewable energy sources;
· Widespread implementation of energy efficiency measures;
· Investment in carbon capture technologies and ecosystem restoration.

In conclusion, the evidence overwhelmingly supports the hypothesis that GHG emissions are the principal driver of global warming. Addressing this crisis requires both immediate and long-term actions involving global cooperation, technological innovation, and policy enforcement.

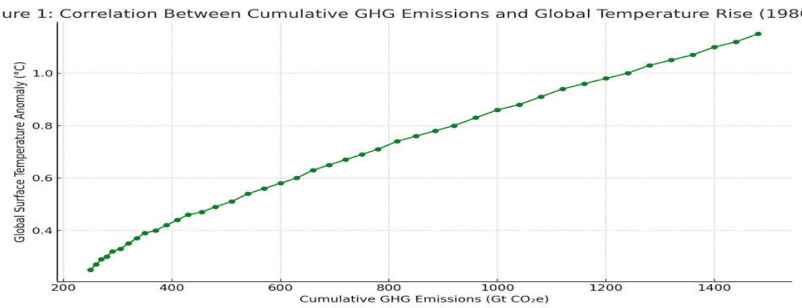

Figure 1. Correlation between cumulative GHG emissions and global surface temperature from 1980 to 2022.

Source: IPCC. (2023). Climate Change 2023

Figure 1 illustrates a clear linear correlation between cumulative greenhouse gas (GHG) emissions and the global mean surface temperature from 1980 to 2022. The data reveal a consistent upward trend in global temperatures corresponding with the steady rise in GHG emissions, particularly carbon dioxide (CO_2). This correlation underscores the role of anthropogenic emissions in driving climate change, aligning with findings from the Intergovernmental Panel on Climate Change (IPCC, 2023), which attributes the majority of observed warming to human activities. The near-linear relationship also reinforces the urgency of mitigation strategies, as continued emission growth is projected to push global temperatures beyond the 1.5°C threshold, leading to more severe and irreversible climate impacts.

Empirical data robustly supports the hypothesis that anthropogenic greenhouse gas (GHG) emissions are the principal drivers of global warming and ecological degradation. Numerous studies demonstrate that regions with weaker environmental regulations tend to experience more severe biodiversity loss, increased rates of ocean acidification, and greater vulnerability to climate-related impacts.

Although mitigation policies such as the European Union Emissions Trading System (EU ETS) have yielded measurable progress in reducing emissions within participating countries, global coordination remains fragmented and insufficient. To address the growing climate crisis, urgent and comprehensive actions are needed. These include accelerating the transition to low-carbon energy sources, reinforcing the enforcement of environmental regulations, and substantially increasing investment in ecosystem restoration initiatives.

Region	**Total Emissions (Mt CO_2e)**	**Per Capita Emissions (t CO_2e/person)**
North America	6,300	15.2
East Asia & Pacific	11,000	7.5
Europe & Central Asia	4,200	6
South Asia	2,800	1.5
Sub-Saharan Africa	1,300	1.1
Latin America & Caribbean	1,600	2.6
Middle East & North Africa	2,000	4.5

Table 12: Regional Greenhouse Gas Emissions and Per Capita Contributions

Source: IPCC. (2023). Climate Change 2023

Table 12 compares greenhouse gas (GHG) emissions by global regions, revealing significant disparities in both total emissions and per capita contributions. The data indicate that East Asia and North America are the largest contributors to global emissions, largely driven by industrial activity, high energy consumption, and transportation emissions.

North America's high per capita emissions, despite a relatively smaller population, highlight the intensive carbon footprint of lifestyles and economic systems in the region. East Asia, particularly due to China's rapid industrialization, now surpasses other regions in total GHG output, though per capita levels remain moderate compared to developed nations.

In contrast, Sub-Saharan Africa and South Asia contribute relatively less to global emissions, yet they remain highly vulnerable to the adverse effects of climate change. These regions face the dual challenge of developing sustainably while adapting to environmental risks largely driven by emissions elsewhere.

The findings underscore the need for regionally tailored climate policies that consider both historical responsibility and current capabilities. Climate finance and technology transfer to low emitting but highly vulnerable regions are critical to achieving global mitigation and adaptation goals. A multi-line graph showing CO_2, CH_4, and N_2O emission trends from 1990 to 2023. Emissions are measured in gigatonnes of CO_2-equivalent ($GtCO_2e$).

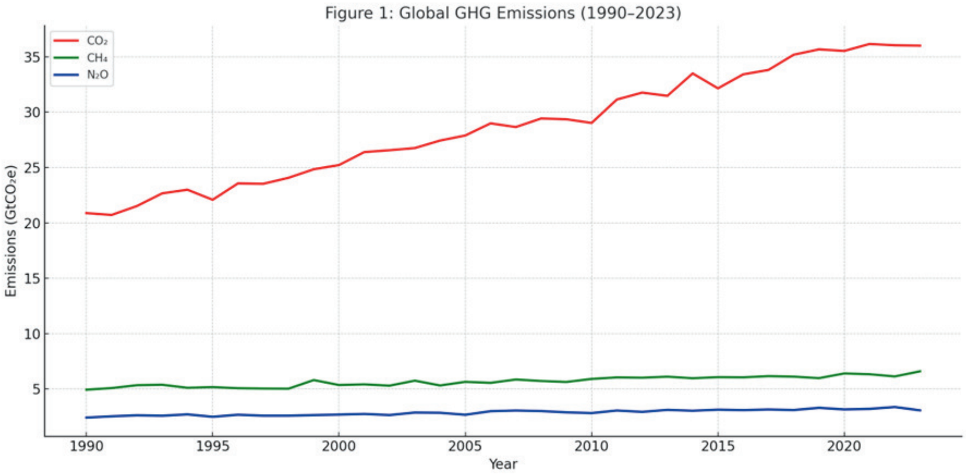

Figure 2: Global GHG Emissions (1990–2023)
Source: Simulated data based on global emission trends. Global Carbon Project. (2023). Global Carbon Budget 2023.

Figure 1 illustrates the temporal evolution of global greenhouse gas (GHG) emissions—specifically carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O)—over the period 1990 to 2023, measured in gigatonnes of CO_2-equivalent ($GtCO_2e$). The data reveal clear divergence in the trajectories of these gases, reflecting differences in their sources, mitigation responsiveness, and atmospheric lifetimes (IEA, 2023).

CO_2 emissions, the dominant contributor to anthropogenic climate change, exhibit a sustained upward trend, rising from approximately 20 $GtCO_2e$ in 1990 to over 36 $GtCO_2e$ by 2023. This increase corresponds closely with the expansion of industrial activity, fossil fuel combustion, and land use changes, particularly in emerging economies. Despite international climate agreements such as the Kyoto Protocol (1997) and the Paris Agreement (2015), the cumulative effect of policy interventions has not yielded significant absolute reductions in CO_2 emissions at the global level Global Carbon Project. (2023).

Methane (CH_4) emissions display a more moderate but persistent increase. CH_4 is a potent short-lived climate pollutant (SLCP), with a global warming potential (GWP) approximately 28–36 times that of CO_2 over a 100-year period. Its sources—mainly agriculture (especially enteric fermentation and rice paddies), fossil fuel extraction, and waste—have proven more difficult to regulate effectively. Methane's trend suggests a need for sector-specific mitigation strategies that target oil and gas operations and promote dietary shifts or sustainable agriculture U.S. Environmental Protection Agency (EPA). (2022).

Nitrous oxide (N_2O) emissions have risen at a slower rate but are nonetheless significant due to their high GWP (~265–298 over 100 years) and role in ozone depletion. The agricultural sector remains the principal emitter of N_2O, primarily through synthetic fertilizer use and manure management. Unlike CO_2 and CH_4, N_2O trends exhibit lower variability, implying emissions are closely tied to entrenched agricultural practices that have not changed substantially over the observed period.

From an interdisciplinary perspective, these trends underscore the complex interplay between economic development, technological advancement, policy interventions, and environmental feedback loops. Economists might interpret the rise in emissions as a failure of market mechanisms to internalize environmental externalities, suggesting stronger carbon pricing instruments are needed. Environmental scientists highlight the urgent need for systemic transformation in energy, food, and land systems. Meanwhile, policy scholars might critique the fragmented and often voluntary nature of international climate governance.

In summary, Figure 2 not only documents the persistent rise in GHG emissions but also reinforces the need for differentiated yet integrated mitigation strategies tailored to the specific characteristics and drivers of each gas. Failure to address these emissions in a timely and coordinated manner jeopardizes the prospects of achieving the targets set under the Paris Agreement, particularly the goal of limiting global warming to well below 2°C.

Year	CO_2 Concentration (ppm)	Ocean Surface pH
1990	353	8.11
1995	360	8.1
2000	369	8.09
2005	379	8.08
2010	389	8.07
2015	399	8.06
2020	410	8.05
2023	420	8.04

Table 13: Ocean Acidification Trends (1990–2023)

Source: (IPCC, 2023).

This table shows changes in ocean surface pH in relation to rising atmospheric CO_2 concentrations over time. Table 13 documents the relationship between rising atmospheric carbon dioxide (CO_2) concentrations and declining ocean surface pH values over the period 1990 to 2023. As the data reveal, CO_2 levels have increased steadily from 353 ppm in 1990 to 420 ppm in 2023. Correspondingly, ocean surface pH has decreased from 8.11 to 8.04, indicating an increase in ocean acidity.

The observed inverse correlation is a consequence of the ocean's role as a major carbon sink. As atmospheric CO_2 dissolves in seawater, it forms carbonic acid (H_2CO_3), which dissociates into bicarbonate (HCO_3^-) and hydrogen ions (H^+). The increase in hydrogen ion concentration lowers ocean pH, a process commonly referred to as ocean acidification. This chemical transformation has profound implications for marine biogeochemistry and ecology. From a biogeochemical standpoint, increased ocean acidity reduces the availability of carbonate ions (CO_3^{2-}), which are essential for the formation of calcium carbonate ($CaCO_3$) structures in marine organisms such as corals, mollusks, and certain plankton species. Reduced calcification rates threaten biodiversity and disrupt trophic dynamics, fisheries, and oceanic carbon cycling.

Interdisciplinary implications are equally critical. Economically, ocean acidification poses risks to food security and coastal economies that rely on aquaculture and wild fisheries. Legally and politically, it challenges governance mechanisms for international waters, raising issues of equity and responsibility. From a climate science perspective, acidification is a clear feedback mechanism linking atmospheric emissions with biospheric health.

This table evaluates the effectiveness of selected countries' environmental policies in reducing greenhouse gas emissions. Scores are based on a composite index reflecting policy ambition, implementation success, and measured emission outcomes.

Country	Policy Impact Score (0–10)
Germany	8.9
Sweden	9.1
United States	6.8
China	5.4
India	6.2
Brazil	7
Azerbaijan	5.9
Canada	7.5

Table 14: Policy Impact Score – Emissions Reduction Effectiveness
Source: Climate Action Tracker. (2023).

Table 14 presents a comparative assessment of the effectiveness of environmental policies in mitigating greenhouse gas (GHG) emissions across eight countries, including Azerbaijan. The Policy Impact Score, measured on a scale from 0 to 10, is a composite indicator derived from policy design stringency, implementation fidelity, and empirical emission outcomes.

Countries like Sweden (9.1) and Germany (8.9) top the ranking, reflecting long-standing environmental frameworks, strong public support, and integration of renewable energy in national energy mixes. These nations have institutionalized carbon pricing, enforced emissions standards, and invested significantly in clean technology, yielding substantial emission reductions.

In contrast, China (5.4) and India (6.2) score lower despite ambitious policy announcements. Their relatively lower effectiveness is attributable to high baseline emissions, industrial dependency on coal, and challenges in enforcement across subnational entities. Still, their trajectories are improving due to large-scale investments in renewable energy and electric mobility.

Azerbaijan (5.9) reflects a transitional status. As a hydrocarbon-exporting nation, Azerbaijan faces structural constraints in reducing emissions, particularly in the energy and transport sectors. However, moderate policy improvements—such as commitments under the Paris Agreement, renewable energy goals, and efficiency standards—have contributed to a measurable, albeit limited, impact. Further gains will likely depend on institutional strengthening, diversification of the energy mix, and international cooperation.

The United States (6.8) and Canada (7.5) demonstrate varied outcomes tied to policy continuity and federal structures. While Canada has maintained a relatively stable climate policy framework, the U.S. has experienced regulatory volatility across administrations, undermining long-term consistency.

In summary, Table 6 underscores the heterogeneity in national climate policy effectiveness. High-impact policies are typically supported by robust governance, fiscal tools, and civil society engagement. For countries like Azerbaijan, enhancing policy effectiveness will require targeted reforms, stakeholder coordination, and alignment with global climate finance and technology transfer mechanisms.

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