Sunstone Institute

Global Energy Transition Scoreboard

Pathways and Progress Towards Carbon Neutrality

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1. Introduction

The Imperative of Energy Transition

The global energy system stands at a critical juncture, compelled by the dual imperatives of mitigating climate change and fostering sustainable development. The transition from economies predominantly reliant on fossil fuels to resilient, low-carbon systems represents an undertaking of unprecedented scale and complexity. This transformation is not merely an option but a necessity, underscored by mounting scientific evidence and the increasing frequency of climate-related disruptions. The International Energy Agency (IEA) has cautioned that while limiting global warming to 1.5 $^\circ$C remains possible, the path is exceptionally challenging, demanding immediate and concerted action across all sectors and nations.

Introducing the Energy Transition Score (ETS)

To navigate this complex transition, robust analytical tools are indispensable. The Energy Transition Score(ETS) serves as a pivotal composite benchmark, designed to quantify and track the progress of countries in transforming their energy sectors. Developed to provide a comprehensive assessment, the ETS evaluates nations on two primary dimensions: their current energy system performance and the conduciveness of their enabling environment for the future adoption of renewable energy sources and sustainable practices.[2] This dual focus allows for an understanding of both the present state of energy systems and their preparedness for future advancements, offering a holistic view of transition dynamics.

Significance of the ETS for Carbon Neutrality

Indexes such as the ETS are instrumental in facilitating the global energy transition. They provide market participants, policymakers, and investors with standardized metrics and diverse options across various asset classes, serving as crucial benchmarks to assess performance, mitigate risks, and identify emerging opportunities within the intricate global energy market. The ETS, by evaluating progress towards sustainable energy systems, directly informs efforts to achieve carbon neutrality.

The drive towards a low-carbon future is propelled not only by the urgent need to address climate change but also by significant technological advancements and powerful market forces. Innovations have led to dramatic cost reductions in renewable energy technologies, such as the 86% drop in solar photovoltaic prices between 2010 and 2023. These developments, coupled with increasing investor interest in sustainability and growing consumer demand for clean energy, are rendering renewable solutions not only ethical imperatives but also economically viable and attractive financial investments. Consequently, the ETS is more than a ranking system; it functions as a strategic compass, guiding stakeholders through the multifaceted landscape of the energy transition, reflecting both the urgency of climate action and the burgeoning economic opportunities inherent in clean energy.

Report Objectives and Structure

This report aims to provide a full, detailed analysis of the Energy Transition Score, to evaluate and score countries on their progress towards carbon neutrality. The analysis will dissect the ETS's components, examine global and regional performance trends, and explore the outlook for the energy transition.

The report is structured as follows:

Section 2: Defining the Energy Transition Score

This section explores the conceptual foundation and key dimensions of the ETS, as derived from available data.

Section 3: Global Energy Transition Country Rankings

This section provides a global overview of energy transition performance, including comparisons across regions and income groups.

Section 4: Energy Transition Insights

This section offers an in-depth analysis of operational efficiency in various energy sectors and countries.

Section 5: Energy Transition Forecast

This section discusses the future trajectory, potential challenges, and emerging opportunities in the global energy transition.

Section 6: Energy Transition Case Studies

This section presents case studies focusing on the USA, China, and India.

2. Defining the Energy Transition Score

The Energy Transition Score(ETS) evaluates countries based on two key elements: the current performance of their energy systems and their advancement towards a more sustainable and equitable energy future.

A successful energy transition is complex and goes beyond simply implementing renewable energy. It involves a comprehensive transformation that includes reducing emissions, improving energy efficiency, ensuring fair access to energy, and managing the decrease in fossil fuel reliance. This integrated approach is vital because achieving carbon neutrality requires systemic changes throughout the entire energy value chain and its interactions with economic and social systems.

The analytical framework is thoroughly explained in the "A1 Data Methodology" and "A2 Selecting Indicators" sections.

2.1 Data Source

Table 1 details the data sources and datasets chosen for this analysis. The reliability and factual accuracy of our findings are directly contingent on the quality of the information utilized, making the selection of dependable data sources crucial. Consequently, a stringent selection process ensures that all data points originate from credible and verifiable sources. Data was further validated through cross-referencing with multiple sources.

For a truly global and representative index, extensive data coverage across most countries is vital. This prevents biases from limited geographic representation and ensures meaningful insights into energy transitions across diverse nations. Without broad data availability, the index would misrepresent the global energy transition.

Our methodology also considers data continuity, enabling continuous updates and insights from new reports. This commitment to ongoing data integration ensures our analysis remains current, relevant, and reflective of the latest energy transition developments, providing an up-to-date and accurate representation of the energy sector's progress and challenges.

Our website features an interactive interface that allows users to explore the dataset from this analysis.

Table 1: Data Sources by Sector

Source	**Datasets**
Emissions Database for Global Atmospheric Research (EDGAR)	Greenhouse Gas Emissions
Energy Institute	Fossil Fuel Production and Consumption
International Renewable Energy Agency (IRENA)	Renewable Energy Production and Installation
U.S. Energy Information Administration (EIA)	Fossil Fuel Production and Consumption, Electricity Statistics, Greenhouse Gas Emissions
International Energy Agency (IEA)	Fossil Fuel Production and Consumption, Electricity Statistics, Electric Vehicles
World Health Organization (WHO)	Access to Clean Cooking
World Bank	Population, Gross Domestic Product (GDP), Access to Electricity
UN Trade and Development	International Trade, Maritime Transport

2.2 Energy Transition Score Components

The Energy Transition Score(ETS) provides a comprehensive framework for evaluating a nation's journey towards achieving carbon neutrality. It meticulously assesses progress across a multitude of interconnected dimensions, with each contributing factor weighted to formulate an overarching score that reflects the country's performance. A core principle underpinning the ETS's methodology is its unwavering commitment to transparency, ensuring that the criteria and data used for assessment are readily accessible and understandable. Furthermore, the index places a strong emphasis on continuity, meaning that its methodology and data collection are designed to allow for consistent tracking of progress over time, facilitating meaningful comparisons and trend analysis. This focus on both transparency and continuity is crucial for policymakers, investors, and the public to accurately gauge a country's dedication and effectiveness in transitioning to a sustainable energy future.

2.2.1 Greenhouse Gas (GHG) Emissions

Greenhouse Gases (GHGs) are atmospheric gases that trap heat, thereby increasing the surface temperature of celestial bodies such as Earth. This analysis focuses on GHGs originating from human activities and the burning of fossil fuels, with data primarily sourced from the EU Emissions Database for Global Atmospheric Research.

Figures 1 and 2 present the total and per capita GHG emissions for various countries from 1990 to 2024. To facilitate country-to-country comparisons, we utilize GHG emissions per capita, also referred to as carbon intensity. This metric offers a direct assessment of a country's effectiveness in managing and reducing its greenhouse gas emissions, with lower per capita emissions signifying progress toward carbon neutrality.

$$GHG\ Emissions\ per\ Capita\ =\ \frac{Total\ GHG\ Emissions}{Population}$$

To illustrate the dynamism of each country's decarbonization efforts, we analyzed the prevailing trend in per capita GHG emissions over the past decade by calculating a linear regression for each country's data. As shown in Figure 2, the USA has the highest per capita GHG emissions, although its trend is declining, being surpassed by Russia in 2024. In contrast, both China and India show an increasing trend in their per capita emissions.

Figure 3 displays a world map illustrating per capita GHG emissions for 125 countries in 2024.

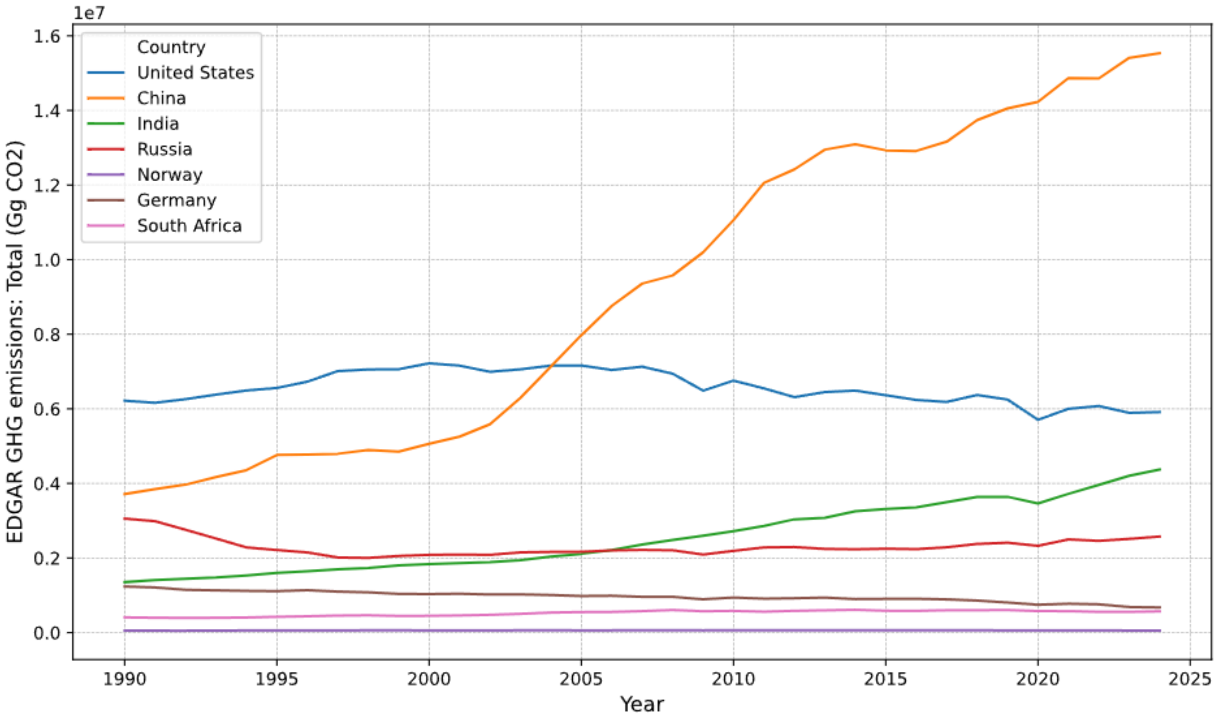

Figure 1: Total GHG emissions

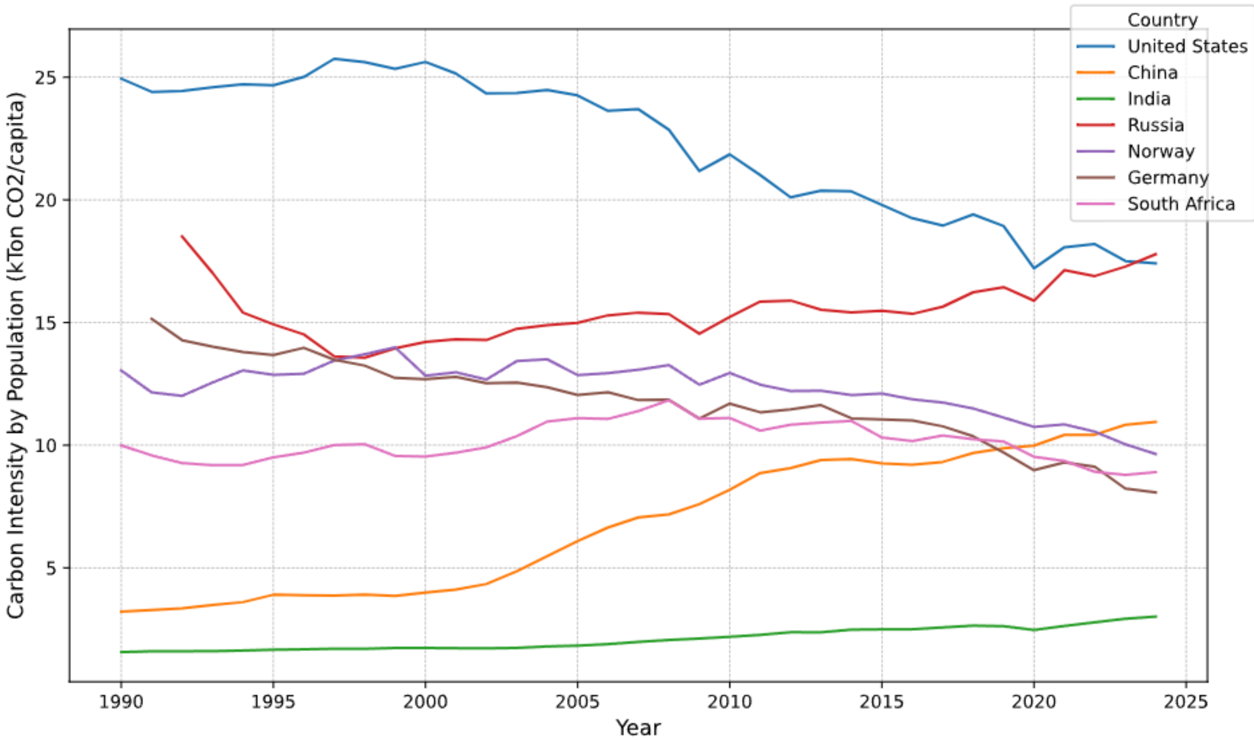

Figure 2: GHG emissions per capita

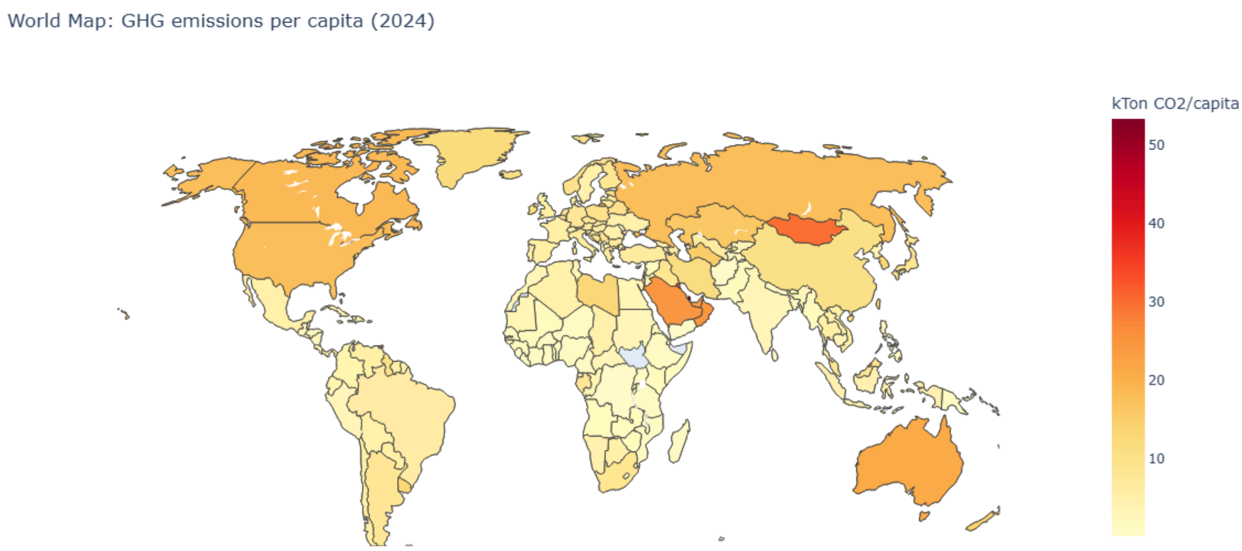

Figure 3: World Map of GHG emissions per capita

2.2.2 Clean Electricity Capacity

Achieving carbon neutrality requires a significant increase in non-carbon emitting energy sources, specifically renewable and nuclear energy, which together constitute clean energy. Figure 4 illustrates the proportion of clean energy in the electricity production of various countries.

We have developed numerous indicators for renewable and nuclear energy (see Appendix A2). After careful consideration, we selected the amount of clean energy capacity as our primary metric. Some countries, such as Nepal, may exhibit a high percentage of clean energy due to low overall consumption. Therefore, we believe that the installed capacity of both renewable and nuclear electricity generation provides a more robust measure than merely the proportion of clean energy. This metric also reflects progress toward a more sustainable society. Consequently, we calculated the installed capacity per capita by dividing the total clean electricity capacity by the population. Figure 5 illustrates the installed clean electricity capacity per capita for various countries.

$$Clean\ Electricity\ Capacity\ per\ Capita\ = \frac{Renewable\ Electricity\ Capacity + Nuclear\ Electricity\ Capacity}{Population}$$

It is crucial to have a robust installed capacity coupled with a consistent and substantial positive trend in adding new clean energy capacity. This continuous expansion is essential not only for directly displacing existing fossil fuel-based power generation but also for effectively decarbonizing the entire electricity sector, a foundational step toward achieving broader climate goals. The rate and scale at which these clean energy sources are integrated into the grid directly impact the pace of emissions reductions and the overall resilience of the energy system.

Germany and China demonstrate significant momentum in clean energy development, contrasting with India and South Africa, which exhibit slower progress.

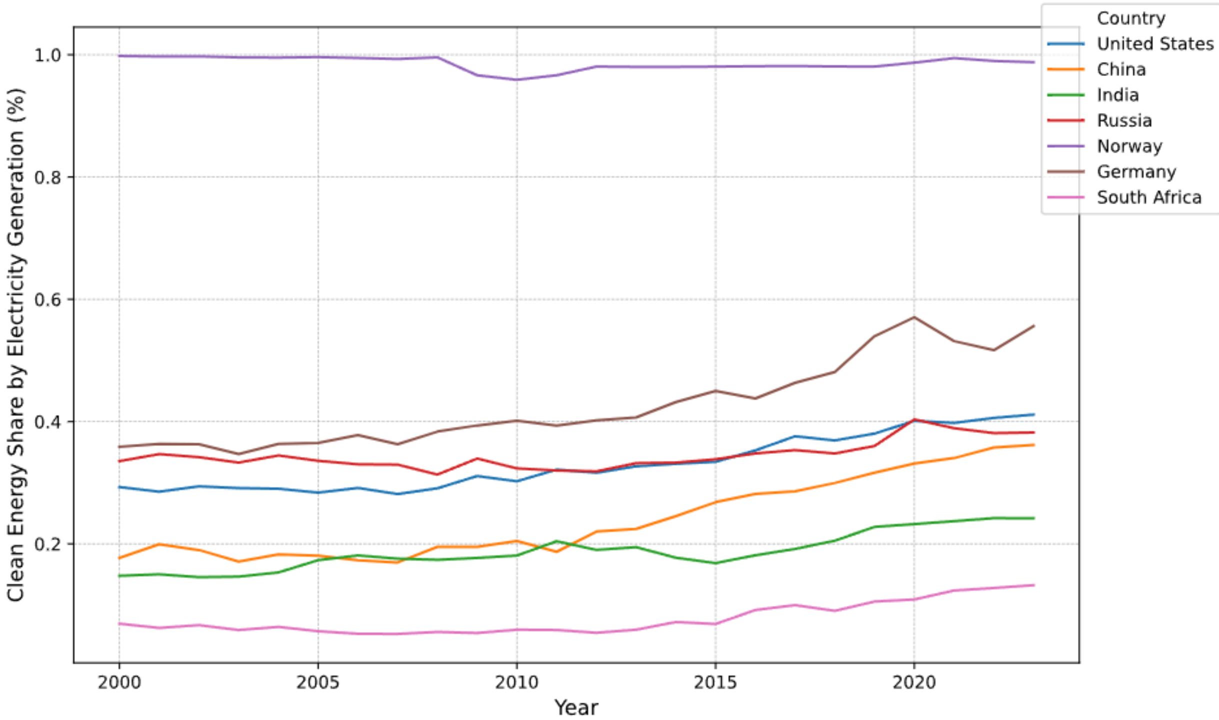

Figure 4: Clean Electricity Percentage

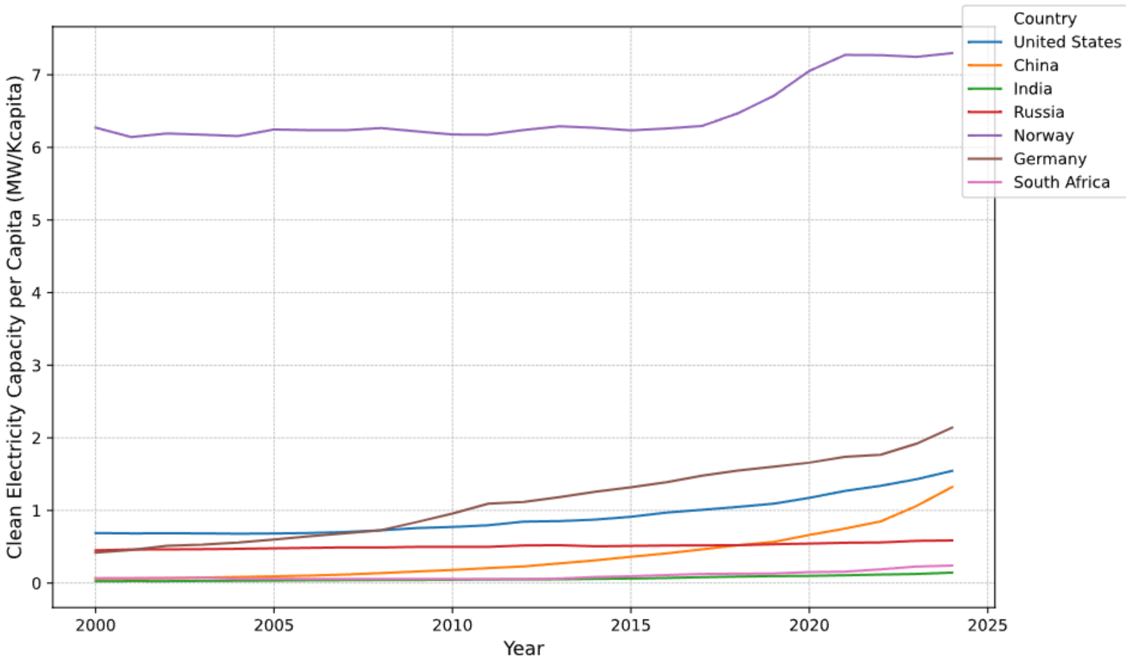

Figure 5: Installed Clean Electricity Capacity Per Capita

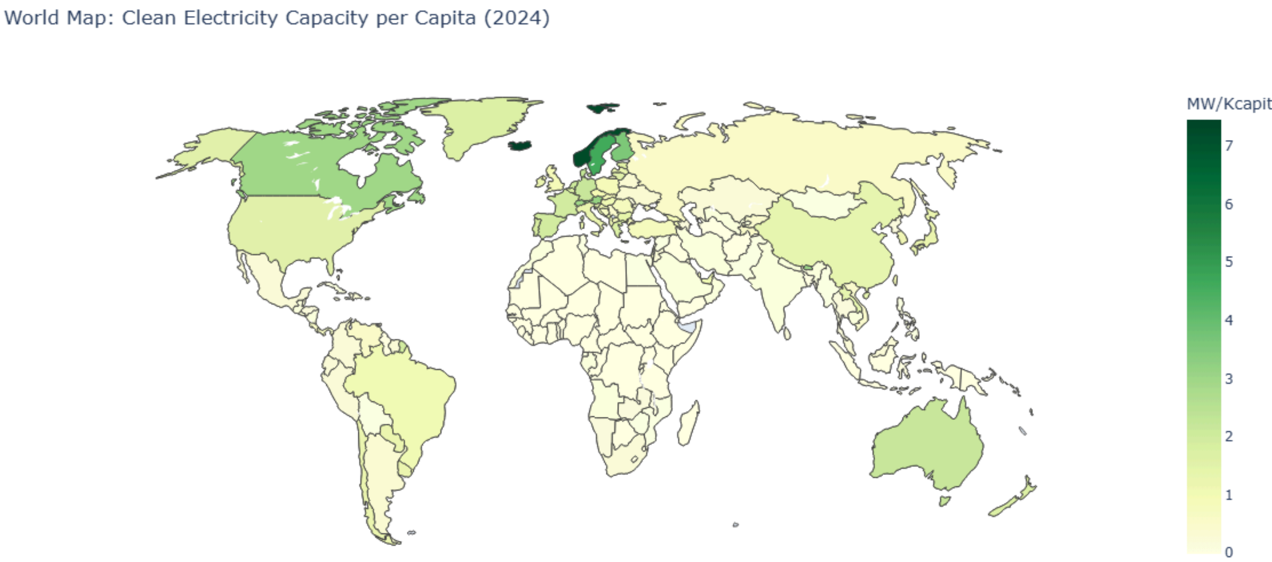

Figure 6: World Map of Installed Clean Electricity Capacity Per Capita

2.2.3 Fossil Fuel Production

A nation's score in this dimension likely reflects its reliance on and involvement in domestic fossil fuel production. Progress toward an energy transition, especially carbon neutrality, typically correlates with declining scores or a strong negative trend in this area. This signifies a move away from carbon-intensive energy extraction and presents a particularly challenging but crucial aspect of the transition for fossil fuel-exporting countries.

To assess countries based on per capita fossil fuel production, we computed a weighted sum of fossil fuels (oil, gas, coal), divided by the population. The weights for oil, gas, and coal are determined by their respective carbon content. Figure 7 illustrates the per capita fossil fuel production of various countries. The trend also serves as an important indicator of a country's efforts to reduce its fossil fuel dependence.

$$Fossil\ Fuel\ Production\ per\ Capita\ =\ \frac{W_{oil}*Oil_{production}+W_{gas}*Gas_{production}+W_{Coal}*Coal_{production}}{Population}$$

While Norway leads in per capita fossil fuel production, its output is decreasing. In contrast, the USA, China, and India show a slight upward trend, with coal production being the primary factor for China and India.

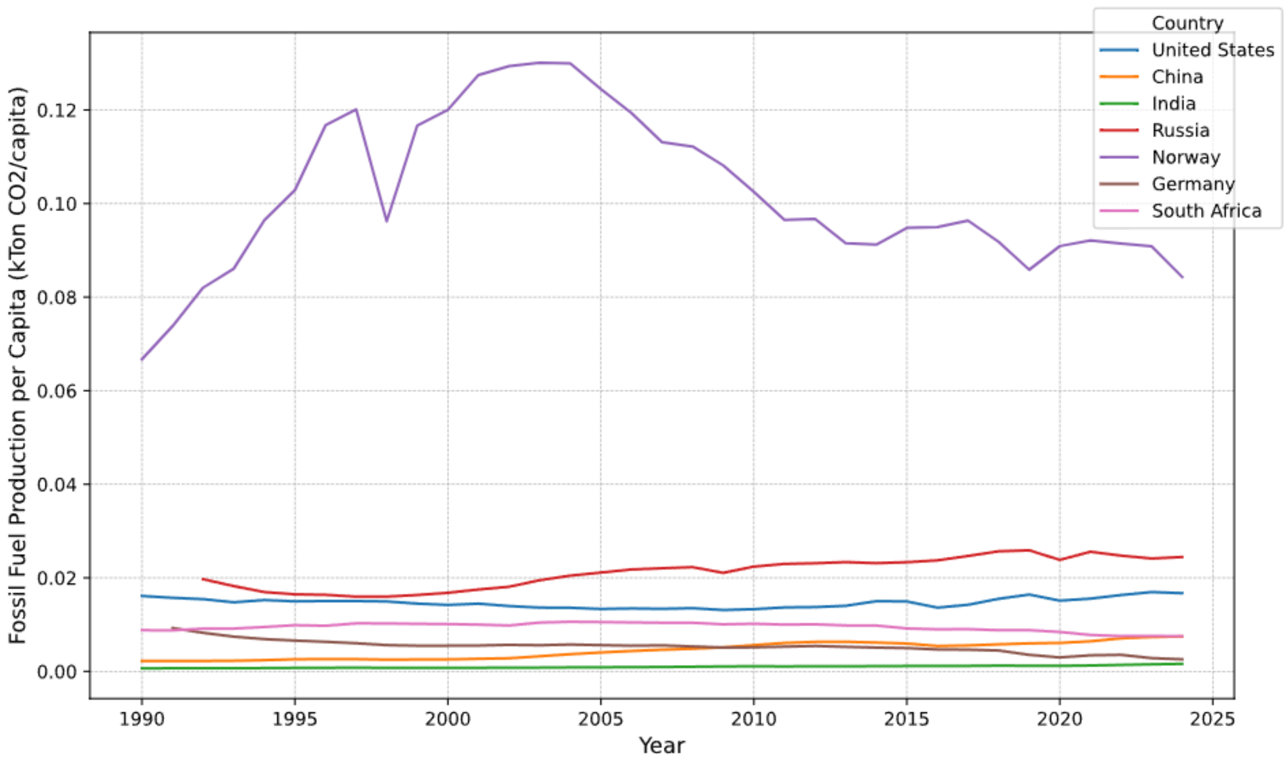

Figure 7: Per Capita Fossil Fuel Production

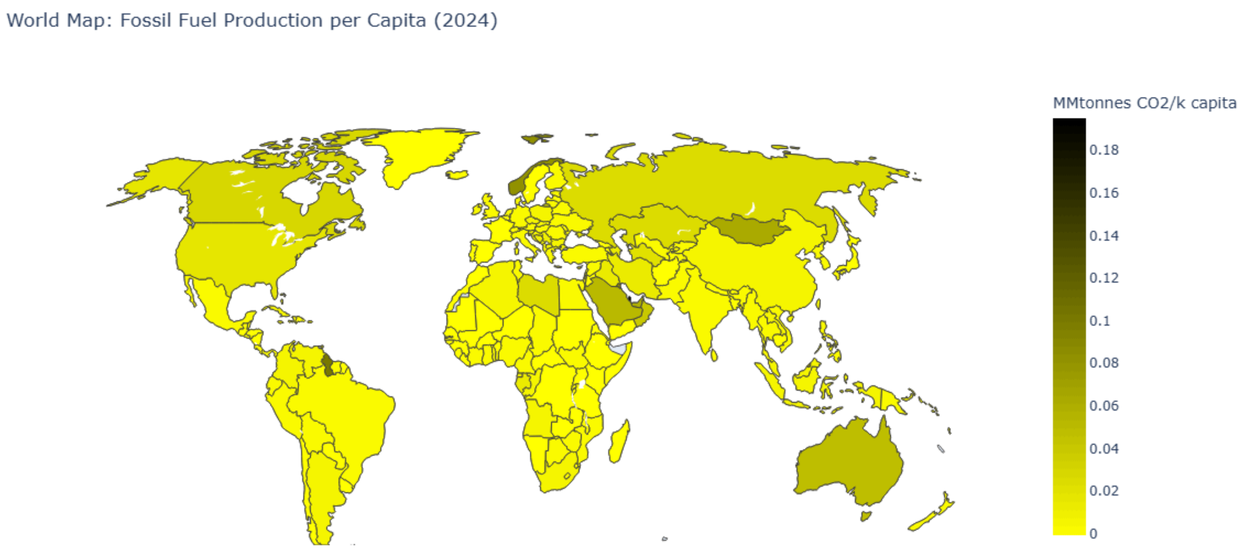

Figure 8: World Map of Per Capita Fossil Fuel Production

2.2.4 Infrastructure and Innovation

- **Energy Efficiency:**

  Energy efficiency, defined as total primary energy consumption divided by Gross Domestic Product at Purchasing Power Parity (GDP at PPP), indicates a country's efficiency in energy utilization across its economy. Enhancements in energy efficiency lead to a reduction in overall energy demand, which in turn facilitates the transition to clean energy sources and lowers associated costs, thereby significantly aiding carbon reduction efforts. Figure 9 illustrates the energy efficiency trends in a selection of countries between 1990 and 2024.

$$Energy\ Efficiency = \frac{Total\ Primary\ Energy\ Consumption}{GDP\ at\ Purchasing\ Power\ Parity}$$

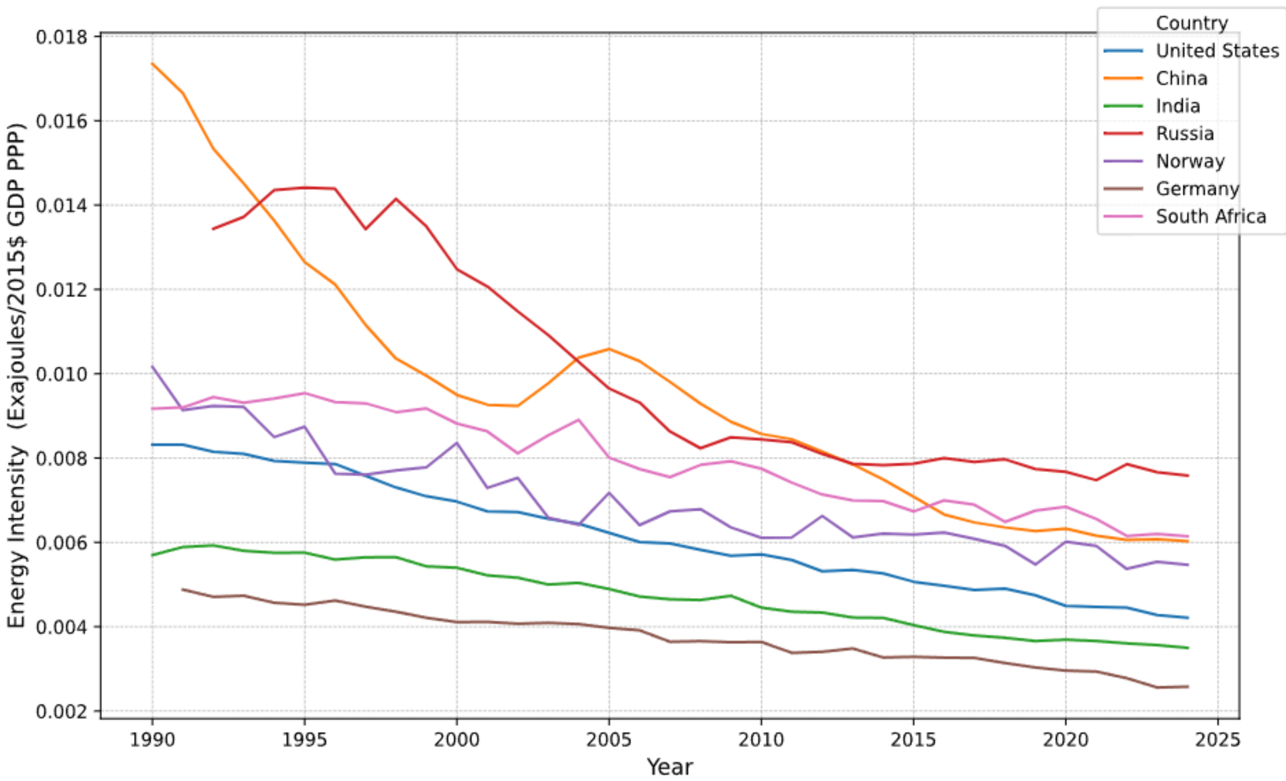

Figure 9: Energy Efficiency

- **Electricity Distribution Inefficiency:**

  This indicator evaluates a nation's power grid efficiency by quantifying energy loss during transmission and distribution. It measures electricity loss across countries as a percentage, derived by dividing the distribution loss by the average of electricity production and consumption. A lower percentage indicates a more efficient system, which in turn reduces the need for surplus generation and minimizes resource wastage. Figure 10 illustrates the Percentage of Electricity Distribution Loss in selected countries.

$$Electricity\ Distribution\ Inefficiency = \frac{Electricity\ Distribution\ Loss}{Electricity\ Generation}$$

India's electricity distribution network struggles with considerable inefficiencies, recording losses of approximately 17.5%, among the highest worldwide. This stands in stark contrast to China, which has developed highly efficient grid infrastructures.

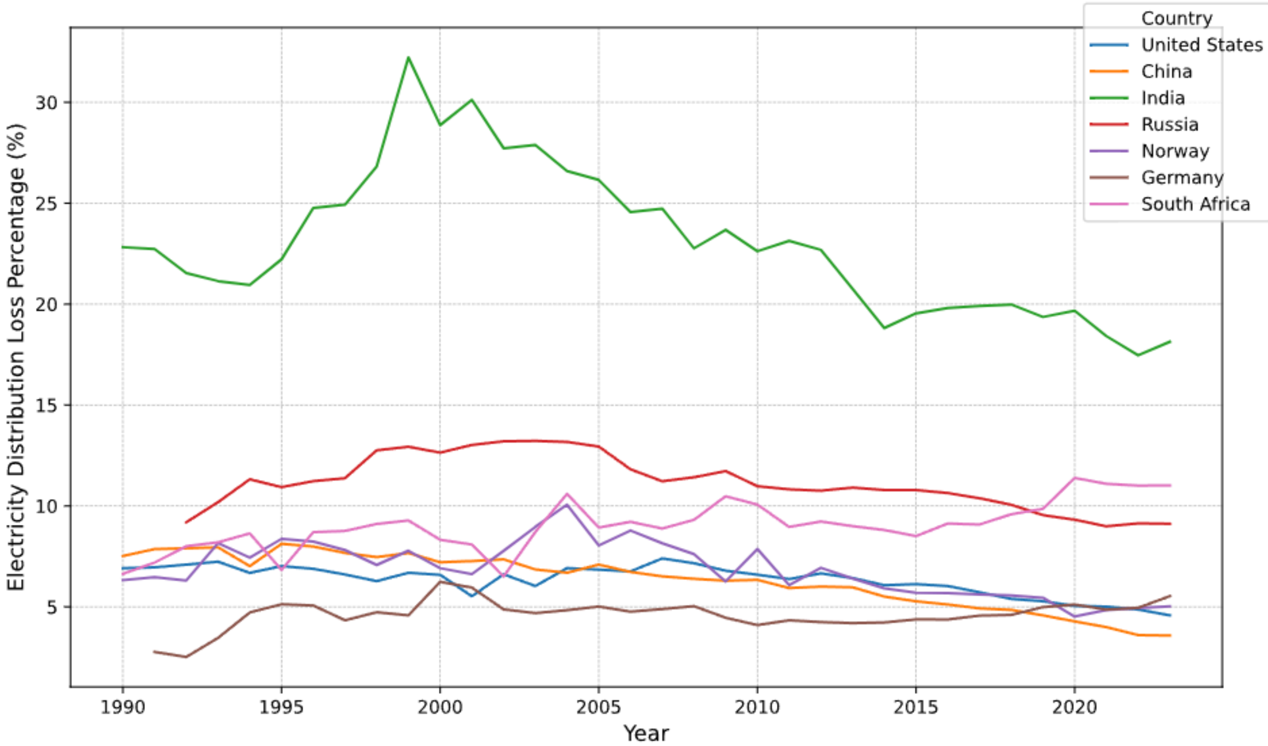

Figure 10: Percentage of Electricity Distribution Loss

- **Access to Electricity:**

  This component is vital for the energy transition's socio-economic dimension, emphasizing inclusivity and universal access to modern energy services. Although not a direct carbon metric, it is crucial for sustainable development and a just transition. Figure 11 demonstrates the percentage of the population with electricity access in various countries.

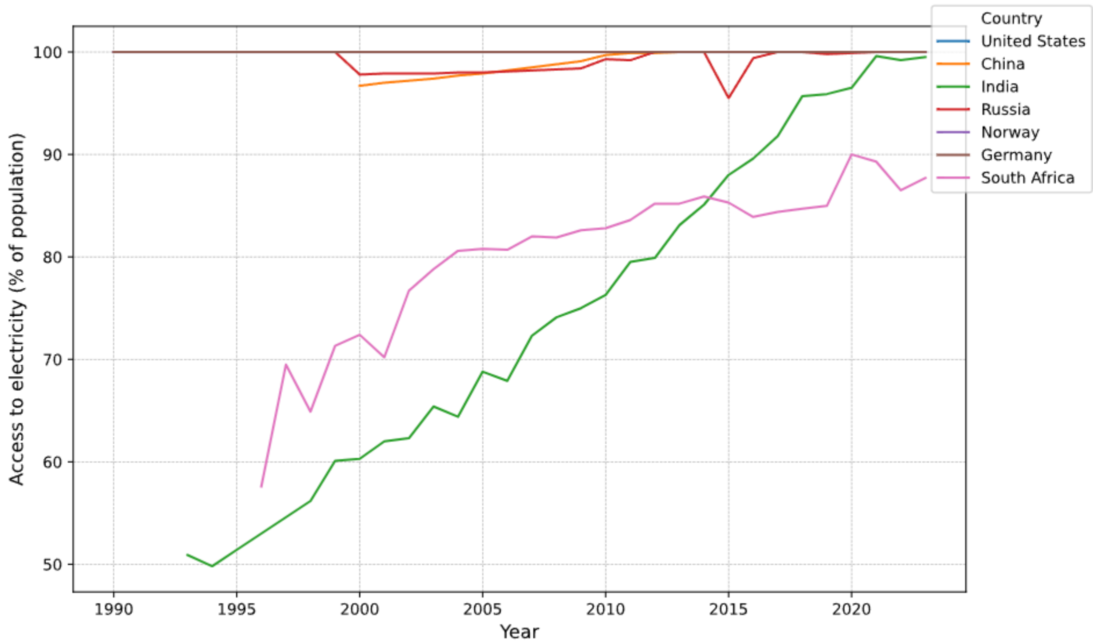

Figure 11: Access to Electricity

- **Access to Clean Cooking:**

  Access to clean cooking fuels and technologies is a key metric, indicating the percentage of the population utilizing these resources. Shifting from traditional biomass for cooking offers substantial health improvements, decreases deforestation, and helps in reducing greenhouse gas emissions. Figure 12 illustrates the global distribution of the population with clean cooking access across different countries.

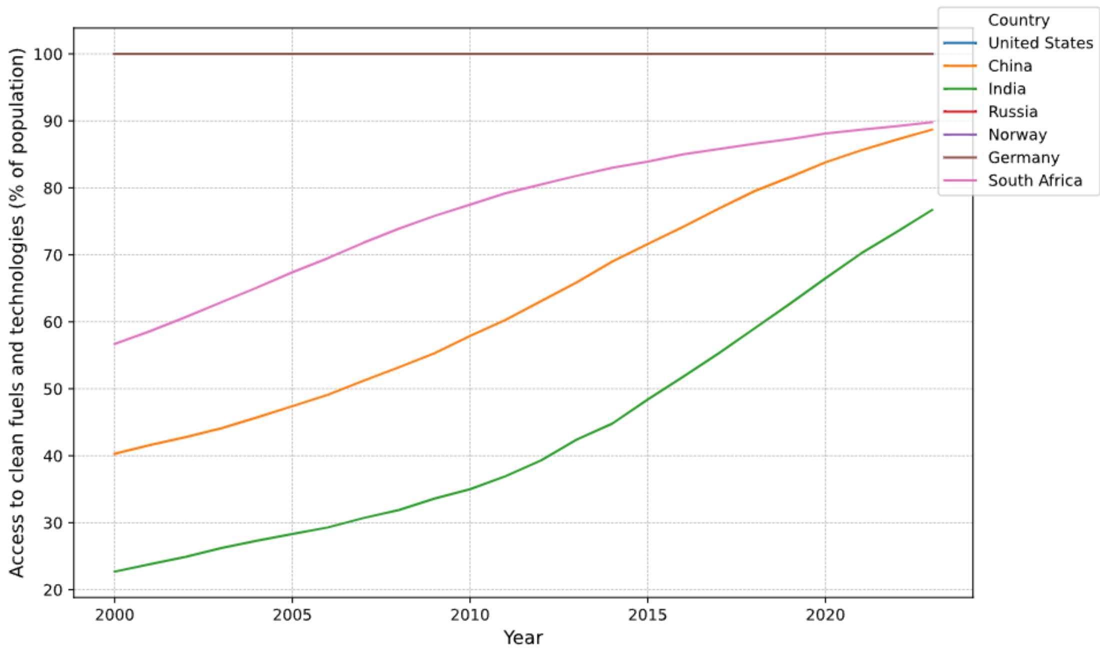

Figure 12: Access to Clean Cooking

- **Electric Vehicle(EV):**

The growing number of Electric Vehicles (EVs) is a significant step towards achieving carbon neutrality. To assess progress, we compared the percentage of EV sales in new vehicle purchases across various countries and calculated the number of public charging points per capita.

It is important to note that EV data was exclusively available for a subset of countries. Figures 13 and 14 present the shares of EV sales and the number of public charging points per capita within these selected nations. Consequently, separate rankings were established for this particular subset of countries. Germany's EV sales have seen a decline since 2022, a trend likely attributable to the rising cost of electricity.

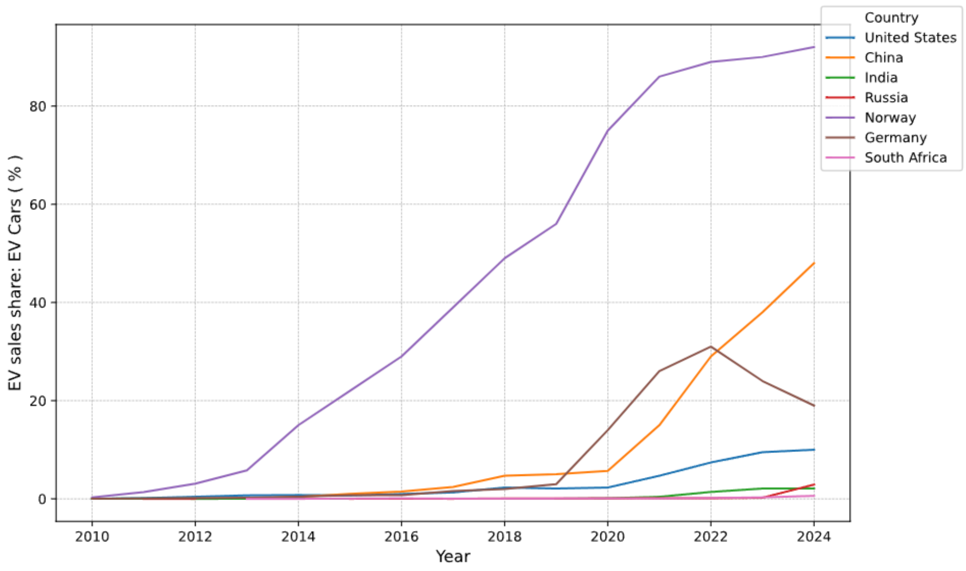

Figure 13: EV sale share

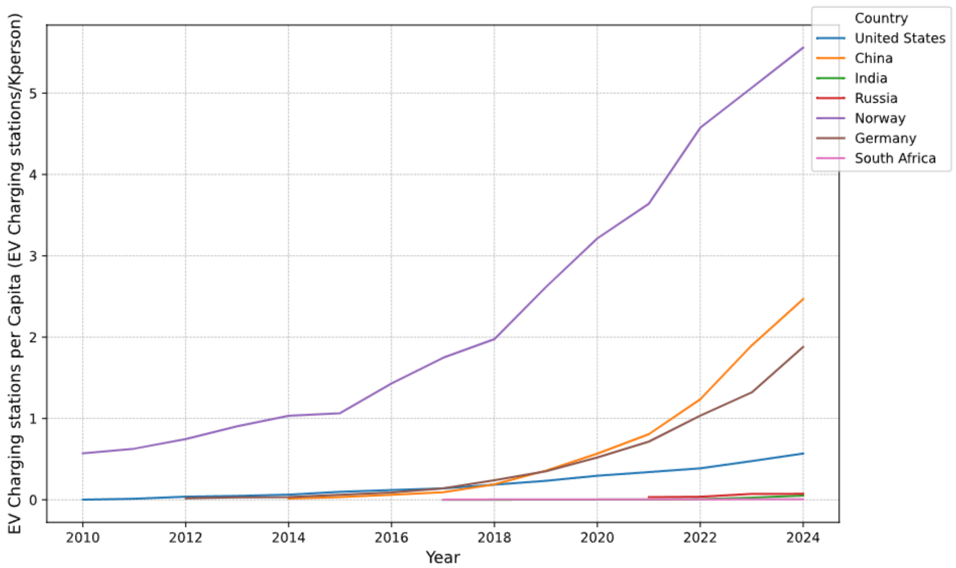

Figure 14: Public charging points per capita

- **Further Innovations to Monitor:**

Achieving carbon neutrality requires new technologies like smart grids, advanced carbon capture and storage (CCS) systems, and robust energy storage utilities. However, data gaps hinder their full potential.

Smart Grids: These intelligent networks enhance efficiency and integrate renewables, but their true impact is hard to quantify due to a lack of standardized public data on resilience, energy losses, and carbon footprint reduction. This impedes understanding ROI and identifying improvements.

Advanced Carbon Capture and Storage (CCS) Systems: Crucial for decarbonizing heavy industry and power generation, CCS effectiveness and viability are debated due to limited public data on capture rates, energy penalties, and long-term storage security. Transparency is vital for trust, investment, and scaling.

Large Scale Energy Storage Utilities: Essential for balancing intermittent renewables and ensuring grid stability, these utilities lack comprehensive real-world performance metrics, lifecycle costs, and demonstrable impact data. This makes comparisons, optimization, and forecasting challenging.

Due to the absence of comprehensive, reliable, and standardized data for smart grids, Carbon Capture and Storage (CCS), and energy storage, these areas could not be incorporated into the composition. We will persist in monitoring data availability to facilitate informed decision-making and expedite the shift towards a sustainable future.

2.3 Energy Transition Score Calculation

The Energy Transition Score (ETS) is determined by a weighted sum of indicator scores, with each score ranging from 0 to 100. A score of 100 represents the highest performance among countries, while 0 denotes the lowest. The assigned weights are arbitrary but reflect the perceived significance of each component in the overall energy transition. Users have the flexibility to adjust these weights to calculate new scores based on their specific priorities. Table 2 provides a summary of the chosen indicators and their corresponding weights.

Beyond a static view of a country's energy system, Trend Scores offer crucial insights into the direction and velocity of change over time. For long-term goals like carbon neutrality, the momentum of transition—whether a country is rapidly improving, stagnating, or regressing—is often more indicative than its current state. These trend scores are vital for identifying countries actively accelerating their transition efforts and achieving tangible progress.

This framework, which emphasizes both current performance and the trajectory of change, enables a more nuanced and forward-looking assessment of national energy transitions. This multi-dimensional approach balances environmental goals with economic realities and social imperatives, highlighting the inherent complexities countries must navigate.

Table 2: Selected Indicators and Their Weights

Category	weight	Indicators	weight
Greenhouse Gas Emissions	30%	GHG Emissions per Capita	20%
		GHG Emissions per Capita Trend	10%
Clean Electricity Capacity	30%	Clean Electricity Capacity per Capita	20%
		Clean Electricity Capacity per Capita Trend	10%
Fossil Fuel Production	20%	Fossil Fuel Production per Capita	13.3333%
		Fossil Fuel Production per Capita Trend	6.66666%
Infrastructure & Innovation	20%	Energy Efficiency	5%
		Electricity distribution efficiency A	5%
		Access to Electricity	5%
		Clean Cooking	5%

3. Global Energy Transition Score Country Rankings

Figure 15 displays the ETS country rankings, providing a quantitative overview of global energy transition efforts. A comprehensive analysis of these scores highlights a wide range of national performance, reflecting the varied pace of progress and the distinct challenges and opportunities each country faces. This diversity underscores the complex nature of the energy transition, as every nation navigates its unique geopolitical, economic, and resource landscapes.

A significant global disparity in scores is evident, ranging from the lowest to the highest. Mongolia, with a score of 31, is at the lower end, indicating substantial obstacles or early stages in its energy transition. Conversely, Sweden leads with an impressive score of 78.9, demonstrating advanced progress and successful implementation of sustainable energy policies and technologies. This considerable gap not only highlights the differing capacities and priorities among nations but also suggests opportunities for knowledge exchange and collaborative initiatives to accelerate progress in less developed countries. These scores are crucial for policymakers, researchers, and international organizations to identify successful areas and those requiring more focused attention and investment.

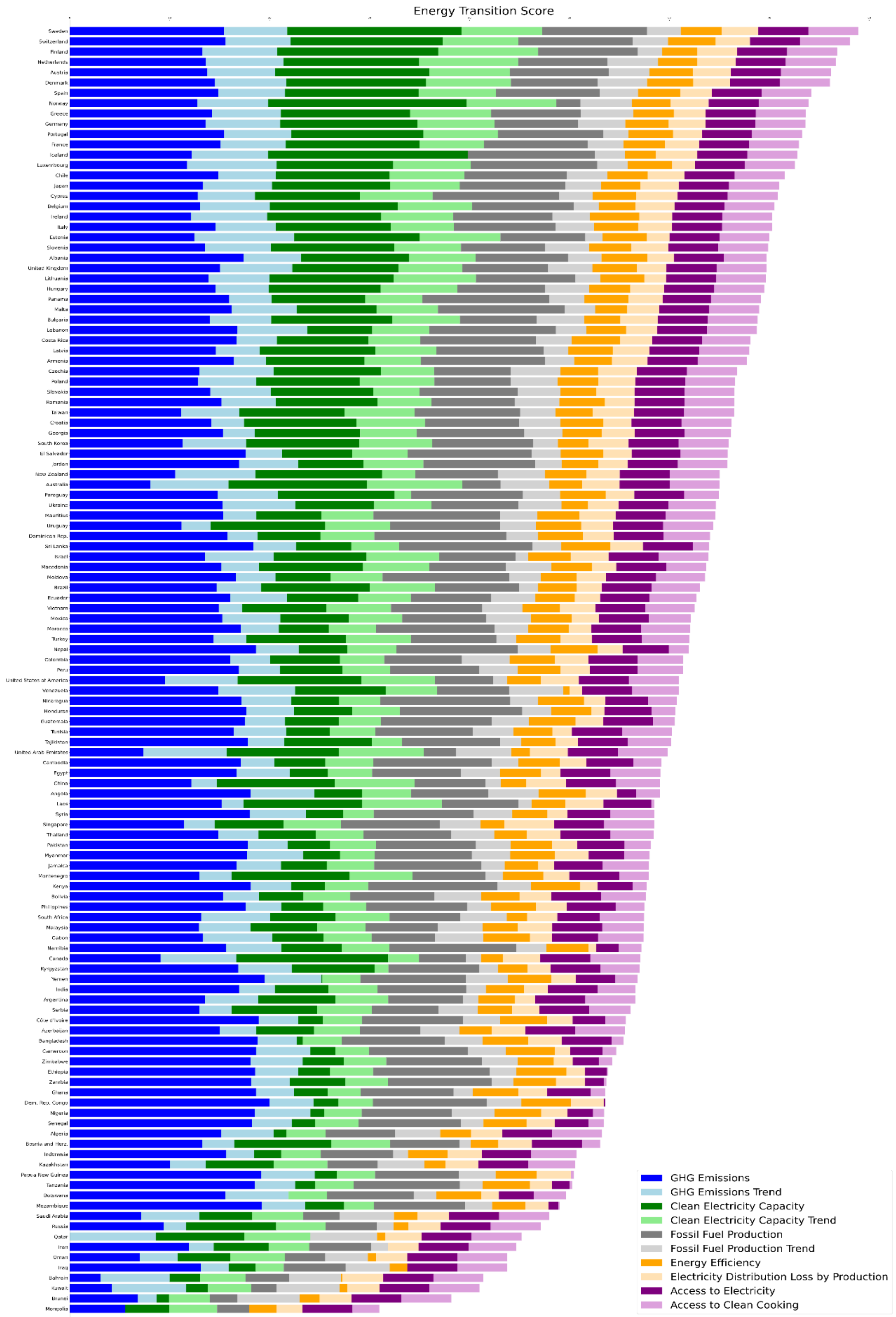

Figure 15: Global Snapshot of Energy Transition

Leaders and Laggards in Energy Transition

The Energy Transition Score (ETS) reveals a deeply fragmented global landscape. Top-performing nations, primarily European countries such as Sweden, Finland, and the Netherlands, owe their success to robust policy frameworks, significant investment in renewable energy and efficiency, stable regulatory environments, and a strong societal commitment to sustainability. Their progress is built on decades of consistent energy policy, early adoption of clean technologies, and integration into interconnected energy markets that help balance variable renewable sources.

In stark contrast, countries at the lower end of the ETS spectrum, including Mongolia, Brunei, and several Middle Eastern and Asian nations, face numerous challenges. These often include heavy economic reliance on fossil fuels, underdeveloped clean energy infrastructure, limited financial capacity for transition investments, political instability, or governance issues hindering effective policy implementation. For these nations, the energy transition necessitates a fundamental economic restructuring, a far more complex undertaking than for countries with diversified economies.

The substantial gap between the highest and lowest scores is a critical concern, as the failure of many countries to accelerate their transitions could jeopardize global climate targets, regardless of the progress made by leading nations. The overall global effort appears imbalanced: while some areas, like renewable technology deployment, are advancing due to favorable economics, other critical areas, such as the comprehensive phase-out of fossil fuels or deep, economy-wide greenhouse gas (GHG) emission reductions, are lagging. This suggests that the current global average score, while indicative, may conceal deeper, systemic challenges in achieving a truly comprehensive and equitable energy transition.

Table 3: Top 5 and bottom 5 Countries by ETS Scores

Section	**Top 5 countries**	**Bottom 5 countries**
Overall ETS	Sweden, Switzerland, Finland, Netherlands, Austria	Mongolia, Brunei, Kuwait, Bahrain, Iraq
GHG Emissions	Dem. Rep. Congo, Yemen, Mozambique, Papua New Guinea, Côte d'Ivoire	Qatar, Bahrain, Kuwait, Mongolia, Brunei
GHG Emissions Trend	Estonia, Luxembourg, Qatar, United Arab Emirates, New Zealand	Mongolia, Brunei, Laos, Russia, Vietnam
Clean Electricity Capacity	Iceland, Norway, Sweden, Finland, Austria	Botswana, Yemen, Bangladesh, Brunei, Algeria
Clean Electricity Capacity Trend	Finland, Netherlands, Australia, Norway, United Arab Emirates	Iceland, Kyrgyzstan, Paraguay, Iraq, Mozambique

Fossil Fuel Production	Sri Lanka, Dominican Rep., Nicaragua, Kenya, Cyprus	Qatar, Norway, Kuwait, Brunei, Mongolia
Fossil Fuel Production Trend	Qatar, Kuwait, Brunei, United Arab Emirates, Venezuela	Mongolia, Bosnia and Herz., Israel, Laos, United States of America
Energy Efficiency	Ethiopia, Dem. Rep. Congo, Ireland, Sri Lanka, Kenya	Iran, Bahrain, Venezuela, Kuwait, Qatar
Electricity Distribution Loss	Singapore, Iceland, Cyprus, Taiwan, Bahrain	Iraq, Namibia, Venezuela, Honduras, Cameroon
Access to Electricity	Most of the countries are at 100%	Papua New Guinea, Dem. Rep. Congo, Mozambique, Tanzania, Angola
Access to Clean Cooking	Most of the countries are at 100%	Dem. Rep. Congo, Ethiopia, Mozambique, Zambia, Tanzania

Spotlight on Notable Performances

Examining individual country performances provides valuable insights beyond broad global averages. Top-performing Energy Transition Score (ETS) countries like Sweden and Finland typically demonstrate strong scores across multiple sub-indices, including high clean electricity capacity, robust emission reduction trends, and high energy efficiency. In contrast, nations such as Qatar and Kuwait, despite high income levels, exhibit low overall ET scores. This is primarily due to extremely high per capita greenhouse gas (GHG) emissions and a continued heavy reliance on fossil fuel production, even as they begin to invest in clean energy. Their trend scores in these crucial areas would reveal the genuine commitment and pace of their transition.

The data indicates that achieving carbon neutrality demands a balanced and accelerated effort across all ETS dimensions. Success in a single area, such as renewable deployment, is insufficient without accompanying progress in emissions reduction, fossil fuel phase-out, and energy efficiency.

These variations underscore that a universal approach to energy transition is impractical. Policy interventions and investment strategies must be customized to specific regional contexts, resource availability, economic structures, and developmental priorities. While some regions are advancing in clean technology deployment, the data suggests that the global challenge of simultaneously phasing out fossil fuels and achieving deep, economy-wide decarbonization remains immense across all regions.

3.1 Energy Transition scores by Regions

Europe and Central Asia lead in Energy Transition, primarily due to early climate policy adoption, substantial renewable energy investments (average Clean Electricity Capacity Trend Score of 6.10), and robust regulatory frameworks, especially within the European Union. This region also demonstrates strong trends in clean electricity capacity addition and GHG emissions reduction. However, progress in phasing out fossil fuel production, particularly natural gas and coal, has been slower due to the complexities of transitioning from established industries.

North America follows with an average score of 59.0, driven by significant renewable energy growth and improving GHG emission trends. While showcasing strong trends in both GHG emissions reduction and clean electricity capacity, the region's lower average in fossil fuel production trend indicates ongoing significant production, highlighting an area for accelerated transition.

Other regions, such as Sub-Saharan Africa (average ETS 54.9) and the Middle East and North Africa (average ETS 53.9), exhibit lower overall scores. These figures, however, mask considerable internal diversity and specific challenges.

Regional Overviews:

- **East Asia and Pacific:** Heavily influenced by large economies like China, this region shows a strong trend in adding clean electricity capacity (average 5.68), with China being a major global renewable energy investor. Despite this, immense energy demand from manufacturing and growing populations leads to more modest GHG emission improvements and continued significant fossil fuel production and consumption.
- **Middle East and North Africa:** This region presents a dichotomy. While there's growing investment and potential in solar energy (Clean Electricity Capacity Trend score of 5.50), its profound economic reliance on oil and gas exports results in very low scores for reducing fossil fuel production (Fossil Fuel Production Trend score of 4.23, implying a slower phase-out). Economic diversification remains an acute challenge for these petrostates.
- **Sub-Saharan Africa:** Often starting with lower existing clean energy infrastructure (Clean Electricity Capacity Trend average of 3.59), many countries show potential for high energy efficiency gains and are increasingly targets for decentralized renewable energy projects to improve "Access to Electricity." The low Fossil Fuel Production Trend score (2.48) suggests a different transition pathway, as many nations are not historically large producers, even if some are emerging as new producers.
- **Latin America and Caribbean:** This region benefits from significant hydropower resources and growing solar and wind deployment, reflected in a good Clean Electricity Capacity Trend score (5.18). Challenges persist in consistently reducing GHG emissions across all sectors and in managing fossil fuel production in its resource-rich countries.
- **South Asia:** Facing the dual challenge of rapidly growing energy demand and the need to transition to cleaner sources, this region shows moderate progress in adding clean electricity capacity but lags in GHG emission reduction trends and in moving away from fossil fuels, particularly coal in some major economies.

Table 4: Average ETS Score by World Bank Regions

World Bank Region	Average ETS Score	Number of Countries
Europe and Central Asia	67.7	46
North America	59.0	2
Latin America and Caribbean	62.8	19
East Asia and Pacific	57.4	18
Middle East and North Africa	53.9	17
South Asia	59.2	5
Sub-Saharan Africa	54.9	18

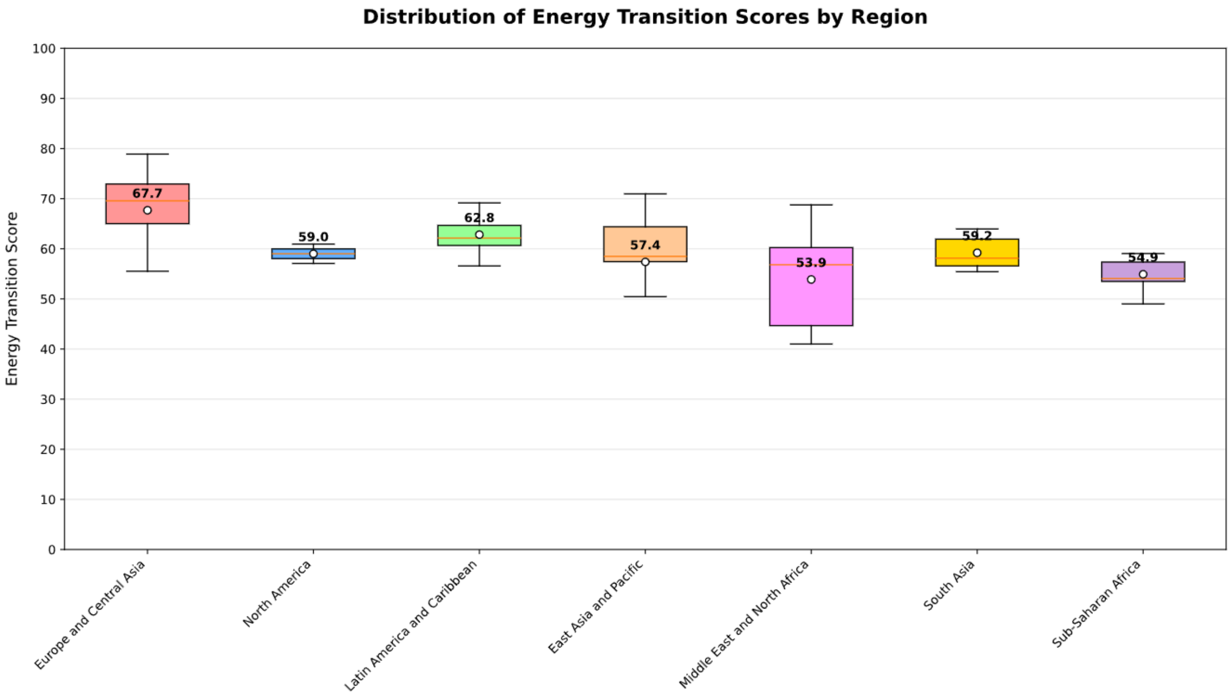

Figure 16: ETS scores by Region

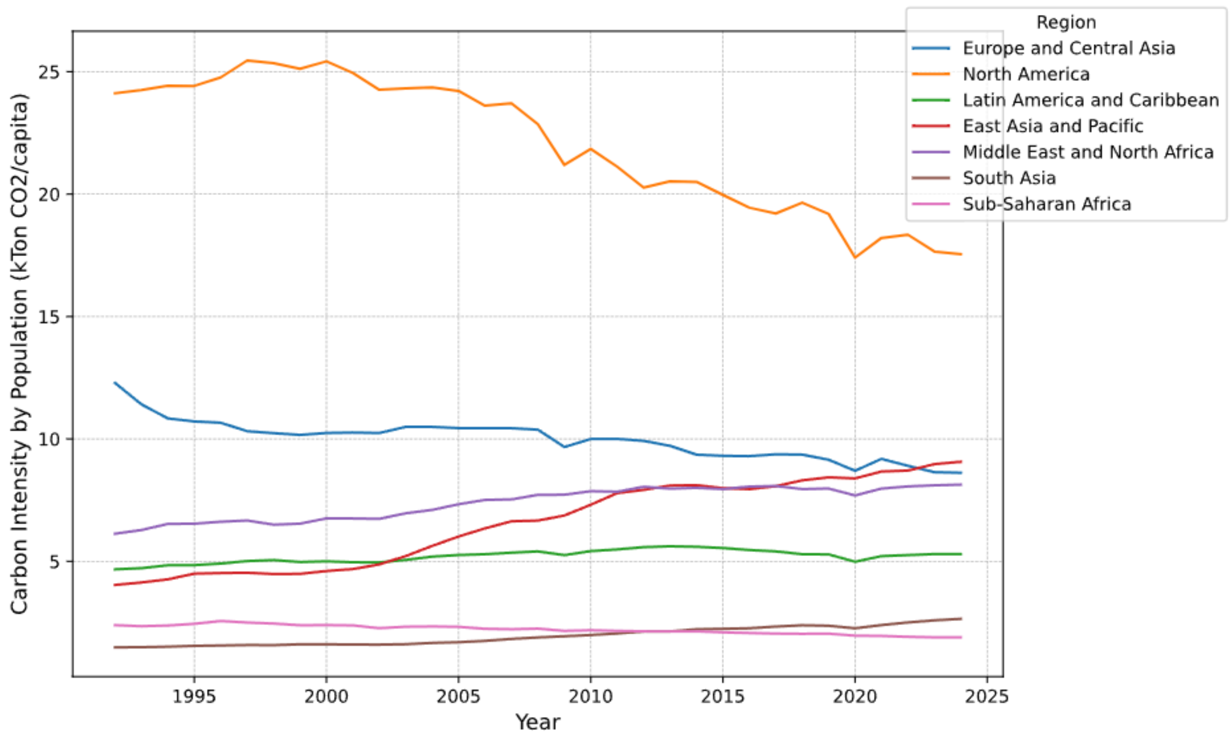

Figure 17: GHG emissions per Capita by regions

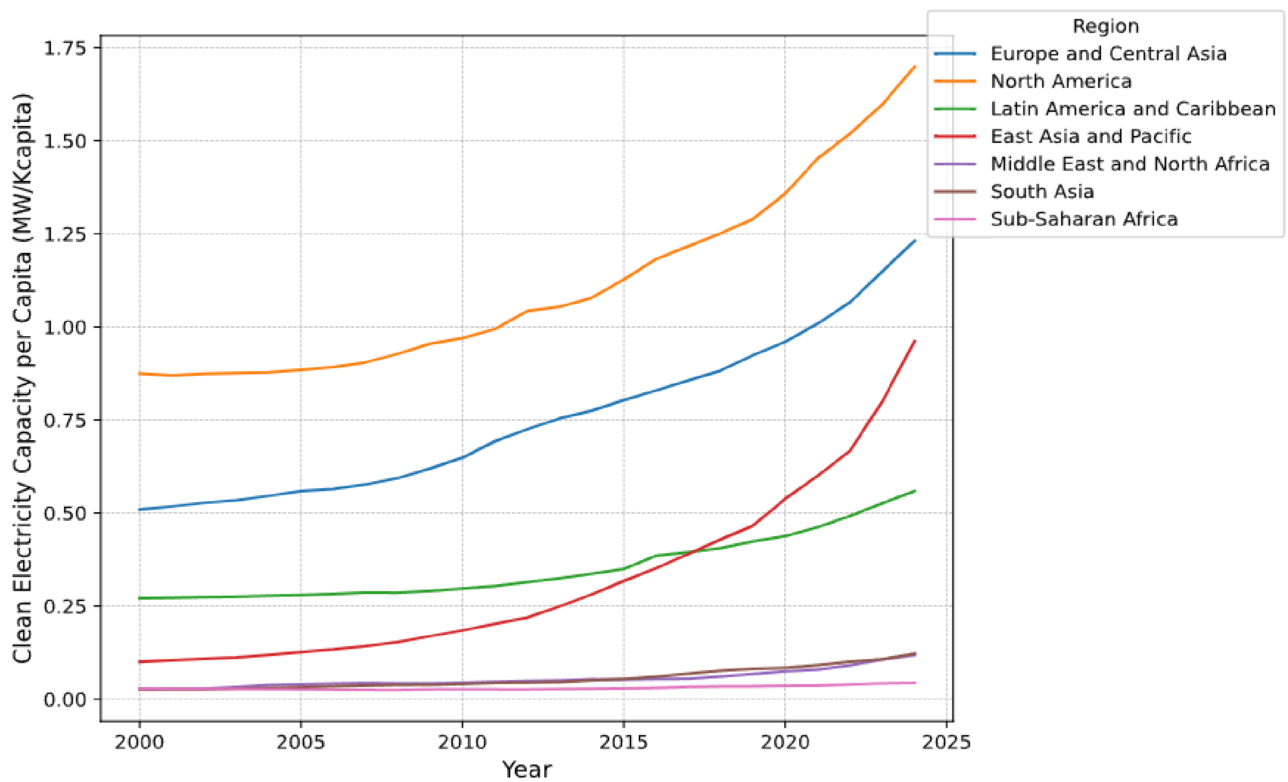

Figure 18: Clean Electricity Capacity Per Capita by regions

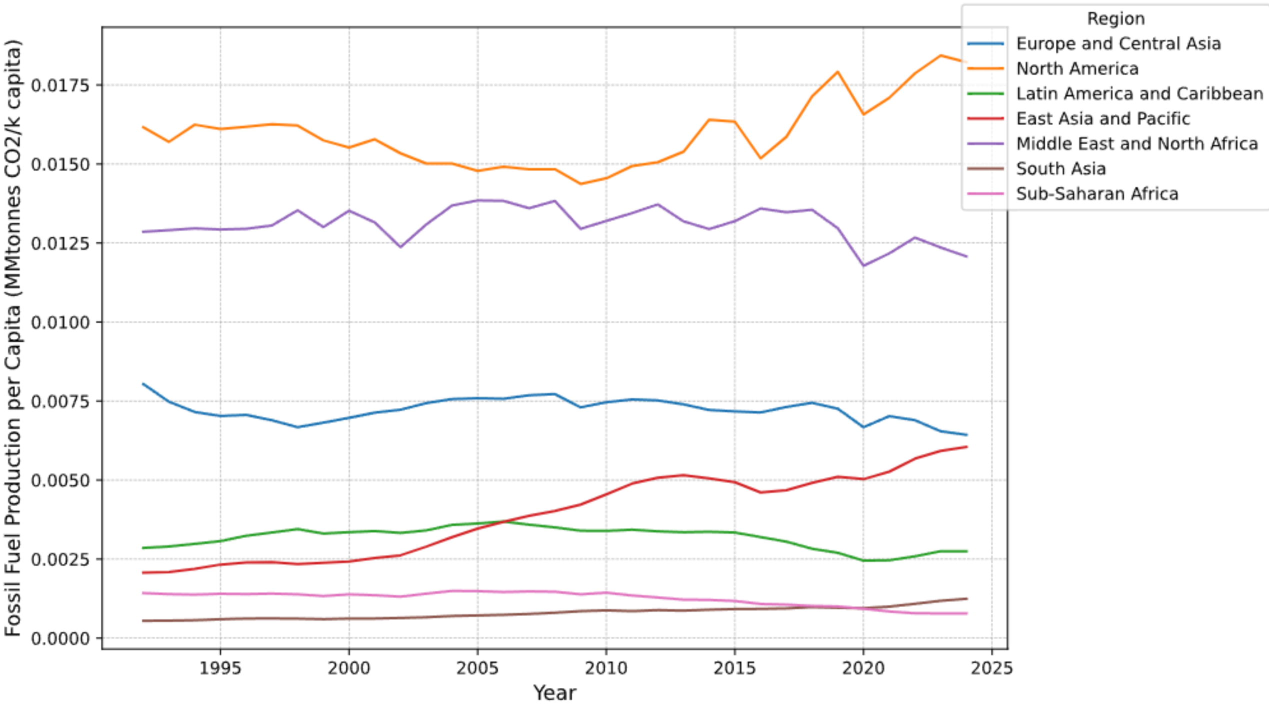

Figure 19: Fossil Fuel Production per Capita by regions

3.2 Energy Transition scores by Income groups

The World Bank Group categorizes global economies into four income brackets—low, lower-middle, upper-middle, and high—based on Gross National Income (GNI) per capita.

Analysis of Energy Transition Score (ETS) scores reveals a strong correlation between income levels and energy transition performance. High-income countries consistently achieve higher ETS scores, with Nordic nations frequently leading. Sweden, Finland, Denmark, the Netherlands, and Switzerland top the ETS rankings, showcasing how economic development facilitates comprehensive energy transitions. These countries benefit from robust institutional frameworks, advanced infrastructure, high innovation levels, and significant financial commitment to clean energy.

Upper-middle-income countries exhibit more varied performance. While often demonstrating strong policy commitment and significant investments in renewable energy infrastructure, they frequently encounter challenges related to energy equity and phasing out existing fossil fuel assets. Lower-middle-income countries often contend with infrastructure bottlenecks, rapid consumption growth, and limited investment capacity, despite making progress in areas like energy access and renewable energy deployment.

Low-income countries face the most substantial energy transition challenges, typically scoring poorly in clean energy development and infrastructure. They are constrained by limited financial resources, institutional capacity gaps, and pressing energy access issues. Many prioritize expanding basic energy access over transitioning to sustainable systems, though some are simultaneously addressing both objectives through decentralized renewable energy solutions.

Table 5: Average ETS Score by World Bank Income groups

Income groups	Average ETS Score	Number of Countries
High Income	66.2	48
Upper Middle Income	59.7	39
Lower Middle Income	56.8	30
Low Income	55.5	8

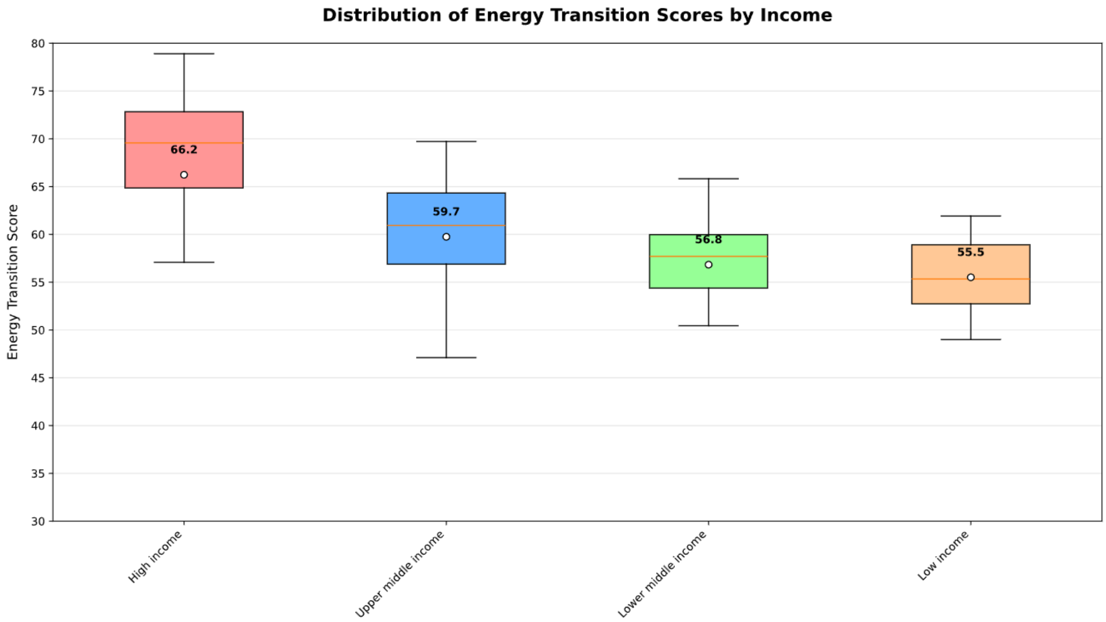

Figure 20: ETS scores by Income groups

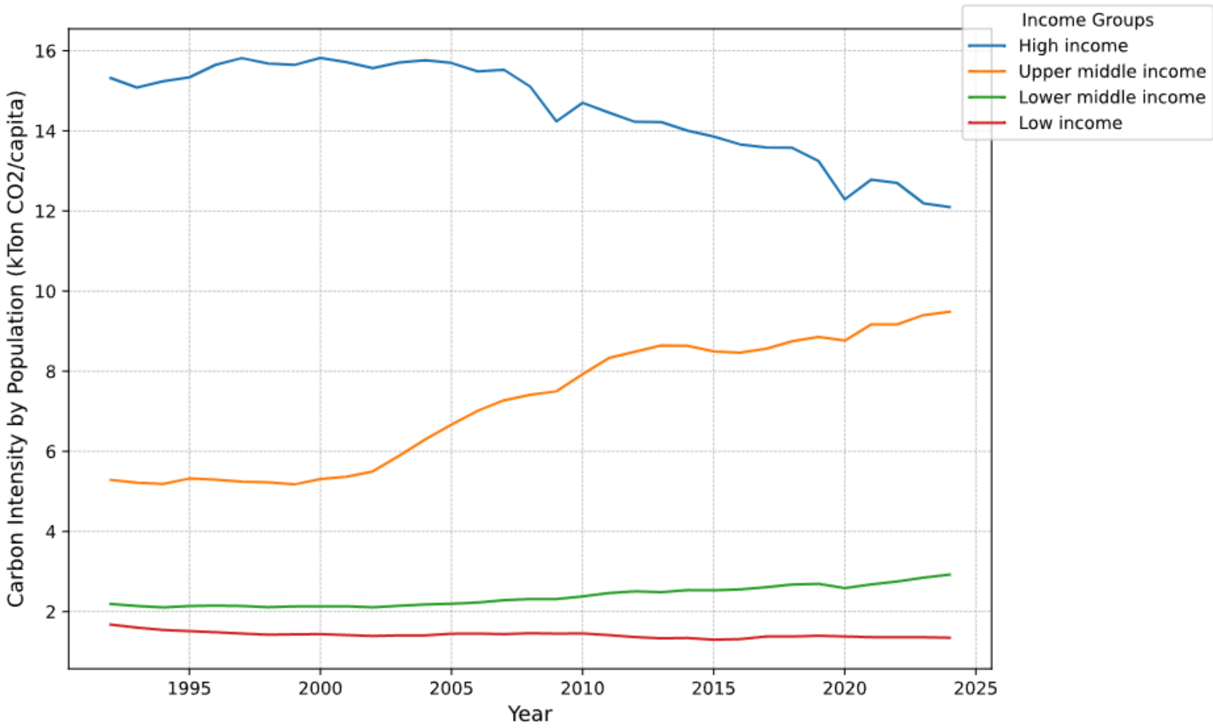

Figure 21: GHG emissions per Capita by Income groups

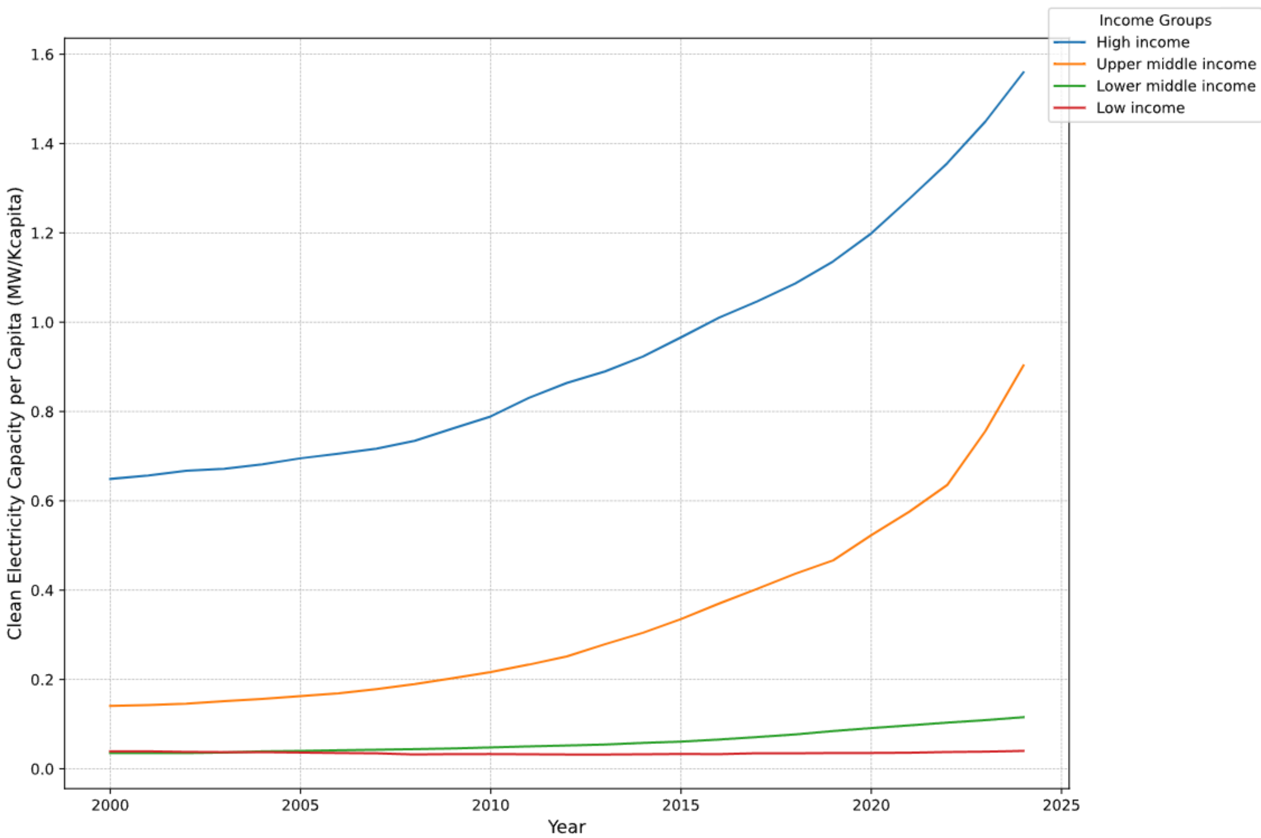

Figure 22: Clean Electricity Capacity Per Capita by Income groups

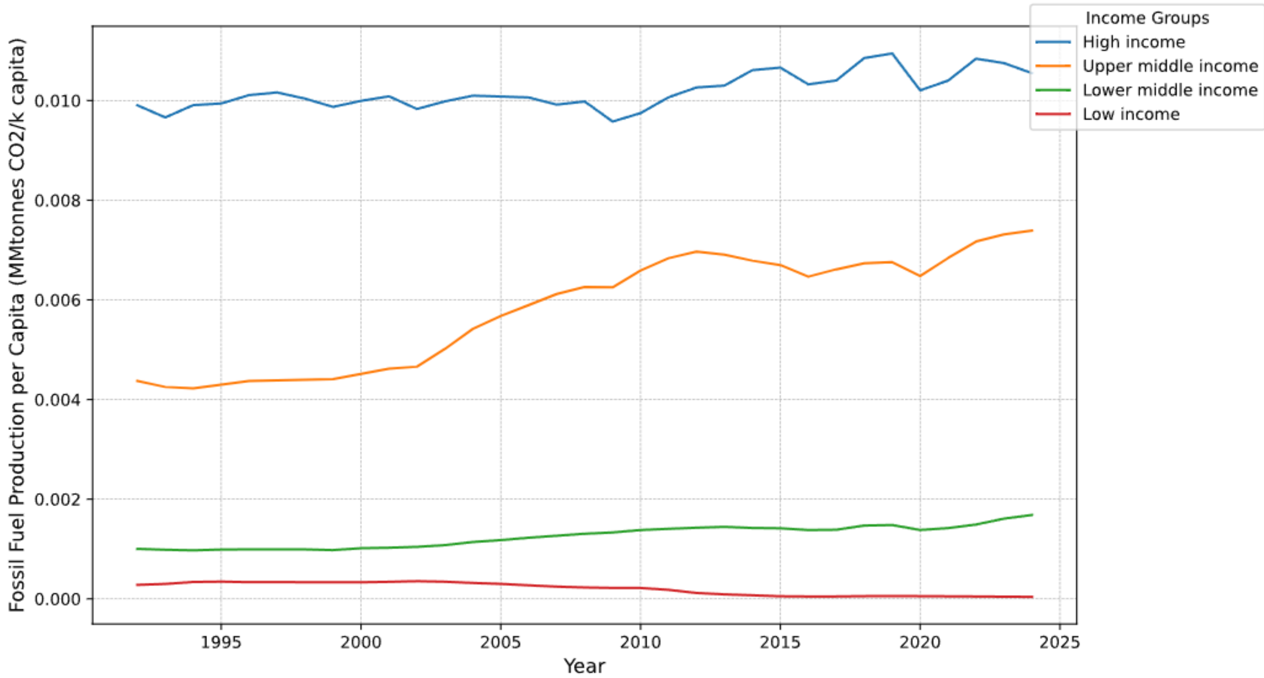

Figure 23: Fossil Fuel Production per Capita by Income groups

4. Energy Transition Insights

4.1 Operation Efficiency in Electricity Production

This section examines the operational efficiency of diverse electricity sources, including the variability inherent in renewable sources like solar and wind, alongside the characteristics of conventional power plants. The goal is to provide a nuanced understanding of each source's operational strengths and weaknesses to inform policy and investment for a resilient, sustainable energy infrastructure.

4.1.1 Electricity Capacity and Generation

Figures 24-28 illustrate the relationship between installed electricity capacity and actual electricity generation for solar, wind, hydro, nuclear, and fossil fuel power plants in 2023. Selected countries are annotated on the plots. China demonstrates leadership in electricity generation and capacity across most resources, with the exception of nuclear energy, where the USA leads.

A clear linear correlation exists between installed electricity capacity and actual electricity generation. However, in some countries, greater capacity does not always translate to higher electricity generation. Consequently, the slope serves as a valuable metric for assessing a country's operational efficiency for a given electricity source.

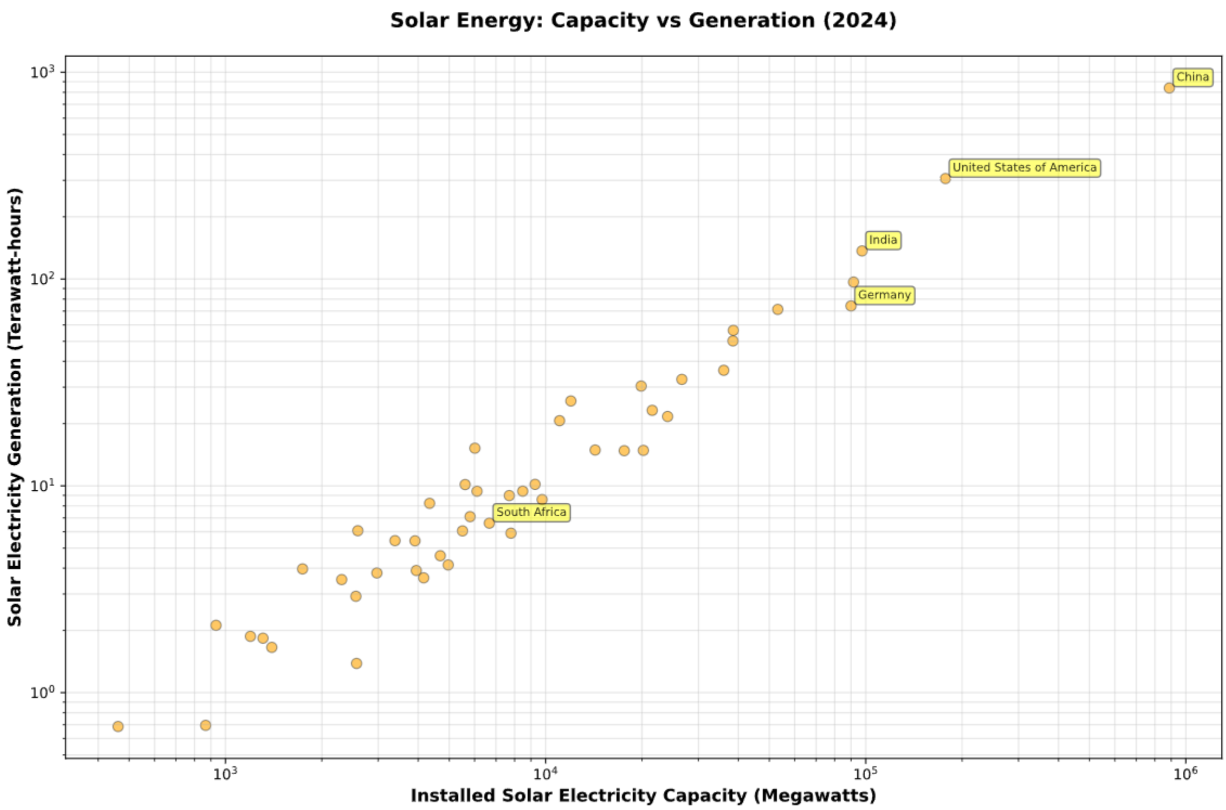

Figure 24: Comparison of installed solar electricity capacity and generation.

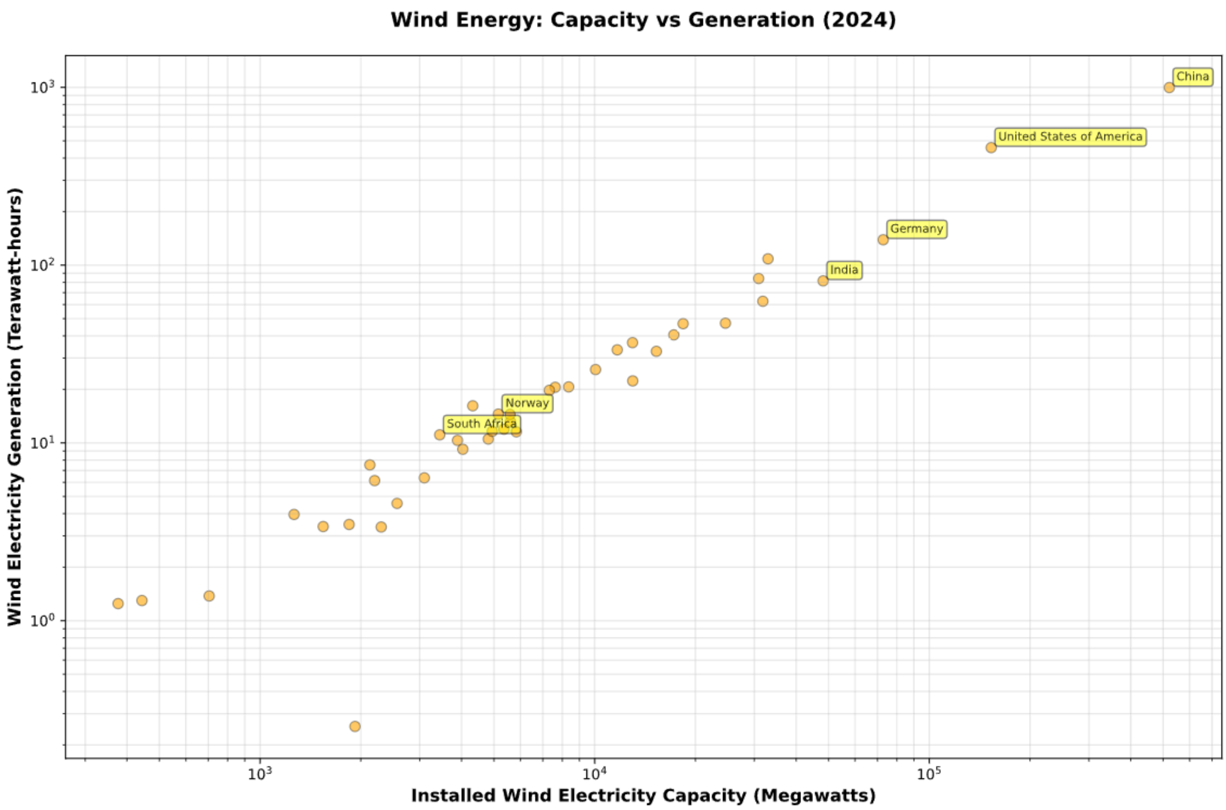

Figure 25: Comparison of installed wind electricity capacity and generation.

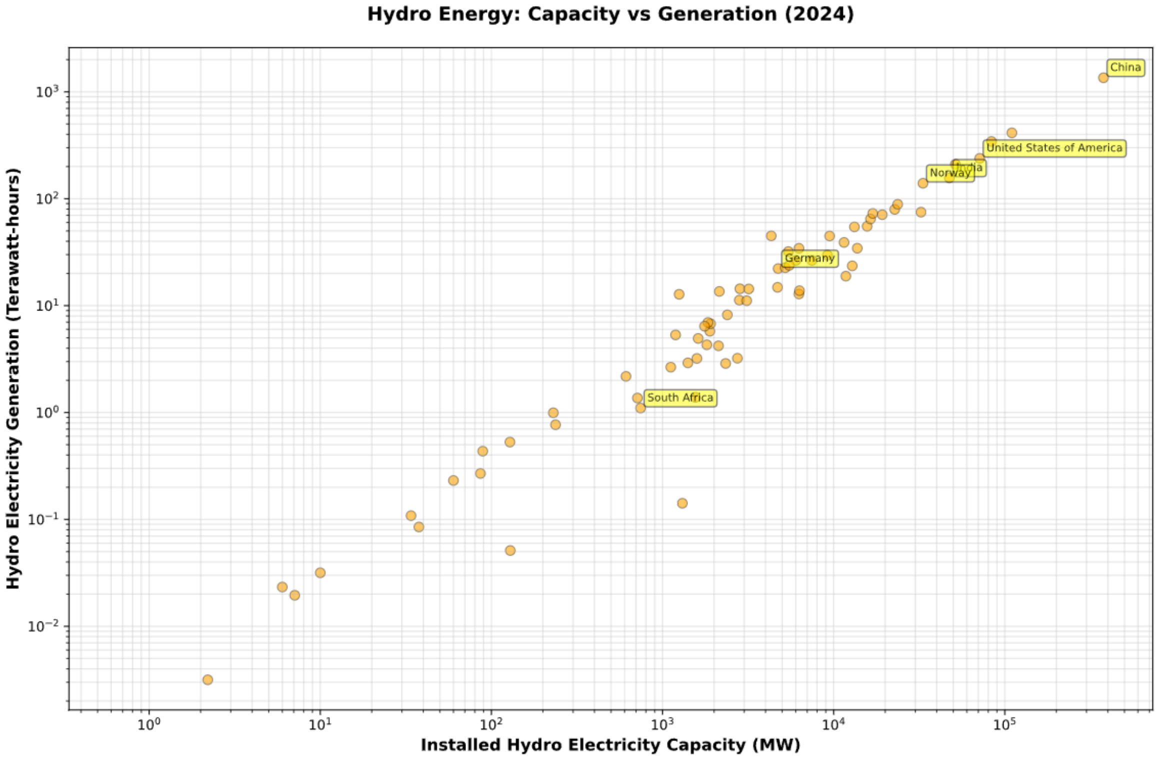

Figure 26: Comparison of installed hydro electricity capacity and generation.

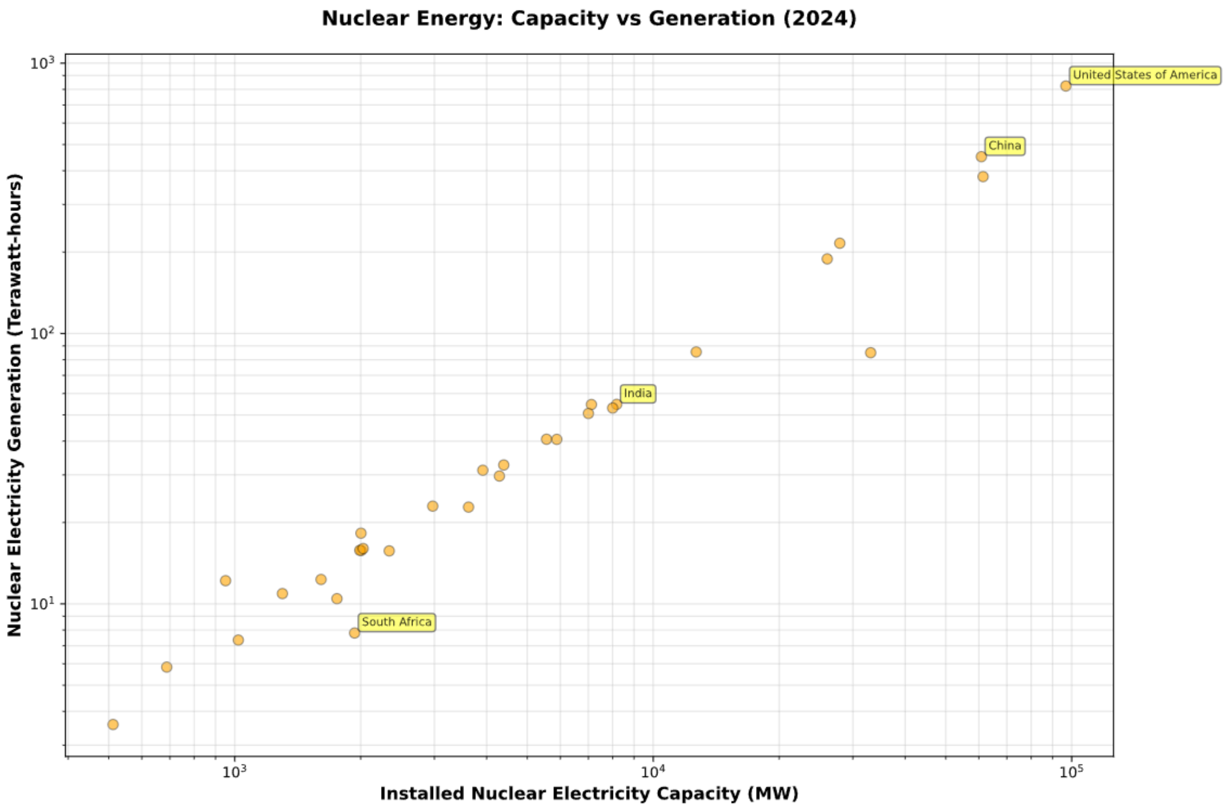

Figure 27: Comparison of installed nuclear electricity capacity and generation

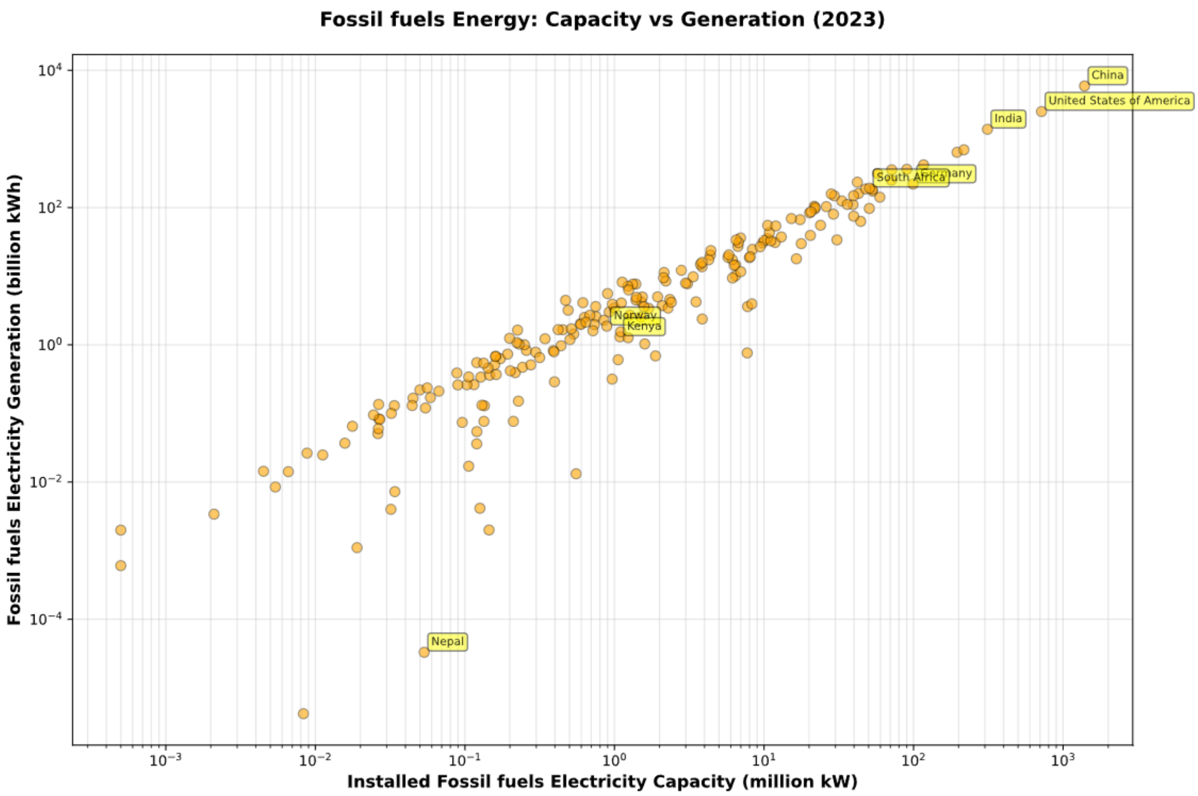

Figure 28: Comparison of installed fossil fuels electricity capacity and generation

4.1.2 Operation Efficiency in Electricity Production

To evaluate operational effectiveness, "Operation Efficiency" is introduced. This metric is determined by dividing total electricity generated by the installed capacity, multiplied by the number of hours in a year, reflecting a country's proficiency in operating its power plants.

$$Operation\ Efficiency = \frac{Electricity\ Generation}{Installed\ Electricity\ Capacity\ * 24 * Days\ of\ the\ Year}$$

Operational efficiency is influenced by various factors. Grid infrastructure, technical issues, and maintenance are significant, as are environmental elements like weather and geographical location for solar and wind power. Hydropower, on the other hand, is susceptible to rainfall levels and drought conditions.

Figure 29 illustrates the average operational efficiency of different global electricity generation sources (solar, wind, hydro, nuclear, and fossil fuels) from 2000 to 2024. Nuclear energy emerges as the most reliable and efficient source, with approximately 80% efficiency. Hydropower and fossil fuel power plants currently demonstrate reliable efficiency levels of 40% and 45%

respectively, though their trend is declining. In contrast, while wind and solar power show relatively lower efficiency, their operational efficiency is on an upward trend. This improvement is likely attributable to technological advancements and more efficient grid systems. The efficiency of wind power is highly dependent on the strategic placement of wind farms, whereas solar power efficiency is primarily determined by the duration of sunshine hours.

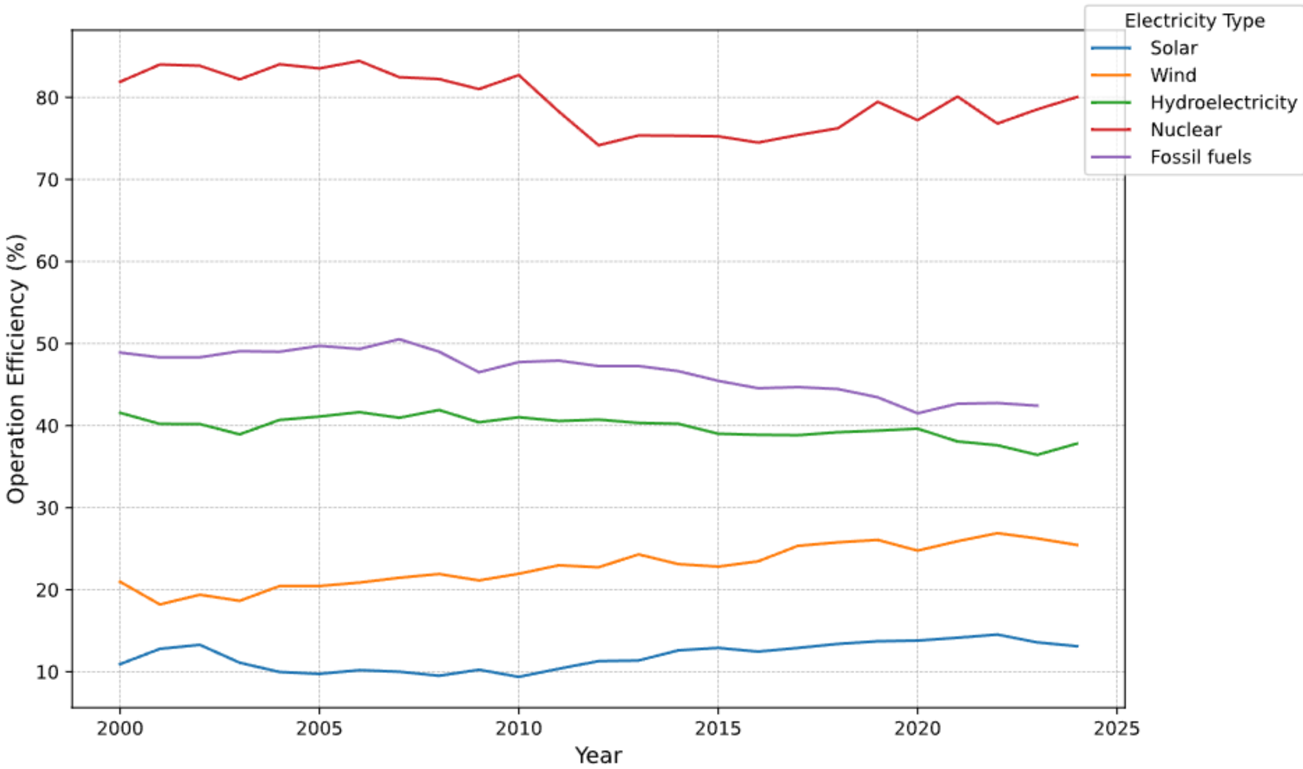

Figure 29: Average operational efficiency of electricity sources worldwide

4.1.3 Country Operational Efficiency

High operational efficiency in electricity production is paramount, especially within the context of the global energy transition. It underpins the successful shift to sustainable energy systems for several key reasons:

- **Maximizing Renewable Energy Output:** For intermittent sources like solar and wind, high operational efficiency ensures the maximum possible electricity is generated from installed capacity. This is vital for maintaining a reliable power supply and reducing reliance on fossil fuel backups.
- **Optimizing Resource Utilization:** Efficient operation ensures that significant capital investments in power generation infrastructure are fully utilized. This minimizes wasted capacity and enhances the return on investment for clean energy projects.
- **Reducing System Costs:** Efficiently operating power plants typically lead to lower per-unit operating costs. This contributes to stable and affordable electricity prices, which is essential for broad public acceptance and the economic viability of the energy transition.

- **Enhancing Grid Stability and Reliability:** High operational efficiency contributes to a more stable and reliable electricity grid. By maximizing predictable output and minimizing unexpected downtime, it helps to balance supply and demand, particularly as more variable renewable energy sources are integrated into the grid.
- **Accelerating Decarbonization:** Ultimately, higher operational efficiency of clean energy sources directly leads to greater displacement of fossil fuel generation. This accelerates the reduction of greenhouse gas emissions and brings countries closer to achieving their carbon neutrality targets.

To effectively compare operational efficiencies in solar, wind, and hydro power, our analysis focuses exclusively on countries with significant capacity in each respective sector. This approach ensures a fair comparison, accounting for diverse geographic characteristics and decision-making processes. Table 6 presents a critical analysis of renewable energy operational efficiency, highlighting both leading and lagging nations in solar, wind, and hydropower. A striking finding is the unexpectedly low efficiencies observed in several countries, a trend seemingly unrelated to their geographical features. This suggests that factors beyond natural resource availability, such as strategic investment and policy execution, are crucial determinants of a nation's renewable energy performance.

Table 6: Countries Ranked by Operational Efficiency

Section	Top countries	Bottom countries
Solar	United Arab Emirates, Egypt, Argentina, Morocco, Mexico, Saudi Arabia	Lithuania, Poland, Switzerland, Slovakia, Germany, Sweden
Wind	Argentina, Morocco, Iran, Brazil, New Zealand, United States of America	Ukraine, South Korea, India, Italy, Russia, Pakistan
Hydro	Switzerland, Ukraine, Iceland, Peru, Malaysia, Egypt	Morocco, Algeria, Iraq, Greece, Bulgaria, South Africa
Nuclear	Taiwan, Slovakia, United States of America, Slovenia, Romania	Japan, South Africa, Argentina, France, Pakistan, Ukraine

To address these inefficiencies and foster a more sustainable global energy landscape, underperforming nations must learn from top performers. A key strategy for improvement involves significantly prioritizing investment in research and innovation within the renewable energy sector. This includes funding for the development of advanced renewable energy technologies, optimizing existing systems, and exploring novel methods for energy generation, storage, and distribution. Furthermore, such investments should extend to fostering a skilled workforce capable of driving these advancements and implementing best practices. By focusing on these areas, lagging countries can bridge the efficiency gap and contribute more effectively to global sustainability goals.

Analyzing operational efficiency, therefore, provides a deeper understanding of how effectively countries are converting their installed capacity into actual electricity, offering key insights into their technical capabilities and the effectiveness of their energy policies.

4.2 GDP Growth and GHG emissions

Figure 30 presents a crucial visual analysis of the global energy landscape in 2024, specifically illustrating the intricate correlation between a country's Gross Domestic Product (GDP) at power purchasing parity (PPP) and its corresponding greenhouse gas (GHG) emissions. This figure serves as a vital diagnostic tool, with the slope of the data points directly representing the energy efficiency of each nation. A steeper slope indicates lower energy efficiency, signifying that a country generates a greater amount of GHG emissions for every dollar of GDP produced. Conversely, a flatter slope suggests higher energy efficiency, where economic output is achieved with relatively fewer emissions. This comparative analysis allows for a nuanced understanding of how different economic structures and energy policies influence environmental impact.

Building upon this foundational understanding, Figure 31 delves deeper into the dynamics of economic growth and environmental change by comparing GDP growth with the corresponding changes in GHG emissions. The year 2024, in particular, witnessed a widespread trend: the majority of countries experienced a parallel increase in both their GDP and GHG emissions when compared to the preceding year, 2023. This often reflects a continued reliance on carbon-intensive industries and energy sources to fuel economic expansion.

However, Figure 31 also highlights several compelling exceptions to this general trend, offering valuable insights into alternative development pathways. For instance, the case of Kuwait stands out as a critical area for further investigation. Despite experiencing negative GDP growth, Kuwait surprisingly recorded an increase in its GHG emissions. This atypical pattern could indicate a number of underlying factors, such as a significant shift in industrial activity, a decline in energy efficiency, or the continued operation of highly polluting sectors even amidst economic contraction.

In stark contrast, countries like Norway and Nepal present optimistic models of sustainable development. These nations successfully achieved positive GDP growth while simultaneously demonstrating a reduction in their GHG emissions. Norway's success can often be attributed to its substantial investments in renewable energy sources, particularly hydropower, alongside robust carbon pricing mechanisms and a strong policy focus on green technologies. Nepal, while having a different economic structure, has also shown progress in decoupling economic growth from emissions, potentially through enhanced energy efficiency measures, increased adoption of clean cooking fuels, and forest conservation efforts.

Another noteworthy example is Estonia, which, despite experiencing a slight decrease in its GDP, managed to achieve a significant reduction in its GHG emissions, nearly dropping by 4.5 percent. This outcome suggests that even in periods of economic slowdown, deliberate policy choices and technological advancements can lead to substantial environmental improvements. Such a reduction could be the result of effective energy efficiency programs, a transition away from fossil fuels in certain sectors, or successful carbon sequestration initiatives.

Collectively, Figures 30 and 31 provide a comprehensive snapshot of global energy and economic trends in 2024. They underscore the urgent need for countries to prioritize policies that promote energy efficiency and accelerate the transition to cleaner energy sources. While economic growth has historically been intertwined with increased emissions, the examples of Norway, Nepal, and Estonia demonstrate that decoupling these two factors is not only possible but also crucial for achieving a sustainable future. The data presented in these figures serves as a critical benchmark for policymakers, researchers, and international organizations as they work towards mitigating climate change and fostering sustainable economic development worldwide.

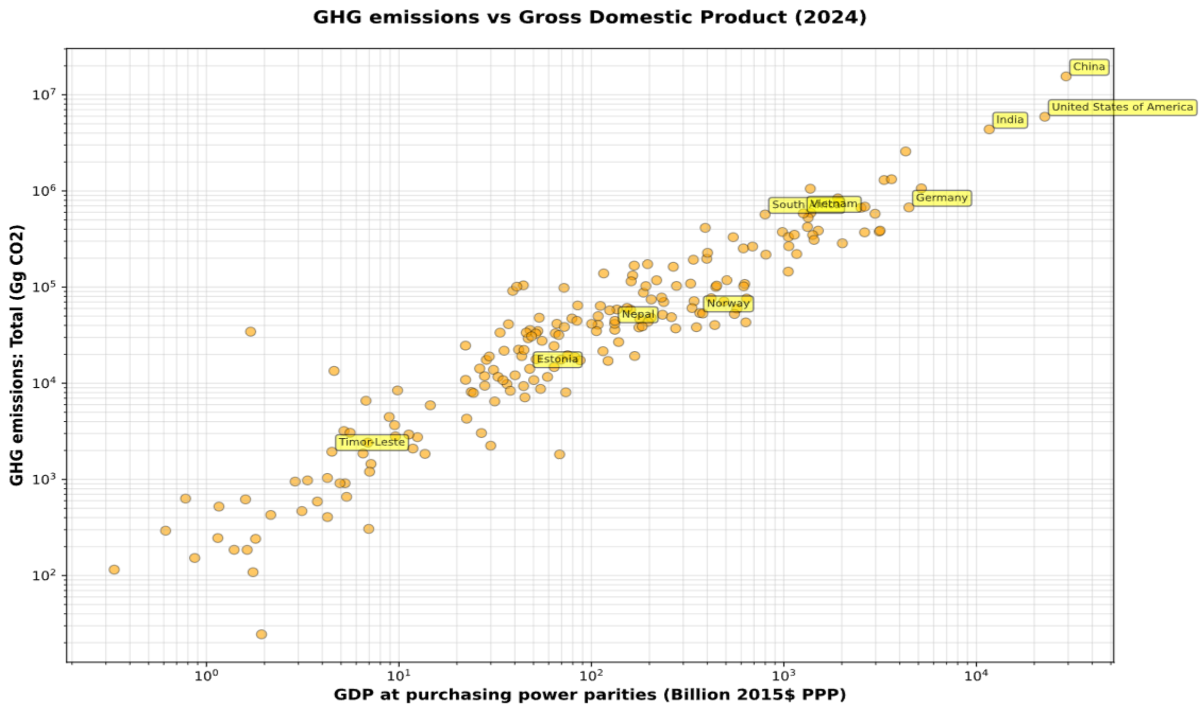

Figure 30: Gross Domestic Product and GHG emissions

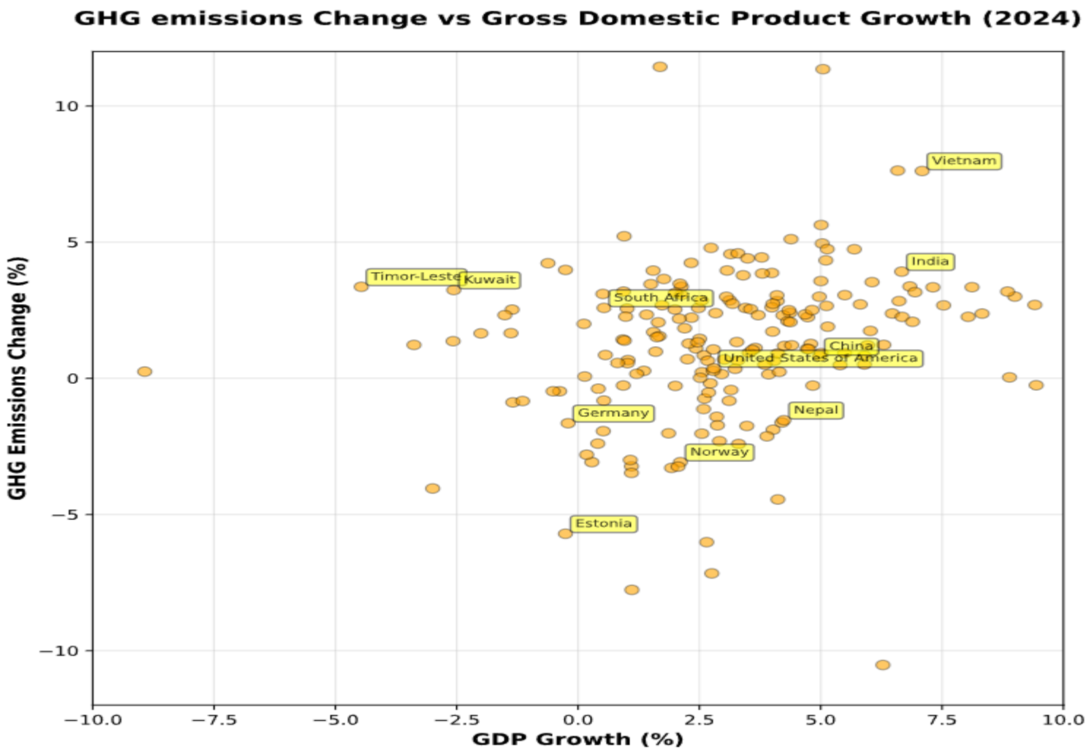

Figure 31: GDP Growth and GHG emissions

4.3 International Aviation and Shipping: GHG Emissions

Greenhouse gas (GHG) emissions from international aviation and shipping represent a growing challenge in the global effort to mitigate climate change. As illustrated in Figure 32, these sectors contribute an increasingly significant portion of global emissions. Figure 33 further details this, showcasing the percentage share of these emissions within the total global GHG output.

Examining the trend over time, a general increase in emissions from both international aviation and shipping is evident. The most notable exception to this upward trajectory occurred during the COVID-19 pandemic years. This period saw a substantial reduction in international aviation emissions, directly attributable to the sharp decline in air travel due to lockdowns and travel restrictions. Shipping emissions also experienced a drop, albeit a smaller one, reflecting the impact of disruptions to global supply chains and trade volumes.

The strong correlation between activity levels and emissions in these sectors is clear. Specifically, emissions from international aviation are closely tied to the number of international flight passengers, as demonstrated in Figure 34. Similarly, emissions from international shipping show a direct relationship with the world's seaborne trade volume, a correlation highlighted in Figure 35. These relationships underscore the difficulty in decoupling economic activity and global connectivity from the emissions generated by these vital sectors. Addressing these emissions will require a combination of technological advancements, operational efficiencies, and policy frameworks that promote sustainable alternatives without hindering global commerce and mobility.

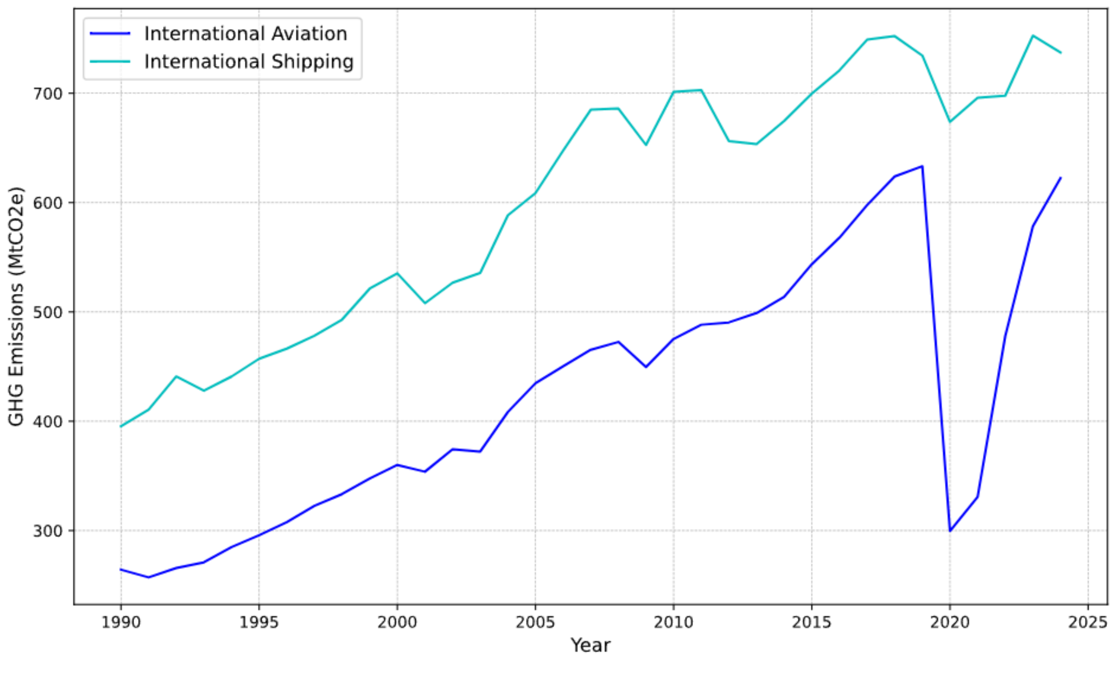

Figure 32: International Aviation and Shipping Emissions

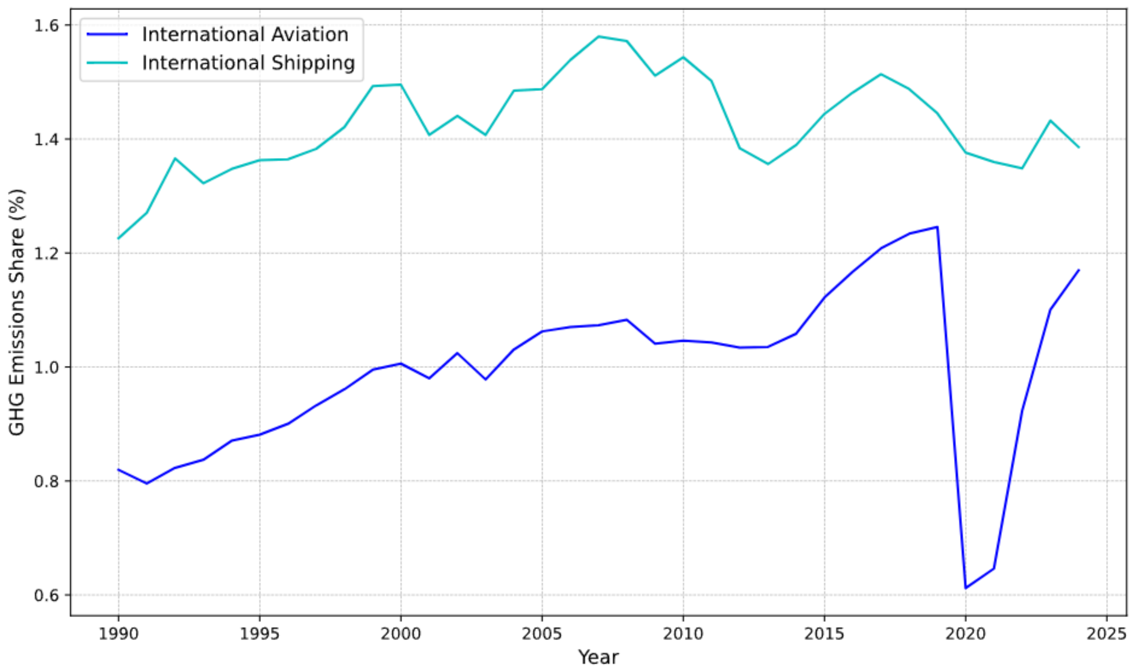

Figure 33: International Aviation and Shipping Emission share

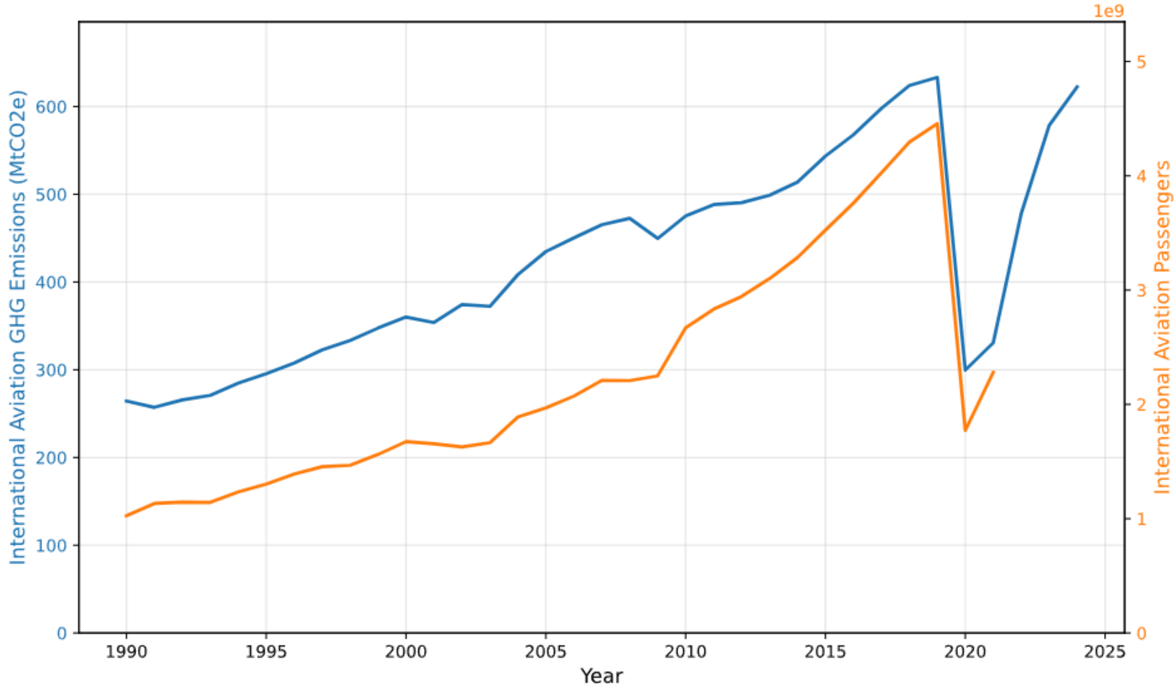

Figure 34: International Aviation Emission and Passengers

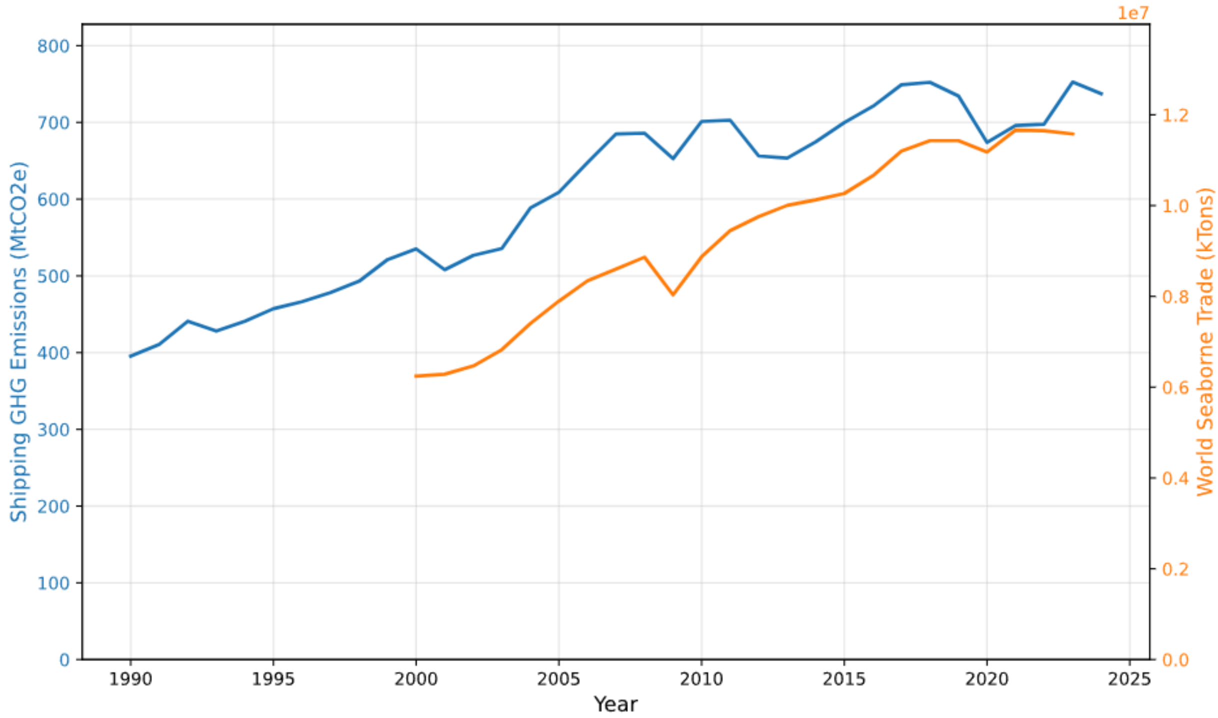

Figure 35: International Shipping Emission and World Seaborne Trade Volumes

5. Looking Ahead

The global energy transition stands at a critical juncture, marked by both notable advancements and significant obstacles. An assessment of its current trajectory, drawing on Energy Transition Score (ETS) findings and broader energy market analyses, offers a crucial yet sobering perspective on the likelihood of achieving long-term climate objectives.

Current Trajectory and Global Targets

ETS data and recent expert assessments indicate that despite substantial investments and progress in clean energy technologies, the world's current path is likely insufficient to meet the ambitious targets of the Paris Agreement, such as limiting global warming to 1.5 °C or achieving net-zero emissions by 2050. Reports suggest that reaching net-zero by 2050 is now considered "unlikely," and the 1.5 °C pathway is described as "very difficult." This highlights a significant disparity between aspirations and reality.

While global investment in the low-carbon energy transition reached a record $2.1 trillion in 2024, driven by electrified transport, renewable energy, and power grids, its growth rate has slowed compared to previous years. More critically, this investment level falls considerably short of the estimated $5.6 trillion annually required from 2025 to 2030 to align with a global net-zero by 2050 pathway. This financial deficit, compounded by continued reliance on fossil fuels, presents a major impediment.

Key Challenges on the Horizon

The energy transition faces several significant, interconnected challenges that could hinder its progress and widespread adoption:

- **Policy and Governance Instability:** Governments are increasingly prioritizing energy affordability and economic growth, sometimes at the expense of immediate sustainability goals. This leads to re-evaluation of energy strategies and climate policies, creating uncertainty due to shifting political priorities and short-term policy signals, which are insufficient for a stable, long-term transition.
- **Persistent Fossil Fuel Reliance:** Global demand for fossil fuels remains excessively high, posing a major obstacle to achieving climate targets. The economic and political complexities of phasing out these deeply embedded energy sources are substantial, particularly for nations heavily reliant on their production and existing infrastructure. Additionally, efforts to mitigate potent methane leaks from fossil fuel operations frequently fall short.
- **Disparities in Investment:** Beyond a general investment deficit, there's a significant imbalance in funding allocation between mature and emerging clean energy technologies. While established and commercially viable solutions like renewables and electric vehicles attract the majority of investment, critical nascent technologies such as clean hydrogen, carbon capture and storage (CCS), and sustainable aviation fuels struggle to secure adequate funding, experiencing a 23% drop in investment in 2024.
- **Supply Chain Vulnerabilities and Geopolitical Factors:** The concentration of clean energy technology manufacturing, such as solar panels and batteries, in a limited number of countries (primarily China) introduces considerable supply chain risks and geopolitical challenges. Western economies seeking to reduce this dependence and develop domestic manufacturing capabilities face the need for substantial investment and strategic planning. The energy transition itself is evolving into a "multidimensional" process, with varying priorities and technological approaches across different regions.
- **Challenges in Large-Scale Technological Integration:** A major hurdle lies in transitioning emerging technologies from pilot and demonstration phases to widespread commercial deployment. This requires not only technological maturity but also the development of new infrastructure, effective market mechanisms, and supportive regulatory frameworks.
- **Inadequate Climate Adaptation and Resilience Planning:** Despite the escalating financial risks of climate change, projected to reach $25 trillion by 2050, a worrying minority of major companies (only 35%) have implemented climate adaptation plans. This highlights a significant lack of preparedness for the unavoidable impacts of climate change.

Emerging Opportunities and Enablers

Despite the challenges, several key opportunities and enabling factors can accelerate the energy transition:

- **Technological Advancements:** Continuous innovation is dramatically reducing the costs of clean energy technologies. For instance, solar PV costs decreased by 86% between 2010 and 2023. Significant progress is also evident in energy storage, smart grids, and the development of next-generation nuclear power and green hydrogen production.

- **Investment Momentum:** Despite a slowdown in growth, total investment in the energy transition has reached a record high, indicating a substantial market shift and increasing investor confidence in clean energy. Companies in the S&P 500, for example, have collectively reduced their carbon emissions by 62% over the last two decades, partly due to market forces favoring cleaner operations.
- **Market Forces:** Beyond regulatory mandates, growing investor interest in sustainability and rising consumer demand for clean energy are creating strong market incentives for the transition. Renewable solutions are increasingly seen as not just ethical choices but also sound financial investments.
- **Role of Artificial Intelligence (AI):** AI holds significant potential to transform the energy sector by optimizing production and distribution, improving supply chain efficiency, enhancing grid stability with high shares of renewables, and accelerating R&D for new clean energy solutions.
- **International Collaboration and Frameworks:** Global cooperation is crucial for sharing best practices, mobilizing finance, and ensuring an equitable transition. Initiatives like the World Bank's Energy Storage Partnership foster international collaboration. Additionally, well-designed indexes and benchmarks can guide investment and help market participants navigate the complexities of the transition.

Accelerating the Energy Transition: Key Strategic Imperatives

Achieving a successful energy transition requires a coordinated approach focused on several critical strategic imperatives:

1. **Robust Policy and Regulatory Frameworks:** Governments must establish clear, consistent, and ambitious long-term policies and regulations. These frameworks should incentivize clean energy investments by reducing risk and disincentivize emissions.
2. **Strategic Financial Mobilization and Allocation:** Bridging the investment gap necessitates a significant increase in capital from both public and private sectors. This funding must be strategically directed towards high-impact areas, including emerging technologies and infrastructure in developing economies.
3. **Driving Innovation and Swift Deployment:** Sustained support for research, development, and demonstration (RD&D) of next-generation clean technologies is essential. Simultaneously, policies must be in place to accelerate the adoption of proven clean energy solutions.
4. **Ensuring Social Equity:** A just transition involves proactively addressing the negative impacts on workers and communities currently dependent on fossil fuel industries. It also means guaranteeing equitable access to affordable, clean energy for all.
5. **Strengthening International Collaboration:** Enhanced cooperation is crucial for a truly global transition, particularly concerning technology transfer, financial assistance, and policy harmonization across nations.
6. **Adopting a Pragmatic and Balanced Approach:** The transition must carefully balance ambitious climate objectives with economic realities, energy security considerations, and the critical need for energy access, especially in developing

countries. This "pragmatic path forward" acknowledges and respects regional differences and priorities.

Despite record investment levels, the increasing difficulty in achieving 2050 net-zero targets suggests that financial flows, while vital, are not the sole determinant of success. Systemic barriers, inconsistent policies, the slow retirement of existing fossil fuel infrastructure, and insufficient funding for crucial emerging technologies are collectively hindering the necessary acceleration. While "pragmatism" acknowledges real-world complexities, it must not become an excuse to dilute ambition or delay essential but challenging actions. The future of the energy transition hinges on navigating these complexities with strategic foresight and unwavering commitment.

6. Energy Transition Case Studies

6.1 United States of America

Table 7 offers a comprehensive overview of the United States' energy transition performance, analyzed across several key sections. A notable finding from this assessment is the country's poor ranking in per capita Greenhouse Gas (GHG) emissions, a metric that typically reflects the environmental impact of individual citizens. However, this seemingly unfavorable position is juxtaposed with a positive trend in reducing these emissions, suggesting a movement in the right direction despite the current high levels.

This intriguing dichotomy can be largely attributed to the exceptional strides the United States has made in the development of clean electricity. The nation demonstrates strong performance both in its existing clean electricity capacity and, crucially, in the momentum of its expansion. This indicates a robust and accelerating commitment to decarbonizing the energy sector. The substantial investment and progress in renewable energy sources like solar, wind, and hydropower, as well as the continued operation of low-carbon nuclear power, are significant drivers of this positive trend. These efforts are actively contributing to a reduction in the carbon intensity of the electricity grid, thereby mitigating overall GHG emissions.

Further insight into these trends is provided by Figure 36, which visually depicts the trajectory of per capita GHG emissions alongside the growth of clean electricity capacity over an extended period. This figure traces these critical indicators from 2000 to 2024, allowing for a detailed examination of their interrelationship and the impact of clean electricity expansion on the nation's carbon footprint over more than three decades. The visual representation likely highlights periods of significant policy shifts, technological advancements, and economic changes that have influenced both emissions and clean energy adoption in the United States.

Table 7: The USA's Ranking in Energy Transition Sections.

ETS			Other Indicators		
Section	**Rank**		**Section**	**Rank**	
	2024	2023		2024	2023
Overall ETS Score	64 / 125	65 / 125			
GHG Emissions per Capita	114 / 125	114 / 125	Total GHG Emissions	124 / 125	124 / 125
GHG Emissions Trend	17 / 125	19 / 125	Renewables Electricity Share	83 / 125	82 / 125
Clean Electricity Capacity	20 / 125	20 / 125	Renewables Electricity Capacity	24 / 125	20 / 125
Clean Electricity Capacity Trend	23 / 125	16 / 125	Renewables Electricity Capacity Trend	23 / 125	14 / 125
Fossil Fuel Production	112 / 125	112 / 125	Fossil Fuel Consumptio n	115 / 125	116 / 125
Fossil Fuel Production Trend	121 / 125	120 / 125	Fossil Fuel Consumptio n Trend	19 / 125	17 / 125
Energy Efficiency	96 / 125	96 / 125	Energy Intensity	115 / 125	115 / 125
Electricity Distribution Loss	13 / 125	15 / 125			
Access to Electricity	100%	100%	EV Sales Share	31 / 51	30 / 47
Access to Clean Cooking	100%	100%	EV Charging stations per Capita	21 / 39	18 / 33

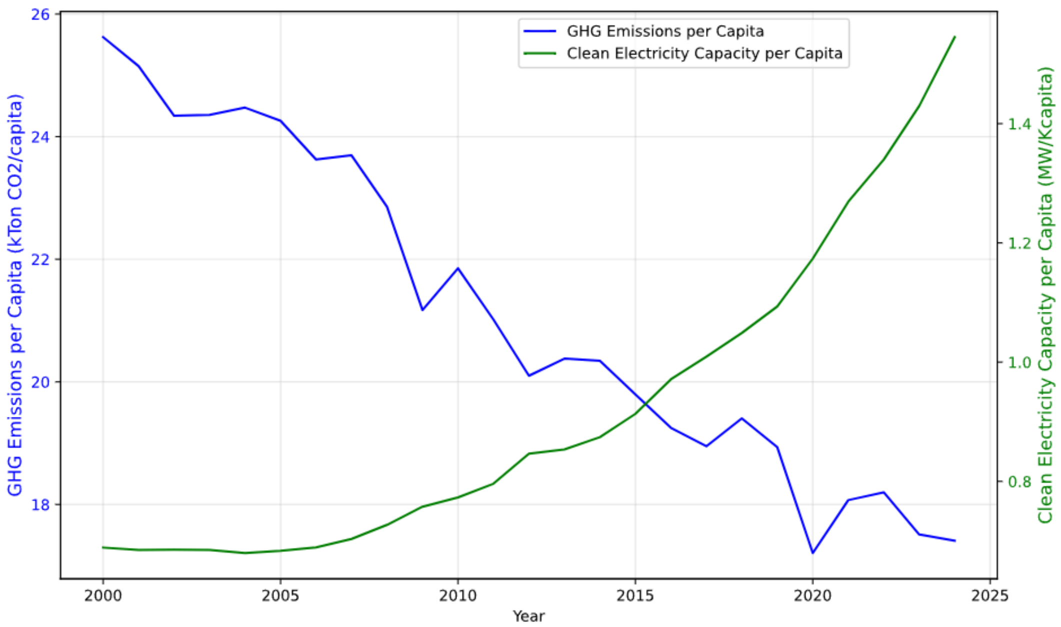

Figure 36: Per capita GHG emissions and clean electricity capacity in the USA.

USA: Declining GHG Emissions

Since 2005, the United States has made notable progress in reducing its overall greenhouse gas (GHG) emissions, as shown in Figure 37. This downward trend, however, presents a nuanced picture when examining the contributing sectors. While the aggregate figures demonstrate a positive trajectory, a closer inspection reveals a significant divergence in the performance of different segments of the economy.

A primary driver of the overall emissions reduction has been the electricity generation sector. This sector has undergone a substantial transformation, largely attributed to a combination of factors. The increasing adoption of renewable energy sources, such as solar and wind power, has played a pivotal role in displacing fossil fuel-based generation. Concurrently, the greater utilization of natural gas, a cleaner-burning fossil fuel compared to coal, has further contributed to a decrease in the carbon intensity of electricity production. Moreover, advancements in energy efficiency across various industries and consumer behaviors have reduced the overall demand for electricity, thereby lowering associated emissions.

In stark contrast, the transportation sector has experienced a steady increase in its GHG emissions over the same period. This upward trend is multifaceted, stemming from several interconnected factors. A growing population and economic expansion have led to a corresponding increase in the demand for personal and commercial vehicles. Furthermore, a consumer preference for larger, less fuel-efficient vehicles, such as SUVs and light trucks, has exacerbated the problem. The expanding network of freight transportation, driven by global supply chains and e-commerce, also contributes significantly to this sector's rising emissions.

This striking divergence between the electricity and transportation sectors underscores the complex and multifaceted nature of decarbonization efforts in the United States. While significant strides have been made in cleaning up the power grid, these gains are being partially offset by the persistent and growing emissions from transportation. This highlights the urgent need for targeted and comprehensive solutions specifically designed to address the unique challenges within the transportation sector. Achieving ambitious climate goals will necessitate a concerted effort to promote electric vehicles, invest in public transportation infrastructure, develop more sustainable freight logistics, and encourage shifts in consumer behavior towards more fuel-efficient modes of transport. Without addressing this critical imbalance, the nation's overall progress in mitigating climate change will remain constrained.

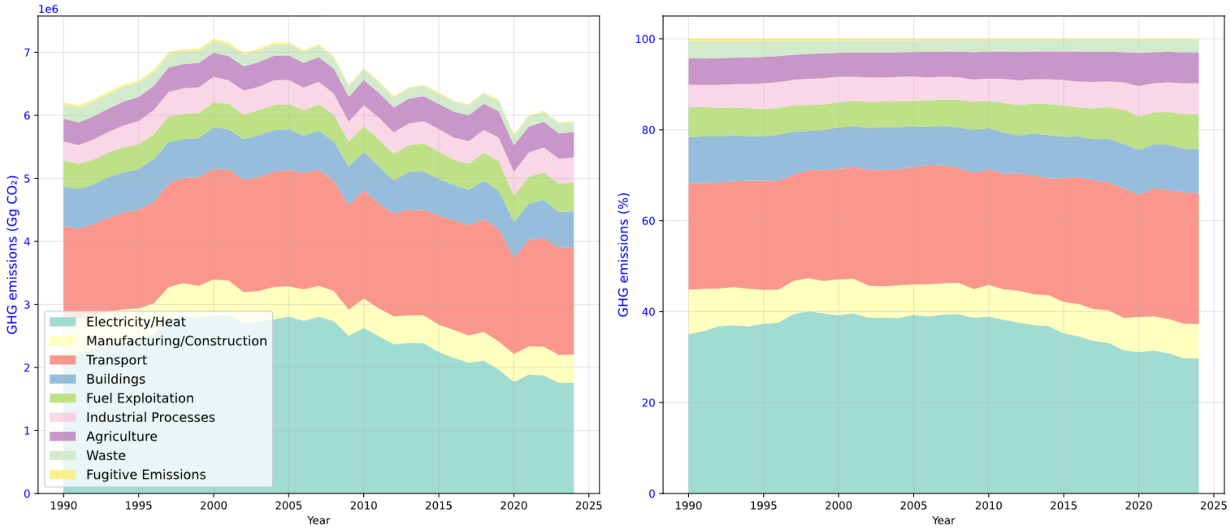

Figure 37: GHG emissions in the USA.

USA's Fossil Fuels Sector: A Net Exporter

The energy landscape of the United States reveals a pronounced dependence on fossil fuels, a characteristic that places it in lower global rankings concerning both production and consumption efficiency. A closer examination, as depicted in Figure 38, highlights a notable shift in energy trends over the past two decades.

Coal, once a cornerstone of American energy, has experienced a precipitous decline in both production and consumption since 2008. This dramatic downturn can largely be attributed to a confluence of factors, including the increasing availability and affordability of natural gas, stricter environmental regulations, and a growing national commitment to climate initiatives, notably the Paris Agreement. The retirement of numerous coal-fired power plants and the shift towards cleaner energy sources have further accelerated this trend, signaling a significant move away from this carbon-intensive fuel.

In stark contrast to coal's decline, the production of oil and natural gas has witnessed rapid and sustained growth since 2005. Technological advancements in hydraulic fracturing and horizontal drilling have unlocked vast reserves, transforming the U.S. into a leading global producer of these hydrocarbons. This surge in domestic production has had profound geopolitical and economic implications, reducing reliance on foreign imports and stimulating economic activity in energy-producing regions.

Concurrently, natural gas consumption has also seen a substantial increase. This heightened demand is primarily driven by the expanding electricity sector, where natural gas is increasingly used as a cleaner-burning alternative to coal for power generation. Furthermore, the rising proliferation of electric vehicles (EVs) and the burgeoning needs of the computing industry, both of which require significant electrical power, have further fueled the demand for natural gas-fired electricity.

Oil consumption, while remaining high, has exhibited a more fluctuating pattern over the past decade. This volatility can be influenced by a range of factors, including global economic conditions, changes in transportation habits, and the gradual adoption of more fuel-efficient vehicles and electric alternatives. Despite these fluctuations, oil continues to be a dominant fuel for transportation and various industrial processes, underscoring its enduring role in the U.S. energy mix.

The U.S. energy landscape is characterized by a complex interplay of evolving production and consumption patterns. While the role of coal steadily diminishes, oil and gas continue to be pivotal, even as the nation explores cleaner energy pathways and upholds its commitment to environmental sustainability. The U.S. is a net exporter of oil, gas, and coal.

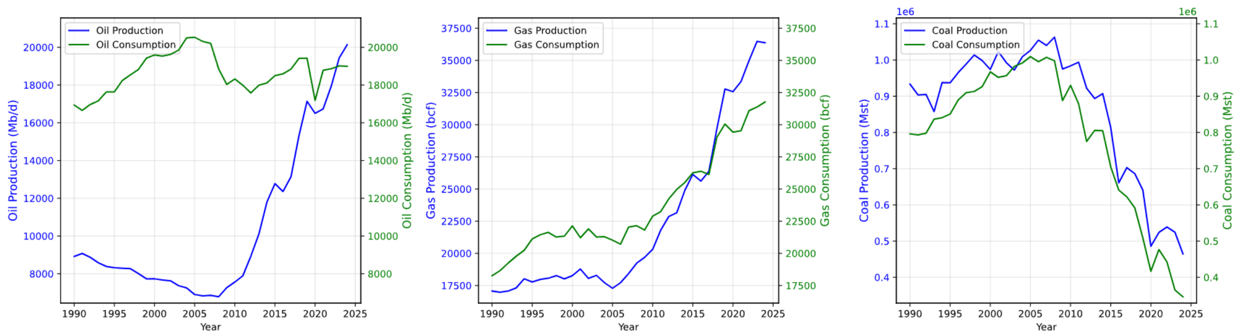

Figure 38: Oil/Gas/Coal production and consumption in the USA.

USA's Electricity Sector: Stable production with increasing renewable energy

Over the last ten years, the United States has maintained a consistent level of total electricity production. Within this stable output, nuclear energy generation has remained a steady and reliable contributor to the national grid. While the overall share of fossil fuels in the energy mix has been on a downward trend, there has been a notable and significant increase in the contribution from renewable energy sources. This growth is particularly evident in the expansion of wind and solar power, which are becoming increasingly vital components of the nation's electricity supply.

Looking ahead, a crucial area demanding in-depth investigation and strategic planning is how this evolving landscape of electricity generation capacity will effectively meet the rapidly escalating demand from artificial intelligence (AI) data centers. The proliferation of AI technologies is driving unprecedented growth in data processing requirements, which, in turn, necessitates a substantial and continuous supply of electricity. Understanding and addressing this challenge will be paramount to ensuring the sustained development of both the energy sector and the burgeoning AI industry. This will involve examining potential shortfalls, exploring new energy storage solutions, and assessing the feasibility of integrating more renewable sources to power these energy-intensive facilities.

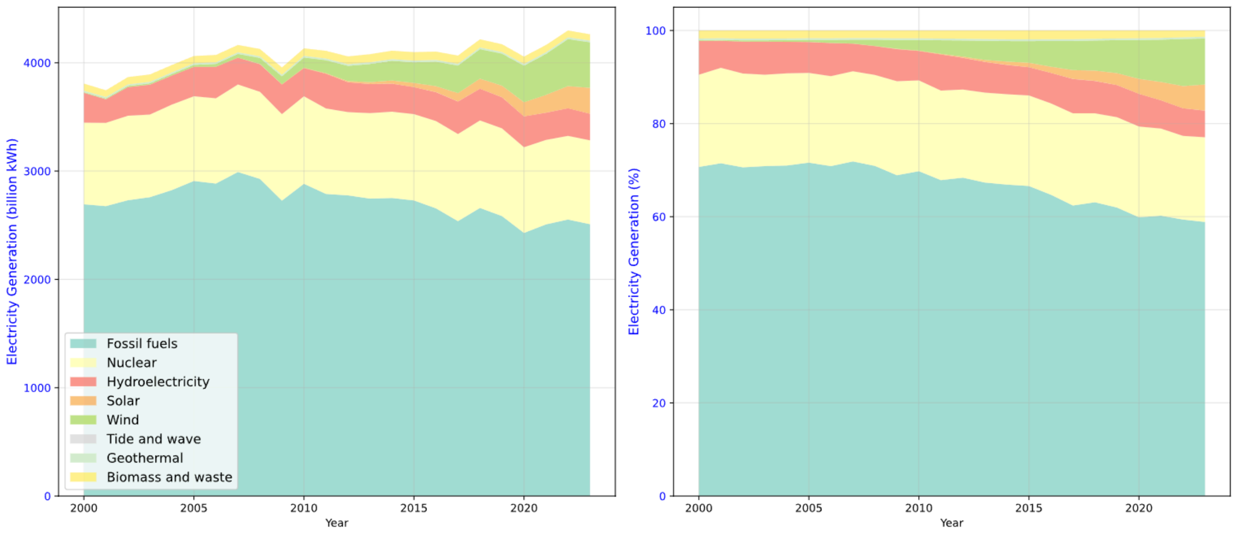

Figure 39: Electricity generation in the USA.

Figure 40: Electricity capacity installation in the USA.

6.2 China

China's performance in the energy transition presents a complex picture, as summarized in Table 8, which details the country's ranking across various sections of this global shift. A key area of concern lies in China's per capita Greenhouse Gas (GHG) emissions, where the nation demonstrates poor performance. This poor standing is not only reflected in the current emission levels but also in the concerning trend of these emissions, indicating a growing challenge in curbing individual carbon footprints.

In stark contrast to its GHG emission performance, China has achieved remarkable success in the realm of clean energy production. The country exhibits strong momentum in this sector, consistently delivering excellent results. This impressive growth in clean energy capacity underscores a significant commitment to renewable sources and a strategic focus on decarbonizing the energy supply.

However, a critical challenge arises when comparing the rapid growth in clean energy with the equally rapid increase in overall energy demand. Despite the substantial advancements in clean energy generation, the pace of its expansion has not been sufficient to keep up with the escalating energy consumption across the country. This imbalance has significant consequences for China's environmental targets.

As a direct result of this disparity, Figure 41 visually illustrates a paradoxical trend: both per capita GHG emissions and clean electricity capacity are simultaneously on the rise. This seemingly contradictory scenario highlights the core dilemma faced by China in its energy transition journey. While the nation is making commendable strides in boosting clean energy infrastructure and output, the overarching surge in energy demand continues to push up overall emissions. This suggests that while the energy mix is becoming cleaner, the sheer volume of energy consumed, particularly from fossil fuels, still contributes significantly to the rising GHG levels. Therefore, future strategies must not only focus on accelerating clean energy deployment but also on managing and potentially curbing the overall growth in energy demand to achieve a more sustainable energy transition.

Table 8: China's Ranking in Energy Transition Sections.

ETS			**Other Indicators**		
Section	**Rank**		**Section**	**Rank**	
	2024	2023		2024	2023
Overall ETS Score	74 / 125	86 / 125			
GHG Emissions per	104 /	106 /	Total GHG	125 /	125 /

Capita	125	125	Emissions	125	125
GHG Emissions Trend	119 / 125	120 / 125	Renewables Electricity Share	70 / 125	70 / 125
Clean Electricity Capacity	25 / 125	33 / 125	Renewables Electricity Capacity	21 / 125	29 / 125
Clean Electricity Capacity Trend	12 / 125	11 / 125	Renewables Electricity Capacity Trend	13 / 125	11 / 125
Fossil Fuel Production	103 / 125	103 / 125	Fossil Fuel Consumption	101 / 125	101 / 125
Fossil Fuel Production Trend	117 / 125	114 / 125	Fossil Fuel Consumption Trend	120 / 125	115 / 125
Energy Efficiency	110 / 125	113 / 125	Energy Intensity	94 / 125	97 / 125
Electricity Distribution Loss	8 / 125	8 / 125			
Access to Electricity		100%	EV Sales Share	6 / 51	7 / 47
Access to Clean Cooking		88.7 %	EV Charging stations per Capita	10 / 39	10 / 33

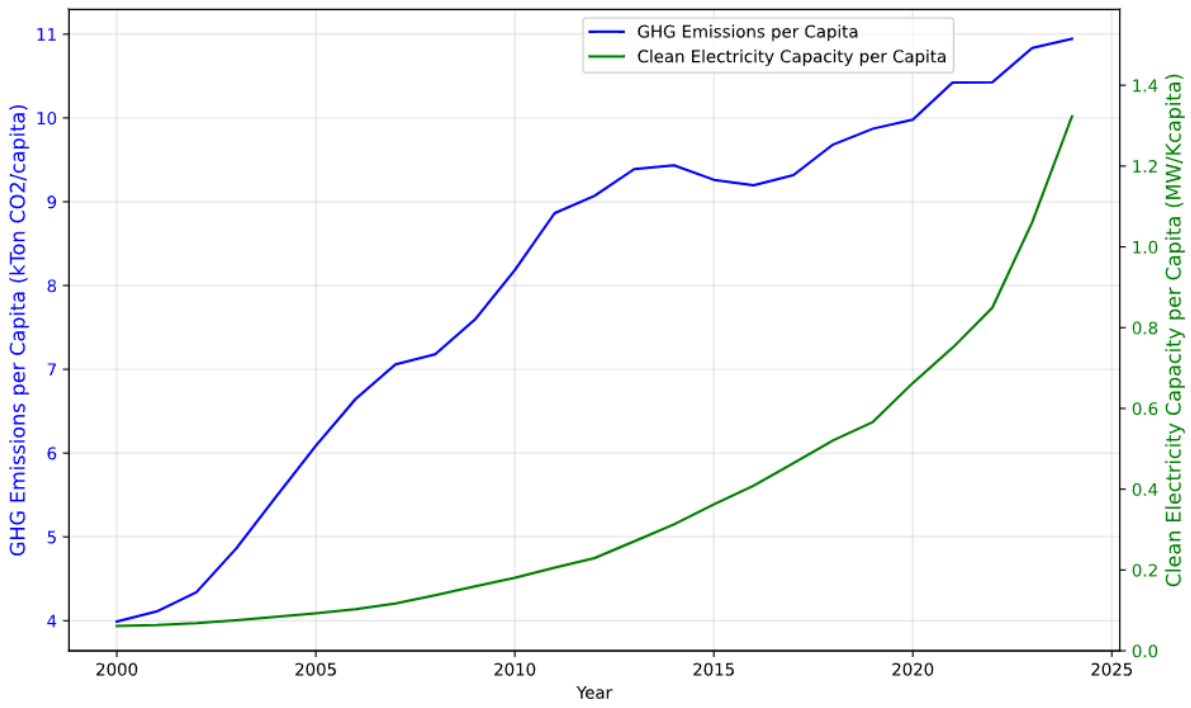

Figure 41: Per capita GHG emissions and clean electricity capacity in China.

China's GHG Emission Profile: A Persistent Increase

China's remarkable economic ascent over the past two decades has been accompanied by significant shifts in its GHG emission profile, positioning it as the world's largest contributor to these emissions. This surge is primarily attributable to the rapid expansion and intensification of its electricity generation, industrial, and transportation sectors, as visually represented and further detailed in Figure 42.

The electricity generation sector, fueled predominantly by coal, has experienced immense growth to meet the burgeoning energy demands of a rapidly urbanizing and industrializing nation. This reliance on fossil fuels has led to a substantial increase in CO_2 emissions. Similarly, China's manufacturing prowess, a cornerstone of its economic miracle, has driven a proportional increase in industrial emissions, stemming from energy-intensive processes, material production (like steel and cement), and chemical industries. Concurrently, the burgeoning transportation sector, propelled by a dramatic rise in vehicle ownership and an expanding logistical network, has seen a corresponding escalation in emissions from burning fossil fuels.

In stark contrast to these expanding sectors, the agricultural sector's share of China's overall GHG emissions has notably and consistently decreased over the past two decades. This decline is a powerful indicator of China's profound economic transformation, illustrating its strategic shift from a predominantly agrarian society to a global manufacturing and industrial powerhouse. While agricultural practices still contribute to emissions (e.g., methane from livestock and nitrous oxide from fertilizer use), their relative impact on the national emissions portfolio has diminished as the industrial and energy sectors have undergone exponential growth. This dynamic interplay between economic development and sectoral emission contributions highlights the complex challenges and opportunities China faces in its ongoing efforts to balance economic prosperity with environmental sustainability.

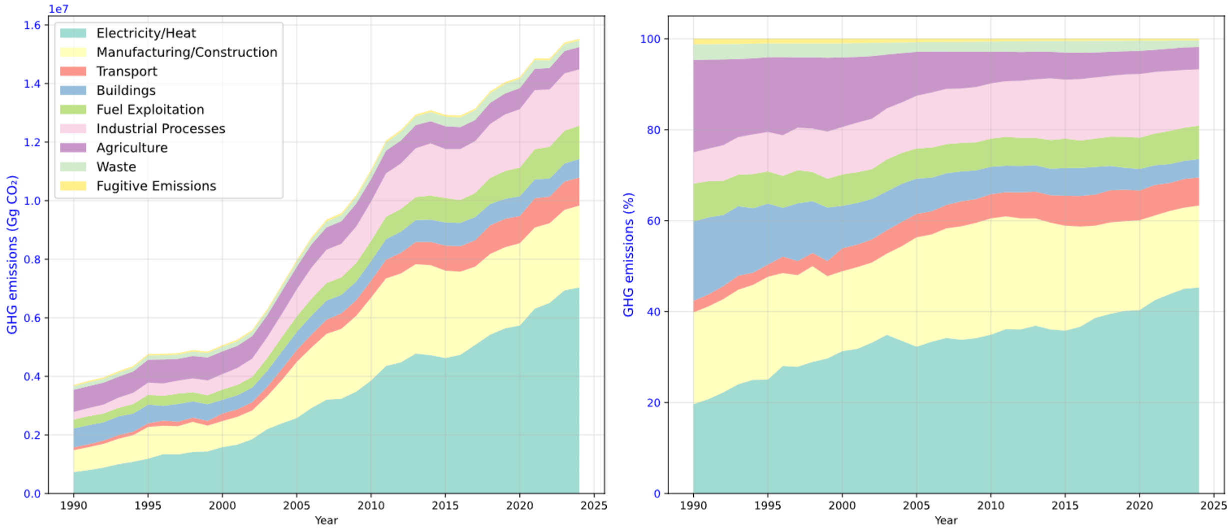

Figure 42: GHG emissions in China.

China's Fossil Fuels Sector: Larger Oil and Gas Importer

China's energy landscape is currently dominated by a heavy reliance on fossil fuels, posing significant environmental and economic challenges. The nation's substantial domestic coal production, while fueling its rapid industrial expansion, is a primary contributor to global greenhouse gas emissions and air pollution. This dependence on coal has been exacerbated by China's impressive economic growth since 1990, which has driven a dramatic surge in overall energy demand.

As a result of this escalating demand, particularly for oil and natural gas, China has transitioned into a large importer in oil and gas. This reliance on imported energy resources introduces vulnerabilities related to global energy price fluctuations, geopolitical stability, and supply chain security. While China has made considerable strides in renewable energy development, the scale of its energy consumption and its existing infrastructure mean that a substantial portion of its energy mix continues to be met by fossil fuels. Addressing these challenges requires a multi-pronged approach, including further investment in clean energy technologies, improvements in energy efficiency, and a gradual but deliberate shift away from its current fossil fuel dependence.

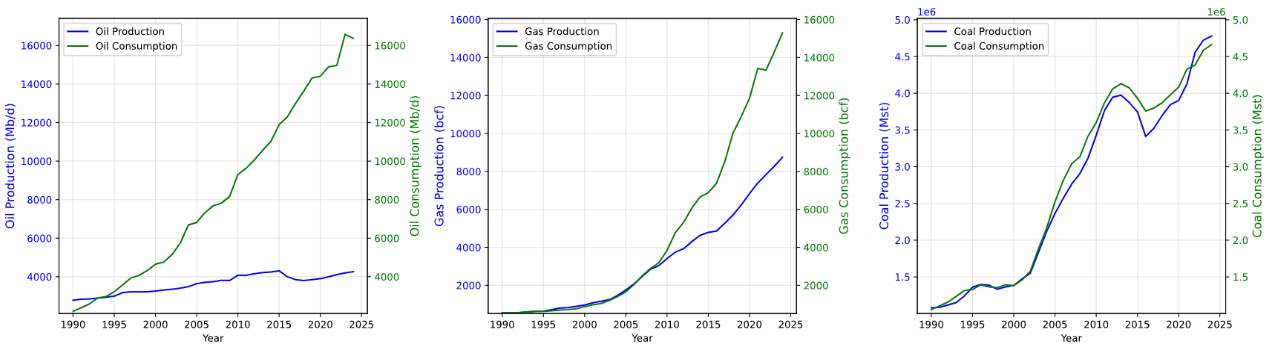

Figure 43: Oil/Gas/Coal production and consumption in China.

China's Electricity Sector: A Rapid Transition Towards Renewables

Figures 44 and 45 provide a comprehensive overview of China's remarkable progress in electricity generation and capacity development. A significant trend highlighted is the declining reliance on fossil fuels, which has decreased from over 80% to approximately 65% of the total electricity mix. This substantial shift is a testament to China's vigorous pursuit of a renewable energy transition.

The primary driver behind this reduction in fossil fuel dependency is the exponential growth in the installation of solar and wind power capacities. China has emerged as a global leader in renewable energy deployment, consistently adding more solar and wind power than any other nation. This aggressive expansion in new renewable energy installations underscores China's unwavering commitment to decarbonizing its energy sector and addressing climate change. The strategic emphasis on these intermittent renewable sources necessitates ongoing advancements in grid infrastructure and energy storage solutions to ensure stability and reliability of the electricity supply. The continued evolution of policies and technological innovations will be crucial in sustaining this trajectory and further solidifying China's position at the forefront of the global energy transition.

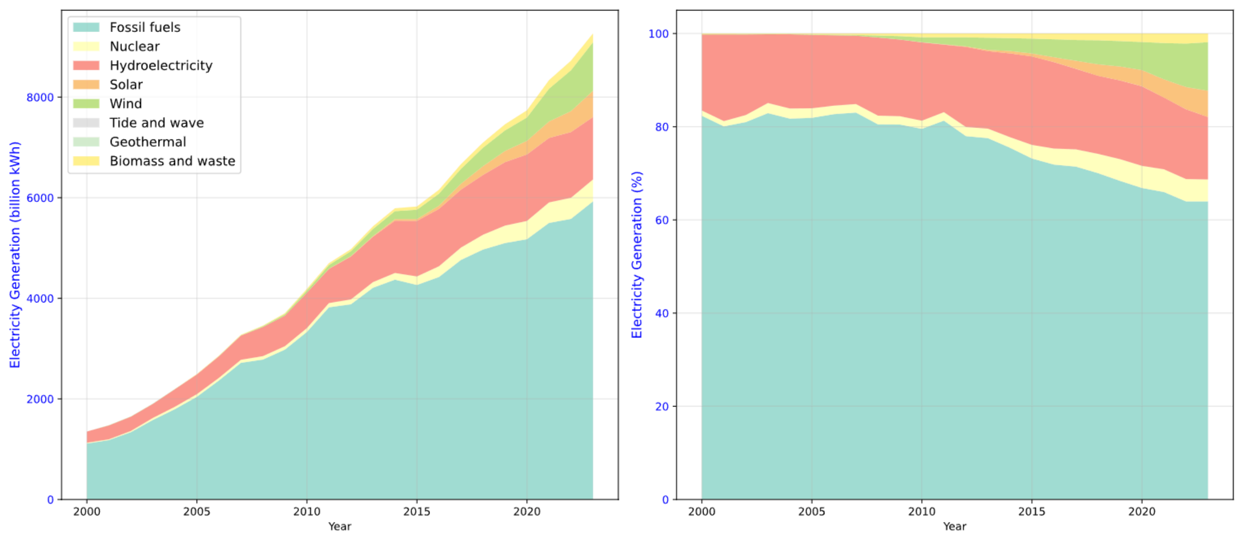

Figure 44: Electricity generation in China.

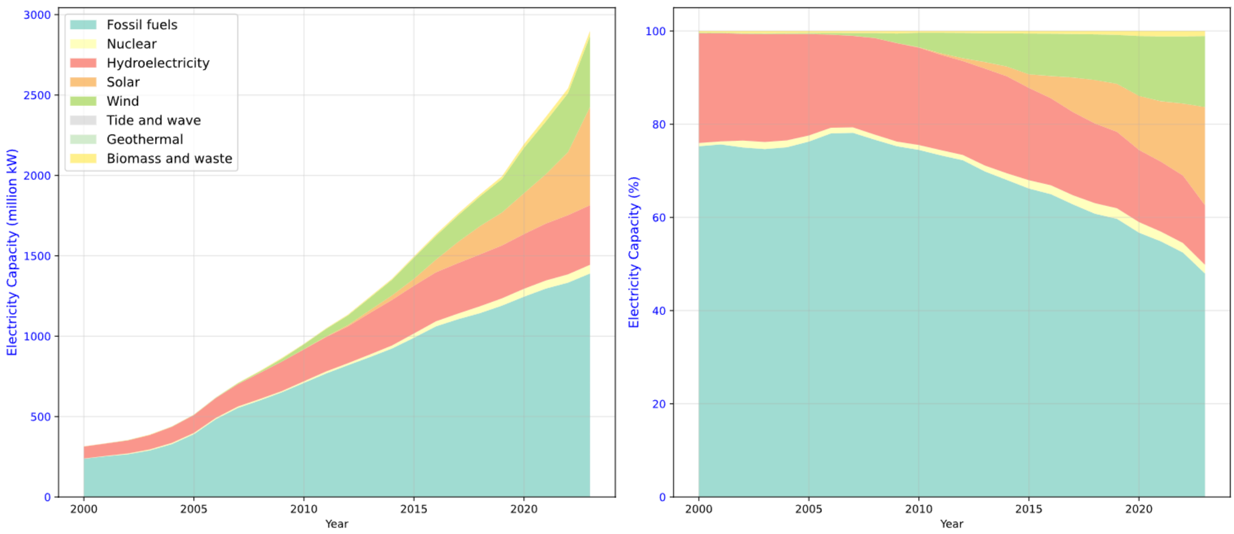

Figure 45: Electricity capacity installation in China.

6.3 India

India's energy transition faces several challenges and opportunities. While the country's per capita Greenhouse Gas (GHG) emissions are significantly lower than those of major economies like China and the USA, they are on an upward trend, necessitating proactive environmental measures.

A key area for improvement lies in India's commitment to and efforts in developing clean energy sources. Compared to the aggressive strides made by China and the USA, India's progress appears relatively subdued. This suggests a need for increased investment, policy reforms, and technological adoption to accelerate its clean energy transition. Although India's clean energy growth seems rapid, Figure 46 indicates it is insufficient to meet rising consumption demand due to its currently low scale.

Furthermore, high electricity distribution losses highlight substantial inefficiencies within the country's grid infrastructure. This not only results in wasted electricity but also impedes effective power delivery, impacting economic productivity and access to reliable energy. Modernizing grid infrastructure, implementing smart grid technologies, and improving maintenance practices are crucial steps for India's energy security and sustainability. Table 9 provides a comprehensive overview of India's country ranking across various sections pertinent to its energy transition.

Table 9: India's Ranking in Energy Transition Sections.

ETS			Other Indicators		
Section	Rank		Section	Rank	
	2024	2023		2024	2023

Overall ETS Score	94 / 125	94 / 125			
GHG Emissions per Capita	31 / 125	31 / 125	Total GHG Emissions	123 / 125	123 / 125
GHG Emissions Trend	103 / 125	96 / 125	Renewables Electricity Share	88 / 125	86 / 125
Clean Electricity Capacity	87 / 125	89 / 125	Renewables Electricity Capacity	89 / 125	89 / 125
Clean Electricity Capacity Trend	73 / 125	73 / 125	Renewables Electricity Capacity Trend	73 / 125	72 / 125
Fossil Fuel Production	72 / 125	69 / 125	Fossil Fuel Consumptio n	48 / 125	46 / 125
Fossil Fuel Production Trend	108 / 125	109 / 125	Fossil Fuel Consumptio n Trend	107 / 125	108 / 125
Energy Efficiency	78 / 125	78 / 125	Energy Intensity	32 / 125	32 / 125
Electricity Distribution Loss	101 / 125	101 / 125			
Access to Electricity		99.5%	EV Sales Share	50 / 51	44 / 47
Access to Clean Cooking		76.7%	EV Charging stations per Capita	35 / 39	31 / 33

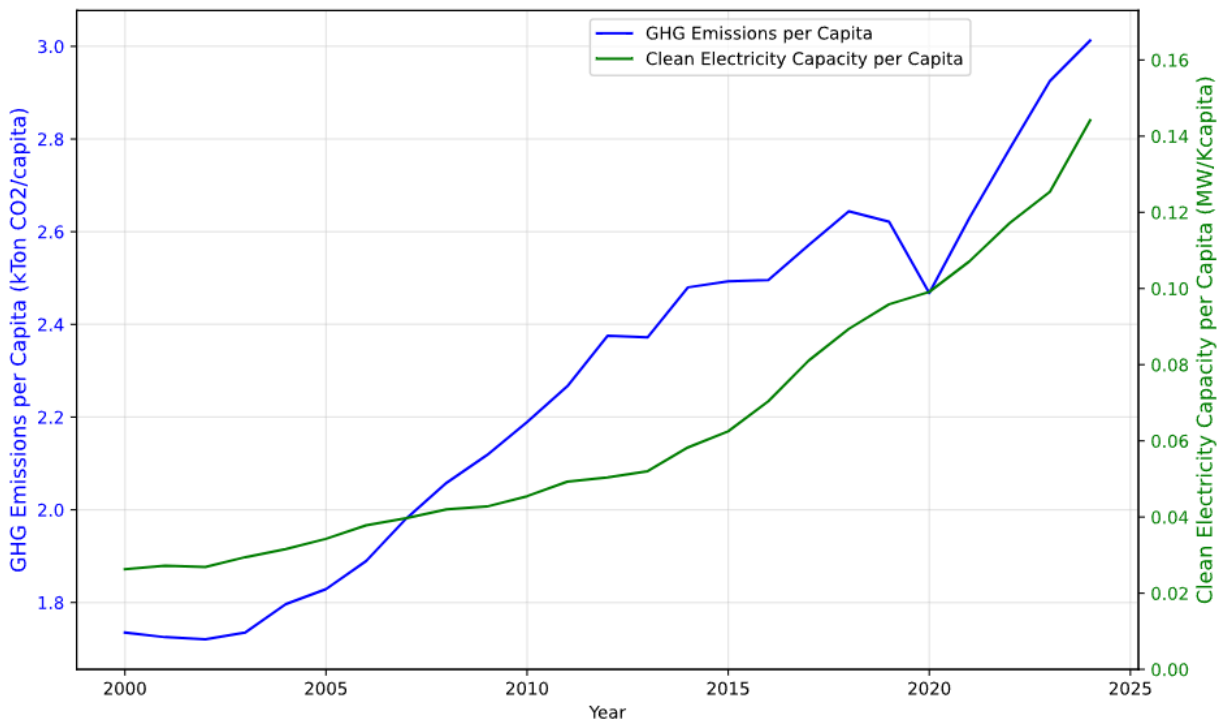

Figure 46: Per capita GHG emissions and clean electricity capacity in India.

India's GHG Emissions: Low Per Capita, but Rising

India's greenhouse gas (GHG) emission profile, as depicted in Figure 47, reveals a significant trend: the electricity sector stands out as the primary catalyst for the nation's escalating emissions. This considerable increase is predominantly a consequence of India's heavy reliance on fossil fuels, particularly coal, for the generation of the vast majority of its electricity.

The nation's rapid economic growth and expanding population have fueled an ever-growing demand for energy, which has historically been met by the cheapest and most readily available resources. This has led to a dominant energy mix where coal-fired power plants play a central role, contributing substantially to atmospheric carbon dioxide and other greenhouse gases. The emissions from these power plants encompass not only direct combustion byproducts but also fugitive emissions from coal mining and transportation.

While other sectors such as industry, agriculture, and transport also contribute to India's overall GHG emissions, the electricity sector's impact is disproportionately high due to the sheer scale of its energy production and the carbon intensity of its primary fuel source. Addressing this challenge necessitates a comprehensive shift towards renewable energy sources, enhanced energy efficiency measures, and the exploration of cleaner fossil fuel technologies, alongside sustainable development strategies to mitigate the environmental footprint of India's energy landscape.

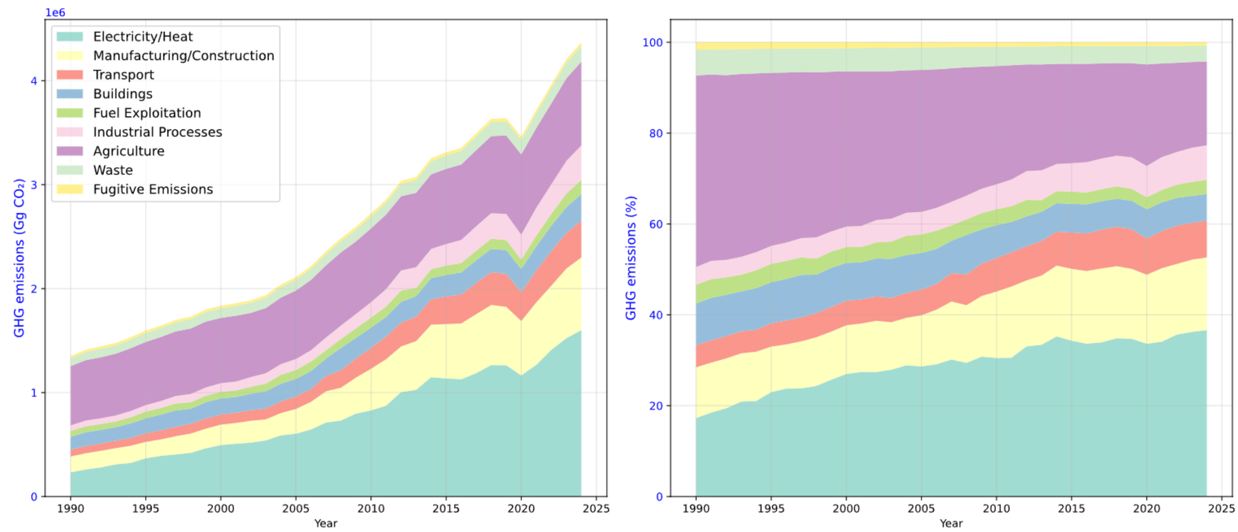

Figure 47: GHG emissions in India.

India's Fossil Fuels Sector: A Net Importer

India's burgeoning economy and population growth have placed immense pressure on its energy resources, leading to significant energy security challenges. Like China, India is a net importer of critical energy resources, including oil, natural gas, and coal, making it vulnerable to global energy market fluctuations and geopolitical instabilities. The widening disparity between India's domestic production and its burgeoning consumption of oil and gas, as illustrated in Figure 48, is particularly alarming and underscores this growing dependency on external sources.

This increasing reliance exposes India to a multitude of risks, including susceptibility to volatile global price fluctuations, which can significantly impact its economic stability and inflation. Furthermore, it faces the constant threat of supply disruptions due to geopolitical tensions in energy-producing regions or along critical shipping routes. Such disruptions could cripple industrial output, transport, and daily life, highlighting the urgent need for strategic shifts in its energy policy.

Therefore, a strategic imperative for India is to accelerate its transition towards a more diversified and sustainable energy portfolio. This involves a multi-pronged approach that prioritizes the rapid expansion of renewable energy sources. Solar energy, with India's abundant sunshine, holds immense potential for large-scale power generation, distributed rooftop installations, and off-grid solutions. Wind energy, particularly in coastal and high-altitude regions, also offers a significant avenue for clean power. Hydropower, while facing environmental considerations, remains a vital component of its renewable energy mix, providing baseload power and grid stability.

Alongside renewables, the development of India's nuclear energy capabilities is crucial for mitigating energy security risks. Nuclear power offers a reliable, low-carbon baseload electricity source, reducing reliance on fossil fuels and providing a stable foundation for the energy grid. Strategic investments in advanced nuclear technologies and fuel cycle management are essential to realize this potential.

This comprehensive shift would not only significantly reduce India's import dependency, thereby strengthening its economic resilience and insulating it from global energy shocks, but also align with global efforts towards combating climate change and achieving sustainable development goals. By embracing a diversified and sustainable energy future, India can ensure a resilient energy supply, foster long-term economic stability, and enhance its geopolitical standing. This transformation is not merely an energy security measure but a fundamental pillar of India's long-term national security and sustainable development strategy.

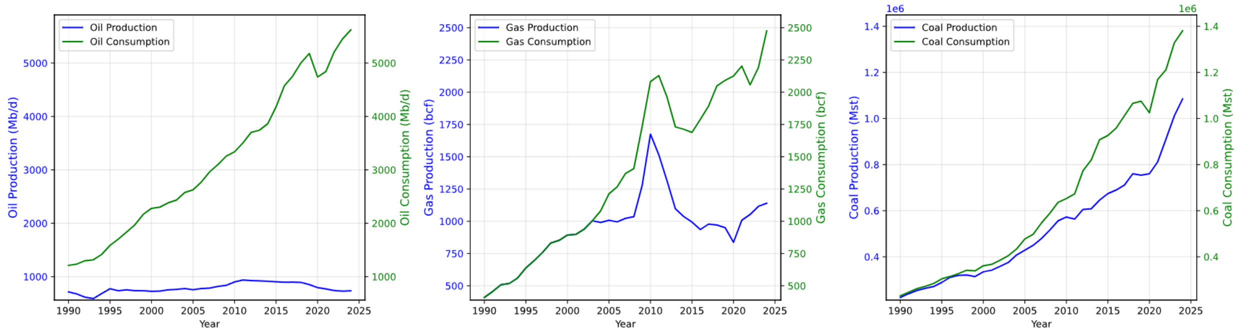

Figure 48: Oil/Gas/Coal production and consumption in India.

India’s Electricity Sector: High Share of Fossil Fuel Energy

India's energy landscape is characterized by a dynamic tension between rapid development and persistent challenges. The nation has witnessed a remarkable surge in both electricity generation and installed capacity, reflecting its burgeoning economy and growing population. However, this growth has been predominantly fueled by conventional sources, leaving India heavily reliant on fossil fuels. Approximately 75% of the country's electricity continues to be generated from fossil fuels, a proportion that has decreased at a comparatively slow pace despite increasing awareness and international pressure to decarbonize.

This reliance on fossil fuels, particularly coal, poses significant environmental and health challenges, contributing to air pollution and greenhouse gas emissions. The slow transition away from these traditional sources is influenced by several factors, including the perceived abundance and affordability of domestic coal reserves, the existing infrastructure built around fossil fuel power plants, and the substantial investment required for a large-scale shift to renewable alternatives.

Nevertheless, a notable and encouraging development in India's energy transition has been the substantial growth of solar energy since 2015. Driven by ambitious government policies, declining technology costs, and increasing private investment, solar power has emerged as a key player in diversifying India's energy mix. Large-scale solar parks, rooftop solar installations, and off-grid solar solutions have all contributed to this expansion, demonstrating India's commitment to harnessing its vast solar potential. This rapid growth in solar capacity represents a crucial step towards mitigating the environmental impact of its energy sector and moving towards a more sustainable future, though the overall dependency on fossil fuels remains a significant hurdle to overcome.

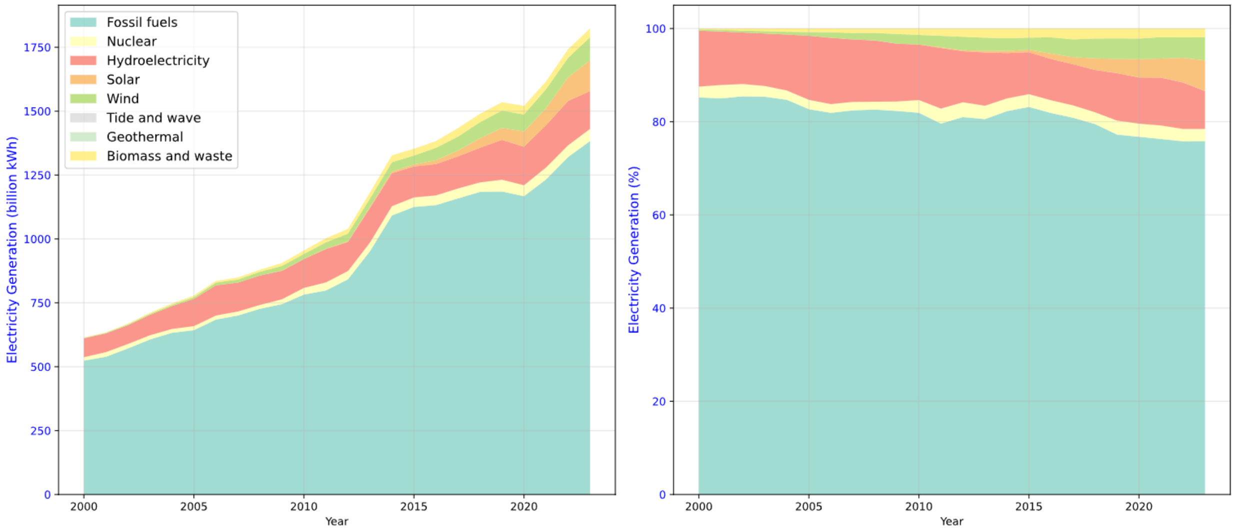

Figure 49: Electricity generation in India.

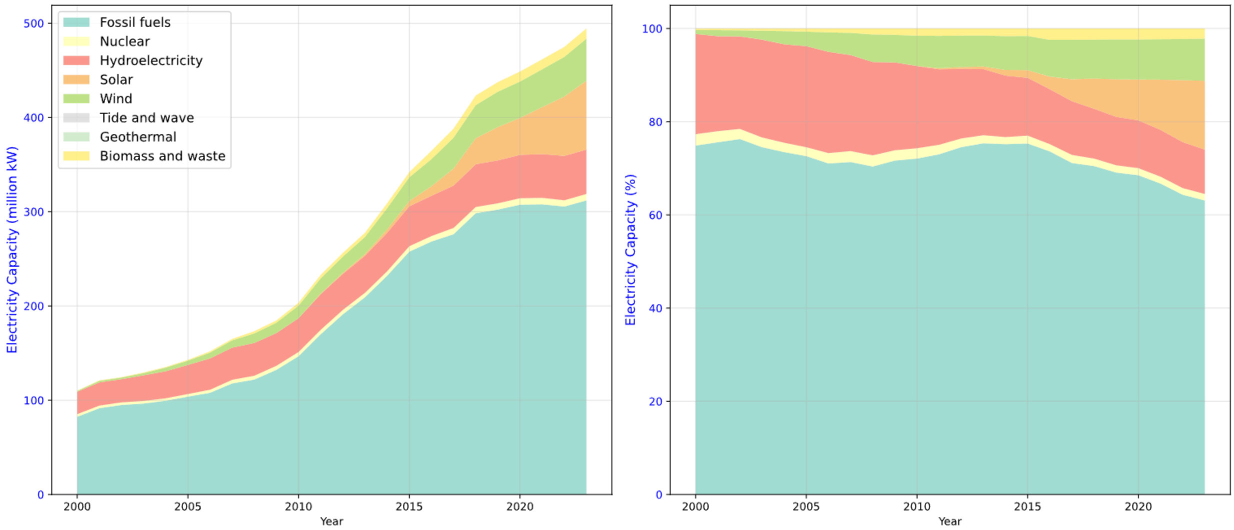

Figure 50: Electricity capacity installation in India.

6.4 Germany

Germany's Energiewende, or energy transition, has demonstrated significant progress in its dual objectives of reducing greenhouse gas (GHG) emissions and improving energy efficiency, as comprehensively detailed in Table 10. A closer examination reveals a noteworthy decline in per capita GHG emissions, indicating a successful shift towards a lower-carbon economy. This reduction is further substantiated by an impressive increase in clean electricity capacity, underscoring the nation's commitment to renewable energy sources.

Figure 51 visually reinforces these positive trends, illustrating the substantial strides made between 2000 and 2024. The graph clearly depicts a consistent downward trajectory in per capita GHG emissions, reflecting the cumulative impact of various policy measures, technological advancements, and public awareness campaigns. Concurrently, the upward trend in clean electricity capacity signifies a robust expansion of renewable energy infrastructure, including solar, wind, and hydropower. This expansion has been a critical driver in displacing fossil fuel-based electricity generation, thereby contributing to the overall reduction in emissions. The data collectively paints a picture of a nation actively transitioning away from traditional energy sources towards a more sustainable and environmentally responsible future.

Table 10: Germany's Ranking in Energy Transition Sections.

ETS			Other Indicators		
Section	Rank		Section	Rank	
	2024	2023		2024	2023
Overall ETS Score	10 / 125	7 / 125			
GHG Emissions per Capita	84 / 125	85 / 125	Total GHG Emissions	114 / 125	114 / 125
GHG Emissions Trend	12 / 125	13 / 125	Renewables Electricity Share	44 / 125	50 / 125
Clean Electricity Capacity	10 / 125	9 / 125	Renewables Electricity Capacity	10 / 125	10 / 125
Clean Electricity Capacity Trend	16 / 125	8 / 125	Renewables Electricity Capacity Trend	10 / 125	8 / 125
Fossil Fuel Production	85 / 125	86 / 125	Fossil Fuel Consumption	104 / 125	99 / 125
Fossil Fuel Production Trend	19 / 125	16 / 125	Fossil Fuel Consumption Trend	6 / 125	6 / 125

Energy Efficiency	40 / 125	51 / 125	Energy Intensity	97 / 125	99 / 125
Electricity Distribution Loss	26 / 125	21 / 125			
Access to Electricity		100%	EV Sales Share	17 / 51	15 / 47
Access to Clean Cooking		100%	EV Charging stations per Capita	13 / 39	13 / 33

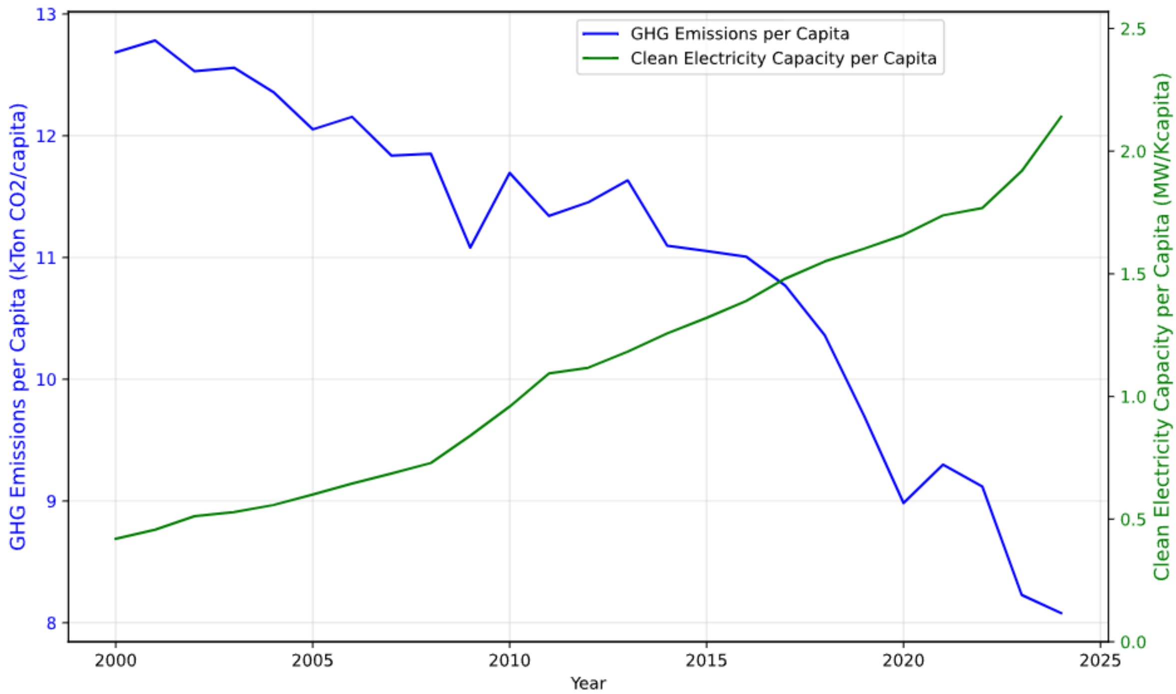

Figure 51: Per capita GHG emissions and clean electricity capacity in Germany

Germany's GHG Emissions: Significant Reduction

Figure 52 provides a detailed breakdown of Germany's greenhouse gas (GHG) emissions, illustrating the percentage contribution of each major economic sector. A comprehensive analysis of the data reveals a general trend of decreasing emissions across the majority of these sectors. This reduction is particularly pronounced in the electricity and manufacturing/construction sectors, which have demonstrated the most substantial declines in their GHG output. This significant drop in emissions within these sectors could be attributed to a variety of factors, including the country's ongoing transition to renewable energy sources, improvements in energy efficiency within industrial processes, and potentially a contraction or restructuring within Germany's manufacturing industry.

In contrast to the observed reductions in other sectors, emissions originating from transport and fugitive sources have remained relatively constant over the period examined. This stagnation indicates a persistent challenge in mitigating emissions from these areas, suggesting that current policies or technological advancements have yet to yield significant reductions.

As a direct consequence of these divergent trends, a notable shift in the proportional contribution of each sector to Germany's total GHG emissions is evident. The electricity sector, having achieved significant reductions, is now contributing a smaller percentage to the overall national GHG footprint. Conversely, due to their steady emission levels while other sectors decline, the shares attributed to transport and fugitive emissions are progressively increasing. This recalibration highlights the evolving landscape of Germany's emission profile, underscoring the success in some areas while also pointing to the critical need for more effective strategies to address emissions from the transport and fugitive sectors. Further investigation into the specific drivers of these trends, such as the uptake of electric vehicles, the efficiency of public transport, and the control of methane leaks, would provide valuable insights for future policy development.

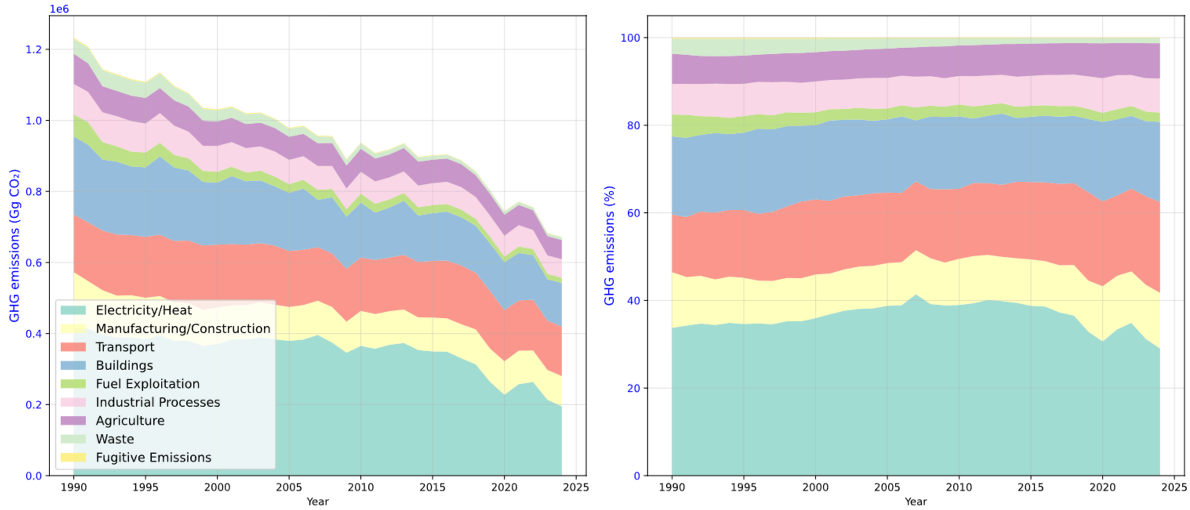

Figure 52: GHG emissions in Germany.

Germany’s Fossil Fuels Sector: Heavily reliant on imports

In 2024, Germany's energy landscape continued to be characterized by a profound reliance on imported fossil fuels, as depicted in Figure 53. The nation's domestic production of gas and coal remained minimal, and its oil extraction was very limited. This scarcity of indigenous fossil fuel resources meant that nearly 98% of Germany’s fossil fuel energy requirements were met through imports. This substantial dependence on external sources underscores a significant strategic vulnerability and a driving factor in Germany's ongoing energy transition efforts.

While the consumption of oil and coal has demonstrated a consistent downward trend, reflecting a broader shift towards cleaner energy sources and efficiency improvements, gas consumption has remained remarkably stable. This stability in gas demand, despite declining trends in other fossil fuels, highlights the continued critical role of natural gas in Germany's energy mix, particularly in sectors such as heating, industrial processes, and electricity generation as a bridging fuel during the transition to renewables. The interplay between decreasing oil and coal use and persistent gas consumption illustrates the complex challenges and varying paces of decarbonization across different energy sectors within the German economy.

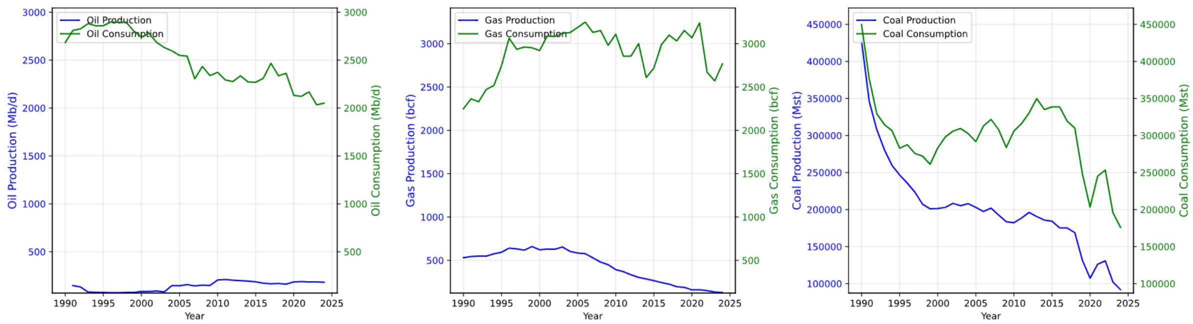

Figure 53: Oil/Gas/Coal production and consumption in Germany.

Germany’s Electricity Sector: Rapid Renewable Energy Growth

Germany's energy policy has undergone a profound transformation, particularly since the 2011 Fukushima Daiichi nuclear disaster. This event served as a catalyst for the country to embark on its ambitious "Energiewende," or energy transition, a comprehensive strategy to move away from nuclear and fossil fuels towards a sustainable, renewable energy system. A core component of this transition was the accelerated phase-out of nuclear power. This led to a deliberate and gradual reduction in nuclear electricity generation, culminating in the closure of the last three remaining nuclear power plants in April 2023. This final closure proceeded despite a temporary extension granted in late 2022, a pragmatic decision made in response to concerns about energy supply stability stemming from the broader geopolitical instability and the war in Ukraine.

While Germany has demonstrably increased its overall installed electricity generation capacity by a considerable margin over the past decade, a paradoxical trend has emerged: total generated electricity has been on a downward trajectory since 2017. This divergence suggests that, despite significant investments and rapid deployment, the growth of renewable energy sources, notably solar photovoltaics and wind power, has not yet fully compensated for the substantial void left by the departure of nuclear power from the energy mix. Although there has been remarkable development in these renewable sectors since 2011, the sheer scale of the increase in their installed capacity has not been sufficient to entirely bridge the energy generation gap. This shortfall can be attributed, in part, to the inherent characteristics of certain renewable technologies; for instance, the operational efficiency of solar power in Germany is relatively lower compared to sunnier regions, due to geographical and climatic factors.

To effectively achieve its decarbonization goals and ensure a stable and secure energy supply, Germany faces the critical imperative of significantly expanding its renewable energy capacity well beyond current levels. This expansion is essential not only to offset the complete removal of nuclear power but also to progressively displace existing fossil fuel-based generation. The challenge lies in integrating a larger proportion of intermittent renewable sources into the grid, requiring substantial investments in grid infrastructure, energy storage solutions, and advanced smart grid technologies. A deeper understanding of these dynamics, including the intricate interplay between generation capacity and actual electricity output, can be gleaned from detailed data. Figures 54 and 55, for example, would typically provide a comprehensive visual representation and further quantitative insights into Germany's electricity generation profiles by various energy types and their corresponding installed capacities, illustrating the historical trends and the current state of the energy transition. These figures would highlight the progress made in renewable deployment while also underscoring the ongoing challenge of ensuring sufficient and consistent electricity supply in a post-nuclear, low-carbon future.

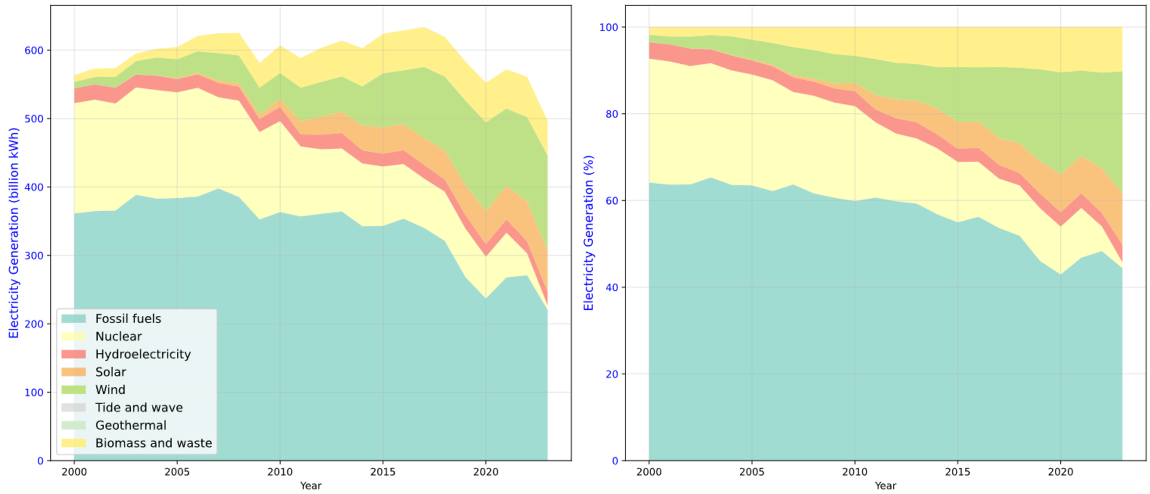

Figure 54: Electricity generation in Germany.

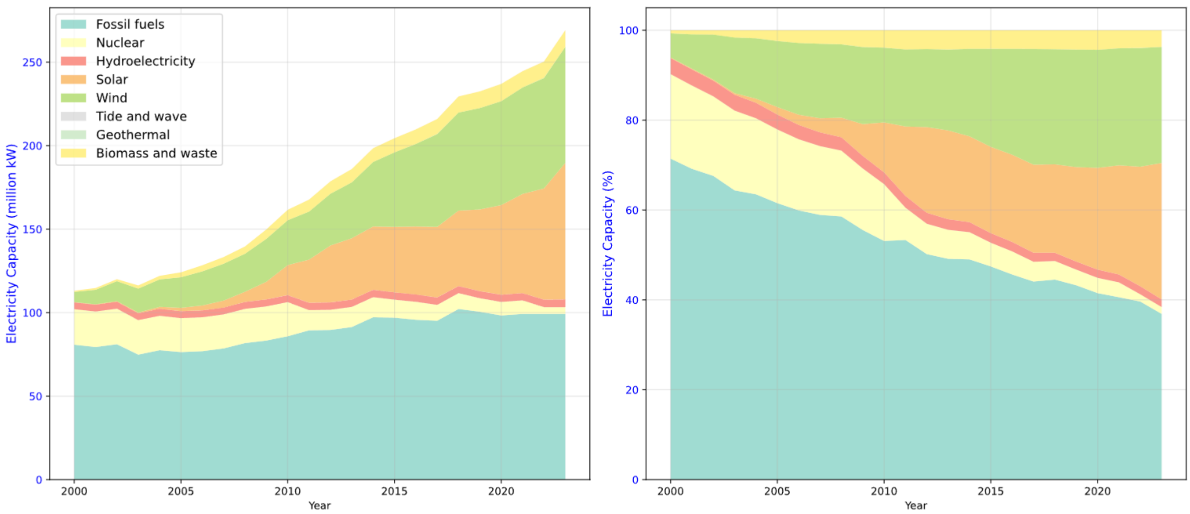

Figure 55: Electricity capacity installation in Germany.

7. Conclusion

The Energy Transition Score (ETS) provides a critical lens through which to assess global progress towards a sustainable, low-carbon energy future. This analysis, based on country-level data and broader energy sector trends, reveals a complex and multifaceted landscape characterized by notable achievements, significant disparities, and urgent challenges.

Globally, the energy transition is underway, with an average Energy Transition score indicating that nations are, in aggregate, making headway. However, this overarching figure masks a deeply fragmented reality. A wide chasm separates leading nations, predominantly in Europe, which have demonstrated sustained commitment through robust policies and investments, from those struggling with economic dependencies on fossil fuels, developmental challenges, or inadequate enabling environments. This divergence poses a substantial threat to the collective attainment of global climate objectives.

Sub-index analysis underscores that progress is uneven across different facets of the transition. While the deployment of clean electricity capacity shows positive momentum globally, driven by falling technology costs and supportive policies, this is not yet translating into sufficiently rapid reductions in overall greenhouse gas emissions. The rate of emission decline remains modest, and the crucial task of phasing out fossil fuel production and consumption is lagging significantly. Energy efficiency, a cost-effective tool for decarbonization, also appears to be an underutilized lever on a global scale.

Regional insights further illuminate the diverse pathways and specific hurdles faced across the world. Europe and North America lead in overall transition scores but must accelerate the displacement of entrenched fossil fuel systems. East Asia and the Pacific, while a powerhouse in renewable energy manufacturing and deployment, grapples with enormous energy demand and continued reliance on coal. The Middle East and North Africa face the profound challenge of economic diversification away from oil and gas. Sub-Saharan Africa, Latin America, and South Asia each navigate unique combinations of developmental needs, resource endowments, and investment landscapes.

Looking ahead, the journey towards carbon neutrality is fraught with difficulties. Achieving 2050 net-zero targets appears increasingly unlikely under current trajectories, despite record financial investments in the transition. Key challenges include policy inconsistencies, the persistent allure of fossil fuels, substantial investment shortfalls (especially for emerging technologies crucial for deep decarbonization), geopolitical tensions surrounding clean energy supply chains, and the need for greater societal adaptation to climate impacts.

Nevertheless, significant opportunities exist. Technological innovation continues to enhance the viability of clean energy solutions. Market forces, including investor and consumer preferences, are increasingly aligning with sustainability. The transformative potential of digital technologies like AI offers new avenues for optimization and efficiency.

To accelerate the transition and navigate towards a carbon-neutral future, a multi-pronged strategic approach is imperative. This includes:

- **Unwavering Policy Commitment:** Governments must establish and maintain clear, stable, and ambitious policy frameworks that incentivize clean energy and disincentivize emissions.

- **Scaled and Strategic Finance:** Mobilizing trillions, not billions, in annual investment is necessary, with a focus on bridging the gap for emerging technologies and supporting developing economies.
- **Accelerated Innovation and Deployment:** Fostering a continuous cycle of innovation and ensuring the rapid, widespread deployment of proven clean technologies are critical.
- **Just and Equitable Transition:** Ensuring that the benefits of the transition are broadly shared and that vulnerable communities are supported is paramount for social acceptance and sustainability.
- **Enhanced Global Collaboration:** Climate change is a global challenge that demands unprecedented international cooperation on technology, finance, and policy.

The energy transition is not merely a technological shift; it is a fundamental reshaping of economies and societies. While the ETS reveals that the path is arduous and the current pace insufficient, it also highlights the tools, strategies, and opportunities available to forge a more sustainable and secure energy future. The coming decade will be decisive in determining whether the global community can collectively rise to this challenge.

A1. Data Methodology

This section outlines the rigorous methodology employed for data collection, processing, and normalization to ensure the robustness and comparability of the Energy Transition Score (ETS).

A1.1 Data Collection

Data for the ETS is sourced from a diverse set of reputable international organizations and national agencies, as detailed in Table 1 (Section 2.1). This multi-source approach minimizes reliance on single data providers and enhances data integrity. Key considerations during data collection include:

- **Global Coverage:** Prioritizing datasets with extensive country coverage to ensure the ETS's global representativeness.
- **Time Series Consistency:** Selecting data series that allow for consistent tracking of indicators over time, facilitating trend analysis.
- **Definition Harmonization:** Carefully reviewing and, where necessary, harmonizing indicator definitions across different sources to ensure comparability.

A1.2 Data Validation and Pre-processing

Raw data often contains inconsistencies, missing values, or outliers that can skew analytical results. A systematic pre-processing and cleaning protocol is applied:

- **Handling Missing Values:** For individual missing data points, estimations are sought by finding the closest values or by calculating an average of adjacent years. If data is extensively missing, a determination is made regarding the meaningful inclusion of the indicator.
- **Outlier Detection and Treatment:** Statistical methods (e.g., Z-score) are employed to identify outliers. Outliers are then either winsorized (capped at a certain percentile) or treated through imputation, depending on their impact and underlying cause.
- **Unit Conversion:** All data points are converted to consistent units to ensure accurate aggregation and comparison.

A1.3 Normalization

To aggregate diverse indicators with different scales and units into a single composite index, each indicator is normalized. Min-Max normalization is applied, transforming all indicator values to a scale between 0 and 100. This ensures that each indicator contributes proportionally to the overall ETS score, regardless of its original magnitude.

This ensures that for all indicators, a higher normalized score consistently indicates better performance.

A1.4 Weighting and Aggregation

As detailed in Section 2.3 and Table 2, the ETS is calculated as a weighted sum of the normalized scores of its constituent indicators. The assigned weights reflect the perceived relative importance of each component in the overall energy transition. The aggregation formula is:

ETS = Σ (Normalized Indicator Score * Indicator Weight)

Where the sum is taken over all selected indicators, and the weights sum up to 100%.

A1.5 Trend Score Calculation

To capture the dynamism of a country's energy transition, Trend Scores are calculated for key indicators (GHG Emissions per Capita, Clean Electricity Capacity per Capita, Fossil Fuel Production per Capita). A linear regression model is applied to the past decade of data for each indicator to determine its average annual rate of change. This rate of change is then normalized and incorporated into the overall ETS calculation, providing insight into the momentum of a country's transition efforts.

A1.6 Data Validation and Review

A continuous data validation process is implemented, involving:

- **Cross-referencing:** Key data points are cross-referenced with alternative reputable sources to confirm accuracy.
- **Expert Review:** The selection of indicators, data sources, and methodological approach undergoes periodic review by subject matter experts.
- **Transparency:** The methodology and underlying data are made publicly available where possible to foster transparency and allow for independent verification.

A2. Selecting Indicators

A2.1 All Indicators

Table 11: All Indicators Calculated from the Data

Indicator	Formula	Unit	Category	Trend
GHG Emissions per Capita	$GHG\ Emissions\ per\ Capita = \frac{Total\ GHG\ Emissions}{Population}$	kTon CO2/ Kperson	Greenhouse Gas, Fossil Consumption	Yes
Renewable Energy Share	$Renewable\ Energy\ Share = \frac{Renewable\ Energy}{Fossil\ Energy + Nuclear\ Energy + Renewable\ Energy}$	%	Renewable/Clean Energy	Yes
Renewable Electricity Share	$Renewable\ Electricity\ Share = \frac{Renewable\ Electricity}{Fossil\ Electricity + Nuclear\ Electricity + Renewable\ Electricity}$	%	Renewable/Clean Energy	Yes
Clean Energy Share	$Clean\ Energy\ Share = \frac{Nuclear\ Energy + Renewable\ Energy}{Fossil\ Energy + Nuclear\ Energy + Renewable\ Energy}$	%	Renewable/Clean Energy	Yes
Clean Electricity Share	$Clean\ Electricity\ Share = \frac{Nuclear\ Electricity + Renewable\ Electricity}{Fossil\ Electricity + Nuclear\ Electricity + Renewable\ Electricity}$	%	Renewable/Clean Energy	Yes
Renewable Electricity Capacity per Capita	$Renewable\ Electricity\ Capacity\ per\ Capita = \frac{Renewable\ Electricity\ Capacity}{Population}$	kW / Kperson	Renewable/Clean Energy	Yes
Clean Electricity Capacity per Capita	$Clean\ Electricity\ Capacity\ per\ Capita = \frac{Renewable\ Electricity\ Capacity + Nuclear\ Electricity\ Cap}{Population}$	kW / Kperson	Renewable/Clean Energy	Yes
Fossil Fuel Production per Capita	$Fossil\ Fuel\ Production\ per\ Capita = \frac{W_{oil} * Oil_{production} + W_{gas} * Gas_{production} + W_{Coal} * Coal_{production}}{Population}$	kTon CO2/ Kperson	Fossil Fuel Production	Yes
Fossil Fuel Consumption per Capita	$Fossil\ Fuel\ Consumption\ per\ Capita = \frac{W_{oil} * Oil_{Consumption} + W_{gas} * Gas_{Consumption} + W_{Coal} * Coal_{Consumptio}}{Population}$	kTon CO2/ Kperson	Fossil Fuel Consumption	Yes
Energy Intensity	$Energy\ Intensity = \frac{Total\ Primary\ Energy\ Consumption}{Population}$	MM Btu / Kperson	Energy	No
Energy Efficiency	$Energy\ Efficiency = \frac{Total\ Primary\ Energy\ Consumption}{GDP\ at\ Purchasing\ Power\ Parity}$	MM Btu / USD 2015	Energy	No

Electricity distribution efficiency by Production	$Electricity\ Distribution\ Inefficiency\ =\ \frac{Electricity\ Distribution\ Loss}{Electricity\ Generation}$	%	Infrastructure	No
Electricity distribution efficiency by Consumption	$Electricity\ Distribution\ Inefficiency\ =\ \frac{Electricity\ Distribution\ Loss}{Electricity\ Consumption}$	%	Infrastructure	No
Access to Electricity	$\frac{Population\ with\ access\ to\ electricity}{Population}$	%	Infrastructure	No
Clean Cooking	$\frac{Population\ with\ access\ to\ clean\ cooking}{Population}$	%	Infrastructure	No
EV sale share	$\frac{number\ of\ new\ EV\ sale}{Total\ number\ of\ new\ sales}$	%	Innovation	No
Charging stations per Capita	$\frac{Number\ of\ public\ charging\ stations}{Population}$	stations / Kperson	Innovation	No

A2.2 Selecting Indicators

To streamline our analytical framework and eliminate potential issues of multicollinearity and redundant measurements, we undertook a careful selection process for the indicators presented in Table 7. This methodical approach was primarily guided by an analysis of the correlation coefficients among these indicators, as visually represented in Figure 51.

Our fundamental objective in this selection was twofold: first, to systematically exclude indicators that exhibited high degrees of correlation with one another, thereby preventing double-counting of similar underlying phenomena; and second, concurrently, to ensure that we preserved all crucial dimensions and aspects necessary for a comprehensive and robust assessment within our framework. This meticulous process aimed to achieve a balance between parsimony in our indicator set and the retention of critical information, ultimately enhancing the clarity and interpretability of our findings.

Finally, we use 10 selected indicators to calculate the ETS, as shown in Table 2. Figure 52 displays the correlation coefficients among these indicators.

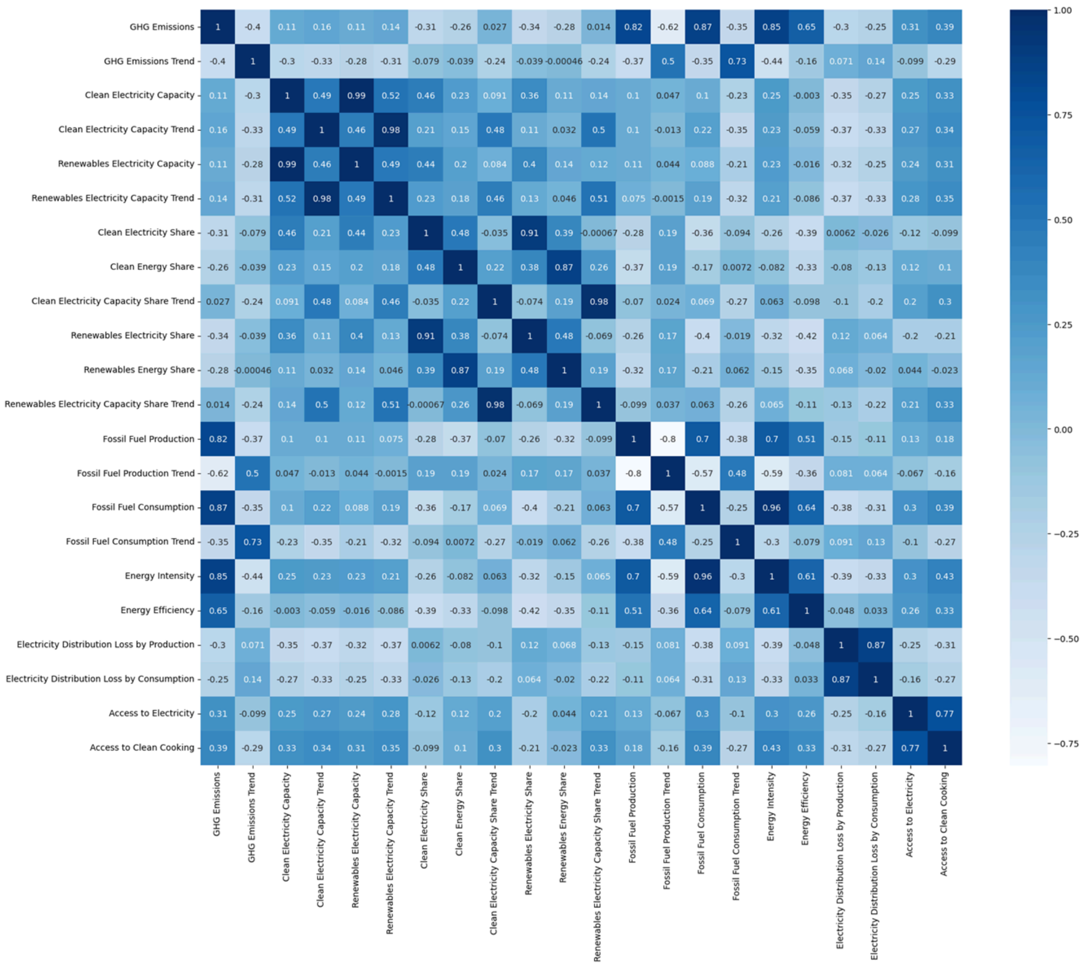

Figure 51: correlation coefficient of all the indicators

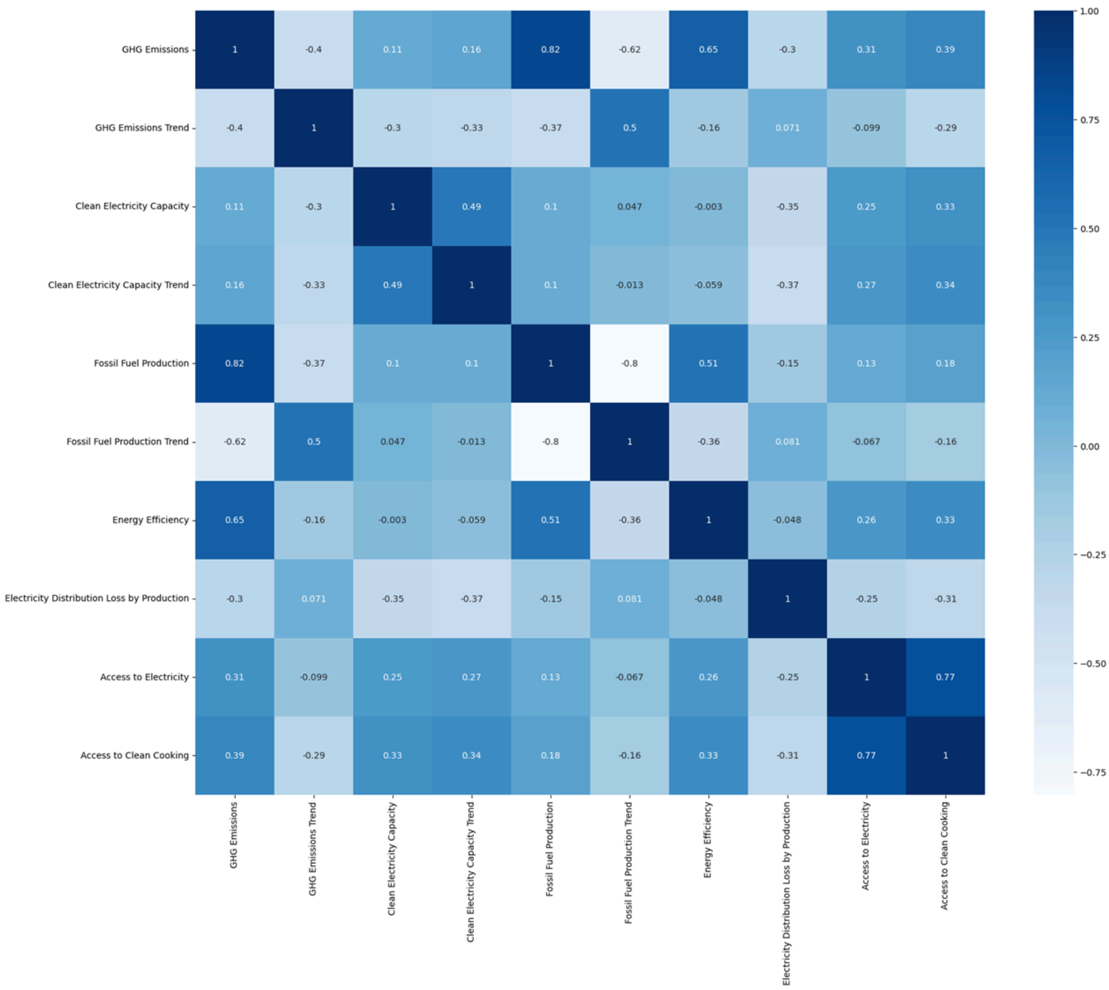

Figure 52: correlation coefficient of selected indicators

Works cited

1. Crippa, M., Guizzardi, D., Pagani, F., Banja, M., Muntean, M. et al., GHG emissions of all world countries - 2025 Report, Publications Office of the European Union, Luxembourg, 2025, doi:10.2760/9816914, JRC143227.

2. 2025 Statistical Review of World Energy, the Energy Institute (EI), June 2025, https://www.energyinst.org/statistical-review

3. Renewable energy statistics 2025, The International Renewable Energy Agency (IRENA), https://www.irena.org/Publications/2025/Jul/Renewable-energy-statistics-2025

4. International Energy Statistics, International Energy Statistics, U.S. Energy Information Administration (EIA), https://www.eia.gov/international/data/world

5. Data and statistics, the International Energy Agency (IEA), https://www.iea.org/data-and-statistics/data-explorers

6. World Health Organization (WHO), https://data.who.int/indicators

7. World Bank Open Data, https://data.worldbank.org

8. UN Trade and Development, https://unctadstat.unctad.org/datacentre/