

Trends, Dynamics and Implications of Green House Gases Emissions in India (1951-2022): An Overview

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Abstract—Greenhouse gases emissions are key driver of climate change. Long term trends and dynamics analysis of these emissions are essential for study of climate mitigation efforts. This study provides detailed and descriptive analysis of India's greenhouse gas emissions for 1951–2022 time period. This analysis is based on three major indicators- total GHGs emissions, per capita emission, and carbon intensity measured as CO₂ emissions per GDP unit. Time series analysis, year on year percentage change and five year rolling averages are used to study and examine long term trends and short term fluctuations. Analysis results show that total emissions increased from about 0.85 billion tons in 1951 to more than 4.0 billion tons in 2022. While per capita emissions reached from nearly 1.5 tons to nearly 2.85 tons. And, carbon intensity peaked in 1990s at around 0.35 kg per dollar and declined to near 0.27kg per dollar by 2022[data source: Global Carbon Budget (2025) – with major processing by Our World in Data]. Result shows that India has improved its carbon efficiency but total emission continue to rise.

Keywords- Emission, Greenhouse Gases, Mitigation, India, Climate Change, Carbon Intensity, Per Capita Emission.

I. INTRODUCTION

Greenhouse gases emissions are reason for global warming. Among these gases, mainly carbon dioxide, methane and nitrous oxide, are key greenhouse gases responsible for global warming (IPCC,2023). Putting check on emission of these greenhouse gases and stopping this ongoing global warming and climate change is need of 21st century for survival human being. So for this purpose, analyzing emission trends of these gases are important because it helps to understand the relationship between economic growth and environmental sustainability. This is especially true for India, as India is one of the fast growing economies in the world (World Bank,2023). Its development process involves industrialization, urbanization, and increasing energy consumption (IEA,2023). These developmental processes are linked to rising GHG emissions (World Bank, 2023). Studying emission trends over long time period gives insights into effectiveness of climate policies and future mitigation progress. This research paper tries to study such aspects and focuses on three major indicators.

- i. Total GHG emissions
- ii. Per capita GHG emissions
- iii. Carbon intensity (CO₂ emissions per GDP unit)

Such indicators together provide a comprehensive understanding of emission dynamics. This research work does a detailed examination of India's greenhouse gas emissions trends and dynamics from 1951-2022.

II. DATA AND METHODOLOGY

This analysis is based on secondary datasets. For total & per capita greenhouse gas emissions data are derived from Jones et al. (2024) which is processed by Our World in Data. And for carbon intensity analysis, data are based on the Global Carbon Budget (2023) and the Maddison Project Database. To analyse these datasets three main analytical methods were used

- Time Series Analysis: A time series plot was constructed to examine long-term trends in emissions. Linear regression trend line was applied to identify overall direction of emissions growth.
- Year on Year (YoY) Percentage Change: Annual percentage change in emissions was calculated and plotted to identify short term fluctuations and growth patterns.
- Rolling Average Analysis: 5 year rolling average of YoY changes was computed to smooth short term volatility and identify medium term trends.

Graphical and statistical analysis has been done to understand how emissions have changed over time.

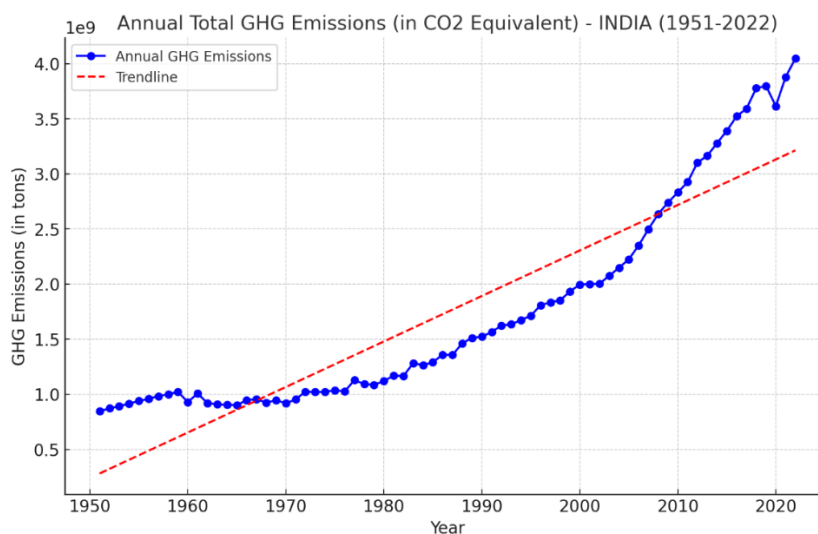
III. ANALYSIS AND DISCUSSION

This study approaches the problem through three interrelated dimensions: total emissions, per capita emissions, and carbon intensity. Studying above mentioned indicators help in complete and comprehensive understanding of emission trends.

IV. TOTAL GREENHOUSE GAS EMISSION TREND FOR 1951–2022 PERIOD

Time series (Graph-A) of total greenhouse gas emission shows clear rising trend from 1951 – 2022 period. Graph-A presents a long-term increase with very few interruptions. In 1951, emission was nearly 0.85 billion tons of CO₂ equivalent. During next two decades, emissions increased slowly and reached close to 1.0 billion tons by early 1960s. Graph-A shows a nearly flat pattern during 1960s. Emissions stayed between 0.95 and 1.0 billion tons. During 1970s, emissions started increasing gradually. It crossed 1.0 billion ton ,reached nearly 1.1 billion tons by 1980. Graph-A may be linked to early industrial development in India during this time. Slope of curve in Graph-A remains gentle. It is moderate growth in emissions. A clear change appears after 1980 ,when trend becomes steeper. By late 1980s, Graph-A shows emissions near 1.4 billion tons. By 1990 it increased further to nearly 1.5 billion tons. Between 1990 - 2000, it was steady increase. Emissions rise from nearly 1.5 billion tons to almost 2.0 billion tons.

Graph -A



Data Source: Global Carbon Budget (2025) – with major processing by Our World in Data

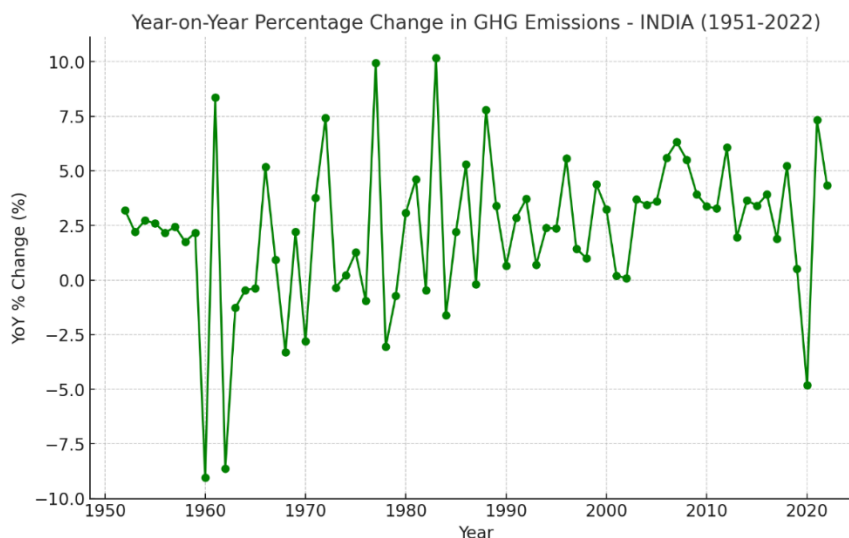
Curve in Graph-A becomes steeper, showing faster growth. Most rapid increase is visible after 2000. Emissions cross 2.0 billion tons around 2003–2004. After that it shows sharp rise. By 2010, emissions reach nearly 3.0 billion tons. Slope of curve in Graph-A becomes much steeper. It represents very fast growth compared to earlier periods. during 2010 -2022, it shows emissions rise from nearly 3.0 billion tons to 4.0 billion tons. This shows sharp rise is visible after 2014. Emissions were nearly 3.28 billion tons in 2014. They increased to nearly 3.8 billion tons by 2019. A small dip appears around 2020. After that, strong rise is visible in 2021 -2022. Emissions cross 4.0 billion tons during these years. Trendline in Graph-A is straight and upward sloping. It confirms consistent increase over time. Steeper curve in recent years shows faster growth rate. Graph-A clearly indicates strong acceleration in emissions in later decades.

VI. YEAR-ON-YEAR PERCENTAGE CHANGE IN EMISSIONS

Year-on-year percentage change (shown in Graph-B) gives clear insight into annual emission changes. Graph B shows early years, from 1950s to early 1960s, had stable growth. Growth mostly stayed between 2% and 4% during this period. However, Graph-B shows sharp negative spikes around 1959–1961 period. Growth rate falls to nearly -9%, showing a strong emission decline.

In 1970s, Graph B shows higher variability in annual growth rates. Values move between about -3% and +5% during this decade. Several peaks cross 5%, showing periods of faster emission increase. Variability becomes stronger in 1980s and 1990s in Graph-B. Many sharp peaks appear, showing rapid changes in growth pattern. Highest peak reaches around 10% in late 1970s and early 1980s. Another clear peak appears around 1994, close to 7.9%. These peaks indicate fast economic and industrial growth periods. After 2000, Graph B shows relatively more stable growth patterns. Most values remain between 2% and 5%, showing steady emission increase. Some fluctuations still appear, with dips near 0% and peaks above 5%. Around 2010–2012, Graph B shows growth near 4% to 6%. This reflects continued expansion of emissions during that phase. A major feature in Graph B is sharp decline in 2020. Growth rate falls to about -4.81%, one of lowest values recorded. This clearly reflects impact of COVID-19 pandemic on emissions. Immediately after, Graph B shows strong rebound in 2021. Growth rises to nearly 7.31%, one of highest recent values. Overall, Graph B shows emissions have increased, but growth rate remains highly variable. Changes are strongly influenced by economic conditions and external.

Graph B

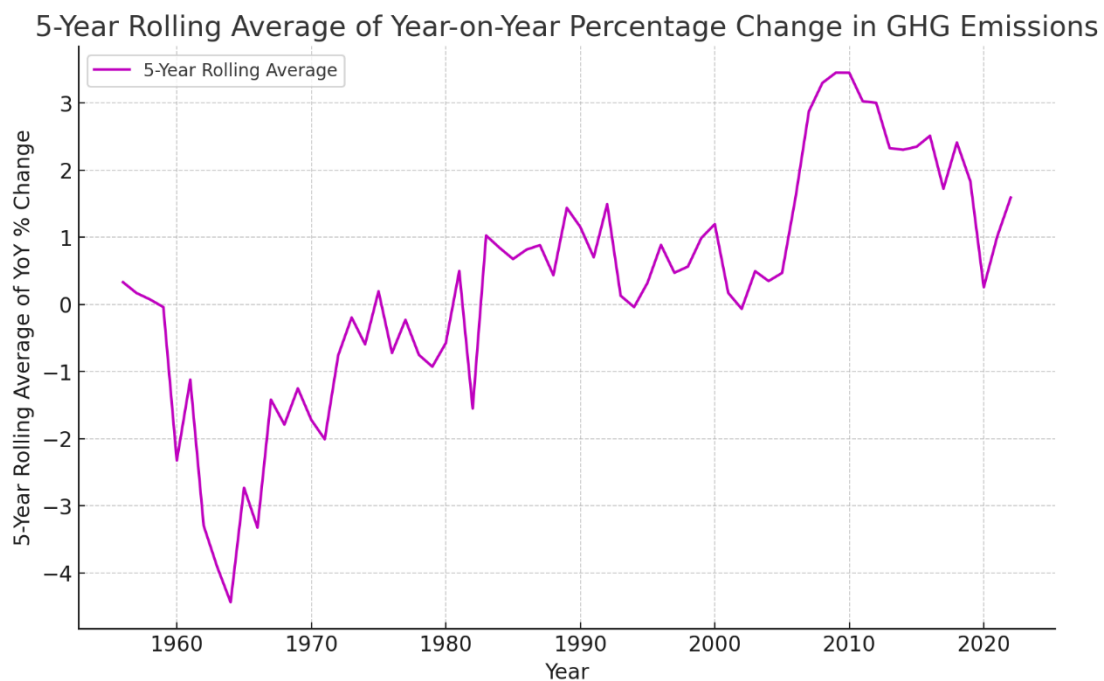


Data Source: Global Carbon Budget (2025) – with major processing by Our World in Data

VII. FIVE-YEAR ROLLING AVERAGE OF EMISSIONS GROWTH

Five-year rolling average (shown in Graph-C) gives a smoother view of emissions growth. In early period, especially 1950s to mid-1960s, it stays between 2% and 3%. However, Graph-C shows a sharp dip in early 1960s period. Rolling average falls below 0% and moves close to -2%. This indicates a phase of declining emissions growth during that time. From late 1960s to 1970s, Graph-C shows recovery and stability. Values remain between 1% and 3% during this period. In 1980s, Graph-C shows a clear upward movement. Rolling average rises to about 3% to 4% range. By late 2000s, it reaches its highest point. This shows average emission growth was strongest during that phase. After 2010, it shows another decline in growth rate. Rolling average moves down to around 2% to 3%. A clear dip appears around 2020 in Graph-C. This reflects impact of pandemic on emission growth pattern. After that, Graph-C shows a slight recovery trend. Pattern suggests emissions are still increasing over time. However, growth rate has slowed in recent years.

Graph -C



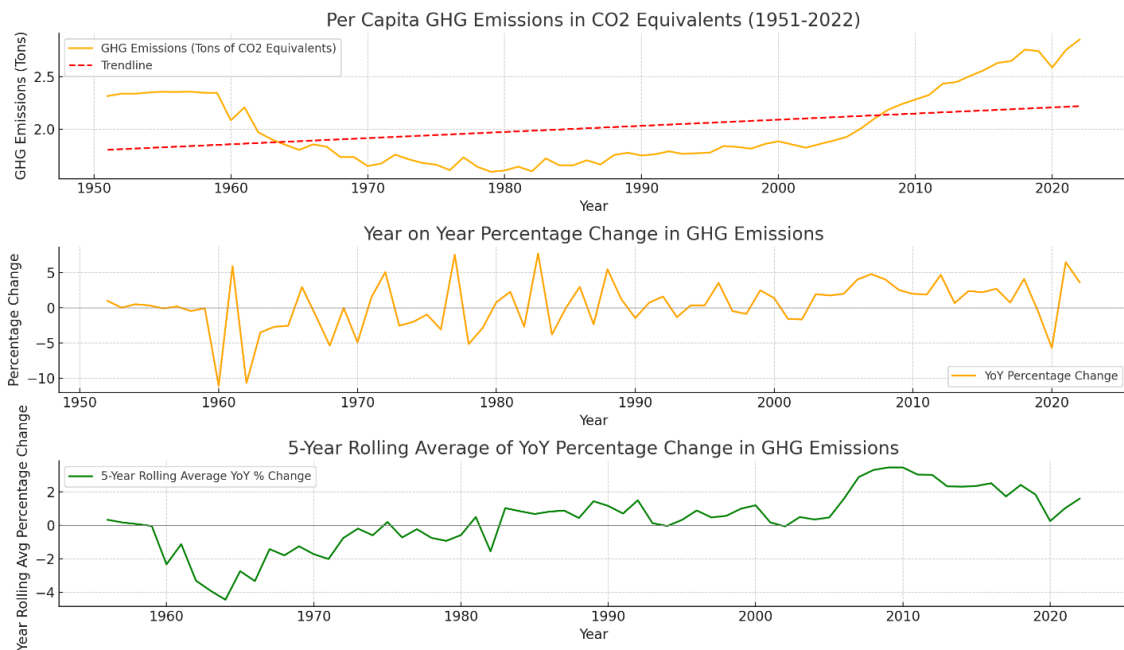
Data Source: Global Carbon Budget (2025) – with major processing by Our World in Data

VIII. PER CAPITA GREENHOUSE GAS EMISSION:

For India, Graph-D shows long-term pattern of per capita emissions. Period from 1951 to 2022 shows gradual and moderate increase. Graph-D shows some fluctuations, but long-term pattern remains stable. Trendline rises slowly across entire time period in Graph-D. This suggests emission growth was steady and not uncontrolled. In 1950s, per capita emissions stay slightly above 2.3 tons. This stability reflects a balanced early development phase. During 1960s and 1970s, Graph-D shows a decline in values. Emissions remain lower during 1970s and early 1980s period. Most values stay between 1.6 and 1.8 tons. This lower level is a positive feature in long-term series. It shows India maintained low per capita emissions during growth phase. From late 1980s onward, it shows gradual increase in emissions. After mid-2000s, upward movement becomes more visible in Graph-D. This rise reflects expansion in economy and industrial development. It also shows improved energy access and wider development progress. At same time, long-term trend remains smooth and stable. Five-year rolling average stays mostly above zero in Graph-D. This indicates consistent growth without sudden instability. A temporary dip appears around 2020 period in. This may be linked to COVID-19 lockdown impact on emissions. After that, it shows quick recovery and highest value by 2022. This

recovery shows resilience and continuity in development path. In global comparison, India shows a relatively favorable position. It shows rising emissions, but overall level remains low globally. UNEP Emissions Gap Report 2024 provides global comparison data. Report shows global average per capita emission near 6.6 tCO₂e. India remains well below this global benchmark level. Report also shows countries like United States and Russian Federation have much higher values. Their per capita emissions are close to three times global average. Overall, it shows steady development with gradual emission increase. It also shows long-term stability and resilience in emission pattern.

Graph -D

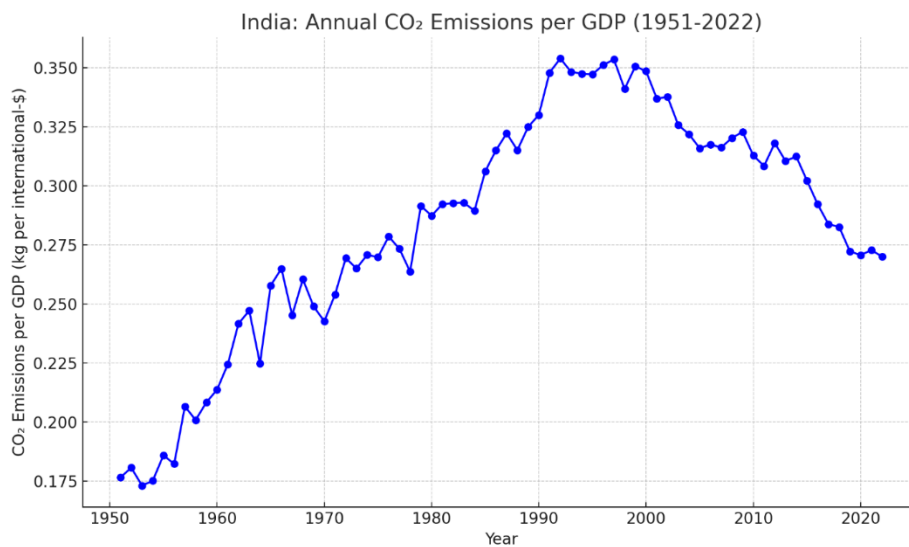


Data Source: Global Carbon Budget (2025); Population based on various sources (2024) – with major processing by Our World in Data

IX. CARBON INTENSITY (CO₂ EMISSIONS PER GDP UNIT)

Carbon intensity shown in graph-E shows a different trend compared to other indicators. Around 1950, value is near 0.17 kg per international dollar. Graph shows steady increase during 1950s and 1960s period. By early 1970s, value rises to around 0.25 kg per international dollar. In 1980s, Graph shows continued increase in carbon intensity. Values reach close to 0.30 during this period. Graph reaches highest point in 1990s decade. Values go above 0.35 kg per international dollar. This shows emissions per GDP unit were highest then. After 2000, Graph shows a clear declining trend. Carbon intensity falls gradually over following years. By 2022, value reaches around 0.27 kg per international dollar level. Curve shows consistent decline in this period. This indicates better energy efficiency across economy. It also reflects shift towards cleaner energy sources over time.

Graph -E



Data source : Global Carbon Budget (2025); Population based on various sources (2024) – with major processing by Our World in Data

X. CONCLUSION

Long-term analysis of India’s greenhouse gas emissions from 1951 to 2022 shows a clear picture of change. Country has experienced fast economic growth while slowly improving environmental performance. Total emissions have increased over time, but this trend needs careful understanding. India has large population, rising economy, and strong development requirements.

One important finding is steady decline in carbon intensity after early 2000s. This means India now produces more output with lower emissions per GDP unit. Trend reflects better energy efficiency and use of improved technologies. It also shows structural changes in economy over time. Policy measures to reduce emission intensity are now showing measurable results. At same time, slower year-on-year emissions growth appears after 2010 period. Emissions still rise in total terms, but growth rate has reduced. This shows shift from fast uncontrolled increase to more stable growth. Such transition is important for any developing economy moving toward sustainability. Analysis of per capita emissions gives more support to this understanding. It is clear that total emissions are increasing steadily in India. However, per capita emissions remain low compared to developed countries. This reflects current stage of development and lower individual contribution globally. It also shows space for future development with cleaner pathways.

Another key observation is response of emissions to external shocks like COVID-19 pandemic. Emissions decline for a short time and then recover in a structured way. This shows strong resilience in economic system over time. It also shows potential to reduce emissions through changes in energy and activity.

Overall, combined trends show declining carbon intensity and slower emission growth. Structural changes in economy are also becoming visible over time. India is moving in a positive direction with balanced development approach. Economic growth continues while sustainability goals are gradually being integrated together.

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