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The Transforming Impacts of Sustainable Logistics Practices in Developed and Developing Countries: A Review

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Abstract:
Sustainable logistics practices are intended to support economic growth; however, they can also contribute significantly to greenhouse gas (GHG) emissions, particularly carbon dioxide (CO_2), which is closely associated with global warming and climate change. This review assesses CO_2 emissions resulting from sustainable logistics practices in both developed and developing countries. Between 1950 and 1990, global CO_2 emissions totaled approximately 6 billion tonnes, with a continuous upward trend in subsequent decades. Between 2021 and 2023, estimated CO_2 emissions from logistics activities reached 72,027.96 million tonnes globally, of which 60% originated from developed countries and 40% from developing countries. During the same period, developed countries accounted for 76% of global gross domestic product (GDP), while developing countries contributed 24%. These figures suggest that developed countries implement more advanced, but also more carbon-intensive logistics systems. Conversely, developing countries show lower adherence to international agreements on CO_2 reduction, possibly due to limited access to low-emission technologies. It is recommended that both developed and developing nations strengthen their efforts to reduce CO_2 emissions e.g. by adopting cleaner, renewable energy sources in logistics operations.

Keywords: Sustainable Logistics**,** transforming impacts, carbon dioxide, developed countries, developing countries.

Introduction

Globally and particularly in developed and developing countries, sustainable logistics practices have produced measurable environmental and socio-economic impacts, both positive and negative. Among the most significant environmental consequences are global warming and climate change, which are closely linked to logistics-related activities such as industrialization, urbanization, and deforestation.

Greenhouse gases (GHGs), including carbon dioxide (CO_2), methane (CH_4), sulphur dioxide (SO_2), and hydrochlorofluorocarbons (HCFCs) used in refrigeration and air conditioning systems, are major by-products of industrial and transport operations. These gases contribute to ozone layer depletion and intensify global warming by reacting with the ozone molecules in the stratosphere, approximately 18 to 30 km above the earth's surface, which ordinarily shield the planet from harmful ultraviolet (UV) radiation, Alkins et al. (1972).

A rise in atmospheric CO_2 concentration from its natural level of around 0.03% significantly accelerates global warming. When infrared radiation from the sun reaches the earth, CO_2 traps this heat energy, preventing it from escaping back into the atmosphere - a process known as the greenhouse effect, Manahan (1994).

The evolution of logistics operations from ancient times through the Middle Ages, the industrial era, and into the 21st century has been marked by shifts in strategic focus. During the Egyptian and Roman empires, logistics emphasized storage and the development of transportation routes, primarily for military mobilization. In the middle Ages, logistical advancements supported the expansion of trade among European regions. The 19th century was defined by the Industrial Revolution, which necessitated efficient transportation systems to move mass-produced goods. The 20th century further expanded logistics through global trade, mechanization, and improved shipping networks, Petrache (2015).

In the late 20th and early 21st centuries, the focus has shifted toward sustainability, driven by growing awareness of environmental challenges. As outlined by Mecalux International (2023), modern logistics is increasingly shaped by digital transformation, including artificial intelligence (AI), the Internet of Things (IoT), autonomous vehicles, and advanced route optimization.

In this study, the term “transforming impacts” refers to measurable environmental and socio-economic changes (variations in CO_2 emissions, GDP per capita, compliance with international agreements) that result from the adoption (or absence) of sustainable logistics practices. Framing the concept in this way highlights how sustainability initiatives in logistics can reshape both economic outcomes and environmental footprints.

To ensure a safer and more sustainable global logistics environment, it is essential to adopt mitigation strategies such as the transition to renewable energy, energy-efficient infrastructure, sustainable land use, and carbon capture and storage technologies, CO_2 Human Emissions (2017); Global Carbon Budget (2024).

The aim of this study is to assess CO_2 emission levels associated with sustainable logistics practices in both developed and developing countries.

LOGISTIC OPERATIONS AND SUSTAINABILITY

The evolution of logistics over time reveals a recurring theme in each era. In the current era, the central focus of global logistics is on environmental sustainability. As such, the key concepts to examine are logistics, environment, and sustainability.

Environmental sustainability refers to the responsible management of natural resources to meet present needs without compromising the ability of future generations to meet theirs. It involves balancing ecological, economic, and social priorities - including reducing carbon emissions, promoting renewable energy, and ensuring equitable access to essential resources. As defined by Mike Weinstein, “needs” include access to clean water, healthy food, and stable housing, yet billions of people still lack access to these basic necessities. For instance, in 2024, approximately 2.2 billion people (one in four globally) lacked access to safe drinking water, Patterson (2024); a situation that has persisted over the past decade, Okon et al. (2018).

Logistics, on the other hand, is the strategic planning framework that enables businesses to store, manage, and transport goods efficiently. It encompasses key functions such as procurement, inventory management, distribution, warehousing, transportation, packaging, and risk management.

When logistics and sustainability are merged, reflecting the dominant theme in today’s global logistics landscape, it gives rise to the concept of sustainable logistics.

This approach involves designing and managing logistics operations in ways that minimize environmental impact, particularly regarding emissions and resource use. As illustrated in *Figure 1* below, sustainable logistics aims to strike a balance between operational efficiency and environmental responsibility. It is not merely about moving goods from point A to point B, but about doing so while reducing the carbon footprint, conserving natural resources, and promoting social responsibility, VASS Company (2024).

Figure 1: Sustainability Logistics Source: Vasscompany (2024)

THE CALL FOR SUSTAINABLE LOGISTICS

In analyzing the transforming impacts of global sustainable logistics, its achievements, challenges, and setbacks, it is important to first understand the origins and necessity of sustainability. The call for sustainability emerged from over four decades of global interest and environmental advocacy by scholars, researchers, and policy stakeholders. A major milestone was the United Nations Conference on the Human Environment, held in Stockholm in 1972, which marked the world's first coordinated action to address the negative environmental effects of industrialization and supply chain operations.

The conference culminated in the adoption of a set of principles for sound environmental management, including the Stockholm Declaration and an Action Plan for the Human Environment. It also led to the establishment of the United Nations Environment Programme (UNEP). This declaration placed environmental concerns at the forefront of international policy and initiated global dialogue between developed and developing nations on the interconnection between economic growth, environmental degradation, and human well-being.

Over the past 50 years, several landmark developments have shaped the progress of global sustainability, particularly within logistics and supply chain operations. As highlighted by Grant, Wong, and Trautrims (2017), the following major events have significantly contributed to this progress:

- The Brundtland Commission (1987) - which introduced the widely accepted definition of sustainable development.
- The UN Earth Summit in Rio de Janeiro (1992) - which endorsed the principle that polluters should bear the costs of pollution.
- The Kyoto Protocol (1997) - which set binding targets for global

greenhouse gas (GHG) emissions reductions.

- The Millennium Summit (2000) in New York - which placed sustainability on the global development agenda.
- The Johannesburg World Summit on Sustainable Development (2002).
- The Copenhagen Climate Change Conference (2009).
- The Rio+20 Summit (2012) - which reinforced prior commitments and introduced new sustainability goals.
- The European Green Deal - This aimed to make Europe climate-neutral by 2050.

According to Grant (2017), one of the most significant and impactful global commitments to date was made at the 2015 Paris Climate Conference (COP21), where nearly 200 countries pledged to limit global warming and reduce CO_2 emissions to net zero, with a target timeline of 2030.

4. GLOBAL CO_2 EMISSION

Before the industrial revolution, CO_2 emission was relatively low. It started rising up from the middle of the 20th century. It has been reported that in 1950, CO_2 emission was 6 billion tonnes which rose up to more than 20 billion tonnes in 1990. For now, emission growth has gone up to 35 billion tonnes each year (Ritchie and Roser, 2020).

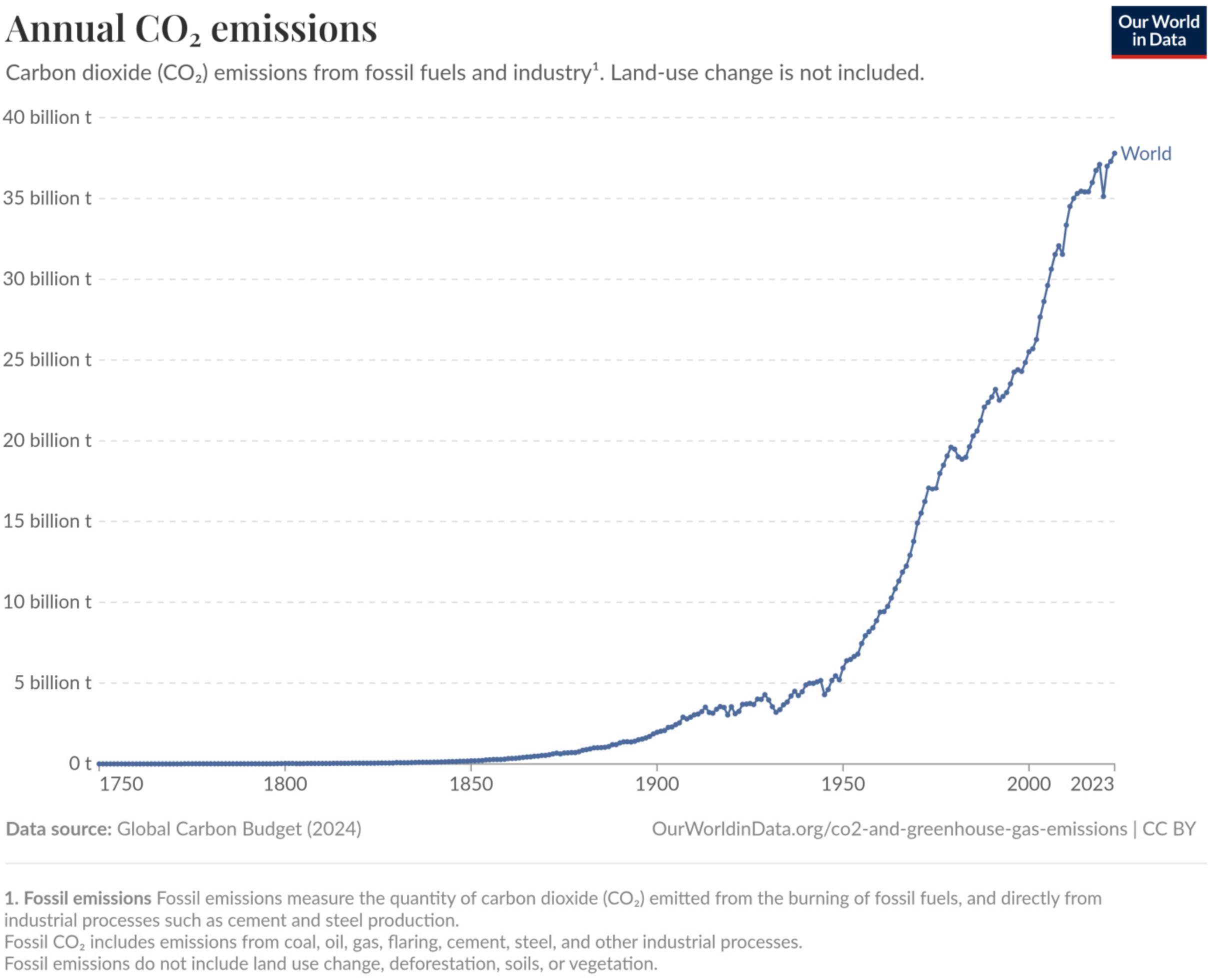

Figure 2: Annual Co_2 Emission Source : *Our World in Data* (Ritchie & Roser, 2024)

The graph above illustrates the annual CO_2 emissions from fossil fuels and industry, which have shown a general decline in recent years. While fossil fuel extraction remains a key contributor, other major sources of emissions include industrialization, power generation, cement production, transportation, land use changes, and deforestation.

On a regional scale, the United States and Europe dominated global CO_2 emissions during the 20th century, largely due to extensive industrial activity and transport infrastructure, Ritchie & Roser (2020). For example, the United Kingdom's CO_2 emissions peaked at approximately 600 million tonnes in 1991, but fell to 305 million tonnes by 2023 - a decline attributed in part to government mitigation policies and the shift toward cleaner technologies, Wappelhorst et al. (2018).

Between 1900 and 1950, Europe and the United States consistently accounted for over 85% of global annual CO_2 emissions, Ritchie & Roser (2020). However, this trend has shifted in recent decades. Countries in Asia, particularly China, have emerged as major emitters, now surpassing both the U.S. and Europe in total emissions.

At a more granular level, individuals also contribute to CO_2 emissions, referred to as emissions per capita. According to Ritchie and Roser (2020), this metric is calculated by dividing a country's total CO_2 emissions by its population. However, such figures can vary significantly depending on whether emissions from international trade are accounted for. For instance, emissions produced within a country's borders may differ from those associated with goods consumed domestically but produced abroad, as shown in *Figure 3*, which highlights global inequalities in per capita emissions.

Oil-producing countries in the Middle East such as Qatar, the United Arab Emirates, Bahrain, and Kuwait, have some of the highest CO_2 emissions per capita, largely due to high energy production and low population size. In contrast, countries like the United States, Australia, and Canada also report high per capita emissions, approximately three times higher than the global average, despite having larger populations.

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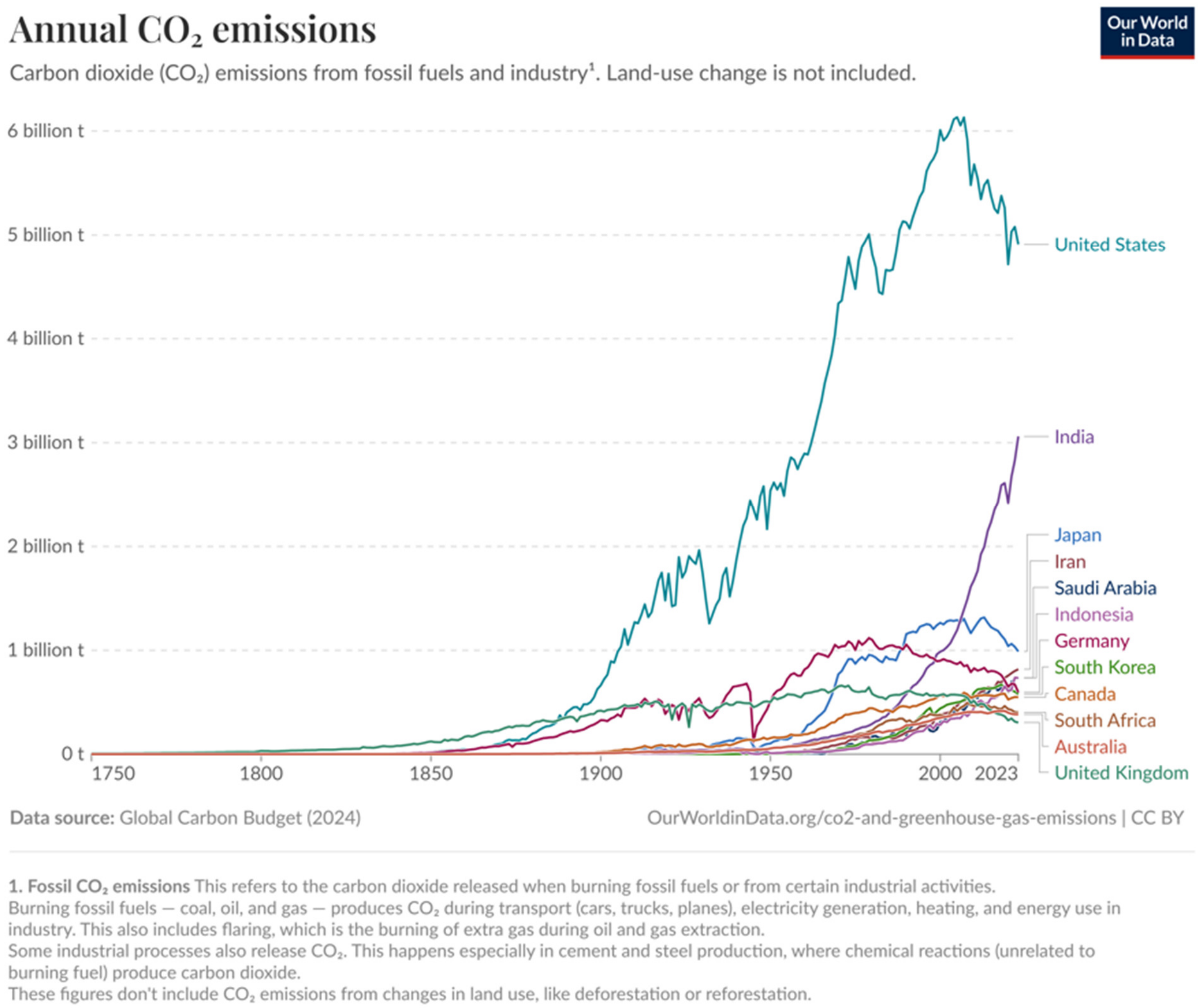

Figure 3: Per capita CO_2 Emission **Source**: *Our World in Data* (Ritchie & Roser, 2020)

It has been widely reported that countries with higher income per capita tend to have larger carbon footprints. However, significant variation exists even among countries with similar standards of living. For example, many European nations maintain much lower per capita CO_2 emissions compared to the United States, Canada, or Australia. This variation is largely influenced by differences in energy sources, policy frameworks, and technological choices.

While energy consumption is a major driver of CO_2 emissions, policy interventions and cleaner technologies can substantially mitigate environmental impact. Several European countries, including Germany, France, the Netherlands, and Belgium, emit CO_2 levels that are near or slightly above the global average, despite their industrialized economies. This demonstrates the potential for decoupling economic prosperity from high emissions through sustainable policy and innovation.

In contrast, many developing countries, particularly in sub-Saharan Africa, have extremely low carbon footprints. On average, their per capita CO_2 emissions are around 0.1 tonnes per year, which is approximately 150 times lower than those of countries like the United States, Australia, and Canada, Ritchie & Roser (2020). For example, the annual emissions of countries such as Mali and Niger are nearly negligible compared to those of major industrialized nations.

However, some oil-producing African countries like Nigeria, Algeria, and Angola, record relatively higher CO_2 emissions compared to their regional counterparts.

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According to *Our World in Data* (2021–2023), these elevated emissions are primarily linked to fossil fuel extraction and export-oriented energy industries.

4.1 Yearly Emission of CO_2 by regions

India, China, and the United States are currently among the leading emitters of CO_2, as illustrated in *Figure 4*, which depicts where CO_2 is produced, rather than where it is ultimately consumed. This distinction is crucial when evaluating national emission responsibilities, particularly in the context of global trade.

When comparing production-based emissions to consumption-based emissions, regional disparities become evident. Asia leads in total CO_2 output, accounting for approximately 50% of global emissions. This is not surprising, given that Asia is home to nearly 60% of the world's population. Despite its large share of global emissions, Asia's per capita CO_2 emissions remain slightly below the global average.

China is the world's largest single emitter, contributing more than one-quarter of total global CO_2 emissions during 2021, 2022, and 2023, *Our World in Data (2024)*. It is followed by North America, which accounts for roughly 25% of global emissions, and Europe, which follows closely behind, Ritchie & Roser (2020).

In contrast, Africa and South America are responsible for only 3-4% of global emissions each, underscoring the significant gap in emissions between industrialized and developing regions.

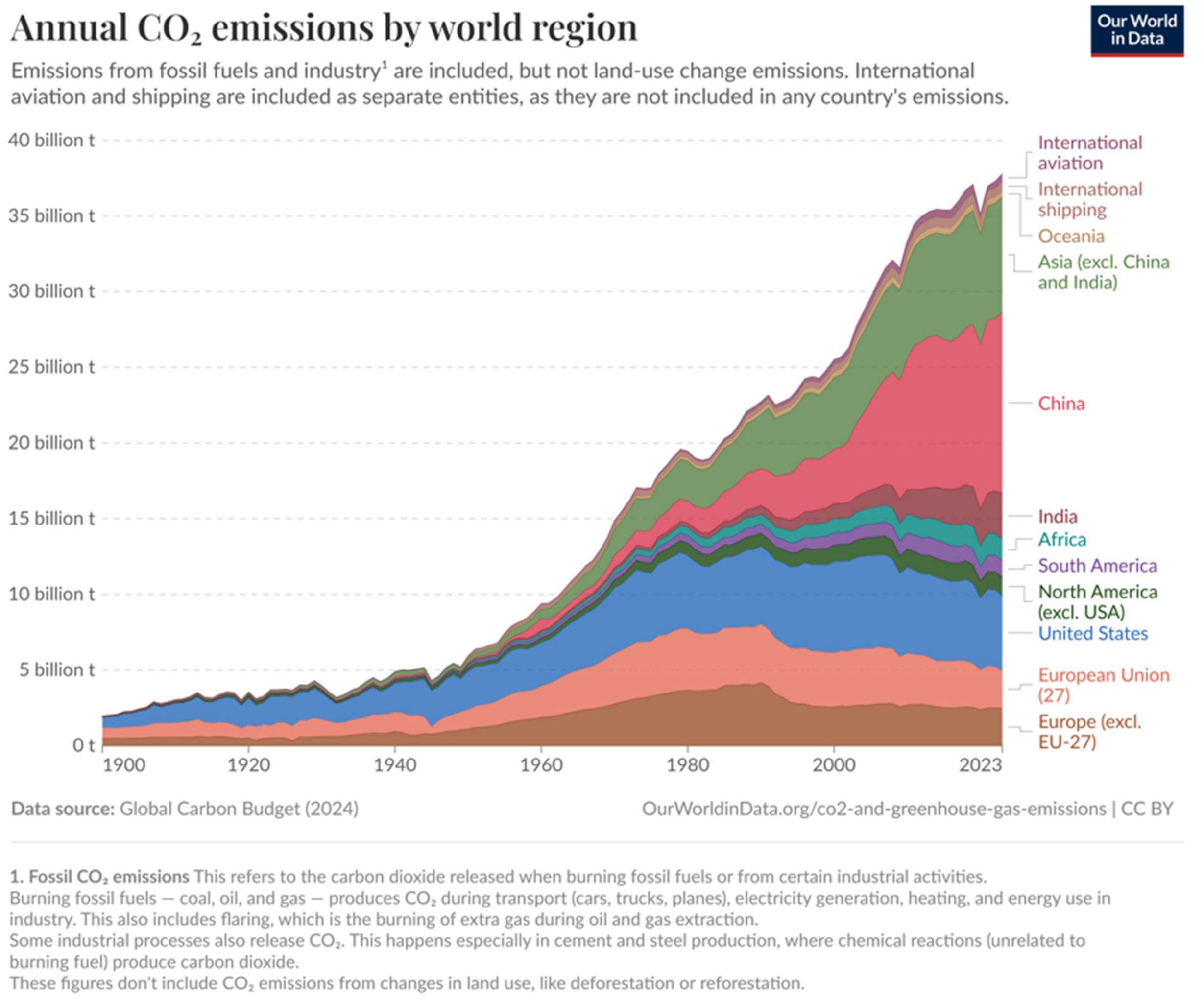

Figure 4 : CO_2 Emission by Region **Source**: *Our World in Data* (Ritchie & Roser, 2024)

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5. Comparable CO_2 Emission and GDP Per Capita in Developed and Developing Countries

Sustainable logistics practices have produced a range of transforming impacts in both developed and developing countries. From an environmental perspective, one of the most significant impacts is the emission of greenhouse gases, particularly carbon dioxide (CO_2), which results from industrial activities, transportation, and widespread reliance on fossil fuels.

From an economic standpoint, GDP per capita is often used as an indicator of national development, reflecting outcomes linked to road infrastructure, power generation, mineral resource exploitation, and other logistics-enabled sectors.

These environmental and economic indicators, specifically CO_2 emissions and GDP per capita, are presented in Tables 1 and 2, which compare selected developed and developing countries.

Economically, sustainable logistics practices have the potential to stimulate national development by increasing gross domestic product (GDP), raising income per capita, and enhancing key sectors such as healthcare, education, agriculture, and food security. Examples of such practices include the promotion of commerce and industry, improvements in energy supply, employment generation, and strategic budgetary allocation to priority areas of the economy.

Table 1: CO_2 emission in developed and developing countries

	CO_2 emission per year(tonnes)			
Developed countries	**2021**	**2022**	**2023**	
USA	5.03billion	5.08billion	4.91billion	
Japan	1.06billion	1.03billion	988.78million	
Germany	678.78million	671.47million	596.15million	
South Korea	616.08million	602.09million	577.42million	
Australia	389.02million	384.36million	382.97million	
Uk	344.51million	313.83million	305.15million	
Total/Ave.	8.06billion	8.05billion	7.76billion	7.96billion
% Global CO_2				**60%**
Developing countries				
India	2.67billion	2.83billion	3.06billion	
Iran	779.76million	800.75million	817.88million	
Turkey	452.70million	437.31million	432.08million	
Mexico	446.83million	465.34million	482.62million	
South Africa	425.92million	405.31million	401.89million	
Egypt	260.04million	271.17million	269.01million	
Total/Ave.	5.04billion	5.30billion	5.506billion	5.23billion
% Global CO_2				**40%**

Source: *Our World in Data* (Ritchie & Roser, 2020)

Table 2: GDP per capita in developed and developing countries

	GDP per capita ($)			
Developed countries	**2021**	**2022**	**2023**	
USA	71,307	72,679	74,159	
Germany	62,531	62,932	62,687	
Australia	58,182	59,884	60,461	
Uk	51,004	52,982	52,503	
South Korea	48,420	49,778	50,414	
Japan	44,355	44,972	45,859	
Total/Ave	335,799	343,227	346,083	341,703
% Global GDP				**76%**
Developing countries				
Turkey	32,748	34,283	35,294	
Mexico	21,392	21,905	22,033	
Egypt	15,579	16,360	16,691	
Iran	14,952	15,331	15,912	
South Africa	13,711	13,777	13,890	
India	8,050	8,594	9,302	
Total/Ave	106,432	110,250	113,122	109,935
% Global GDP				**24%**

Source: *Our World in Data* (Ritchie & Roser, 2020) .

In assessing the impacts of sustainable logistics across different economic contexts, Tables 1 and 2 present data on CO_2 emissions and GDP per capita for selected developed and developing countries. For the developed group, the top six CO_2 emitters were chosen, ensuring at least one representative from each continent, except Africa and South America, which do not have countries classified as developed under most global standards. For the developing group, Africa is represented by two countries, reflecting its large number of developing nations, while Iran was selected to represent the region of Australasia. The remaining continents are each represented by one notable developing country, chosen on the basis of global CO_2 emission indices. These same country groupings were used in the analysis of GDP per capita.

According to Table 1, among the developed countries, USA is the largest emitter of CO_2, with a total of 15.02 billion tonnes recorded between 2021 and 2023, while the United Kingdom represents the lowest among this group, with 963.49 million tonnes in the same period. In the developing category, India recorded the highest CO_2 emissions at 8.56 billion tonnes, while Egypt recorded the lowest at 800.22 million tonnes.

These figures indicate that, on average, developed countries account for 60% of global CO_2 emissions, whereas developing countries contribute 40%. Notably, only India among the developing countries emits CO_2 at a level comparable to that of the developed countries, suggesting that India's logistics and industrial activities may be more developed relative to its peers.

Table 2 highlights GDP per capita figures as an economic indicator of development.

Among developed countries, the United States has the highest average GDP per capita at $72,715, while Japan ranks lowest in this group at $56,062. In contrast, among developing countries, Turkey has the highest GDP per capita at $32,748, while India records the lowest at $8,649, reflecting a lower level of logistics infrastructure and economic development.

Overall, these comparisons suggest that developed countries, with an average of 76% of total global GDP per capita, maintain higher living standards, which is often associated with higher CO_2 emissions. Meanwhile, developing countries average only 24%, reinforcing the disparities in economic capacity and logistics infrastructure. Apart from India, developed countries generally apply more advanced and sustainable logistics practices, contributing both to higher emissions and higher economic output.

6. CO_2 MITIGATION

Following the 1987 Montreal Protocol, finalized in 1989 to address ozone depletion, and the 2016 Paris Agreement focused on CO_2 reduction and climate change mitigation, Climate Change News (2023), both developed and developing countries have made varying degrees of progress toward compliance. Most efforts have centered on reducing CO_2 emissions from fossil fuel combustion, transportation, industrial activities, and deforestation. However, less attention has been paid to the removal of existing CO_2 in the atmosphere, which is critical for long-term climate stability.

There are three main approaches to CO_2 mitigation. No single strategy can be implemented in isolation; rather, they function as a complementary framework for addressing emissions:

1. Limiting CO_2 emitting activities such as fossil fuel extraction, industrial manufacturing (e.g., cement production), transportation, power generation, and deforestation.
2. Removing atmospheric CO_2 through afforestation and reforestation, which use photosynthesis to absorb carbon naturally.
3. Establishing and enforcing effective government policies, underpinned by strong political will, to promote and regulate CO_2 reduction initiatives.

It is important to recognize that CO_2 already present in the atmosphere is largely a byproduct of decades of emissions, much of which stems from global logistics and industrial systems. Therefore, effective CO_2 mitigation requires both technological solutions and coordinated policy frameworks.

According to the United Nations Development Program (2024), CO_2 mitigation involves reducing the concentration of atmospheric CO_2 by limiting emissions from human activities and enhancing natural carbon sinks, such as forests and oceans. This includes decreasing emissions from fossil fuel combustion, industrial processes, and transportation.

The significance of CO_2 mitigation lies in its potential to slow global warming, which causes rising sea levels (due to melting glaciers and polar ice caps), ecosystem disruption, and increased frequency of extreme weather events, UNDP (2024).

Several mitigation strategies have been adopted globally, including:

- Transitioning to renewable energy sources such as solar, wind, and hydropower
- Improving energy efficiency in buildings, transportation, and industries
- Protecting and restoring forests, which absorb CO_2 through photosynthesis

- Promoting sustainable agriculture and enhancing soil health
- Encouraging waste reduction, material reuse, and recycling to minimize resource extraction
- Supporting sustainable mobility and urban tree planting

To evaluate the progress of these strategies, it is useful to examine the compliance levels of developed and developing countries with international agreements like the Montreal Protocol and the Paris Agreement.

Between 1990 and 2023, a number of countries demonstrated significant reductions in CO_2 emissions. According to *Climate Change News (2023)* and *Statista (2025)*, the following countries have reported the following emission change profiles:

- Developed countries with reductions:

  I. United Kingdom: -48.15%
  II. Germany: -42.5%
  III. Italy: -28.4%
  IV. Poland: -22.8%
  V. Japan: -19%
  VI. United States: -6.1%

- Developed countries with increases:

  I. Canada: +30.5%
  II. Australia: +34.5%
  III. Mexico: +86.2%
  IV. Turkey: +82.5%

- Developing countries with increases:

  I. South Africa: +26.5%
  II. Brazil: +111.3%
  III. Iran: +273.6%
  IV. Indonesia: +317%
  V. India: +392%
  VI. Vietnam: +1712.8%

These figures highlight a sharp contrast between countries with strong mitigation policies and those with increasing emissions, particularly among developing economies. Ultimately, the degree of compliance largely depends on the strength of national policies and the political will to enforce sustainable practices which are elements that remain weak or inconsistent in many developing countries, especially across sub-Saharan Africa.

7. CONCLUSION

While many developed countries have established clear targets and robust policies to reduce or eliminate greenhouse gas (GHG) emissions in pursuit of sustainable operations, developing countries continue to lag behind, posing a challenge to the effectiveness of global climate efforts.

Overall, sustainable logistics practices have produced transforming impacts on a global scale, particularly in relation to GHG emissions and gross domestic product (GDP). However, these impacts are more pronounced in developed countries. Although the environmental consequences of GHG emissions such as heatwaves, flooding, and extreme weather events, are experienced in both developed and developing regions, the economic benefits, including higher GDP per capita, are more stabilizing in developed economies.

This study has demonstrated that between 2021 and 2023:

- Developed countries were responsible for approximately 60% of global CO_2 emissions.
- Developing countries accounted for 40% of CO_2 emissions.
- In terms of economic output, developed countries contributed 76% of global GDP, compared to 24% from developing countries.

These figures imply that developed countries, due to higher industrial activity and advanced logistics systems, contribute more significantly to climate change.

It is therefore recommended that:

- Developed countries intensify their efforts to reduce greenhouse gas emissions by accelerating the transition to clean energy and enforcing stricter environmental regulations.
- Developing countries should prioritize the establishment of stable policy frameworks and demonstrate stronger political will to support emissions reduction, adopt clean technologies, and participate actively in global climate commitments.

Acknowldegement
None

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