VISUALIZING CLIMATE CHANGE

This article reviews climate change, demonstrating that human-produced greenhouse gases (GHGs) like CO2, CH4, and N2O are primary drivers of global warming. Utilizing data from sources such as Our World in Data and the IPCC's Sixth Assessment Report, we analyze emissions by country and per capita, highlighting the complexity of attributing responsibility. The study also identifies key emission sources, advocating for innovative methods to reduce emissions. Despite certain limitations, the findings underscore the collective responsibility in addressing this global challenge.

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INTRODUCTION:

During the last decades, climate change and global warming have been topics of discussion around the world in both social and scientific fields. Due to the controversy of this issue, there is a huge amount of information about this topic, which is not always true and often presents a marked political bias. Moreover, despite how widespread this topic is in our society, many people are not really involved and have just heard about it in the news, some political speeches, and maybe in primary or secondary school. Therefore, they remain susceptible to the previously mentioned biased information and ignorant of the empirical evidence that science has provided in recent years. Intuitively, we cannot discard the fact that susceptibility to fake information is probably a consequence of ignorance of the real evidence of climate change. However, we cannot blame people for not being up to date with the latest scientific papers about this and many other topics that have a huge influence on our lives and societies due to different reasons, such as difficulty to read and find if you are not involved on this type of academical communities, the previously mentioned bias on the media that produce a fake feeling of acquisition of the required knowledge, and that usually the average citizen is busy with daily tasks and projects that do not allow him to dedicate time to read complex reports from the IPCC. Considering all these previously mentioned factors that contribute to maintain the most part the population far from acquiring an unbiased and scientifically based knowledge, I decided to write a short article to explain in a simple and visual way the phenomenon of climate change and global warming. This way, readers can have a clearer and more visual understanding of climate change and be able to discern between biased and scientific information and properly analyze which policies and actions can be taken to deal with this problem.

METHODOLOGY AND DATA:

In order to carry out this analysis we will consider different tables extracted from the website of Our World in Data, which collects and stores huge amounts of structured data that comes from different worldwide institutions, such as the Energy Institute (EI), the U.S. Energy Information Administration (EIA), and many others. The reader can find information about the precedence of the data in the bibliography section, at the end of the paper. Moreover, the reader must consider that all the information given in these texts comes from the Sixth Assessment Report (AR6), by the Intergovernmental Panel on Climate Change (IPCC), that, in short, is an international body responsible for assessing the topic of climate change and global warming, established in 1988 by the World Meteorological Organization (WMO) and the United Nations Environment Program (UNEP). Its main purpose is to provide policymakers with regular scientific assessments on climate change, its implications, and potential future risks, as well as establishing a potential path to the mitigation and adaptation of the problem.

More precisely, I am going to consider nine different tables from the same source (Our World in Data), that provide information about the emission of greenhouse gases around the world at a country level, the changes on temperature in both land and ocean, and more sophisticated information that we are going to be reviewing together along this article. This one is going to be divided into three sections. Firstly, we will study climate change in a theoretical framework, analyzing the basic concepts and ideas of the Sixth Assessment Report, and possibly considering some details of previous reports. Secondly, we will validate this theoretical framework through a statistical and data analysis-based framework, that will allow us to corroborate the previously acquired information, and also fomenting a visual way of learning and understanding for the reader, in order to make the information easier to digest. And finally, apart from studying and explaining how climate change is taking place and which evidence do we have to proof it, we will analyze the information in order to analyze the precedence of the elements that primarily contribute to this phenomenon, in order to address and develop potential solutions and policies for this issue.

EXPLAINING CLIMATE CHANGE:

Climate change is defined as a change in the average temperature of a certain zone or region, despite the fact that it usually occurs throughout the whole planet simultaneously. It does not necessarily need to be global warming such as the one we are experiencing nowadays; it might also be a cooling effect such as the Little Ice Age that took place from the 14th to the 19th century, specifically in the North Atlantic Region, due to reduced solar activity, increased volcanic activity, changes in oceanic circulation, and the minor effect of natural climate variability. To properly understand why these events happen, and particularly why we are currently experiencing global warming, we will review the essential concepts and put them all together.

Let us start with our planet, the Earth, and more specifically, the atmosphere, which plays a crucial role in understanding climate change. The atmosphere is the outer layer of Earth composed of gases held in place by gravity. The atmosphere is divided into different smaller layers. The lowest layer is called the troposphere, which extends from the Earth's surface up to about 8-15 km. This is where all our weather events occur, such as rain, snow, and storms. Above it, we find the stratosphere, which extends up to about 50 km. This layer holds the ozone layer, which absorbs and scatters ultraviolet solar radiation, creating a stable atmosphere essential for protecting life on Earth from harmful UV rays. Next, we have the mesosphere, found from 50 km to about 85 km beyond the stratosphere. This layer is where meteors burn up upon entering the Earth's atmosphere. While it plays a minor role in weather and climate, it is critical in protecting the Earth. Finally, we have the thermosphere, which extends from the mesosphere to about 600 km, where temperatures rise significantly due to the absorption of high-energy radiation like X-rays and UV light, and the exosphere, which spans from the top of the thermosphere to about 10,000 km. This is the outermost layer that gradually turns into outer space and has little direct impact on weather and climate.

Our focus now shifts directly to the troposphere, where a key phenomenon to explain climate change occurs, the greenhouse effect. To understand it, we must consider that when the sun emits UV rays (energy) to the Earth's surface, some of this energy is retained on the surface, and some is reflected back in the form of heat (infrared rays). This reflection process is called the albedo effect and directly depends on the color and type of the surface. Lighter-colored surfaces present a greater albedo, meaning they reflect more heat and retain less energy, such as ice or snow. Conversely, darker-colored surfaces present a lower albedo, so they reflect less heat and retain more energy. However, this reflected heat is not lost but is trapped by the troposphere due to a layer of gases that help contain it. This containment effect is called the greenhouse effect, and the gases that contribute to this effect are called greenhouse gases, such as carbon dioxide (CO_2), nitrous oxide (N_2O), methane (CH_4), and the so-called fluorinated gases (CFCs and others). Currently, the proportion of the energy absorbed by the Earth’s surface and the atmosphere is about 70% of the energy that arrives from the sun in the form of UV rays, while the remaining 30% is reflected back and lost. This proportional consideration of the heat absorbed is called the Earth’s energy budget, and to be balanced, it should be around 50%.

Note that the natural levels of these gases in the troposphere have been altered due to human actions in production, transport, and many other activities that we will analyze in the following pages. The main idea of climate change and global warming theory that concerns our societies nowadays is that the massive emissions of these gases have contributed to an increase in the greenhouse effect of the troposphere at a global level, causing the heat captured by it to increase the global temperature. It is important to note that the greenhouse effect by itself is not negative; on the contrary, it is critical for guaranteeing life on Earth. Without it, the whole planet would instantly freeze. However, nothing in excess is good, and an increase in the temperatures on the planet might bring huge consequences.

It is not my intention to emphasize these potential hazards and negative effects that global warming might have on our society and, in general, over all life on Earth. However, we can consider it for a moment and look at them. It is common to first consider the effects that global warming has already had through a current increase of 1.5ºC, such as the increased frequency and severity of extreme weather conditions affecting health and agriculture, the accelerated melting of glaciers contributing to rising sea levels and generating problematic natural phenomena for coastal cities and civilizations, and the threat to ecosystems and biodiversity, with coral reefs and Arctic habitats experiencing severe degradation. Secondly, we can review the predicted effects after an increase of 2ºC in the global average temperature, for example, more intense and longer-lasting heatwaves significantly impacting human health and labor productivity; sea levels will rise further, increasing the risk of frequent and severe coastal flooding, potentially displacing millions of people; ecosystems will face widespread collapse, with coral reefs experiencing near-total decline and a significant loss of biodiversity; agriculture will suffer further declines in crop yields, exacerbating food security issues; water scarcity will become more pronounced, with increased droughts and water shortages impacting freshwater availability; and human health risks will rise, with an increased prevalence of diseases, heat-related illnesses, and greater displacement and conflict over resources.

Apart from the consequences and human actions involved in climate change, the reader must consider that some natural elements also contribute to temperature change and global warming and that have had previous effects on the average temperature in past periods, such as the original Ice Age or the more recent Little Ice Age that we previously described. Two of the indicators that we will consider during this article and that are required for the reader to understand and analyze the natural events contributing to climate change properly are:

- The Multivariate ENSO Index (MEI) measures the intensity of the El Niño-Southern Oscillation (ENSO), a climate pattern involving temperature fluctuations in the central and eastern tropical Pacific Ocean, impacting global weather and climate. El Niño and La Niña events are the warm and cool phases of ENSO, respectively, which can significantly affect global weather patterns, including precipitation, storm activity, and temperature anomalies.

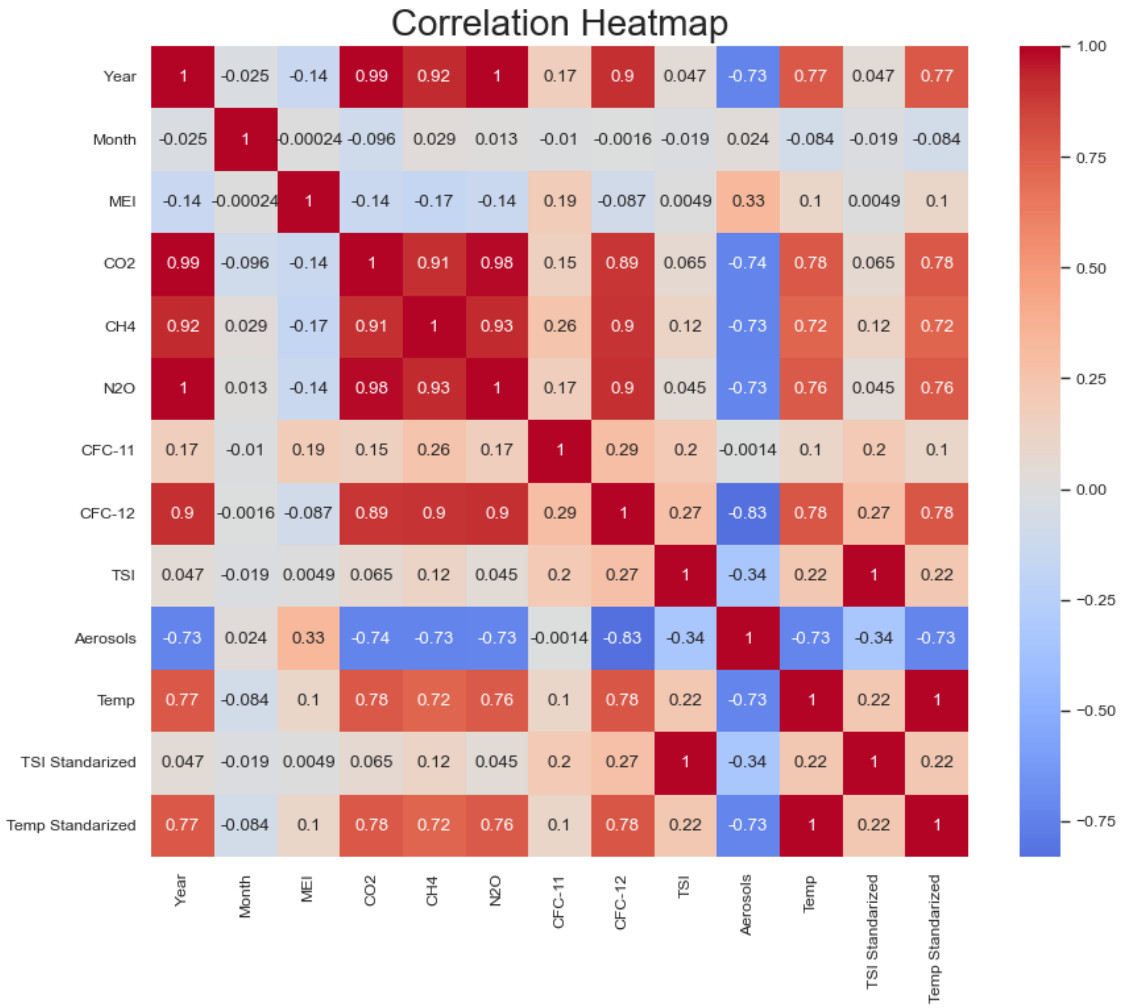
- Total Solar Irradiance (TSI) measures the amount of solar energy received per unit area at the top of the Earth's atmosphere. It varies slightly with the solar cycle, approximately every 11 years. Changes in TSI can influence the Earth's climate by altering the amount of energy that reaches the Earth's surface.

Now that we have a general idea of how global warming is taking place according to the scientific community, mainly shaped by the IPCC whose findings are expressed in their Assessment Reports, we can move forward to analyze the previously mentioned data to address the global warming topic and try to get some insights that lead us to potential solutions that might be translated into policies and measures by governments and unions around the world.

RESEARCH INSIGHTS AND RESULTS:

WHICH ARE THE ELEMENTS CAUSING CLIMATE CHANGE AND GLOBAL WARMING?

Let's start our analysis by trying to identify the elements that might be considered the main causes of climate change, and in particular, global warming, to study them in detail. Correctly identifying the symptoms will be a huge first step in the process of searching for an efficient and effective solution for this issue in socio-economic terms. To do so, let's first plot a correlation heatmap to get a general view of our first data frame, so we can identify critical points and areas to take a focused look afterward. If we focus on the variable "Temp," i.e., Temperature, we can rapidly notice that many variables present significant correlation coefficients in absolute values. Particularly, CO2, CH4, N2O, CFC-12, and Aerosols. Let us take a more detailed look at each of them separately to get a better understanding of these values.



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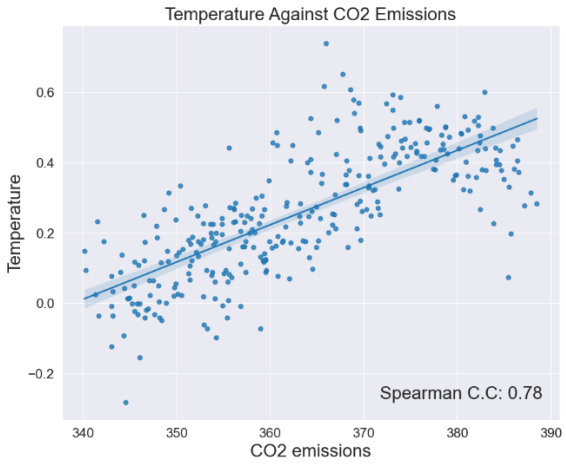
Firstly, by analyzing the graph of Temperature against CO2 emissions, we can see that the scatter plot illustrates a strong positive correlation (Spearman coefficient of 0.78) between CO2 emissions and temperature, confirming that as CO2 levels increase, so does global temperature. This trend supports the theoretical framework of the greenhouse effect, where CO2 traps heat in the atmosphere. CO2 emissions primarily stem from the burning of fossil fuels such as coal, oil, and natural gas, as well as deforestation and various industrial processes. These activities release significant amounts of CO2 into the atmosphere, enhancing the greenhouse effect and contributing to global warming. By the same way, methane, as shown in the second plot, has a strong positive correlation (Spearman coefficient of 0.72) with temperature, indicating that as CH4 emissions increase, global temperature also increases. To provide some context, it is important to remark that currently, methane is a potent greenhouse gas, and its rise contributes significantly to global warming by helping, as the remaining greenhouse gasses do, to retain heat in the surface of the earth by avoiding it to escape out of the atmosphere. Thirdly, the next graph, that plots the correlation between temperature and emissions of N2O demonstrates a strong positive correlation (Spearman coefficient of 0.76), indicating that higher N2O emissions are associated with increased global temperatures. N2O, a potent greenhouse gas, contributes significantly to the greenhouse effect, whose main emissions sources come from agriculture (particularly through the use of fertilizers), industrial activities (including chemical production), and transportation (especially from vehicles using fossil fuels). Next, by analyzing the graph of Temperature against Aerosols emissions, we can see that the scatter plot illustrates a strong negative correlation (Spearman coefficient of -0.73). This trend indicates that as aerosols emissions increase, global temperatures tend to decrease. Aerosols, which include particulate matter from sources like industrial processes, combustion, and volcanic activity, have a cooling effect on the climate by reflecting sunlight back into space and enhancing cloud reflectivity. This cooling effect counteracts some of the warming caused by greenhouse gases, however, the reader must understand that an intended and artificial emission of aerosols also imply significant health risks and can contribute to environmental phenomenon like acid rain. In fifth place, we will analyze the graph of Temperature against CFC-11 emissions, from which we can observe that the scatter plot illustrates a weak positive correlation (Spearman coefficient of 0.1) between CFC-11 emissions and temperature. This trend suggests that while there is some relationship between CFC-11 levels and global temperature, it is not as strong as the correlations observed with other greenhouse gases like CO2, CH4, or N2O. CFC-11, along with other chlorofluorocarbons, was widely used in refrigeration, air conditioning, and as a propellant in aerosol sprays. Despite the fact that its use has been significantly reduced due to international regulations such as the Montreal Protocol, its long atmospheric lifetime means it continues to affect the climate and the ozone layer. The reader must consider that the weak correlation in the plot may reflect the combined effects of historical emissions and current reductions. Finally, we can observe that the last scatter plot shows a strong positive correlation (Spearman coefficient of 0.78) between CFC-12 emissions and temperature, indicating that as CFC-12 emissions increase, so does global temperature. The reader must consider that Chlorofluorocarbons (CFCs), including CFC-12, are potent greenhouse gases that also deplete the ozone layer. CFC-12 emissions primarily come from industrial sources such as refrigeration, air conditioning, and aerosol propellants.



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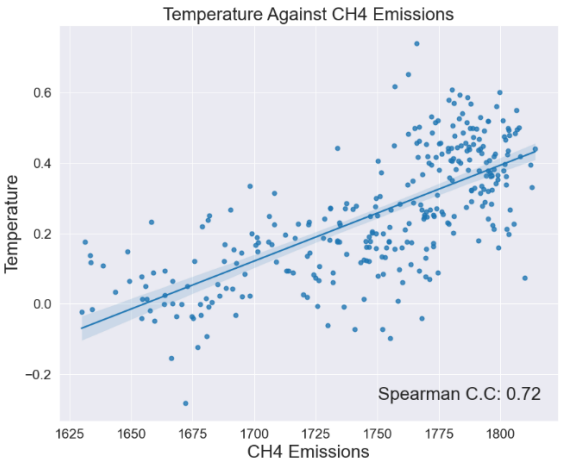

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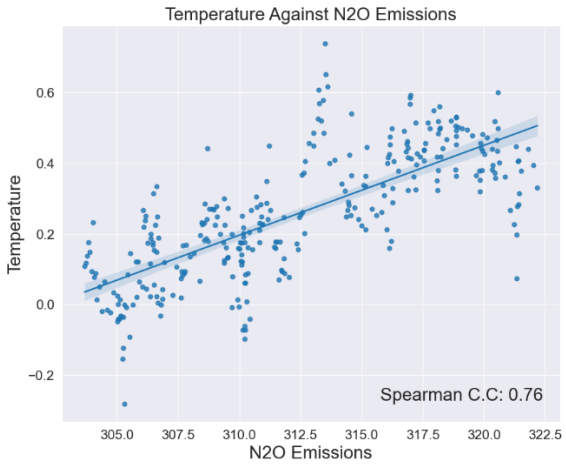

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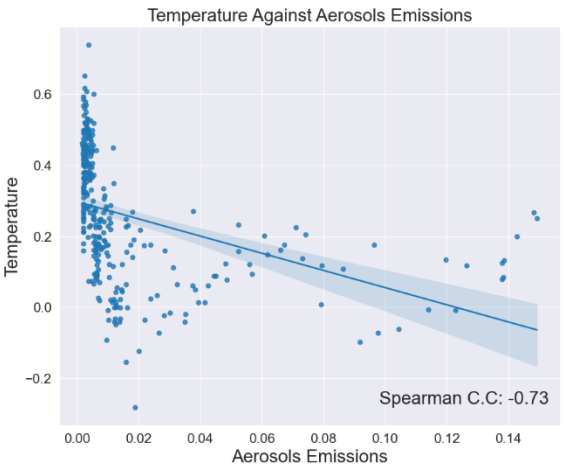

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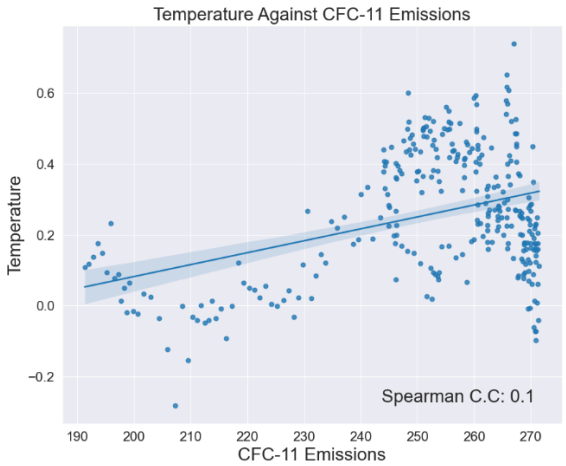

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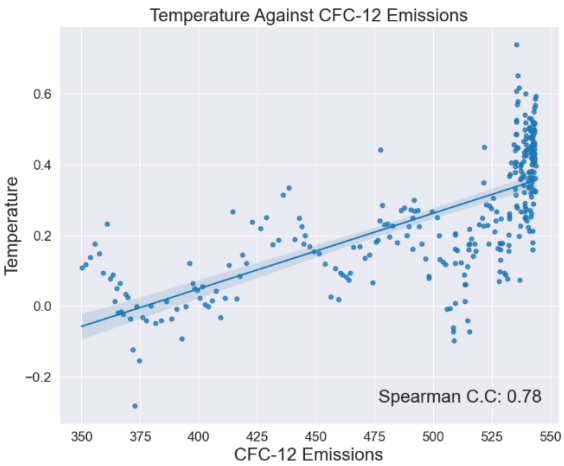

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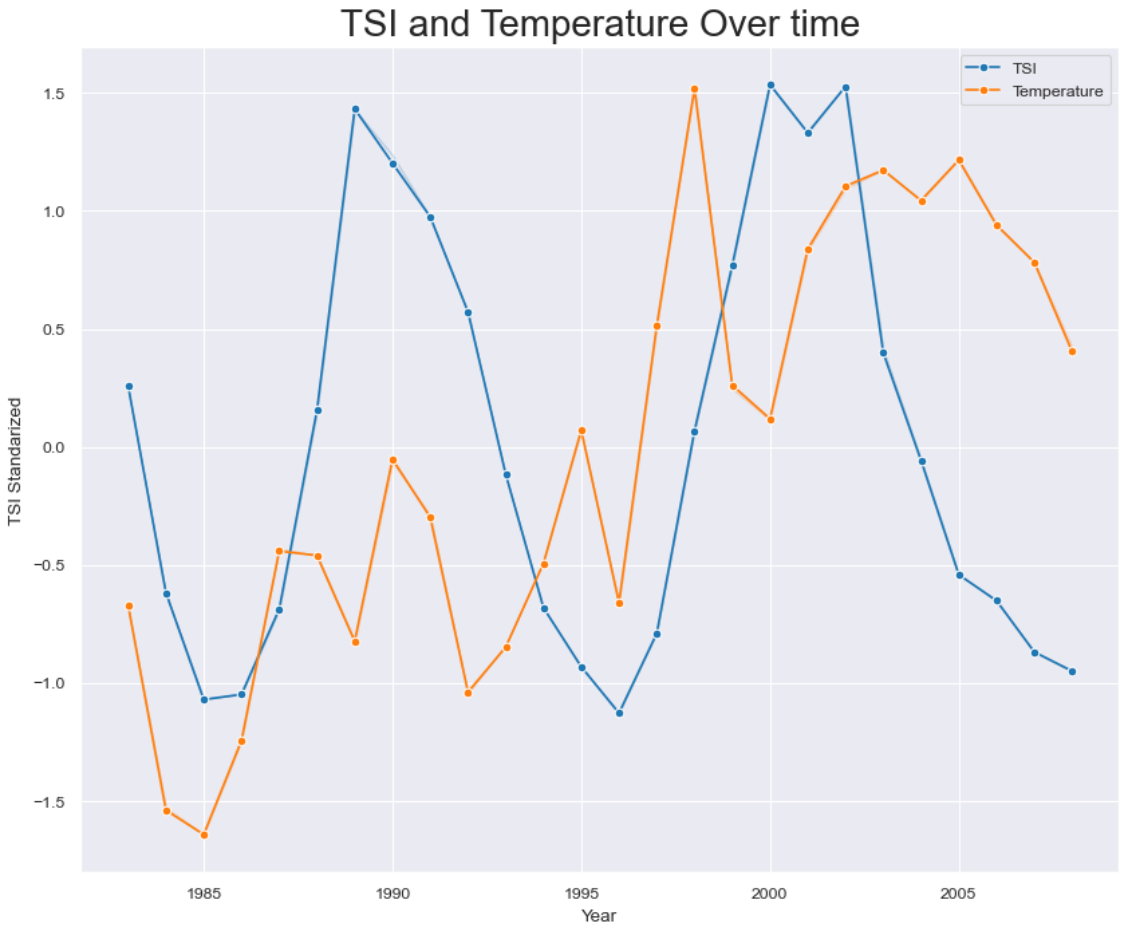
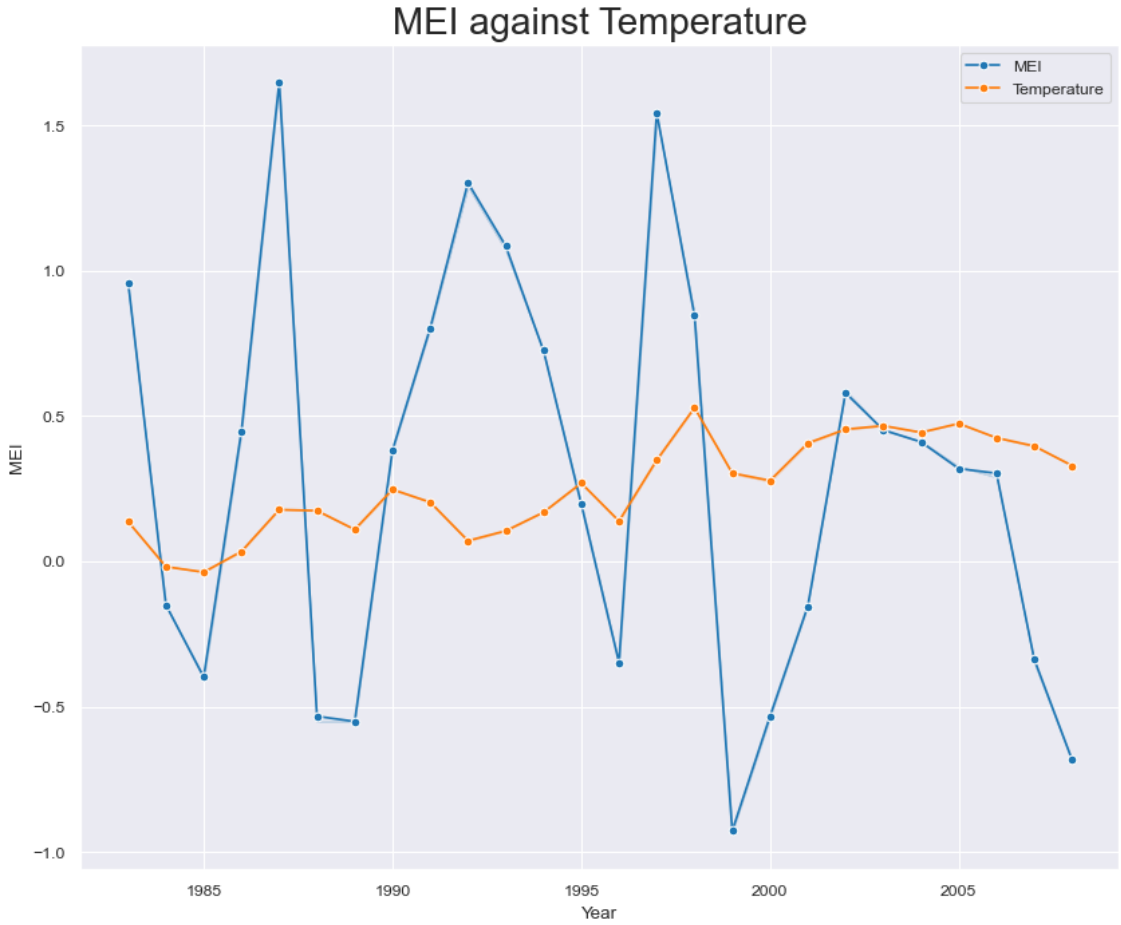
At last, let's analyze the evolution over time of temperature against both MEI and TSI in order to get insights of the impact of these two variables on climate change and global warming.

The first graph, depicting TSI (Total Solar Irradiance) and temperature over time, illustrates the changes in solar energy received by the Earth's atmosphere and its correlation with temperature. Although TSI fluctuates due to the solar cycle, the graph shows that these fluctuations do not consistently align with temperature changes over the same period. This tells us that while solar irradiance plays a role in climate variations, it is not the primary driver of the observed temperature increase. The lack of a strong correlation underscores the significance of other factors, such as greenhouse gas emissions, in driving global warming.



Own Autorship. Source: https://www.kaggle.com/datasets/econdata/climate-change/data

The second graph, showing MEI (Multivariate ENSO Index) against temperature, examines the influence of El Niño-Southern Oscillation (ENSO) events on global temperature. As explained before, the MEI represents the intensity of El Niño and La Niña phases, which significantly impact weather patterns and temperature anomalies. The graph indicates that temperature trends remain relatively stable despite the pronounced fluctuations in MEI. This suggests that while ENSO events cause short-term temperature variations, they do not dictate the long-term upward trend in global temperatures. This further emphasizes the importance of anthropogenic factors, such as greenhouse gas emissions, which we already proved to generate a greater impact.



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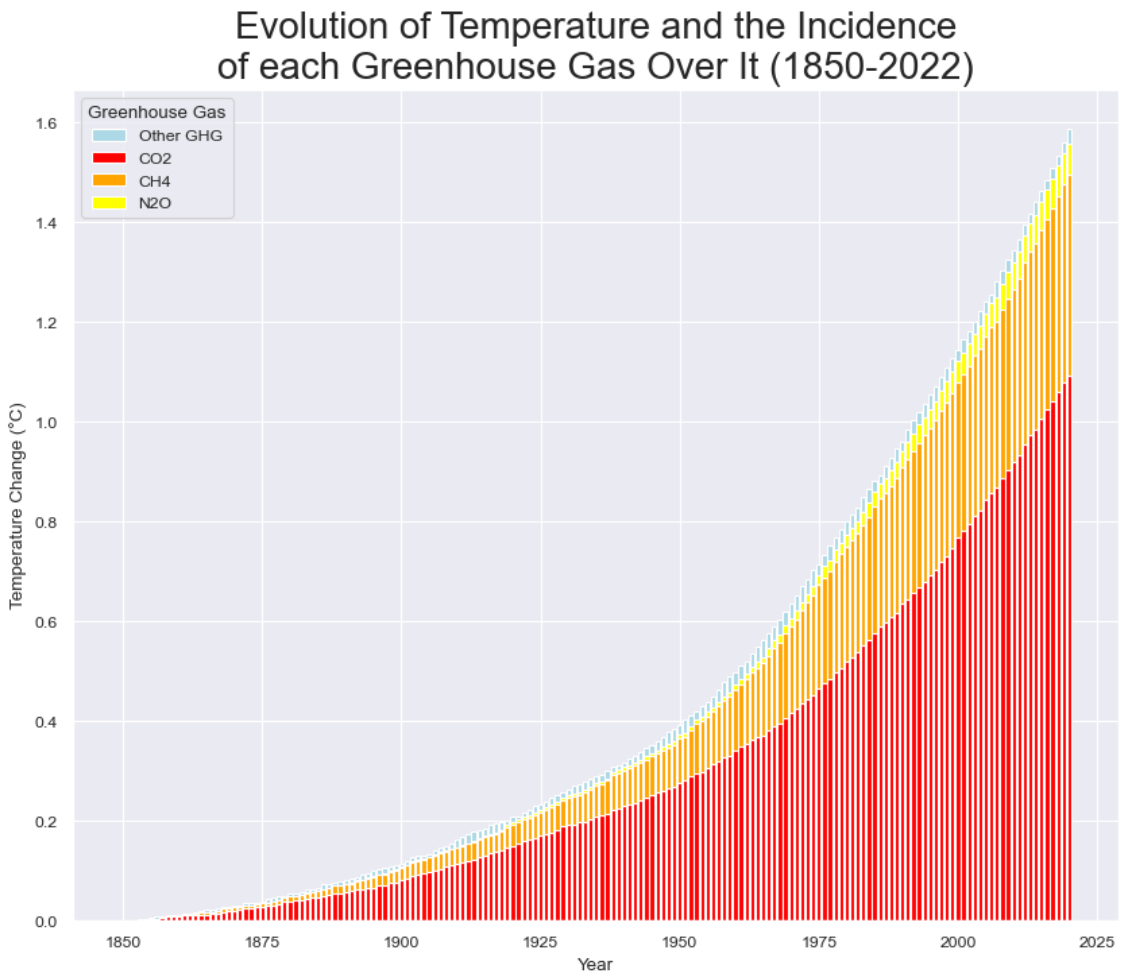
To sum up, we have proved that human-produced greenhouse gasses emissions are directly correlated with the variations of temperature during the lasts decades. These gases, being CO2, CH4, and N2O the main gases that contribute to the greenhouse effects, seem to be the responsible ones for the recent increase of temperatures across the world. Moreover, there seems to be enough evidence to show that some other natural factors, such as TSI and MEI, in spite of being correlated and have an actual impact on temperature, these are not the main drivers of its variance across time, indicating that the origin of climate change is actually in human hands.

Now that we know which are the main elements that contribute to climate change, let's try to focus on which measure they do it. By doing so, we will be able to determine which are the greater roots of the problem, and therefore, which ones to attack first, in order to make our actions as efficient as possible.

WHICH ELEMENTS HAVE A GREATER EFFECT OVER GLOBAL WARMING?

As we have previously seen, CO2 (Carbon Dioxide); CH4 (Methane); and N2O (Nitrous Oxide), are directly correlated with the variance of temperatures during the lasts decades, however, what about other greenhouse gases such as NF3 (Nitrogen Trifluoride); SF6 (Sulfur Hexafluoride); and other groups such as the PCFs (Perfluorocarbons); or the HFCs (Hydrofluorocarbons) and their effect over climate change?

Fortunately, the data that we are analyzing provides us with information about the real and proportional values of the increased temperature that is imputed to each gas, and we can visualize it in the following graph.



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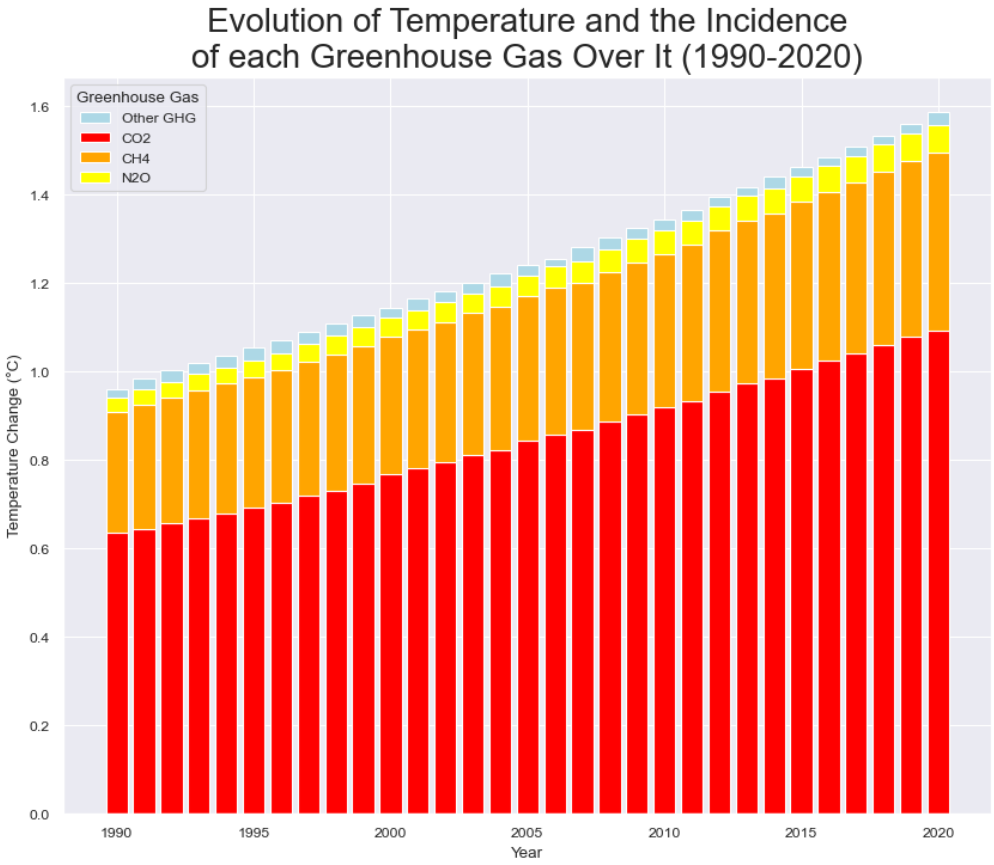
The previous bar plot shows us the evolution of temperature from 1853 to 2021. As we can see, the global warming effect began a few years after 1850, coinciding with the end of the first industrial revolution and the beginning of the second one. The extensive use of fossil fuels marked the step from the first revolution to the second one. Coal powered steam engines during the First Industrial Revolution, and oil and natural gas became prevalent in the Second Industrial Revolution, leading to a significant increase in CO2 emissions. Moreover, agricultural practices transformed with the use of synthetic fertilizers, releasing N2O, and increased livestock farming, producing more methane. Urbanization required more energy for heating, transportation, and infrastructure, further raising emissions, and deforestation for both agricultural and urban development released stored carbon

as CO2. Finally, the transportation revolution, with the development of the internal combustion engine and expansion of railways, automobiles, and ships, significantly increased fossil fuel use. The development of all these elements combined provoked the displayed increase in temperatures that we observe in the graph, which, as we can appreciate, was driven mainly by CO2, CH4, and N2O, in that precise order of relevance respectively.

At first sight, someone just by seeing the previous plot could actually think that the emissions of CO2 are the most harmful for climate stability, since it is the greenhouse gas responsible for at least two-thirds of the total increase in temperature. However, to actually know which is the most detrimental GHG, we should directly compare the imputed responsibility over climate change of each gas with the amount of that gas that was emitted to the atmosphere. In other words, if CO2 is responsible for ≈66% of the increase in temperature, our analysis and conclusions will not be the same if, on the other hand, carbon dioxide represents 80% of the total greenhouse gases emitted as if it were 20%. This occurs due to the fact that, in the first case, ≈66% responsibility while it represents 80% of the emissions would mean that one unit of CO2 emitted has a lower impact on global warming than the effect of other greenhouse gases such as methane or nitrous oxide. Conversely, if CO2 is responsible, as we previously confirmed, for ≈66% of the changes in temperatures, and at the same time represents 20% of the total amount of greenhouse gases emitted, that would mean that a single unit of CO2 has a massively greater warming effect than a single unit of other greenhouse gases.

To carry out this comparison, let's take a look at the following graphs that display specifically the variables that we are interested in, to draw our conclusions.



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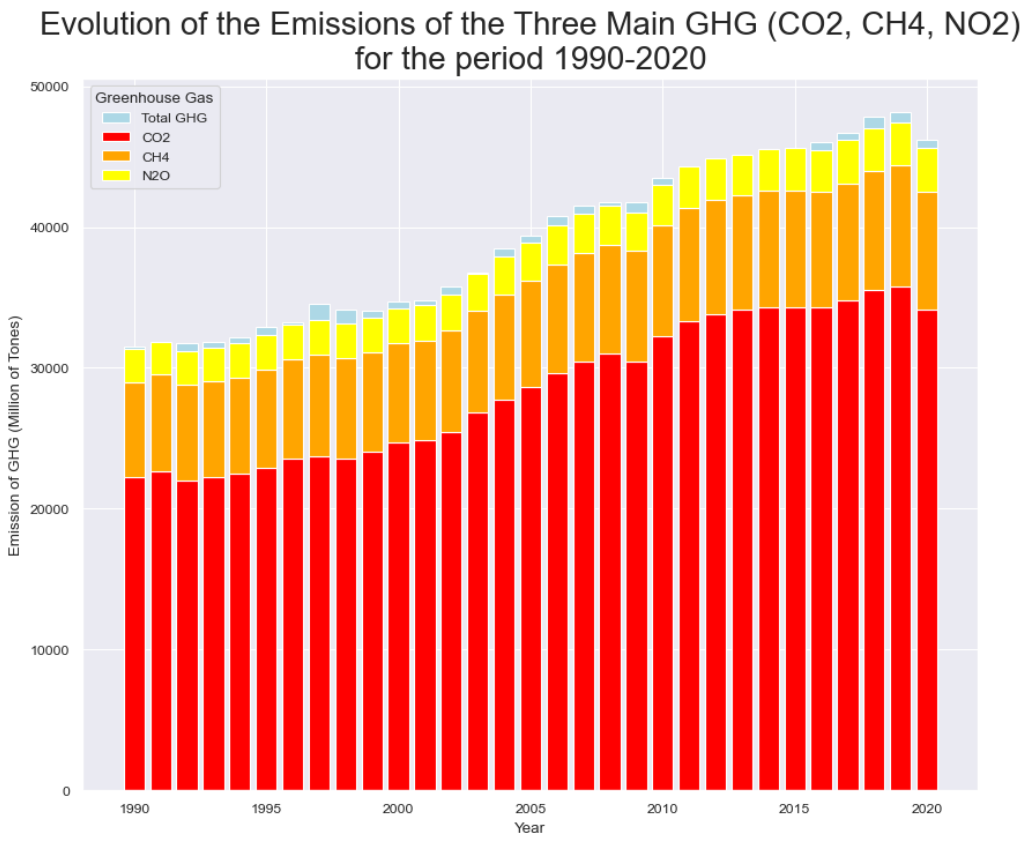

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As we can appreciate, both plots present similar patterns, so we can validate the hypothesis that overall, the effect of one emitted unit of carbon dioxide, methane, and nitrous oxide produces a similar effect on the greenhouse effect and global warming. If we want to be more rigorous, we could comment that by sight, there is enough information to say that the effects of other greenhouse gases are lower than the effects of the three main gases that we are focusing on and that the effect of a unit of methane seems to be smaller than the effect of one unit of nitrous oxide and carbon dioxide. However, these values are not different enough to consider this statistically relevant.

In essence, thanks to the previous analysis, we have found that the three main elements that we should consider as key provokers of the increase in the activity of the greenhouse effect, which is resulting in an increase in temperatures and causing global warming, are CO2 (Carbon Dioxide), CH4 (Methane), and N2O (Nitrous Oxide). Now that we know the causes, we can start to analyze the provenance of these elements to get closer to our goal of developing a set of policies to deal with this problem.

WHICH COUNTRIES EMIT GREATER AMOUNTS OF GREENHOUSE GASES?

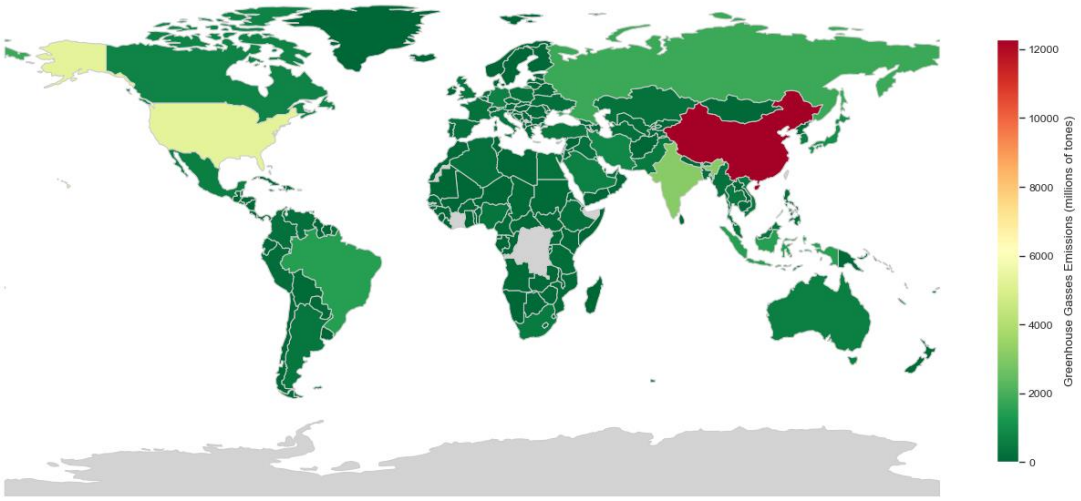
Now that we have proved through empirical data the existence of global warming and, through visual analysis, that the main cause of it is the increase in the activity of the greenhouse effect due to the emission of CO2, CH4, and N2O, we can consider analyzing which countries are the main sources of these gases, to address the development of recommendations, measures, and policies.

If we look at the following graphs, we will notice that China, the United States, India, and Russia are at the forefront of emissions of CO2 (32%, 13.8%, 7.1%, and 4.8% respectively), CH4 (14.2%, 9%, 8.3%, 7.4% respectively), and N2O (17.3%, 8.4%, and 9% respectively. Note that here Russia is not among the greater emitters, but Brazil takes its place with 6.5%), and therefore, at the same time, they are at the forefront of emissions of greenhouse gases overall (26.6%, 11.5%, 6.9%, and 3.9% respectively). According to this data, the four previously mentioned countries represent approximately 50% of the total emissions. At first sight, this might seem to be a red alarm indicating that these countries are probably the cause of half of the increase in temperature due to their irresponsible industrial, agricultural, and other production processes, and that therefore, global warming might see a solution if we force these countries to reduce their activities and consequently, their emissions.

I have already seen, and probably the reader too, on many occasions, that this type of data is used as undeniable facts to politically attack these countries in the media, to favor a political agenda that aligns with the specific ideology of the media outlet in question. However, something they miss, whether due to ignorance or intentional omission, is that these statistics by country mean nothing if we are not considering the per-capita levels of pollution. In other words, we have to make sure that, for instance, China pollutes a lot due to its massive, uncontrollable, and irresponsible means of production, or if it is due to the fact that this country, and others such as the US and Russia, actually do so because they have a huge number of inhabitants and pollution is directly linked to it.

It is reasonable to consider that a country with a greater number of inhabitants will have a greater number of cars, factories, farms, etc., and therefore, its aggregated pollution is going to be greater than that of countries with a lower population. For sure, we cannot expect a country like China, with a population around 1.4 billion, to pollute less than a country like Switzerland, with a population of about 8 million individuals.

World Map of Greenhouse Gasses Emissions in 2020



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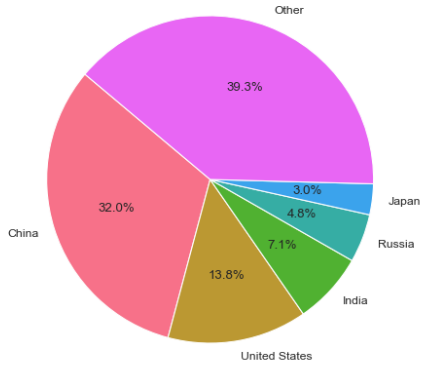
CO2 Emissions by Country as Percentage of Total Emissions 2020



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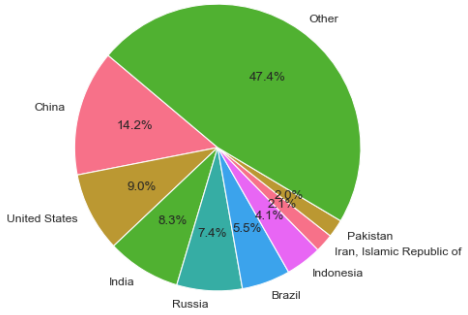
Methane Emissions by Country as Percentage of Total Emissions 2020



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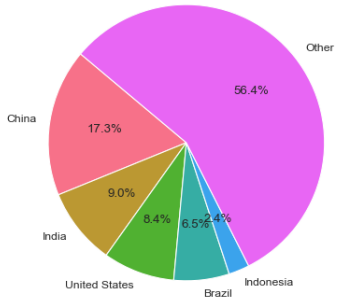
Nitrous Oxide Emissions by Country as Percentage of Total Emissions 2020



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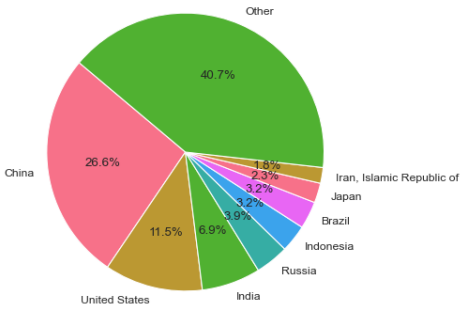
GHG Emissions by Country as Percentage of Total Emissions 2020



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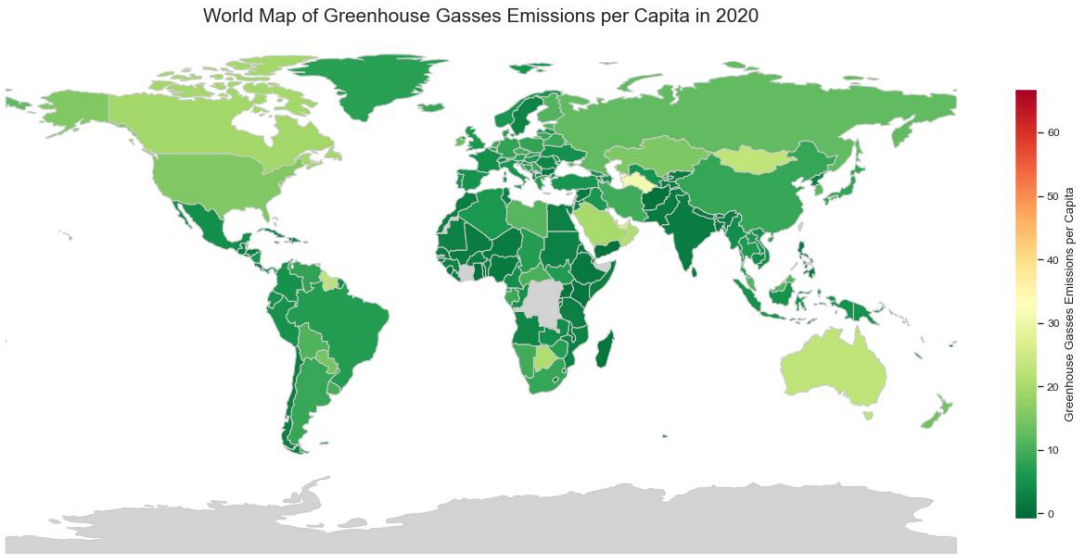
To properly analyze our data and check if there is a country or a group of countries that we can catalog as the responsible ones for climate change and global warming, let's take a look at the following plots illustrating the different levels of greenhouse gas emissions per capita. As we can observe, the first one provides a visualization that shows us the emissions of greenhouse gases per country; however, now it is in per capita terms and not in millions of tons, as previously. By comparing this and the previous map, we can observe that now every country presents a similar tone of green, indicating that the levels of pollution (in terms of greenhouse gas emissions) are pretty similar among all countries in the world. Secondly, the bar plot displays the top forty largest emitters of GHG across the world. At first glance, we can appreciate that the Solomon Islands top the list with the highest GHG emissions per capita. This is unusual for a small island nation and can be attributed to specific local factors such as deforestation for logging, which significantly contributes to CO2 emissions. Additionally, economic activities related to agriculture and limited industrial operations can lead to higher per capita emissions. Moreover, Qatar and Bahrain also rank highly due to their significant industrial activities, particularly in the oil and gas sectors, which drive their high per capita emissions. On the other hand, contrary to what we could previously conclude, countries like the United States, Canada, and Australia also show high per capita emissions but are closer to the global average, much lower than we were expecting. Note that, on one hand, we have a group of countries (China, the US, Russia, and India) that present huge levels of greenhouse gas emissions, which, however, are quite smaller in per capita terms, showing us that there is nothing out of place or atypical with them. On the other hand, there are some countries that present large levels of emissions per capita, but in aggregate terms, the total emissions are not significantly high to be the main source of the increase in the activity of the greenhouse effect.

In essence, the message that I am trying to spread is that there is no such thing as a guilty country or a guilty group of countries. Not even those countries whose aggregated and per capita levels of pollution are notably lower than some other countries are less responsible, since the gases that they are not emitting due to their low industrial or agrarian activities are produced by other exporter countries whose goods and services these "green countries" actually buy to subsist and cover their needs. Due to this, we cannot conclude that a feasible solution for global warming would be to attack those countries whose total emissions are larger, since this is due to their huge population and the fact that these countries usually export the goods and services that other countries consume. Neither should we "attack" the activities of those countries with huge levels of per capita emissions, since at an aggregate level, the potential reduction would be insignificant.



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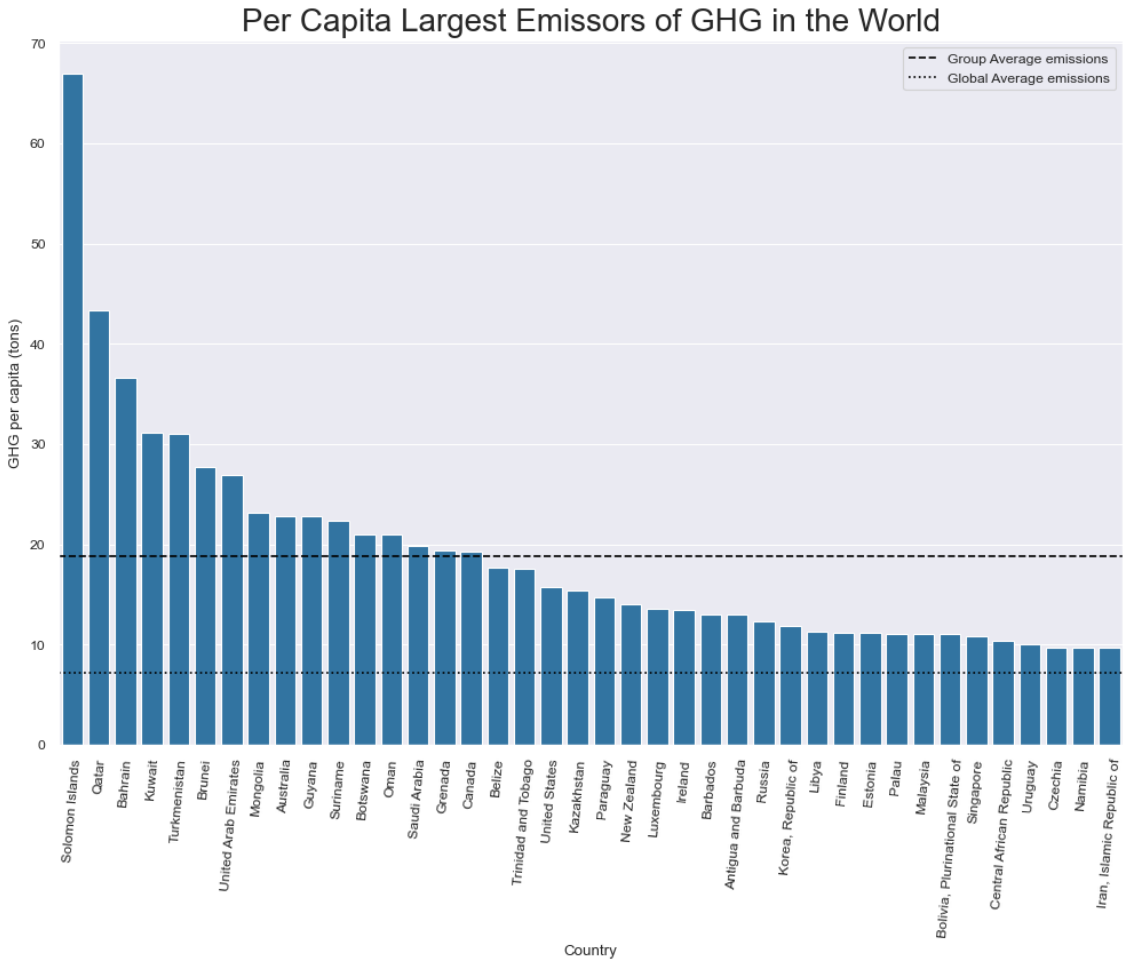

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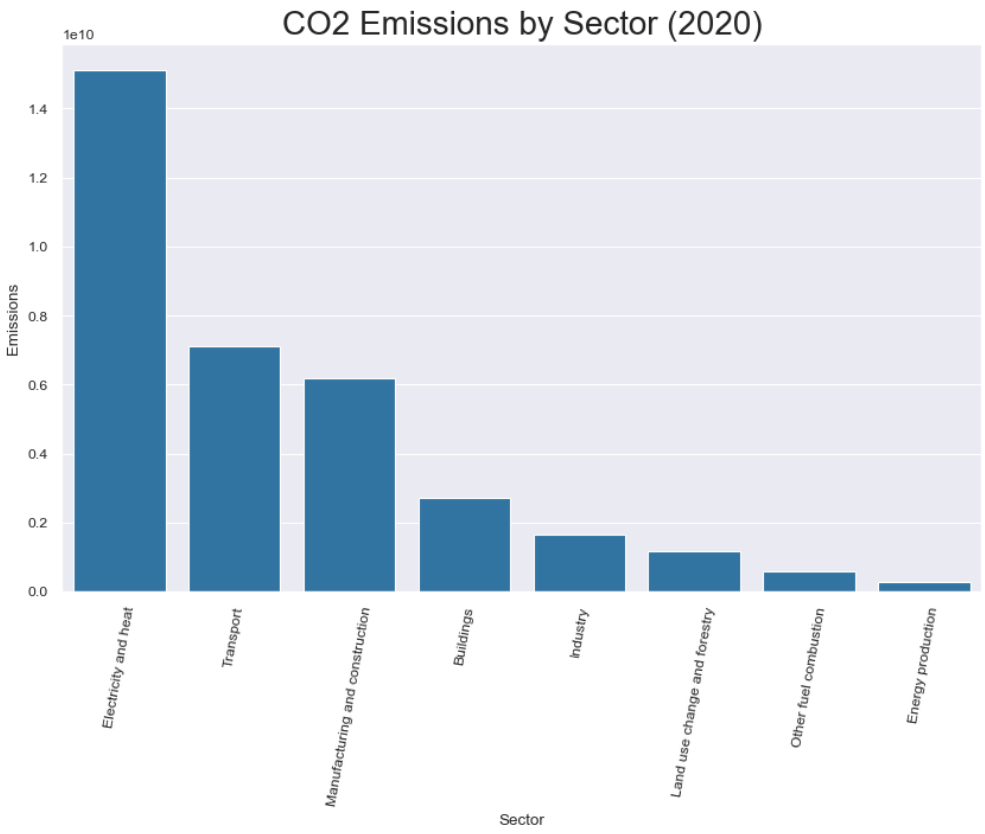
WHICH ARE THE MAIN SOURCES OF EMISSIONS OF GREENHOUSE GASES?

Now that we know attacking the economic activities of countries through the media is not a viable option, and that the industrial and agrarian production processes carried out by these countries are required to satisfy our needs and keep us alive, I consider that the focus should not be on producing less, but on producing differently. To do so, it might be necessary to first identify the sources of emissions of the greenhouse gases, or in other words, to know which economic activities produce each type of GHG and in what amount.

To do so, we can take a look at the following bar plots displayed below that show us the sources of each GHG divided into different categories. As we can appreciate, the main sources of carbon dioxide are electricity and heat, transport, and manufacturing and construction. Secondly, for nitrous oxide, the main source of emissions seems to be agriculture, similar to what happens with methane, but with a lower intensity, since it is closely followed by fugitive emissions from energy production and waste. Finally, we can observe the graph of the overall greenhouse gas emissions. As we might expect, since CO2 is the most commonly emitted gas, its two main sources previously mentioned coincide with the two main sources of the aggregated emissions of GHG. Transport, as a source of emissions, is closely followed by manufacturing and construction and agriculture. After that, for the rest of the sources, the emissions seem to decrease by half for some other sources such as fugitive emissions, industry, buildings, etc.

Thanks to the previous information, we can determine that the design of a proper policy that aims to reduce the emissions of greenhouse gases should focus on the previously mentioned sources of emissions and try to find a way to produce the same amounts of these goods and services through other methods and processes. To accomplish this objective, we could consider many different procedures that might achieve this task, such as the use of “green” or renewable energy, the implementation of nuclear energy, or maybe a set of fiscal policies that incentivize a shift to less polluting production techniques in each of these fields.



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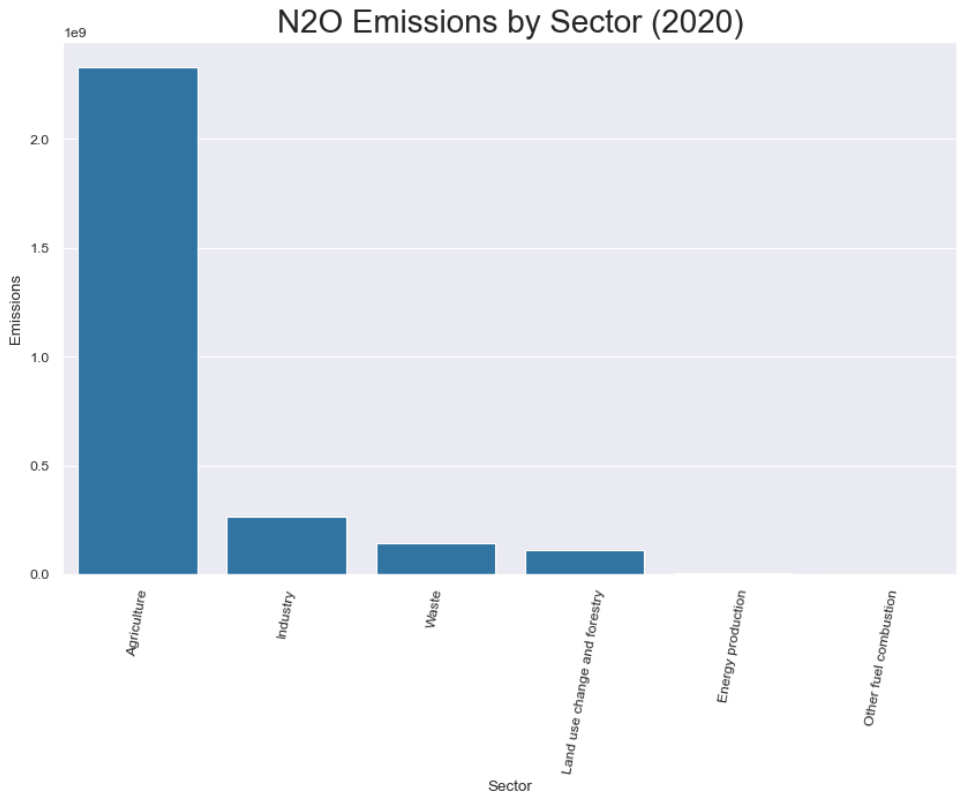

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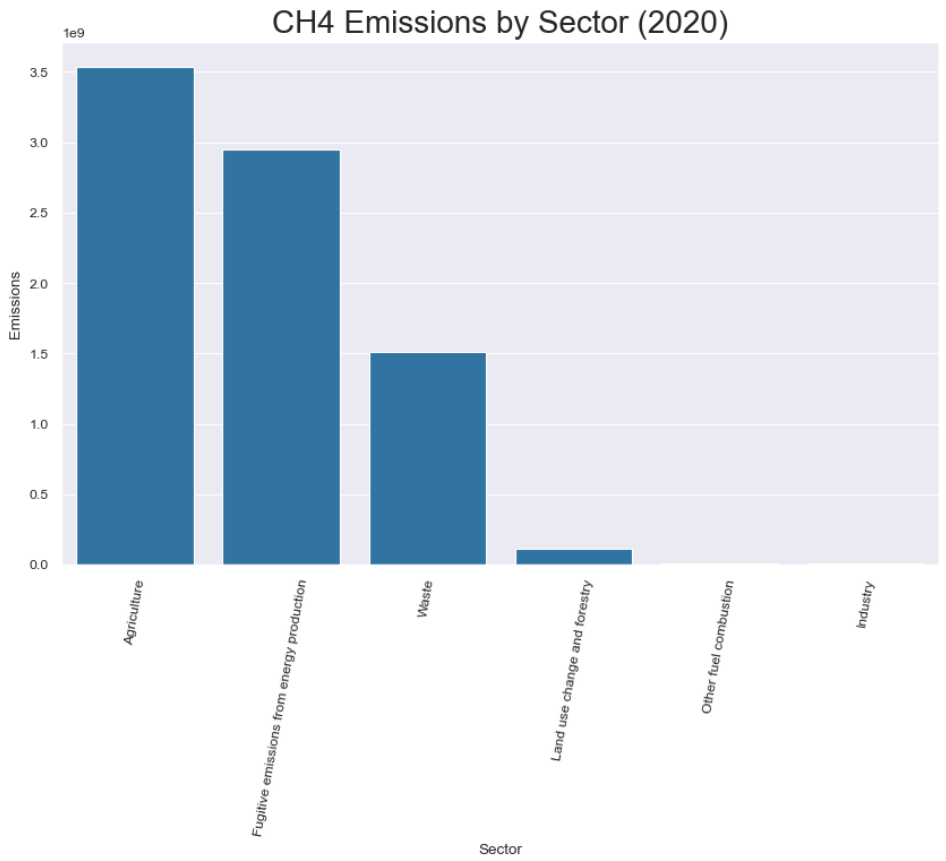

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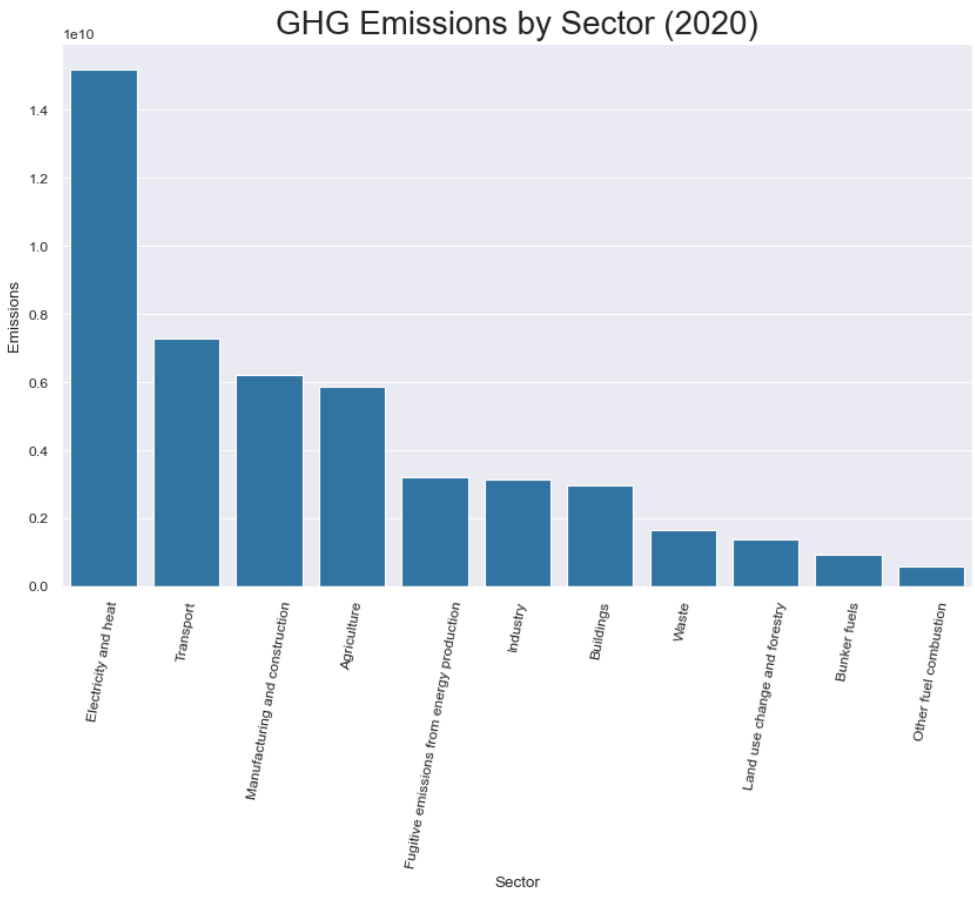

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CONCLUSION:

To encapsulate, in this article we have reviewed the general idea and main concepts of climate change from an informative perspective. I started the article by directly analyzing different datasets that provided us with strong evidence proving that climate change and global warming are primarily driven by human-produced greenhouse gases (GHGs) such as CO2, CH4, and N2O. As we have noticed, these gases are responsible for the enhanced greenhouse effect over the last centuries, which traps heat in the Earth's atmosphere and leads to rising global temperatures.

Next, a closer examination of GHG emissions by country revealed that China, the United States, India, and Russia are the largest aggregate emitters. However, when considering per capita emissions, smaller nations like Qatar and Bahrain emerge as significant contributors, primarily due to their oil and gas industries. This nuanced understanding highlights the complexity of attributing responsibility for climate change solely based on aggregate emissions and allowed us to conclude that there is not a country or a set of countries that are directly culpable. On the contrary, climate change is a phenomenon that is the responsibility of all of us.

Thirdly, we analyzed the main sources of greenhouse gas emissions. This process helped us understand where these gases are produced and released into the atmosphere. Most importantly, the obtained insights can guide future researchers to investigate different ways to shift the current production processes to revolutionary ones that are less polluting and help reduce emissions to mitigate the effects of global warming. Future researchers should also focus on finding new methods of production that are compatible with current consumption levels and consider future forecasts. Finding a way of not producing less, but producing differently, might be the solution and the salvation of our society as we know it today.

Finally, I consider it important to comment on some of the limitations of this article, such as the exclusion of factors like economic development, industrialization policies, and population growth, which play crucial roles in shaping a country's emission profile. Future studies should incorporate these elements to provide a more comprehensive understanding of the dynamics of GHG emissions. Moreover, the study mainly relies on historical and current data without extensively considering future projections. Climate change is a dynamic and evolving issue, and research is necessary to continuously update our understanding and approach to mitigating its impacts. Despite these limitations, the findings of this study provide a solid foundation for understanding the primary drivers of climate change and highlight the collective responsibility needed to address this global challenge.

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