5-2023

NetZero Insight: The Role of Data Analytics and Machine Learning in Combating Climate Change

Tariq Najar
thn7394@rit.edu

Chrissie Aldo
ca3331@rit.edu

RIT

NetZero Insight: The Role of Data Analytics and Machine Learning

in Combating Climate Change

By

Tariq Najar & Chrissie Aldo

A Capstone Project Submitted in Partial Fulfilment of the Requirements for the Degree of Master of Science in Professional Studies: Data Analytics

Department of Graduate Programs & Research

Rochester Institute of Technology

RIT Dubai

May 2023

RIT

Master of Science in Professional Studies: Data Analytics

Capstone Project Approval

Students Names:

Tariq Najar

Chrissie Aldo

Capstone Project Title: NetZero Insight: The Role of Data Analytics and Machine Learning in Combating Climate Change

Capstone Project Committee:

Name	**Designation**	**Date:**
Dr. Sanjay Modak	Chair of Committee	
Dr. Ioannis Karamitsos	Member of Committee.	

ACKNOWLEDGEMENTS

We would like to thank Dr. Ioannis Karamitsos, our mentor, for his guidance and support throughout the project. Working on such a project was very insightful and tackled a crucial topic in today's world: the urgent need to combat climate change. Furthermore, our project came at a time in which the UAE President, His Highness Sheikh Mohammad Bin Zayed, declared, "the Year of Sustainability this year, and the UAE will host the world at its most significant event at COP28 at Expo City Dubai. We believe our insightful analysis of the role of data analytics and machine learning in this regard will go a long way in inspiring more innovations and efforts toward mitigating the effects of climate change.

Reaching this stage reflects our hard work and dedication to this project. We have also sharpened our research skills, as demonstrated in our findings. We are confident that our recommendations, findings, and insights clearly show our understanding of the topic's complexities. Furthermore, we strive for this project to be a testament to our academic and research skills and will undoubtedly contribute to our future professional success.

Working on our capstone project with Dr. Ioannis Karamitsos was very insightful and beneficial. We would also like to express our gratitude to Dr. Sanjay Modak, the Committee Chair, for his unwavering support and patience. Finally, we would like to express our gratitude to Dr. Yousef Al Assaf, President of RIT Dubai, for giving us the opportunity to study and work in this fascinating field.

ABSTRACT

Countries must act urgently to achieve the SDGs and make significant progress for the planet and people by 2030. But there are some key challenges that the world must address. Climate change is one of the most significant challenges of our time, and its impacts can undermine the ability of all countries to achieve sustainable development. However, countries committed to limiting global warming to 1.5°C above pre-industrial levels in the Paris Agreement. Member nations pledge to take urgent action on climate change to save the planet from global warming.

Using data analysis techniques and methodologies, such as CRISP-DM, and visualization tools like R and Tableau, we aim to accomplish several things; First, identify the contribution of each country and sector to global CO_2 emissions. Second, identify the major sectors contributing to CO_2 emissions and create machine learning models (time series models) for predicting CO_2 emissions for the selected countries to determine if they will peak in n 2025 and fall by 43% by 2030 to meet the Paris Agreement and limit global warming to 1.5°C as stated by the IPCC AR6 report. Third, identify the decarbonization indicators most correlated with CO_2 emissions at the sector level. Fourth, determine whether some selected countries meet their commitments in their NDCs, or NetZero policies based on the three trajectories (business as usual based on historical data, NetZero pathways -minimum policy and maximum policy CO_2 emissions). Fifth, investigate and promote the social cost of carbon for the UAE for the first time in the region, as this is currently a lively debate among policymakers.

As RIT students, we would like to contribute to the efforts of the UAE and the world to find solutions to climate change and raise awareness to accelerate the transition to clean energy. However, there are some limitations -Some countries need mechanisms to collect the CO_2/GHG emissions or transparency reporting them, or they need an official CO_2 /GHG emissions inventory. Therefore, the dataset for our project only includes annual data and does not include CO_2 emissions from all countries in the world; the time was another limitation; we tried in our project to have a holistic perspective and to study all sectors, then we decided to focus more on the energy sector (Electricity and the Oil & Gas sectors) since they are the most CO_2 emissions contributors among all other sectors.

Keywords: CO_2 emissions, Climate change, Sustainability, NetZero policies, Paris Agreement, Global warming, SDG, Energy transition, time series

Table of Contents

LIST OF FIGURES

LIST OF TABLES

Chapter 1: Introduction

1.1. Background Information

It is a time of crisis where humanity is at a crossroads. The COVID-19 pandemic is in its third year, and the conflict in Ukraine is exacerbating food, energy, humanitarian, and refugee crises - all set against a climate crisis with full force. The seventeenth Sustainable Development Goals (SDGs) address these crises and the ways to prevent and navigate them; however, ignoring them will be at our risk.

As a result of climate change, there have been impacts on health, food and nutrition, education, the environment, security, and peace, impacting all Sustainable Development Goals (SDGs). Countries must act urgently to achieve the SDGs and make significant progress for the planet and people by 2030. The Member states are committed to implementing urgent climate change measures to save the planet from deforestation. Climate change is one of the most significant challenges of our time, and its counter-impacts may undermine the ability of all countries to achieve sustainable development.

Climate change risks many things, such as the survival of many societies and the biological support systems of the planet. Increases in global temperature, rising sea levels, and ocean acidification will seriously affect coastal areas and low-lying coastal countries, including small, developing, and least-developed ones. The accumulation of CO_2 and other greenhouse gases in the atmosphere causes this. Human activities such as burning coal, oil, and gas, deforestation, agriculture, forestry, and transportation are the leading causes of the growth in these gases. Countries are taking measures to ensure that CO_2 emissions are reduced or controlled to create momentum in tackling this problem. These adaptation and mitigation measures include the national determination contribution (NDCs) and Net Zero policies. Their main goal is to reduce CO_2 or greenhouse gas emissions as much as possible (i.e., close to zero) and to adapt to the change due to climate change. In contrast, the remaining emissions are reabsorbed by the carbon sink, such as (oceans and forests) or offset them.

This project will focus on SDG 7 (Affordable and clean energy) and SDG 13 (climate action). However, countries pledged to limit global warming to 1.5°C above pre-industrial levels in the Paris Agreement. Countries aim to reach global peaking of greenhouse gas emissions as soon as possible to achieve a climate-neutral world by mid-century. So, we aim to tackle climate change and help the policymakers.

UAE has many environmental and climate action achievements, including a stop to gas flaring since the 1970s under the directives of the UAE's Founding Father, the late Sheikh Zayed bin Sultan Al Nahyan. Furthermore, Sheikh Mohammed bin Rashid Al Maktoum, Prime Minister, and Ruler of Dubai, said the UAE's hosting of COP28 will be the UAE's biggest event next year. At COP28, countries will assess the progress of that accord for the first time.

1.2. Problem Statement

There is no doubt that climate change threatens human health and the future of our planet. Any further delay in concerted global action will miss a short and rapidly closing window to secure a livable future. We must urgently call for climate action. When countries pledged to limit global warming to 1.5°C above pre-industrial levels, we need to use data analysis techniques - to assess current and projected levels of CO_2 emissions on a sector-by-sector basis, with a focus on the energy sector, as three-quarters of greenhouse gas emissions now come from the energy sector; to study countries' effective adaptation and mitigation measures, including the National Determination Contribution (NDCs) and NetZero policies; to help policy-makers develop/ update better mitigation and adaptation measures to combat climate change.

1.3. Project Goals

The goal of this project is to apply data analysis techniques to assess current and projected CO_2 emissions for each country and sector, with a focus on the energy sector, to help policymakers determine better mitigation and adaptation measures to address climate change, based on the following:

1. To conduct a comparative analysis of current CO_2 emissions across countries and sectors.
2. To conduct analysis to identify the major sectors contributing to CO_2 emissions and create a time series models for predicting CO_2 emissions for the selected countries to determine if they will peak in 2025.
3. To conduct analysis to examine the decarbonization indicators most correlated with CO_2 emissions, focusing on the energy sector.
4. To conduct trend analysis for the three trajectories (business as usual based on historical data, NetZero pathways - minimum policy and maximum policy) for selected countries. The selected countries are China, India, Europe (EU), United States (US), United Arab Emirates (UAE) and Kingdom of Saudi Arabia (KSA).

5. To investigate the topic of the social cost of carbon in the UAE to provide some recommendations to the government prior to the Conference of the Parties 28 (COP28) hosted by the UAE.

1.4. Research Methodology

Cross Industry Standard Process for Data Mining or CRISP-DM methodology was implemented in this project to achieve the project goals. This structured technique, which is the basis for the Data Science process, has been widely used and proven in industry. Despite the model's idealized order of events, many of the tasks can be accomplished in a different sequence. The CRISP-DM phases are as follows:

1. Business understanding – what does the business need?
   The project started with understanding the business area and defining the project objectives. The project aims to use data analysis techniques to analyze the CO_2 emissions of countries and sectors, particularly the energy sector, to determine whether or not the selected countries are meeting their commitments in their NDCs, so that it could help policymakers to determine better mitigation and adaptation measures.
2. Data understanding – what data do we have or need? Is the data accurate?
   The dataset used in this project was obtained from the Climate Action Tracker website. The dataset was examined to understand the data and its quality.
3. Data preparation – how should the data be set up for modelling?
   The data was preprocessed to improve data quality and the final preprocessed dataset was used for the models. The dataset was split into a training set and a test set in a 70:30 ratios.
4. Modeling – what modelling methods should be used?
   Time series algorithms were used as the data includes annual CO_2 emission by countries and sector. The 4 - time series algorithms are the drift method, the Holt linear method, the damped trend method, and the ARIMA model.
5. Evaluation – Which model best fits the needs of the business?
   The models were evaluated using 4 performance metrics - Root Mean Square Error (RMSE), Mean Absolute Percentage Error (MAPE) and Mean Absolute Error (MAE).
6. Deployment – How do the stakeholders access the results?
   The results of the initial analysis and of the selected model are presented as visualizations and/or dashboards.

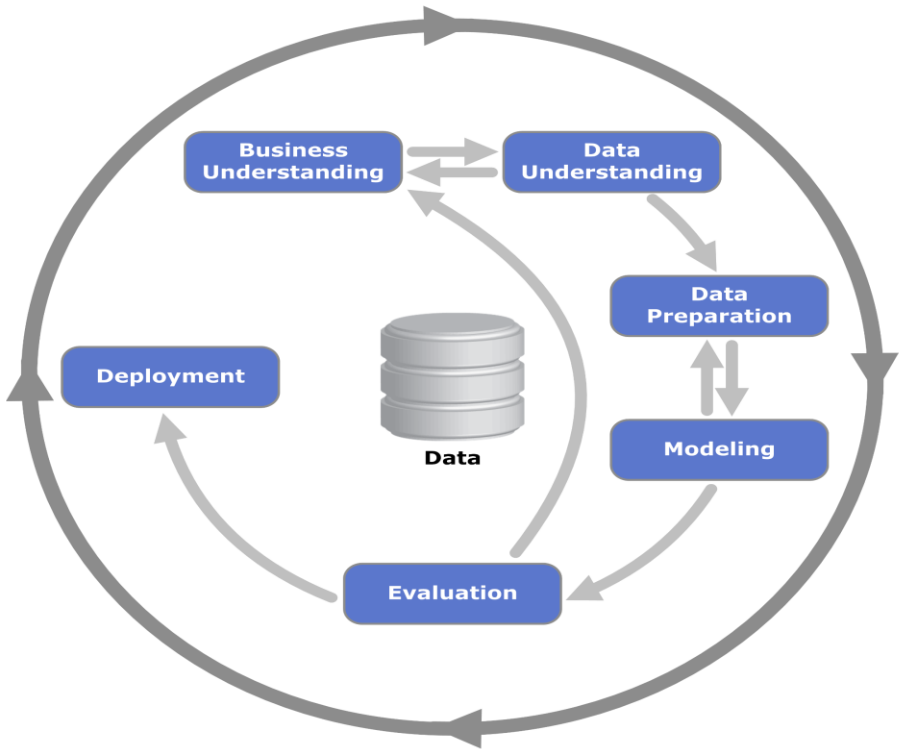


Figure 1: CRISP-DM Process

1.5. Project Limitations

The following are the limitations we encountered in our project that may be considered in future work:

- Some countries need mechanisms to collect the CO_2 /GHG emissions or transparency reporting them, or they need an official CO_2 /GHG emissions inventory. Therefore, the dataset for our project only includes annual data and does not include CO_2 emissions from all countries in the world. The dataset may include weekly or monthly data in future work, as it could help produce a more accurate forecast.
- The project focuses mainly on the energy sector (Electricity sector and Oil & Gas sector). In future work, more sectors should be considered to help the policymakers to develop/update better mitigation and adaptation policies.
- The time was another limitation; we tried in our project to have a holistic perspective and to study all sectors, then we decided to focus more on the energy sector (Electricity sector and Oil & Gas sector) since they are the most CO_2 emissions contributors among all other sectors.

Chapter 2: Literature Review

There is no doubt in the scientific evidence that climate change threatens human health and the planet's future. Any further delay in concerted global action will miss a brief and rapidly closing window to secure a livable future. We must call for urgent climate action as countries pledged to limit global warming to 1.5°C above pre-industrial levels in the Paris Agreement. Numerous studies have been conducted relevant to climate change, in particular evaluation of CO_2 emissions, to tackle this issue and assist in identifying potential solutions.

2.1. Climate Change

SDG's report (UN DESA, 2022)[1] highlights the joining of the crisis, dominated by climate change, COVID-19, and conflicts, which impacted health, food and nutrition, education, the environment, security, and peace. It affects all the Sustainable Development Goals (SDGs). It highlights the area which needs urgent action to save the SDGs and deliver significant progress for the planet and people by 2030. The Member states indicate their commitment to implement urgent climate change action and save the planet from degradation. One of the most significant challenges of our time is climate change, and it is a worry that its counter impacts explore the ability of all countries to obtain sustainable development. Climate change risks many things, such as the survival of many societies and the biological support systems of the planet. Increases in global temperature, rising sea levels, and ocean acidification will seriously affect coastal areas and low-lying coastal countries, including small, developing, and least-developed ones. Out of the seventeenth SDG, we will focus on SDG 7 (Affordable and clean energy). However, as the world continues to accelerate toward sustainable energy targets, the world won't achieve goal number 7 at the current pace of progress; enhancements in energy efficiency, for instance, will require advances to obtain the climate goal of reducing greenhouse gas emissions. The correlated targets of SDG 13 focus on integrating climate change measures into national policy, awareness-raising, enhancing education, and institutional capacity on climate change adaptation, mitigation, and impact reduction. (The Paris Agreement,2015) [2] is a legally binding international agreement treating climate change. On 12 December 2015, 196 Parties adopted it at COP21 in Paris, and on 4 November, this agreement entered into force. It aims to preferably limit global warming to 1.5 degrees Celsius, compared to pre-industrial levels or maximum to well below. Countries aim to reach global peaking of greenhouse gas emissions as soon as possible to achieve a climate-neutral world by mid-century. Based on the best available science, implementing the Paris Agreement requires social and economic transformation. The countries will increase their ambitious climate action aligned with the Paris agreement, a 5-year cycle; they have submitted their Nationally determined contributions (NDCs) for climate action by 2020. The countries communicate actions they are going to take for mitigation and adaptation. The agreement reaffirms that developed countries should be the leader in providing financial assistance to less endowed and vulnerable countries. It creates a technology framework or mechanism to transfer technologies that reduce GHG emissions and enhance resilience to climate change. The Paris agreement created a capacity-building framework for developing countries' climate-related capacity-building. Under this agreement, countries will create an enhanced transparency framework (ETF). Starting in 2024, they will report transparently on actions taken and progress in climate change adaptation, mitigation measures, and support received or provided. After that, this input will feed Global stocktake, which will assess the collective progress towards the long-term climate goals. Next year UAE COP 28 expects countries to recommend countries to set more ambitious plans. Three-quarters of greenhouse gas emissions (IPCC,2023) [3] provides a clear picture of the widespread, negative effects, losses, and harms caused by human-induced climate change to wildlife and humans. Today's global GHG emissions are 54% higher than they were in 1990. Over three billion people, or over half of the world's population, currently reside in areas that are regarded as being extremely vulnerable to climate change. Extreme weather-related mortality increased by 15 times in extremely exposed areas during the previous ten years. Extreme heat has caused hundreds of local species losses, severely harming vital ecosystems or causing irrevocable losses. Communities that are vulnerable and have traditionally contributed the least to climate change are disproportionately impacted. The report's conclusions support the likelihood that global warming will reach 1.5°C in the foreseeable future, most likely in the first half of the 2030s.It cautions that going beyond the 1.5°C limit, or the "overshoot," harms people and ecosystems and is likely to cause numerous irreversible planetary tipping points. It reaffirms that all sectors must reduce greenhouse gas emissions. Keep global warming to 1.5°C above pre-industrial levels. However, in keeping with the most accurate projections of the remaining global carbon budget, it warns that if warming is to be kept to 1.5°C, emissions must peak by 2025 at the latest and be reduced by almost half by 2030. mitigation and adaptation priorities within six areas that hold the most potential: one; Energy system, two; industry and transport, three; cities, settlements, and infrastructure, four; land, ocean, food, and water, five; health and nutrition; six; society, livelihoods, and economies. (IEA, 2021)[4] today come from the energy sector, which is the key to preventing the worst effects of climate change, possibly the most significant challenge humanity has faced. To limit the long-term growth in average global temperatures to 1.5C, decreasing global carbon dioxide (CO_2) emissions to net zero by 2050. The call now is for nothing less than transforming how we produce, transport, and consume energy. The world is optimistic about making positive progress due to the growing political agreement on reaching net zero. The different situations among the countries and their capabilities to make the required changes can slow reaching the NetZero emission. This report highlights the pathway for achieving this goal, coming up with a secure, resilient, and clean energy system that will bring significant benefits to human prosperity and well-being. All governments must seriously strengthen and successfully enforce their energy and climate policies, as this is the global pathway to net-zero emissions by 2050. This report provides a summary for the policymakers of the fundamental requirements for the global energy sector to achieve net-zero CO_2 emissions by 2050. Staying on track with the NetZero emissions requires the quick massive deployment of all available clean and efficient energy technologies; however, the report examines critical uncertainties or barriers to reaching net zero, such as the behavioral changes, roles of bioenergy, and carbon capture. In designing and implementing climate change mitigation policies (Stern & Stiglitz, 2021)[5], the Social Cost of Carbon (SCC) is the most significant economic concept by providing a monetized value of the present and future damages resulting from the emission of a ton of CO_2. Moreover, it depends on ethical establishment because it depends on how we aggregate and value climate change results. Evaluation of the SCC is a crucial component in the cost-benefit analysis of climate policies; the SCC could be used in two ways by policymakers: to fix the emission reduction target in a cap-and-trade system or to set the optimal carbon tax. The larger the optimal mitigation efforts, the higher the value of the SS. In general, regulators have a guide for introducing climate-affecting policies through the SCC, for instance, the incentives for deploying low-carbon technologies. Calculating the SCC is a lively discussion in the policy arena and literature. Critical aspects of impacts on distribution across and within a generation and fundamental aspects of the immense risks are not embodied in many of the standard economic modelling, for instance, Integrated Assessment Models. This paper explored fundamental flaws in the normative and descriptive methodologies frequently used to evaluate climate policy, showing standardized biases, with costs of climate action overestimated and benefits underestimated. This paper gave an alternative methodology to calculate the social cost of carbon, including all the critical elements identified by the paper. Furthermore, the Broader scientific community pushed for urgent and robust action, using versions of Integrated Assessment Models. On January 20, 2021,(White House, 2021)[6] President Biden issued Executive Order 13990, "Protecting Public Health and the Environment and Restoring Science to Tackle the Climate Crisis. “Which stated the Administration's policy to listen to scientific findings, enhance public health and rescue our environment; guarantee access to clean air and water; reduce greenhouse gas emissions; increase resilience to climate change effects. To prioritize environmental justice and union jobs that will yield these goals and environmental justice. Under Executive Order 13990, Federal agencies must immediately examine and take action to deal with the promulgation of Federal regulations and other actions that conflict with these important national objectives and begin fighting the climate crisis immediately. A White House fact sheet published on January 20, 2021, to accompany Executive Order 13990 directed CEQ to review CEQ's 2020 regulations executing the procedural needs of the National Environmental Policy Act (NEPA) and determine required changes or actions to meet the objectives of Executive Order 13990. Executive Order 14008, titled "Tackling the Climate Crisis at Home and Abroad," was signed by President

Biden on January 27, 2021.14008 Executive Order expresses the Administration's commitment to creating resilience at home and abroad against climate change, which is already axiomatic and will continue to strengthen based on current trends. , (Renewable and Sustainable Energy Reviews, 2019) [7] initially examines all viable technologies for producing water desalination (thermal and membrane) and power generation (conventional, renewable, and clean). Second, it goes through the connection between water and energy in general. The various forms of pollution caused by water and energy production are highlighted in the third section. The SCC is defined and quantified in the following section for the UAE and in general. The article discusses the various legislation, policies, and mitigation techniques used in the UAE to lower SCC. This study looked at the various energy-generating and water desalination methods employed in the United Arab Emirates, as well as the CO_2 emissions and SCC they produced as a result. Two possibilities were taken into consideration about energy generation. Scenario (1) presupposed that natural gas was the only resource used for electricity production and disregarded the adoption of mitigation measures. Adopting an energy mix strategy as part of the UAE Vision 2021 for sustainable development was a part of scenario number two. While the SCC is projected to be 6.96 trillion USD by 2030, Scenario 1's first resulted in 139.2 billion tons of CO_2e emissions. By 2030, 109.23 billion tons of CO_2e emissions were predicted by Scenario 2, with an estimated SCC of 5.46 trillion dollars. Around 30 billion tons of CO_2e and 1.5 trillion dollars in SCC were thought to have been saved. Economically The world needs to reconsider its energy options and create fresh legislation to deal with this issue. (The United States of America's First NDC (After rejoining the Paris Agreement), 2021) [8] stated that The United States aims to reduce its net greenhouse gas emissions by 50–52 percent below 2005 levels by 2030 across the industry. It encourages continuing efforts to keep the rise in global average temperature to 1.5 degrees Celsius and the need to move toward net zero global emissions by the year 2050 to achieve the Paris Agreement's goals. The National Climate Task Force, headed by the White House Office of Domestic Climate Policy, conducted sector-by-sector evaluations of emission reduction potential that served as the foundation for the NDC. A thorough, bottom-up system dynamics model that considers capital stock turnover timelines and the relative costs of technology and equipment in each emitting sector of the economy was used to predict future greenhouse gas emissions across the entire economy. It also considered and contrasted with the modeling of the entire economy from 15 outside studies. The study considered how government actions, such as regulations, investments, incentives, taxes, programs, and support for innovation, would reduce emissions. The assessments also considered subnational contributions, observing that states and local governments significantly contribute to national efforts to reduce emissions under the United States federal government. These studies demonstrate that the United States can meet its NDC goals by investing in efficiency, advantageous electrification, renewable energy, plugging methane leaks, tackling direct greenhouse gas emissions from industrial processes, climate-smart agriculture, forestry innovation, and other top priorities. Additionally, these steps will enhance public health, generate quality employment, and advance environmental justice objectives. (The long-term strategy of the United States,2021) [9] states that Currently, the U.S. emits 11% of the yearly global GHGs. There are numerous ways for the United States to achieve net-zero emissions across all sectors and GHGs. Still, each feasible option calls for five fundamental changes: Decarbonize energy first. All facets of the American economy rely on electricity for various services, and the country has set a target of having 100% clean electricity by 2035. The second step is electrifying end uses and transitioning to alternative clean fuels. We can efficiently and affordably electrify most of the economy, including buildings, industrial operations, cars, and transportation. Reduce electricity wastage, third. When new and current technologies use less energy to deliver the same or better service, switching to cleaner energy sources becomes quicker and cheaper. Fourth, cut back on methane and other non- CO_2 emissions. Methane alone is responsible for half of the present net global warming of 1.0°C, caused by non- CO_2 gases such as hydrofluorocarbons (HFCs), nitrous oxide (N_2O), and others. Fifth. Enhance the elimination of CO_2. Our emissions from energy output can be nearly zero in the three decades leading up to 2050. By the middle of the century, it will be challenging to fully decarbonize some emissions, such as non- CO_2, from agriculture. All Americans will gain significantly from mobilizing to attain net zero: • First, public health; next, economic expansion; third, a decline in conflict; and fourth, living quality. There are four strategic foundations to reach net zero: First, invention; second, federal leadership; third, non-federal leadership; and fourth, all-society action.

(China First NDC (Updated submission),2021) [10] addressed China as a developing nation with a populace of up to 1.4 billion people in China. It must overcome some obstacles, including environmental protection, human livelihood improvement, and economic growth, in addition to the apparent contradiction of uneven and insufficient development. One of the nation’s most heavily impacted by climate change is China. China's socioeconomic advancement and ecological environment have been negatively impacted by climate change, which has already posed significant threats to the country's food, water, energy, and urban operation security, as well as the lives and property of its citizens.

China's Intended Nationally Determined Contributions in June 2015. China's updated NDC targets are as follows: to achieve carbon neutrality before 2060 and reach CO_2 emissions peak before 2030; to reduce CO_2 emissions per unit of GDP by over 65% from 2005 levels; to increase the share of non-fossil fuels in primary energy consumption to around 25%; to increase the volume of forest stock by 6 billion cubic meters from 2005 levels; and to increase the installed capacity of wind and solar power to over 1.2 billion kilowatts by 2030. China put forth 15 laws and regulations to combat climate change further. Since then, China has made great strides toward actively and realistically upholding its promises. China's NDCs face significant obstacles and challenges, necessitating significant effort. China, a developing nation with 1.4 billion people, must work hard to develop its economy, better its citizens' standard of living, manage the environment, and combat climate change. (China's Mid-Century Long-Term Low Greenhouse Gas Emission Development Strategy,2021) [11] stated that by 2030, non-fossil energy will account for nearly 25% of overall energy consumption, and there will be more than 1.2 billion kilowatts of installed wind and solar capacity. China will implement a clean, low-carbon, secure, and efficient energy system by 2060, achieve energy efficiency at comparable levels found internationally, and increase the percentage of non-fossil fuels in energy consumption to over 80%. By 2030, the "two wings" thrust of low carbon and digital economy will be realized, and manufacturing organization and production processes will radically change. Energy efficiency in major industries reaches an advanced international level. By 2025, China will speed up the optimization of building energy-use structures; 100% of new buildings in cities and towns will adhere to green building standards, 8% of urban buildings will replace fossil fuels with renewable energy sources, and 50% of new public and factory structures will have rooftop photovoltaic systems. By 2030, the percentage of new and clean energy-powered vehicles will be around 40% of all the vehicles sold, the carbon emission intensity of converted commercial vehicle turnover will be down about 9.5% from the 2020 level, the comprehensive energy consumption per unit of converted railway turnover will be down by 10% from 2020 level, and oil consumption by land transportation will aim to reach its peak. China's forest cover will rise by 6 billion cubic meters over 2005 levels by 2030, reaching a pace of roughly 25%.(European Union First NDC (Updated submission), 2020) [12] mentioned that On December 17, 2020, the European Union and its Member States updated their NDCs.The following (NDC) is being shared by the EU and its Member States (Belgium, Bulgaria, Czech Republic, Denmark, Germany, Estonia, Ireland, Greece, Spain, France, Croatia, Italy, Cyprus, Latvia, Lithuania, Luxembourg, Hungary, Malta, Netherlands, Austria, Poland, Portugal, Romania, Slovenia, Slovakia, Finland, Sweden). By working together, the EU and its Member States are dedicated to a legally binding goal of a net domestic reduction of greenhouse gas emissions of at least 55% from 1990 to 2030.

The EU has passed legislation that outlines how it, and its Member States are accountable for reducing greenhouse gas pollution by at least 40% across all economic sectors. • Directive (EU) 2003/87/EC on reductions to be achieved in the sectors covered by the EU emissions trading system, as most recently modified by Directive 2018/410. • Regulation (EU) 2018/842, which imposes specific, legally binding goals on Member States concerning their greenhouse gas emissions outside of the scope of the EU emissions trading system. Including and accounting for greenhouse gas emissions and removals from land use, land use change, and forestry in the EU system is done through Regulation (EU) 2018/841. • More laws and mitigating policies at the EU and Member State levels add to the cuts required to reach this goal. The EU's commitment to gender equality and cross-cutting objectives are considered when creating the NDC. (The official website of the European Union,2023) [13] states that Europe and the rest of the world are in existential danger from climate change and environmental degradation. The European Green Deal will help the EU become a modern, resource-efficient, and competitive economy to address these issues, guaranteeing that: by 2050, there will be no net emissions of greenhouse gases; economic growth will be independent of resource use, and no one and no place will be left behind. The European Green Deal is what will avert the COVID-19 epidemic. The European Green Deal will be funded with a third of the €1.8 trillion expenditures from the EU's seven-year budget and the Next Generation EU Recovery Plan. To make the EU's climate, energy, transportation, and taxation policies suitable for reducing net greenhouse gas emissions by at least 55% by 2030, compared to 1990 levels, the European Commission has adopted a collection of proposals. REPowerEU: Affordable, Secure, and Sustainable Energy for Europe is an ongoing project Climate: By 2050, become the first region to be climate neutral. Energy: A shift to a clean and efficient energy source, Environment, and ocean: safeguarding our ecosystems and species. Agriculture: A sustainable food system for both humans and the environment. Transportation: Providing quick, secure, and ecologically responsible transportation. Industry: A competitive, environmentally friendly, computerized Europe Research and innovation fostering transformative change. Finance and regional development: Investing sustainably to implement the European Green Deal. New European Bauhaus: An innovative and multidisciplinary project that links the European Green Deal to our daily lives and experiences. (India Updated First Nationally Determined Contribution,2022) [14] stated that India updated its first NDC in August 2022. 1. To promote a sustainable, healthy way of life founded on the customs and principles of moderation and conservation, including through a large-scale "Lifestyle for Environment" movement to stop climate change. 2. To choose, at the corresponding degree of economic development, a path that is more environmentally friendly and cleaner than the one previously taken by others.3. To cut its GDP's emissions intensity by 45 percent from 2005 levels by 2030. 4. With the aid of technology transfer and low-cost international finance, including that from the Green Climate Fund, to accomplish roughly 50% of the total installed capacity of electric power from non-fossil fuel-based energy sources by 2030.5. By 2030, increase the number of trees and forests to produce an extra 2.5 to 3 billion tonnes of CO_2 equivalent of carbon sinks.6. To increase expenditures in programs for vulnerable sectors of the economy, such as agriculture, water resources, the Himalayan region, coastal regions, health, and disaster management. 7. To raise domestic and new and additional funds from developed nations to carry out the mitigation and adaptation measures in light of the resource gap and the necessary resources 8. To establish a domestic framework and international architecture, build capacities, and engage in joint collaborative R&D for such future technologies to speed up the diffusion of cutting-edge climate technology in India. India’s long-term objective of becoming net zero by 2070, and this change to its current NDC, represents progress in that direction. (Long-Term Low-Carbon Development Strategy,2022) [15] stated that nearly one-sixth of the world's population lives in India, one of the world's fastest-growing nations. Its expansion must support the global SDGs. Climate change is one of many obstacles facing India's development plan. The following four important factors form the foundation of India's long-term low-carbon development plan. 1. India has made minimal contributions to GW India 2. India's growth requires much energy. 3. is committed to pursuing low-carbon development strategies and is doing so effectively, given national circumstances. 4. India must increase its climatic adaptability. India's pledges at the (COP26) in Glasgow include the goal of having net-zero pollution by 2070. By 2030, obtain 50% of India's total installed capacity of electric electricity from non-fossil sources. ii. By 2030, cut the GDP's emission rate by 45% from its level in 2005. iii. Promote a sustainable and healthy way of life founded on the customs and principles of moderation and preservation, including through a large-scale movement for LiFE - Lifestyle for Environment as a means of halting climate change. India's (LT-LEDS) key components: low-carbon electricity system growth that supports development; create an integrated, effective, and inclusive low-carbon transportation system; encouragement of urban design adaptation, material, and energy efficiency in construction, and sustainable urbanization; encourage the decoupling of economic growth from emissions and the creation of an innovative, efficient low-emission industrial system, CO_2 removal, and related engineering solutions; increasing the number of trees and biodiversity taking into account ecological and socioeconomic factors. (Saudi Arabia First NDC (Updated submission),2021) [16] stated that In October 2021, the Kingdom made its first NDC change. With 2019 serving as the baseline for this NDC, the Kingdom will carry out the actions, projects, and plans described in this submission to reduce, avoid, and eliminate GHG emissions by 278 million tons of CO2eq yearly by 2030. According to the Kingdom's INDC, this objective represents a more than a two-fold rise over the prior. (130 million tons of CO_2e). So, this submission symbolizes advancement and the highest aspiration. The objectives outlined in this NDC depend on sustained economic expansion and diversification, with hydrocarbon export earnings playing a crucial role in the national economy. The Kingdom has already enacted historically significant changes to how the public sector operates, the economy, and society through its Vision 2030. The Kingdom has started a highly ambitious set of initiatives to achieve its climate goals using the Circular Carbon Economy Framework. The Kingdom is creating and putting into practice comprehensive and coordinated programs, policies, initiatives, and platforms for cooperation to address the problems caused by national, regional, and global climate change. The Circular Carbon Economy National Program, the National Renewable Energy Program, the Saudi Energy Efficiency Program, and the Middle East Green Initiative are a few examples. The Kingdom also participates actively in critical international efforts like the Net-Zero Producers Forum, Mission Innovation, Clean Energy Ministerial, and Global Methane Initiative as a member. The report (World Energy Council, 2022) [17] The Kingdom of Saudi Arabia has abundant natural resources, particularly hydrocarbons. Still, its Vision 2030 is to diversify the economy by using all available resources and taking full advantage of clean technology. A lively society, a thriving economy, and an aspirational nation are the three pillars of the Saudi Vision 2030, the country's long-term growth strategy. By demonstrating the circular carbon economy framework to promote the global transition to renewable energy in 2020, while Saudi Arabia was holding the G20 presidency, the Kingdom assumed a leadership role in controlling carbon emissions. Carbon is conserved through reduction, recycling, reuse, and removal (4 Rs), providing economic value, and promoting sustainable development while preventing the release of carbon dioxide and other greenhouse gases into the environment. By establishing the Saudi Green Initiative (SGI) objectives, the Kingdom has revealed various initiatives to protect the environment and combat climate change. The SGI's inaugural wave of initiatives, first announced in March 2021, comprises initiatives that aim to prevent and lower emissions by more than 278 million tons of carbon dioxide equivalent year by 2030. More than 700 billion Saudi riyals (187 billion US dollars) will be invested in the green economy through this initial set of initiatives. The Kingdom hopes to attain net-zero emissions by 2060, principally using the circular economy approach to carbon. Also, it plays a significant role in regional climate change mitigation and adaptation by participating in the Middle East Green Initiative. (The Updated Second Nationally Determined Contribution of the United Arab Emirates,2022) [18] stated September 2022. It established a goal to reduce greenhouse gas (GHG) emissions by 31% by 2030 compared to the 2030 scenario of business as usual (BAU). This extra 7.5% decrease shows renewed progress toward the highest aspiration. The UAE will work to increase its climate-related goals. COP27 intends to introduce its net zero pathway, guiding increased economic-wide emission reduction goals and improved adaptation and resiliency efforts. By the beginning of 2023, these will be a part of the third NDC or LTS. The UAE decides to quicken its low-carbon growth and aid in implementing the Paris Agreement. In line with the strategy used under Article 4.7 of the Paris Agreement, the UAE's commitment to tackling climate change is supported by the nation's steady economic diversification, which produces additional advantages for climate mitigation and adaptation. The NDC is a broad-based objective for the entire economy that includes all significant sources of pollution of carbon dioxide (CO_2), methane (CH4), nitrous oxide (N_2O), and perfluorocarbons. (PFCs). It will reduce pollution by 93.2 million metric tons of CO_2 equivalent, bringing them down to 208 million metric tons in 2030. Compared to the 301.2 million metric tons of CO_2 equivalent in the BAU reference case. The electricity generation sector is expected to make the largest contributions to this decrease (66.4%) as the power sector becomes increasingly decarbonized. Industry (16.6%), transportation (9.7%), carbon capture, use, and storing (5.3%), and waste (2.1%).(The National Climate Change Plan of the United Arab Emirates 2017-2050,2017) [19] stated that Future forecasts made with climate models, based on an examination of past and present anthropogenic factors, indicate that the UAE's annual average temperature would rise by about one °C by 2020 and 1.5–2°C by 2040. The GHG emissions control system will fully cover each economic area, including energy, transportation, construction, industrial processes, waste, and agriculture. It will be founded on thorough analyses, use best practices from around the world, and elaborate emission factors unique to the local area. Three strategic goals that relate to mitigation and adaptation form the basis of the UAE's "Key Climate Priorities.”. First, manage greenhouse gas (GHG) emissions while preserving economic development; second, boost climate resilience by reducing risks and enhancing adaptive capacity. Third, use creative methods to advance the UAE's economic diversification agenda. Important climate priorities: National GHG Emissions Management, National Adaptation Planning, and Implementation. Third. Private Sector-Driven Innovative Diversification Program. The Climate Plan is based on current policy papers on sustainable development and green growth. These cover various directives, plans, and programs, including the National Innovation Strategy, Green Agenda, and UAE Vision 2021. National Energy Plan for 2050, National Biodiversity Strategy and Action Plan, Abu Dhabi Economic Vision 2030, Abu Dhabi Environment Vision 2030, Dubai Integrated Energy Strategy 2030, Dubai Carbon Abatement Strategy 2021, and Dubai Municipality Climate Change Policy Statement are additional pertinent policy documents at the federal and emirate levels. Thus, the Climate Plan is not a stand-alone declaration of policy.

The study (Tudor, 2016)[20] investigates the evolution of CO_2 emissions in Bahrain by using seven models - the Holt-Winters model, the ARIMA, the structural time series model (STS), the naive model, the exponential smoothing state space model (ETS), the BATS / TBATS (Exponential Smoothing State Space Model with Box-Cox Transformation, ARMA Errors, Trend, and Seasonal Components) model, and the Neural Network Time Series Forecasting Method (NNAR) model – which were implemented in R and these models were evaluated using the performance indicator - RMSE. According to their findings, Bahrain does not reduce its CO_2 emissions. It cannot fulfil its presumptive obligation under the Doha Amendment to the Kyoto Protocol, which mandates that by 2020, all nations must reduce their emissions by 18% from 1990 levels. The authors (Malik et al., 2020)[21] implemented the ARIMA model on the three emission inventories REAS (Regional Emission Inventory in Asia), CDIAC (Carbon Dioxide Information Analysis Center) and EDGAR (Emission Database for Global Atmospheric Research) to forecast Pakistan's CO_2 emissions for energy consumption with a particular emphasis on the CPEC (China-Pakistan Economic Corridor) and to assess whether Pakistan will succeed in reducing its CO_2 emissions by 2030. The stationarity of the datasets was tested using the Augmented Dickey-Fuller test, the significance of the trend in the inventory data sets was examined using the Mann-Kendall test, and the performance of the model was evaluated using the three performance measures -MAPE, MSE, and RMSE. The projection led the authors to the conclusion that Pakistan would not be able to meet its NDC (Nationally Determined Contributions) and sustainable targets as promised at COP21 because of the high emission level.

The study (Tudor et al., 2022)[22] addresses the question of how CEE (Central and Eastern Europe) can meet the challenging EU pollution reduction targets. The total GHG emissions of the nine countries of

CEE were predicted using seven models - the Exponential Smoothing State Space Model (ETS), the Holt-Winters Model (HW), the TBATS Model, the ARIMA Model, the Structural Time Series Model (STS), the Neural Network Auto-Regression Model (NNAR), and naïve model – which were implemented in R. These models were evaluated using the RMSE and robustness was examined using the KSPA (Kolmogorov-Smirnov Predictive Accuracy) test. The authors discovered that the EU Green Deal 2030 sets specific targets for the total quantity of greenhouse gas emissions to be attained by 2030 based on the model's projection. The authors also found that some of the CEE countries will miss the target while others will meet the targets set by the EU. In the paper (Kunda et al., 2017)[23], the authors highlighted the evolution of CO_2 emissions from fossil fuels in Zambia and the industries that contribute most to CO_2 emissions, as well as the projection of CO_2 emissions for 2021 using WEKA. The SMOreg algorithm was used for trend analysis in WEKA. The findings indicate that the transportation sector is the major source of CO_2 emissions and that despite the implementation of the carbon emission tax, the rate of CO_2 emissions has not significantly lowered; In contrast, CO_2 emissions from the generation of electricity and heat will gradually decline, and CO_2 emissions from the residential, commercial, and other sectors will show a slight decline but remain constant during the same time period. The author (Tudor et al., 2021) [24] focused on producing an accurate prediction of greenhouse gas emissions, which was essential for effective policy-making procedures and solving pressing global climate problems, by implementing seven models - the ETS, HW, TBATS, ARIMA, STS, NNAR, and a naïve model- and the performance of these models were evaluated using RMSE and MASE. From the findings, the authors discovered that no country would reach its NDCs under the Paris Agreement and stronger regulations are required to properly combat global pollution. The author (Qader et al., 2021)[25] implemented three models to predict the CO_2 emission of Bahrain - Gaussian Process Regression Rational Quadratic (GPR-RQ) Model, neural network time series nonlinear autoregressive (NNTS-NA), and Holt's method; and RMSE was used to evaluate the models performance. To forecast the CO_2 emissions in Hebei, China, (Wei et al., 2018)[26] the author proposed a hybrid model. Extreme Learning Machine and Random Forest were used to create the hybrid model (a neural network with a single hidden layer and feedforward) and the model's performance was enhanced by the use of Moth Flame Optimization, a heuristic approach inspired by nature and based on the moth's spiral motion, which has two essential components: moths and flames. Ten most significant variables (GDP of primary production, urbanization, etc.) were extracted as external factors influencing the prediction of CO_2 emissions, taking the actual situation into consideration and this extraction was based on the Gini index, where the larger the mean decrease in Gini impurity, the stronger the association with the response. RMSE, MAPE, MdAPE, and MaxAPE were employed to assess the model's performance. The authors concluded from the findings that urban population growth is accompanied by an increase in CO_2 emissions, and that despite resident activity, the time of rapid economic growth—during which the sharp increase in private car ownership occurs—is characterized by the highest CO_2 emissions. The study (Kumari et al., 2022)[27] discusses the negative impacts of India's CO_2 emissions along with a forecast of CO_2 emissions using three statistical models (ARIMA, SARIMAX [X- exogenous factor], and Holt-Winter model), two machine learning models (random forest and linear regression), and one deep learning model (LSTM model) and this forecast assisted the authors in understanding the rate of emissions and the necessary steps to maintain reasonable temperatures. Nine performance indicators (MSE, RMSE, MSLE, MAE, MAPE, MedAE, max error, R-square error, and EVS) were used to evaluate the models as well as to determine which model performed the best statistically, the authors used the Friedman test. From the findings, the authors discovered that India's CO_2 emissions will double from their current level by 2050. The author (Ma et al., 2021)[28] proposed three models - Gaussian Process Regression (GPR), a nonparametric Bayesian kernel prediction technique together with traditional least squares and robust least squares - that can be used to forecast the CO_2 emission in China, and the models were evaluated using four performance metrics - MSE, RMSE, MAE, and R-square. The study (Li et al., 2022)[29] focused on CO_2 emissions in the transportation sector. The three machine learning techniques - OLS (ordinary least squares), SVM (support vector machine), and GBR (gradient boosting regression) - were utilized by the authors to analyze the CO_2 emission trends in the transportation industry. MAE MAPE, rRMSE (relative root mean square error), and R-square were used to evaluate the performance of the models, and GBR was found to be the best forecasting model. According to the findings, the authors discovered that SoEco factors like GDP and TRAN feature to influence the five nations with the highest emissions.

In conclusion, numerous studies have been carried out to examine CO_2 emissions and discover solutions or approaches that could assist in resolving the issue, i.e., the rise in CO_2 emission that causes climate change. CO_2/GHG emissions have been predicted using models like ARIMA, LSTM, NNAR, and many others. Future studies could include additional sectors and/or variables like population, per capita energy consumption, energy mix, etc. to create a multivariate model that forecasts CO_2 emissions while taking these factors into account and can be used for future projections.

2.2. Takeaways from Literature Review

After reviewing the literature, the following are the takeaways:

- There is a gap since the countries want to achieve sustainable development goals by 2030, but the world is facing a key crisis dominated by climate change, conflicts, and COVID-19, while countries pledged to limit global warming to 1.5°C above pre-industrial levels in the Paris Agreement. There is a need to apply data analytics techniques to climate change to evaluate CO_2 emissions, to tackle this issue and help the policymakers to set or adjust NDCs and policies to mitigate and adapt to climate change.

- The energy sector contributes three-quarters of greenhouse gas emissions today, which is the key to preventing the worst effects of climate change, perhaps mankind's greatest challenge. Global carbon dioxide (CO_2) emissions must be reduced to net zero by 2050 to limit long-term warming to 1.5C.
- The Social Cost of Carbon (SCC) is the most significant economic concept. Providing a monetized value for the present and future damages resulting from the emission of a ton of CO_2, it's currently a lively debate among policymakers. It could be one of the solutions to tackle climate change.
- CO_2 emissions were predicted using machine learning models such as ARIMA, Holt Winters, STS, ETS, LSTM, SVM, NNAR, random forest and others; the models were evaluated using performance metrics such as MSE, RMSE, MAPE, MAE, R-square, etc.
- The studies focused either on a single indicator, such as the total annual fossil fuel combustion for all sectors, the total CO_2 emissions for all countries, etc.; or general indicators, such as the population, energy consumption, economic growth, etc.; or on a particular sector, such as the transportation sector, the energy sector, etc.

Chapter 3: Project Description

In this project, the method CRISP-DM was used. The dataset used for the project came from the Climate Action Tracker to analyze country and sector CO_2 emission. The project started with understanding the business area and defining the project objectives, followed by understanding and exploring the selected data. The data is then pre-processed and used for analysis and modeling to gain insights from the data.

3.1. Dataset Exploration

We have explored and visualized our historical dataset using Tableau software. The historical dataset consists of around 35,000 observations between the years 1990-2020 that represent the CO_2 emission intensity for the following sectors (Agriculture, Buildings, Electricity, industry, Oil and Gas, and Waste), while the maximum policy scenario consists of 1800 observations and the minimum policy scenario consists of 2200 observations.

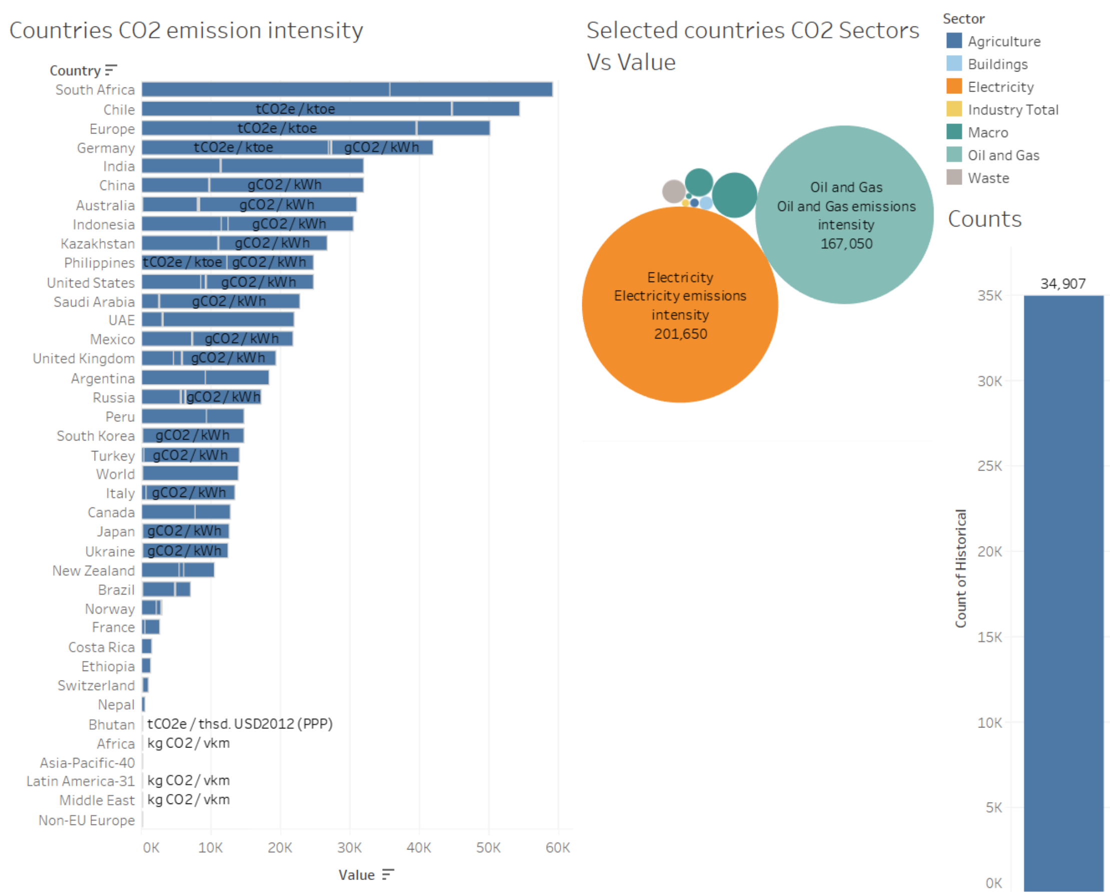


Figure 2: The Emission Intensity of the Countries

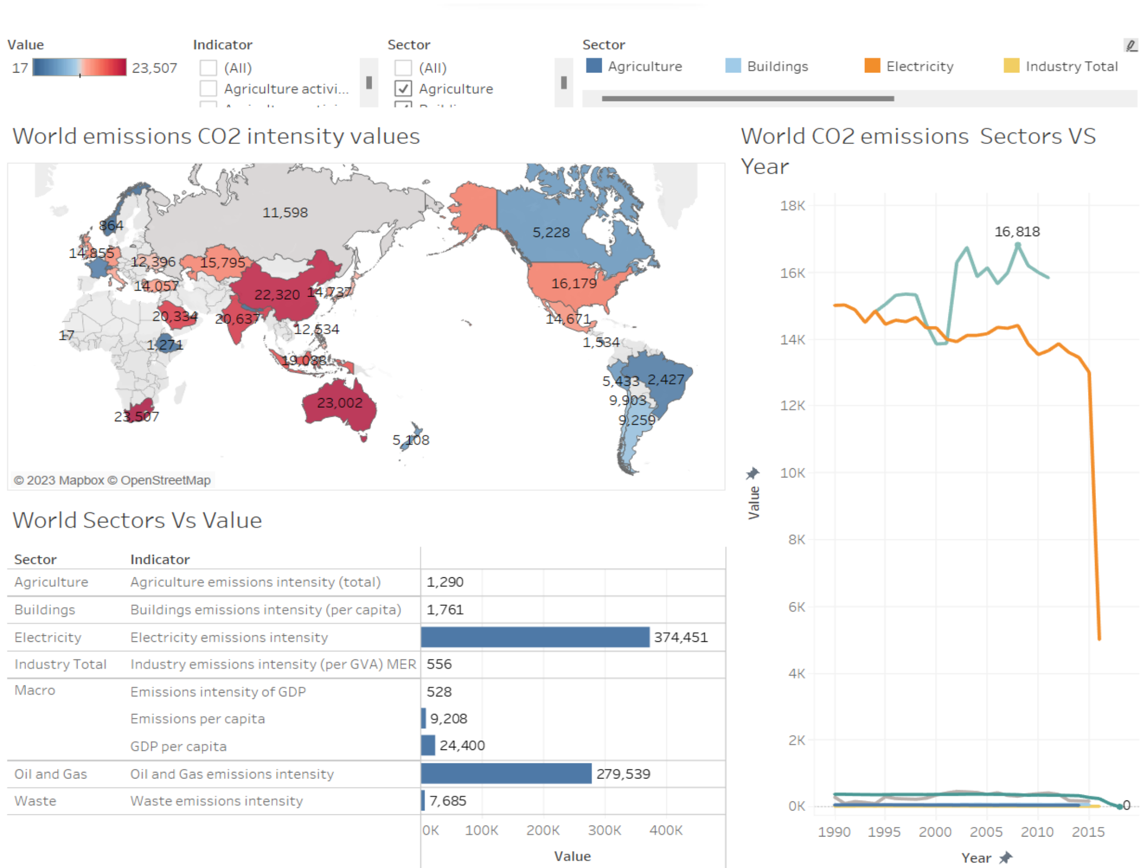


Figure 3: World CO_2 Emission Intensity

Our observations from the graphs above (Figure 2 & 3) are as follows:

1. The five countries with the highest emissions are South Africa, Chile, Europe, Germany, and India.
2. The electricity sector contributes the highest CO_2 emissions intensity to climate change. This is followed by the CO_2 emission intensity of Oil & Gas.

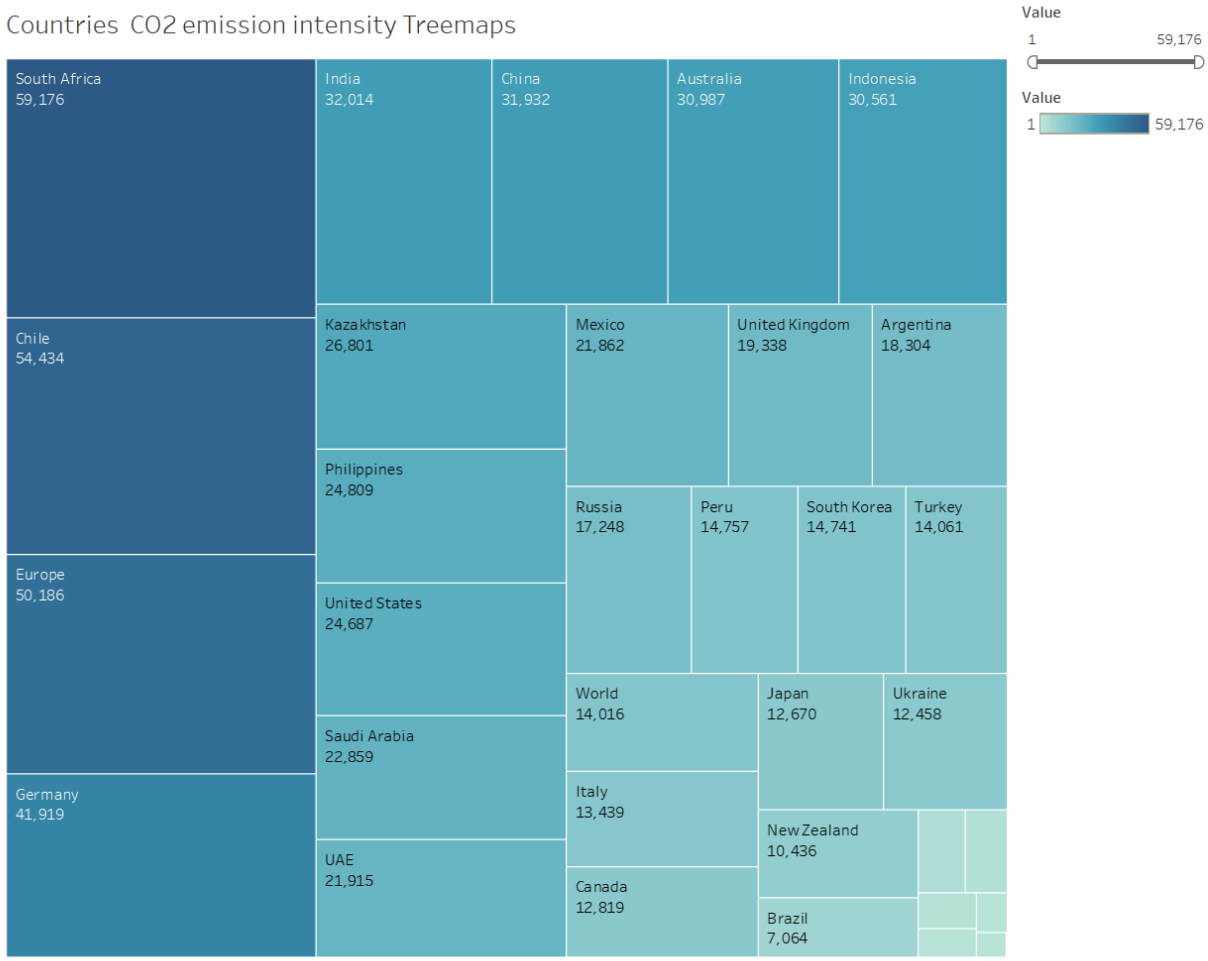


Figure 4: CO_2 Emission Intensity of the Countries

We also have represented the countries CO_2 emission intensity as Tree map, and we found that the five countries with the highest emissions are South Africa, Chile, Europe, Germany, and India.

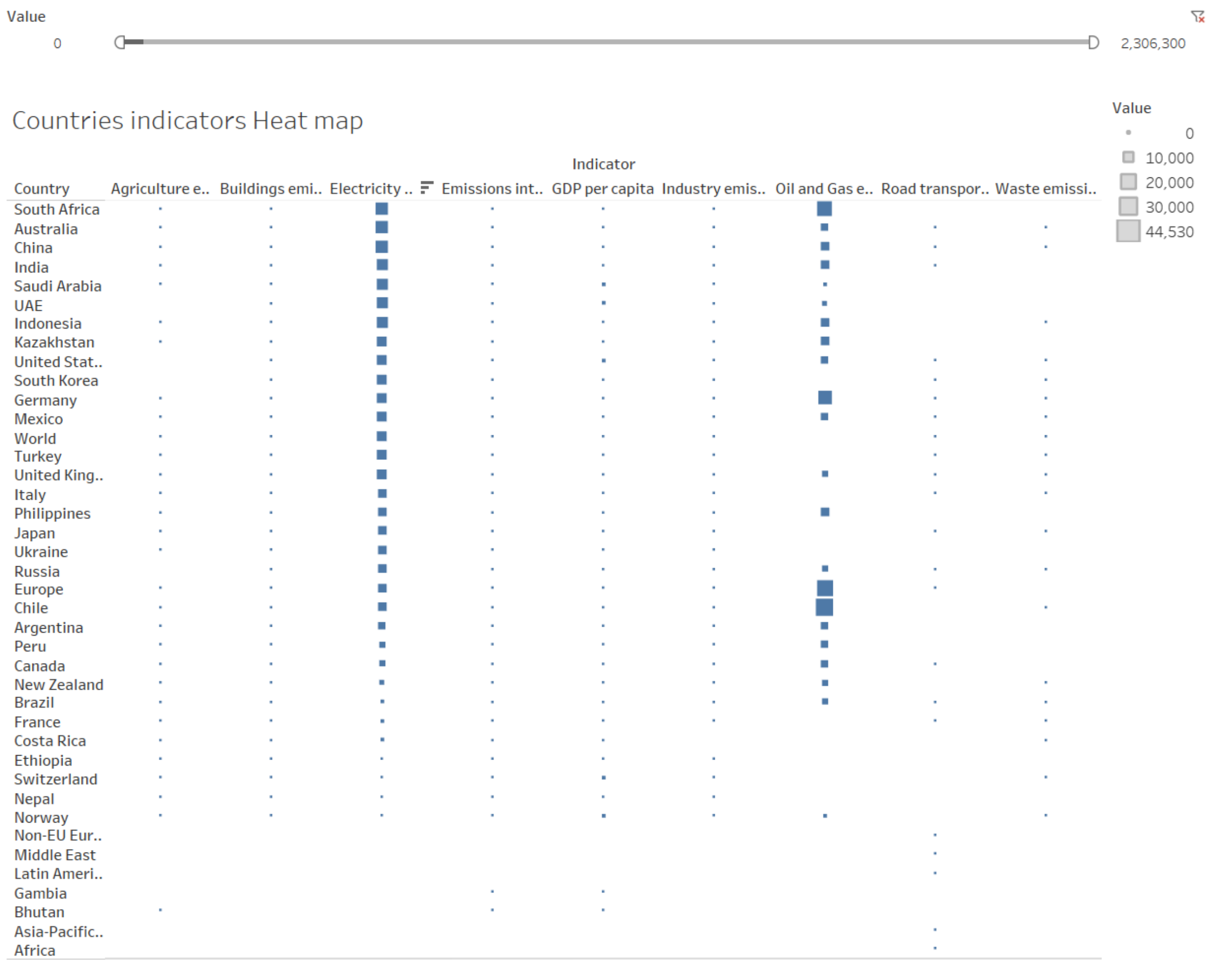


Figure 5: Countries Indicators

We noticed from the country's indicators heat map for the CO_2 emissions intensity that the top five countries are South Africa, Australia, China, India, and Saudi Arabia, while the lowest are Ethiopia, Switzerland, Nepal, Gambia, and Bhutan.

We have visualized all the decarbonization indicators (shown in Figure 5), which is around 67 indicators in all sectors, that have the highest value and found the most correlated ones in order to provide recommendations to the policymakers to develop some mitigation climate change covering these areas, which will significantly impact the CO_2 emission intensity in these sectors.

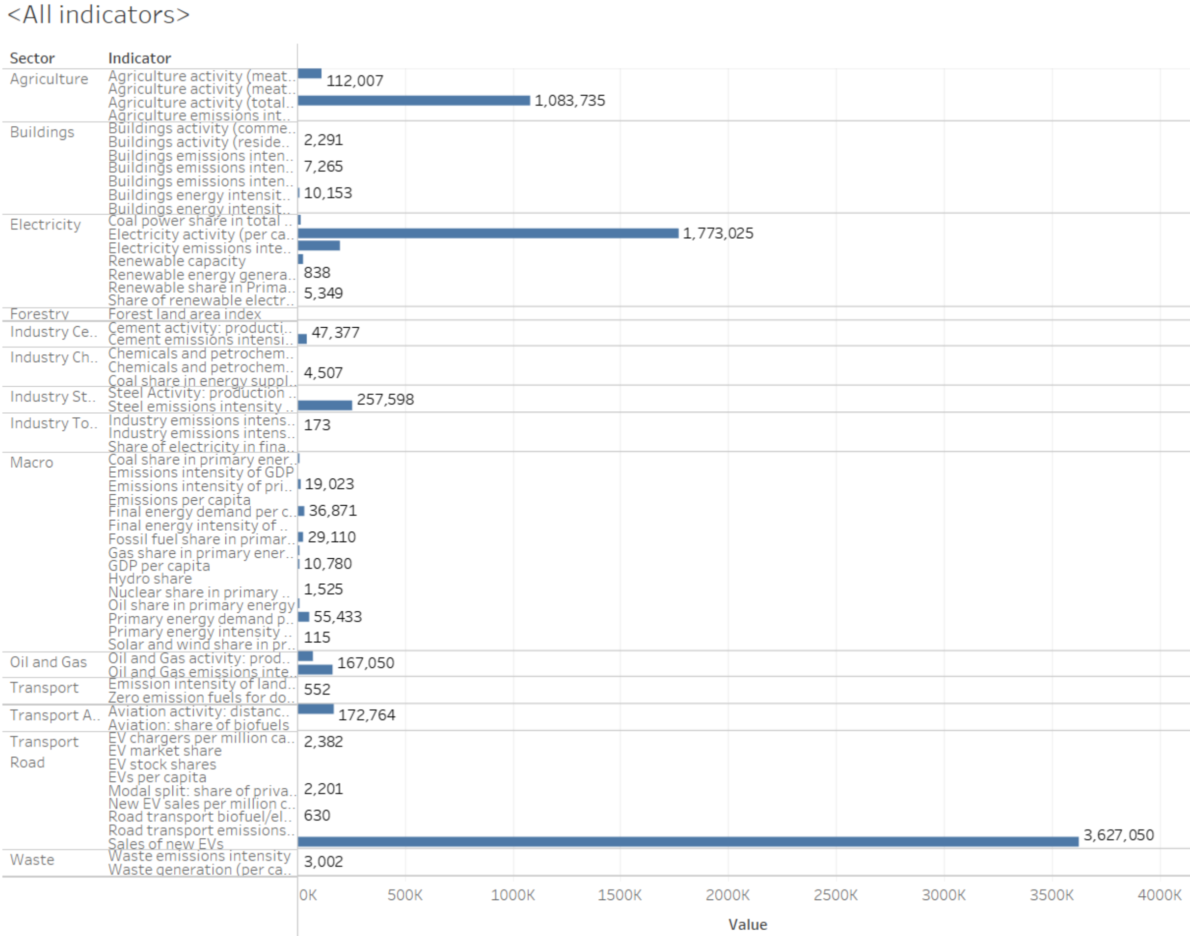


Figure 6: Indicators by Sectors

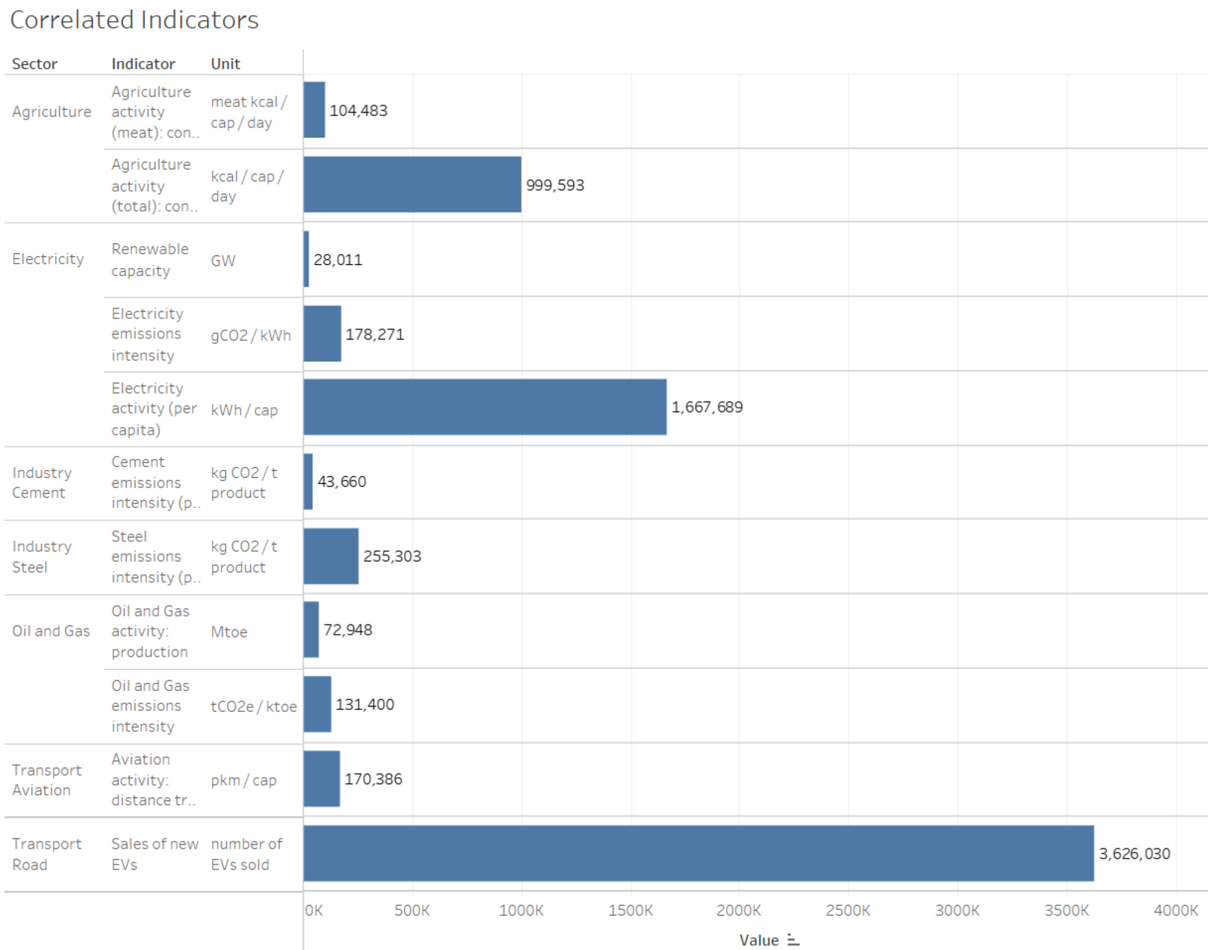


Figure 7: Correlated Indicators

Based on our Analysis, our recommendation

1. For the policymakers to develop new policies or reinforce the current ones
2. The involved stakeholders to advance the current technologies.

To cover these top five areas that will significantly help to mitigate climate change as follows: Sales of new EVs, Electricity activity (per capita), Agriculture emissions intensity (total), Steel emissions intensity (per product) and Electricity emissions intensity.

Electricity Sector

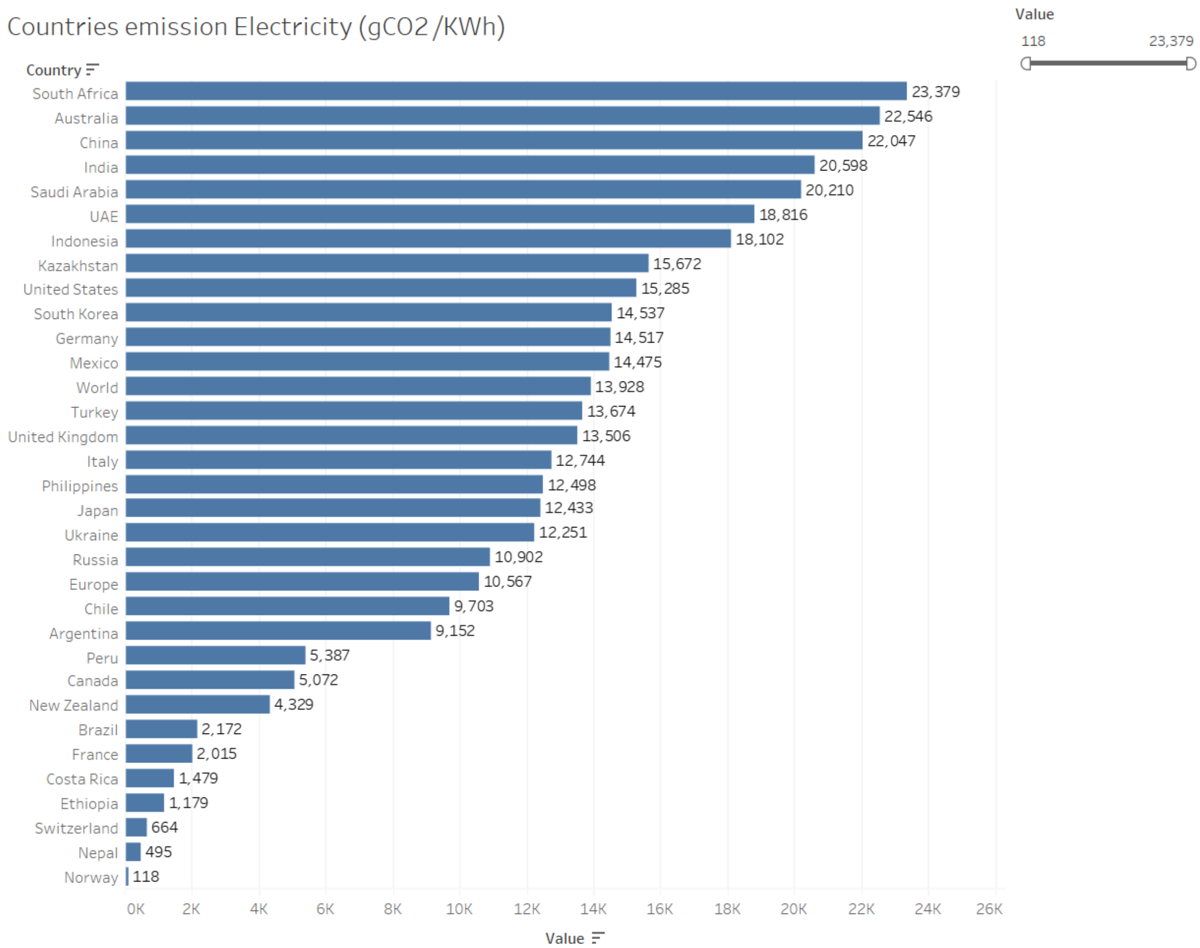


Figure 8: Country Emission for Electricity Sector

Regarding the highest five countries contributing to CO_2 emission intensity (gCo_2/kWh) in the electricity sector, we have found them as follows: South Africa, Australia, China, India, and Saudi Arabia.

Oil & Gas Sector

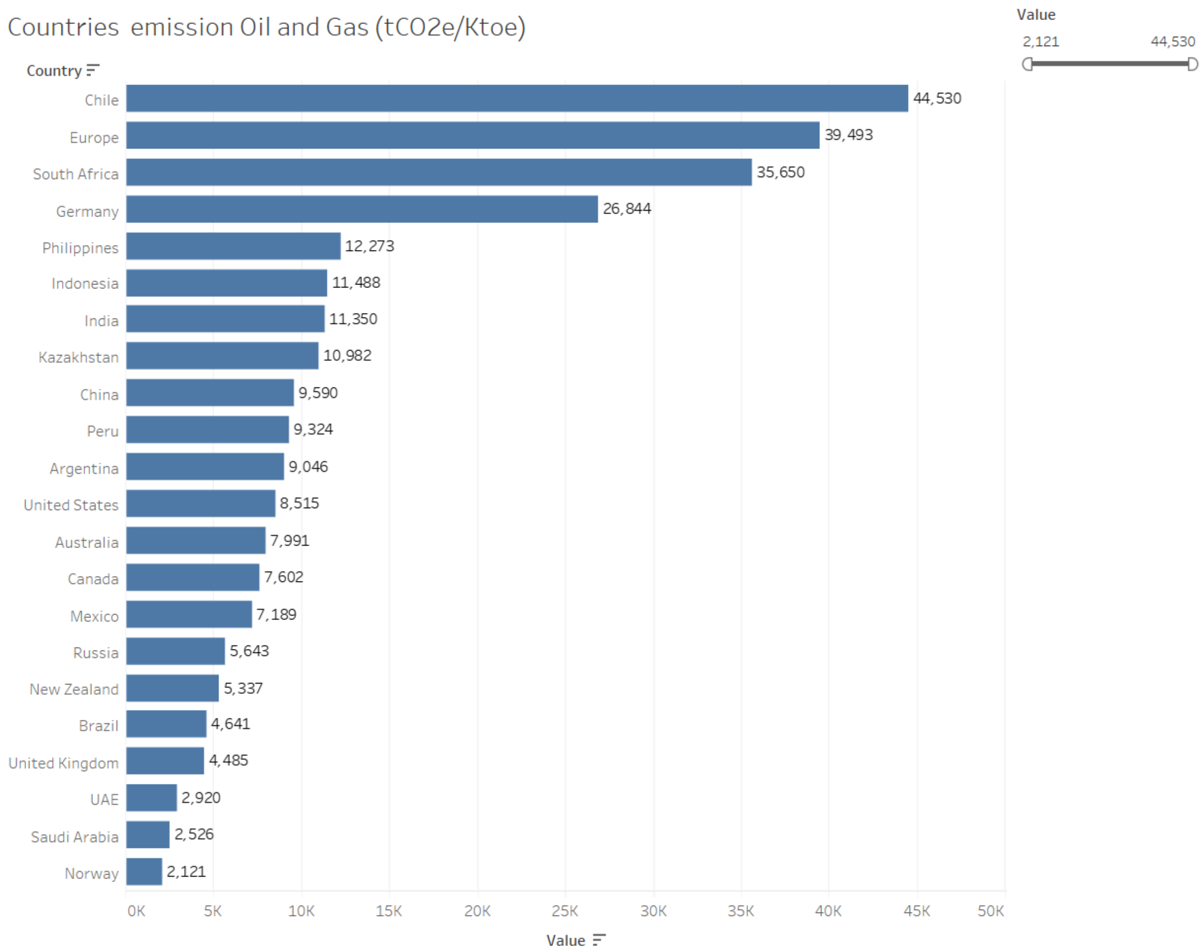


Figure 9: Country Emission for Oil & Gas Sector

Regarding the highest five countries contributing to CO_2 emission intensity (tCO_2 /Ktoe) in the Oil and gas sector, we have found them as follows: Chile, Europe, South Africa, Germany, and Philippines.

Building Sector

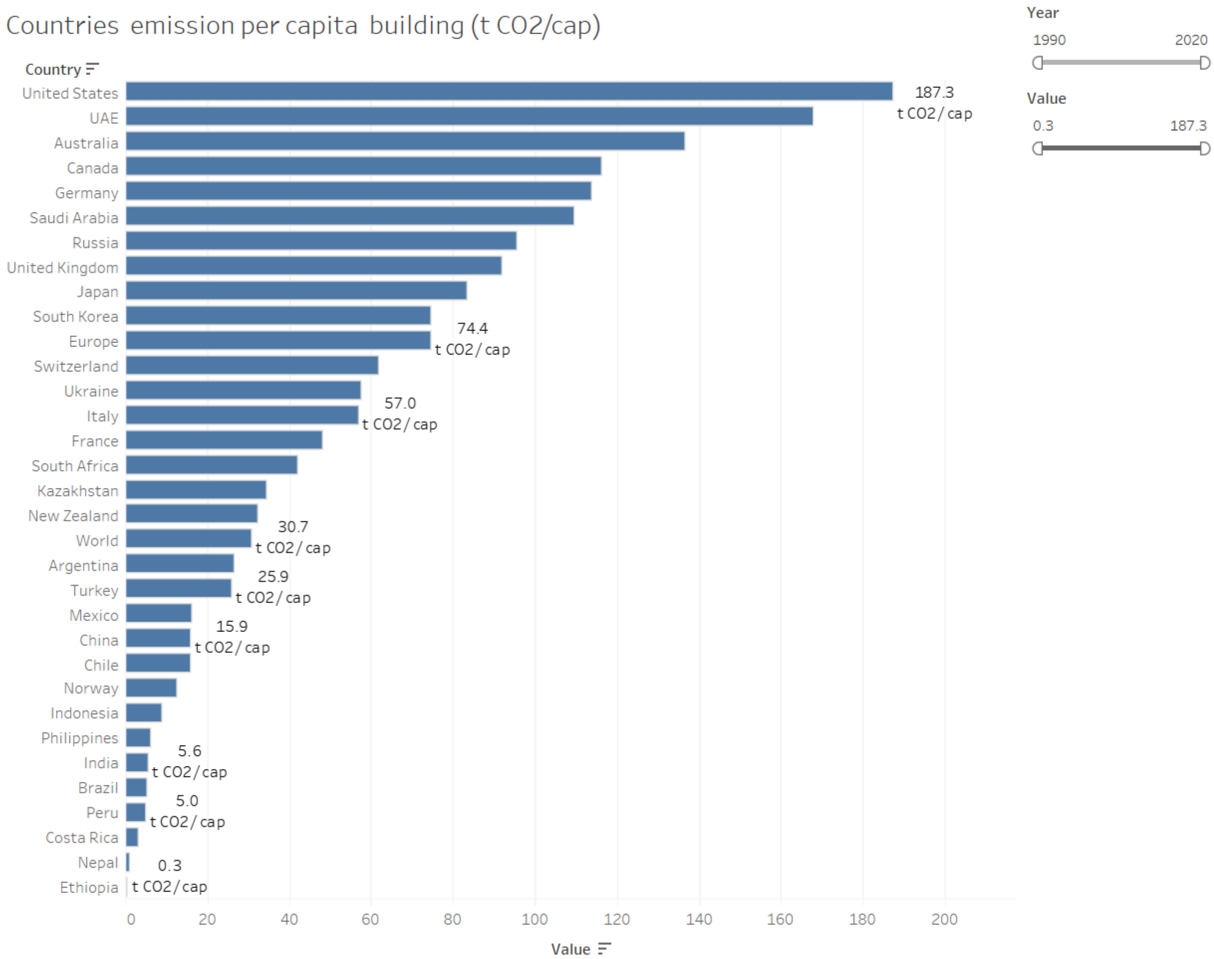


Figure 10: Country Emission for Building Sector

Regarding the highest five countries contributing to CO_2 emission intensity (tCO_2/capita) in the building sector, we have found them as follows: United states, UAE, Australia, Canada, and Germany.

Industry sector

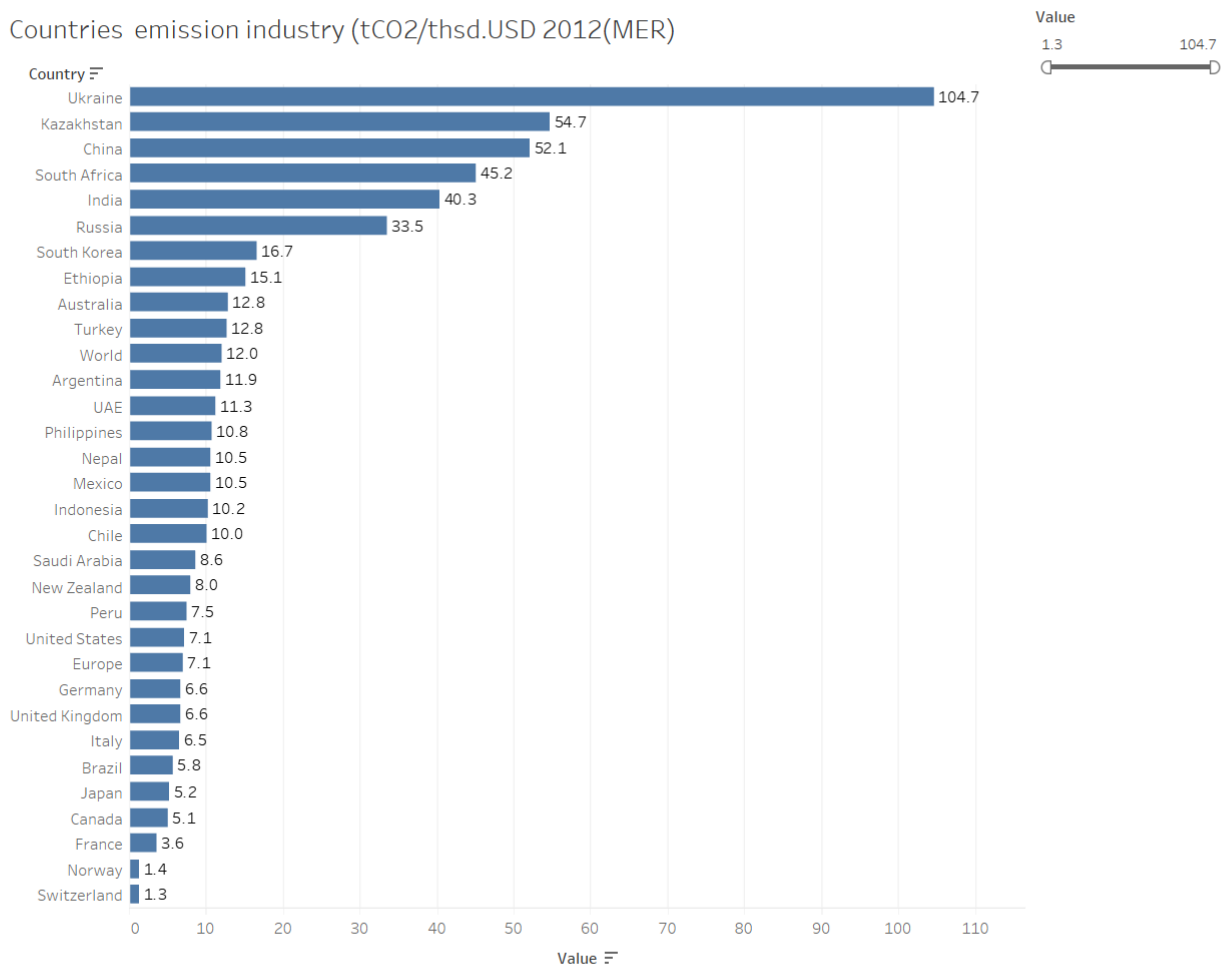


Figure 11: Country Emission for Industry Sector

Regarding the highest five countries contributing to CO_2 emission intensity ((tCO_2/ tCO_2/ thsd) USD2012 (MER)) in the industry sector, we have found them as follows: Ukraine, Kazakhstan, China, South Africa, and India.

Transport sector

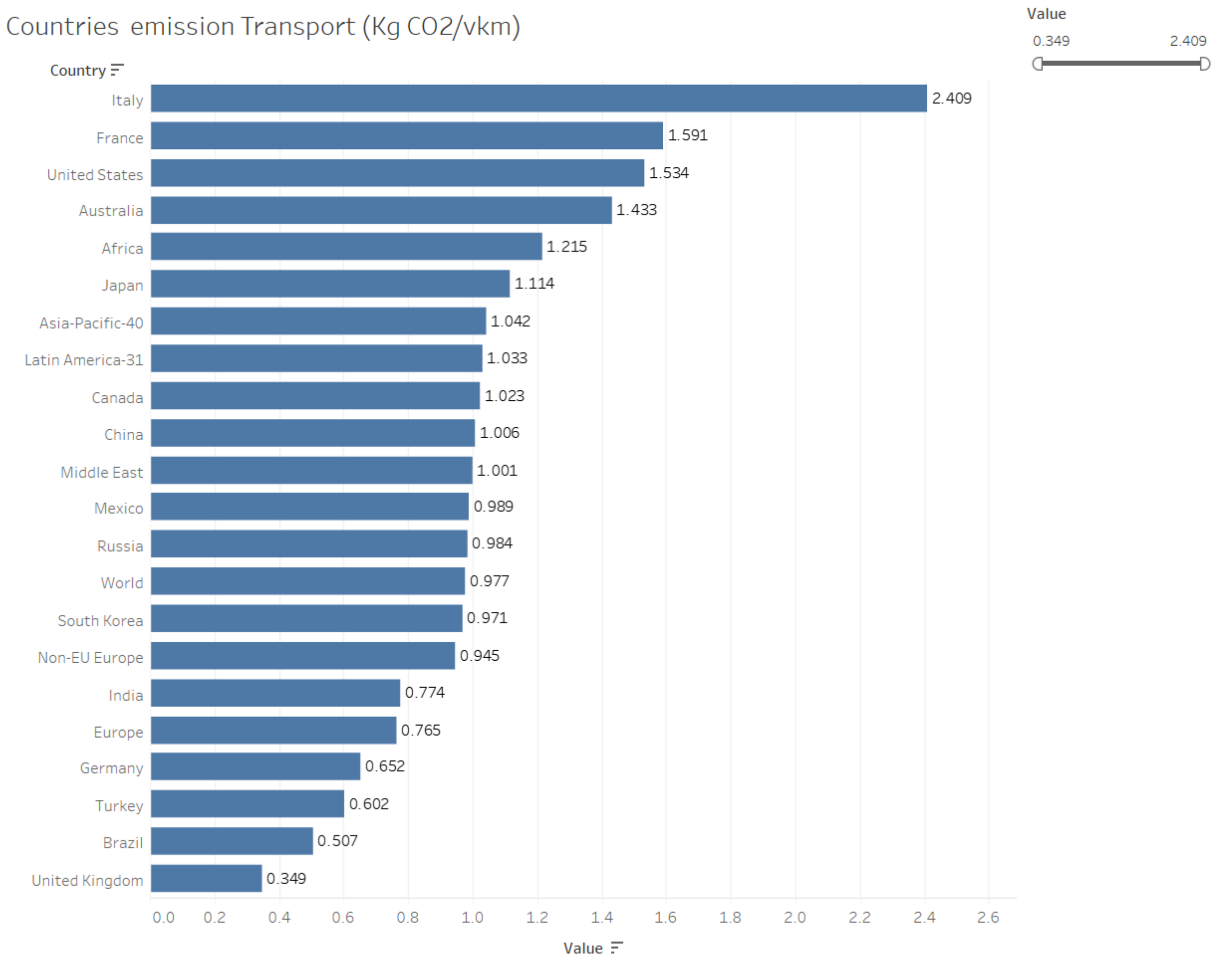


Figure 12: Country Emission for Transport Sector

Regarding the highest five countries contributing to CO_2 emission intensity ($KgCO_2$/vkm) in the road transportation sector, we have found them as follows: Italy, France, United states, Australia, and Japan.

Agriculture sector

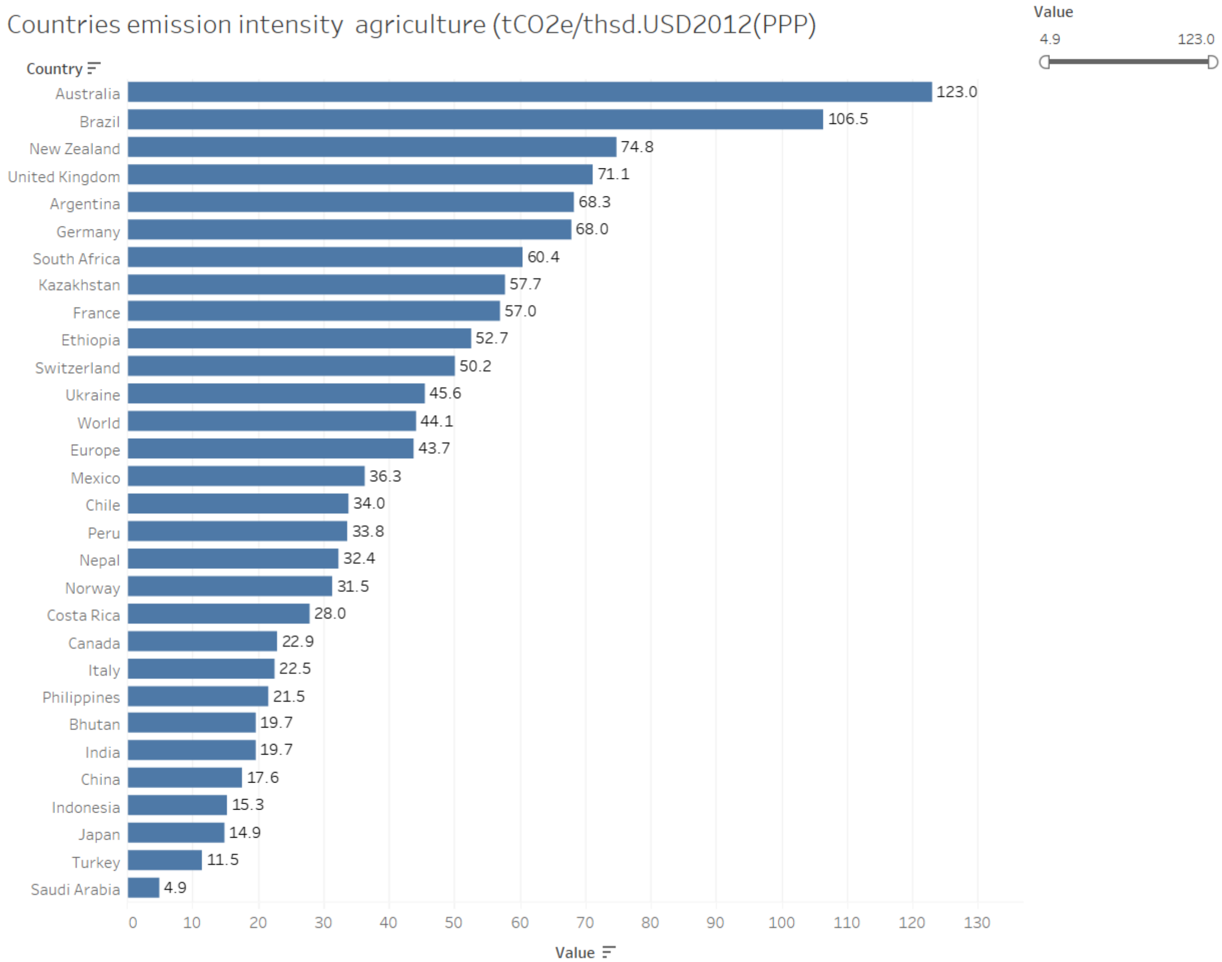


Figure 13: Country Emission for Transport Sector

Regarding the highest five countries contributing to CO_2 emission intensity (CO_2/ thsd. USD2012 (PPP) in the agriculture sector, we have found them as follows: Australia, Brazil, New Zealand, United Kingdom, and Argentina.

Waste sector

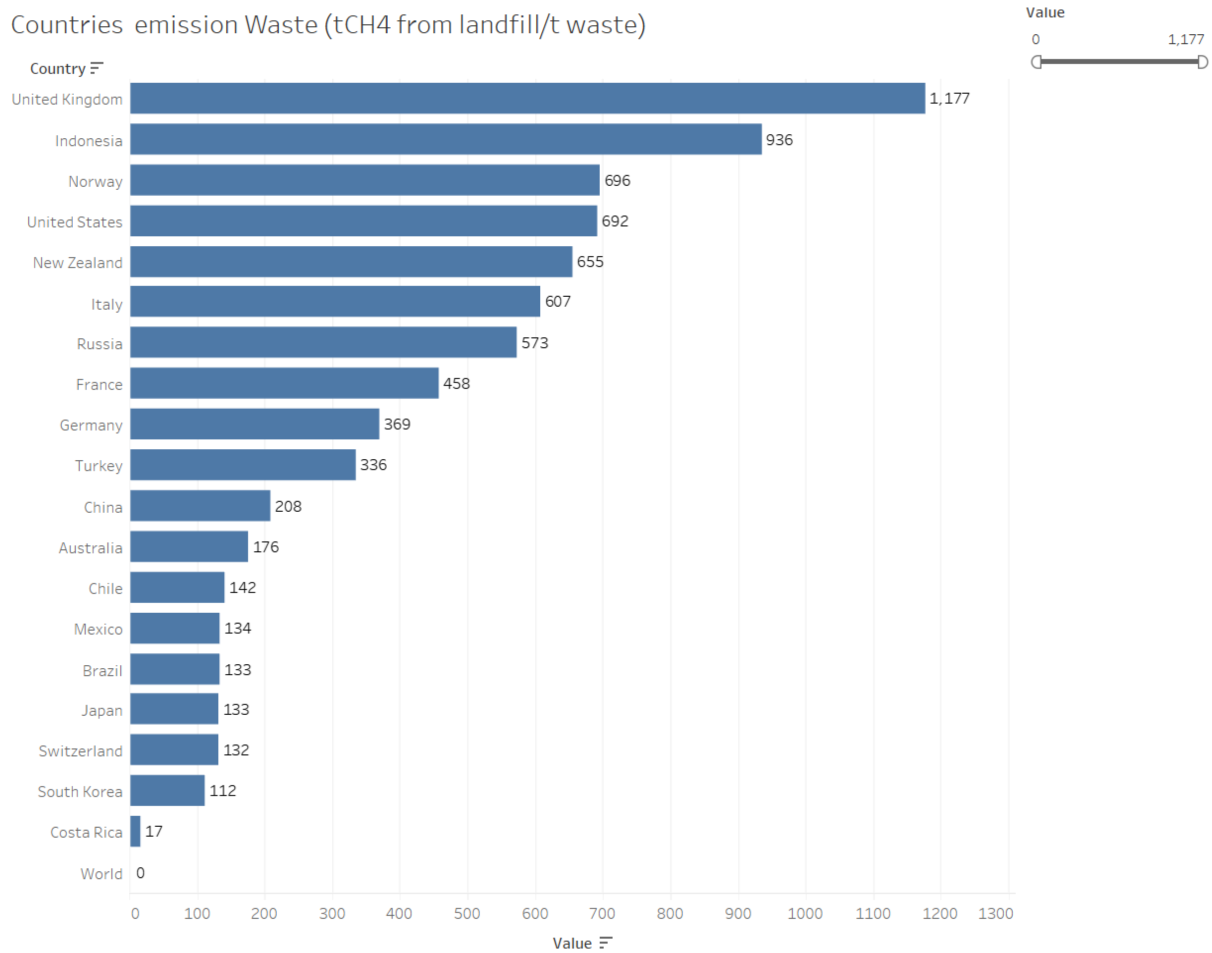


Figure 14: Country Emission for Waste Sector

Regarding the highest five countries contributing to emission intensity (Tch4 from Landfill/ t waste) in the Waste sector, we have found them as follows: United Kingdom, Indonesia, Norway, United states, and New Zealand

.

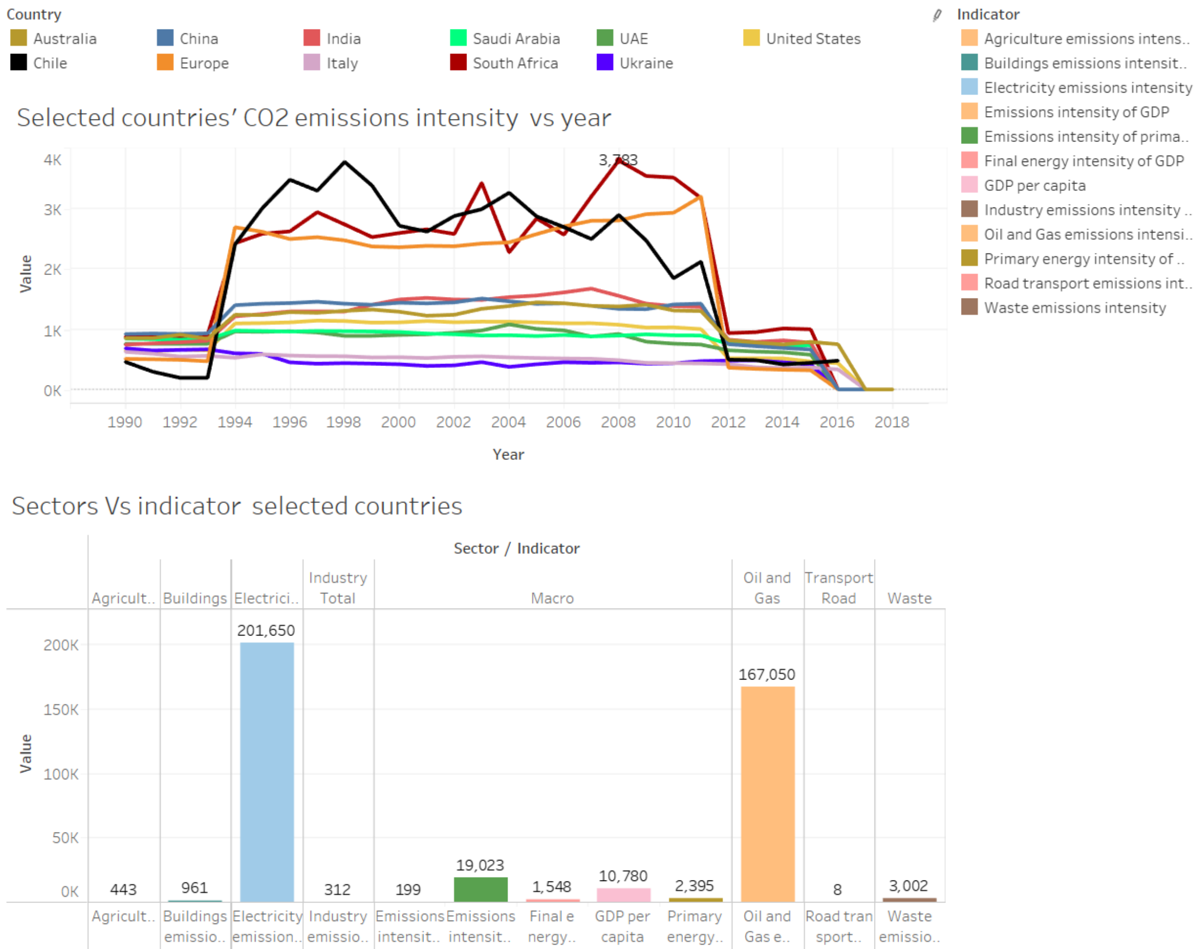


Figure 15: Selected Countries Emission Intensity

We visualized the selected indicators in all sectors comparing the selected highest CO_2 emission intensity countries (Australia, China, India, Saudi Arabia, UAE, United States, Chile, Europe, Italy, South Africa, and Ukraine) in all sectors in the period from 1990 to 2018 and made the following observations:

1. The country with the highest CO_2 emission intensity among the selected countries is South Africa with a value of 3783 in 2008.
2. The CO_2 emission intensity of electricity is the highest with 201,650, followed by Oil & Gas sector with 167,050 among the selected countries.

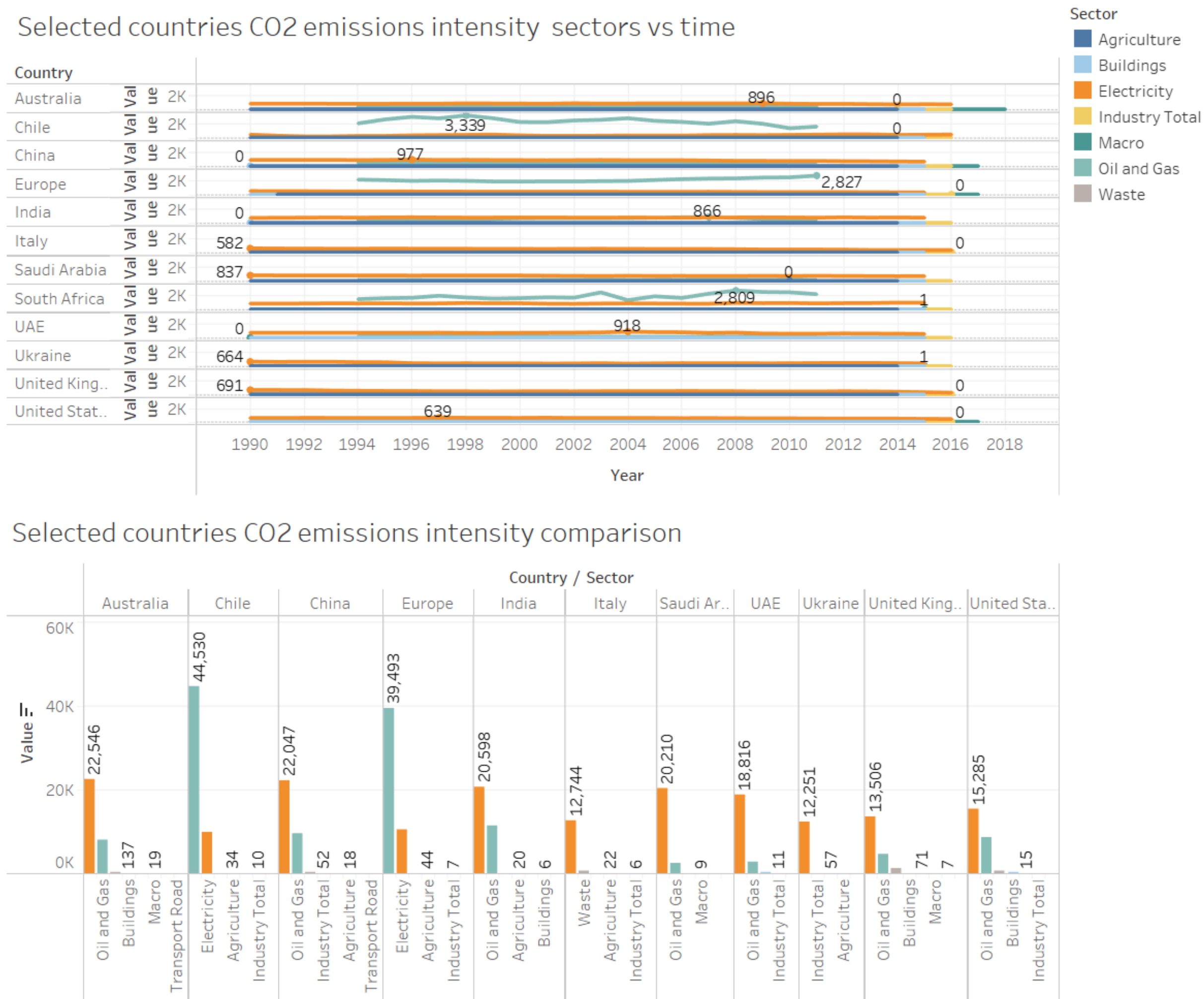


Figure 16: Selected Countries Emission Intensity Comparison

We also performed a sectoral comparison between the selected countries with the highest CO_2 emission intensity (Australia, China, India, Saudi Arabia, UAE, United States, Chile, Europe, Italy, South Africa, and Ukraine) over the years 1990 to 2018 and made the following observations:

1. In Europe, Chile, and South Africa, the Oil & Gas sector is the largest contributor to CO_2 emission intensity over the 1990-2018 period among all selected countries.
2. The electricity and oil & gas sectors contribute the most to CO_2 emission intensity over the 1990-2018 period among all other sectors.
3. Countries have a different year in which they contribute the most to the CO_2 emission intensity of 1990-2018. For instance, countries such as Chile, China and United States made the largest contribution before 2000, while countries such as Australia, Europe, India, South Africa, UAE, and Ukraine made the largest contribution to CO_2 emission intensity after 2000.

Below are the selected countries emission intensity over the time.

1. Europe

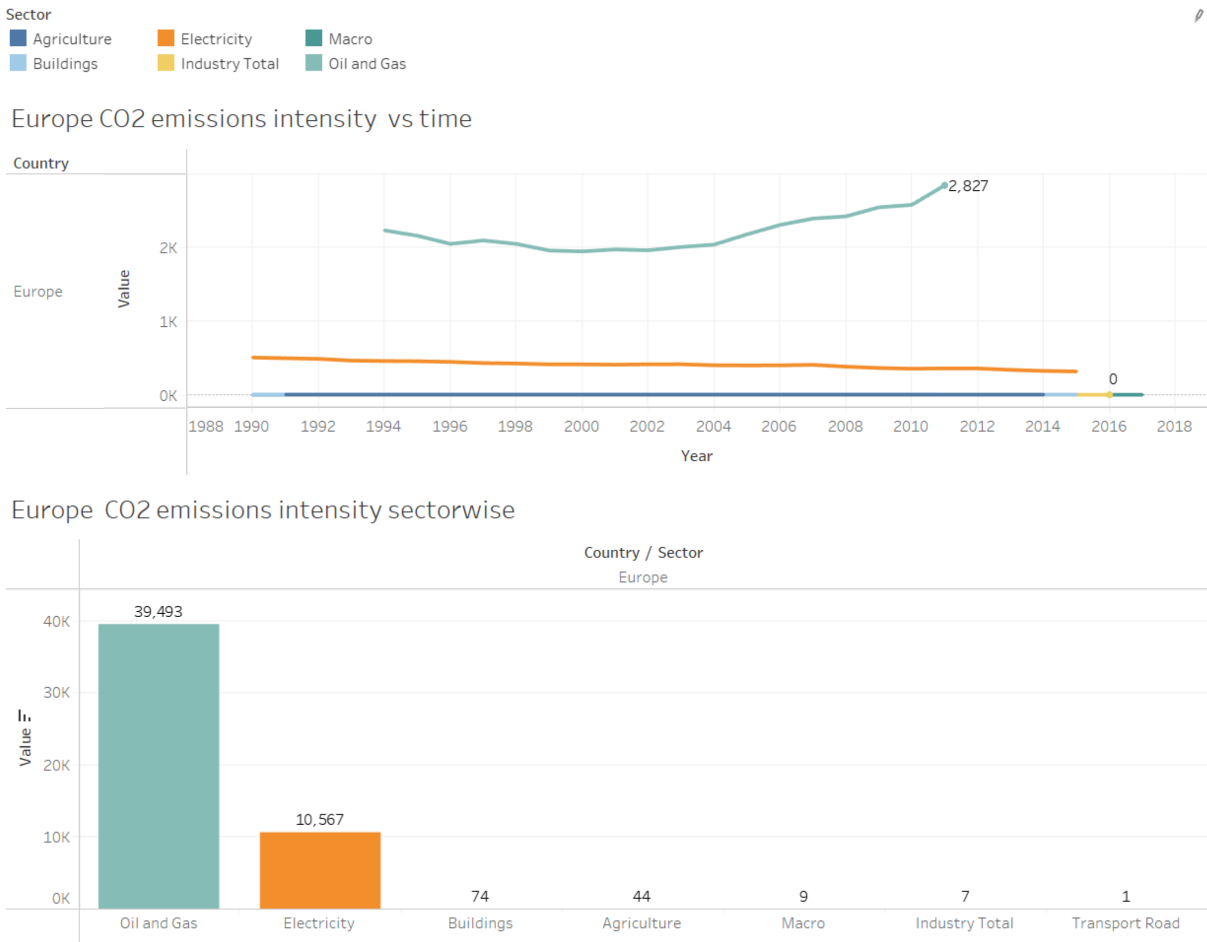


Figure 17: Europe's CO_2 Emission Intensity

- This graph shows that Europe has a higher Oil and Gas sector CO_2 emissions intensity than the Electricity sector CO_2 emissions intensity.
- The Oil and Gas sector's CO_2 emissions started a slight decrease after 1994 until 2004, then it started increasing until it reached a peak in 2011.
- The electricity sector's CO_2 emissions intensity decreased slightly from 1990, slightly after that year.

2. India

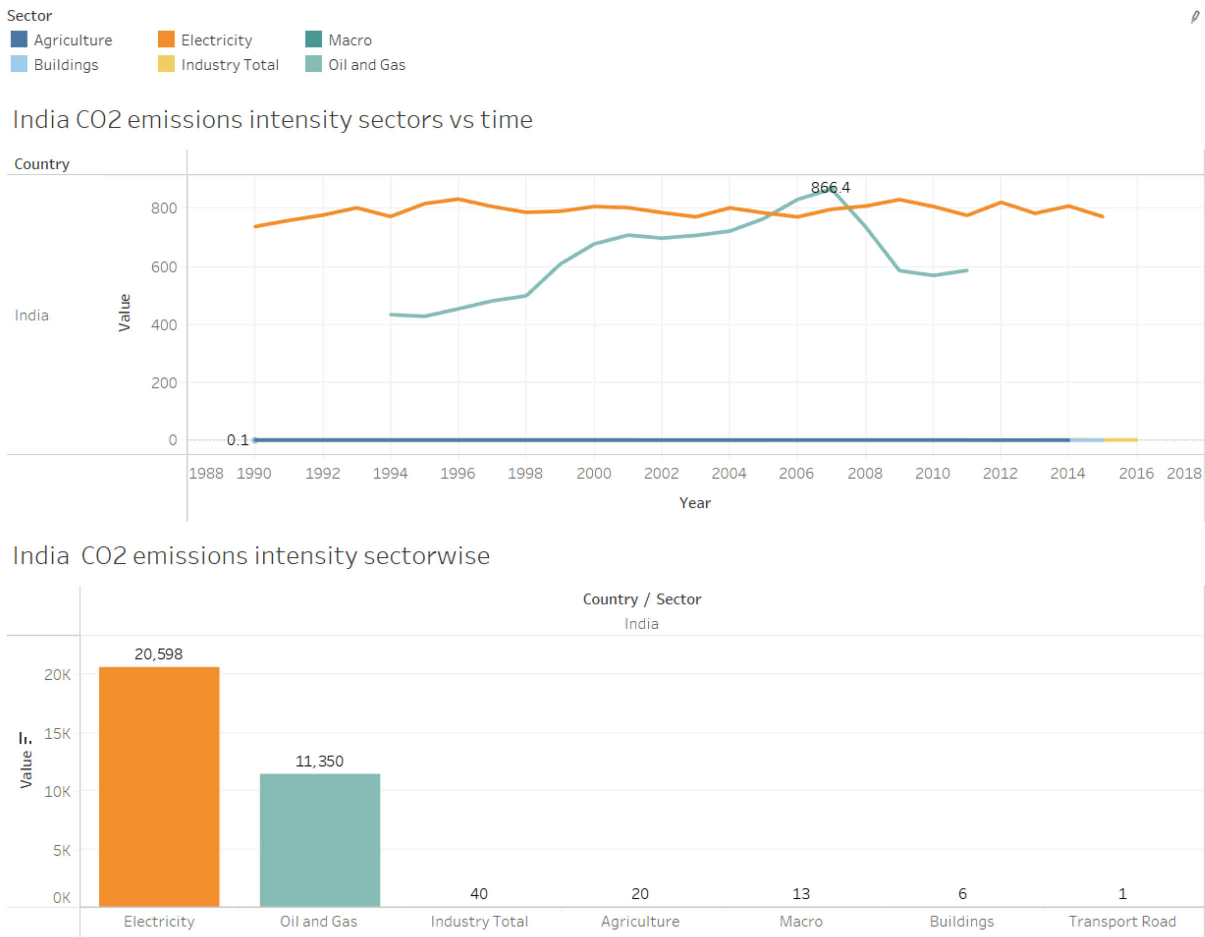


Figure 18: India's CO_2 Emission Intensity

- This graph shows that India has a higher CO_2 emissions intensity Electricity sector than the Oil and Gas sector's CO_2 emissions intensity.
- The Oil and Gas sector's CO_2 emissions started increasing from 1994 until 2007, when they peaked that year, then decreased until 2011.
- The electricity sector's CO_2 emissions intensity doesn't have a fixed trend. It changes nearly every two years, which requires putting in place some firm policies in this sector.

3. China

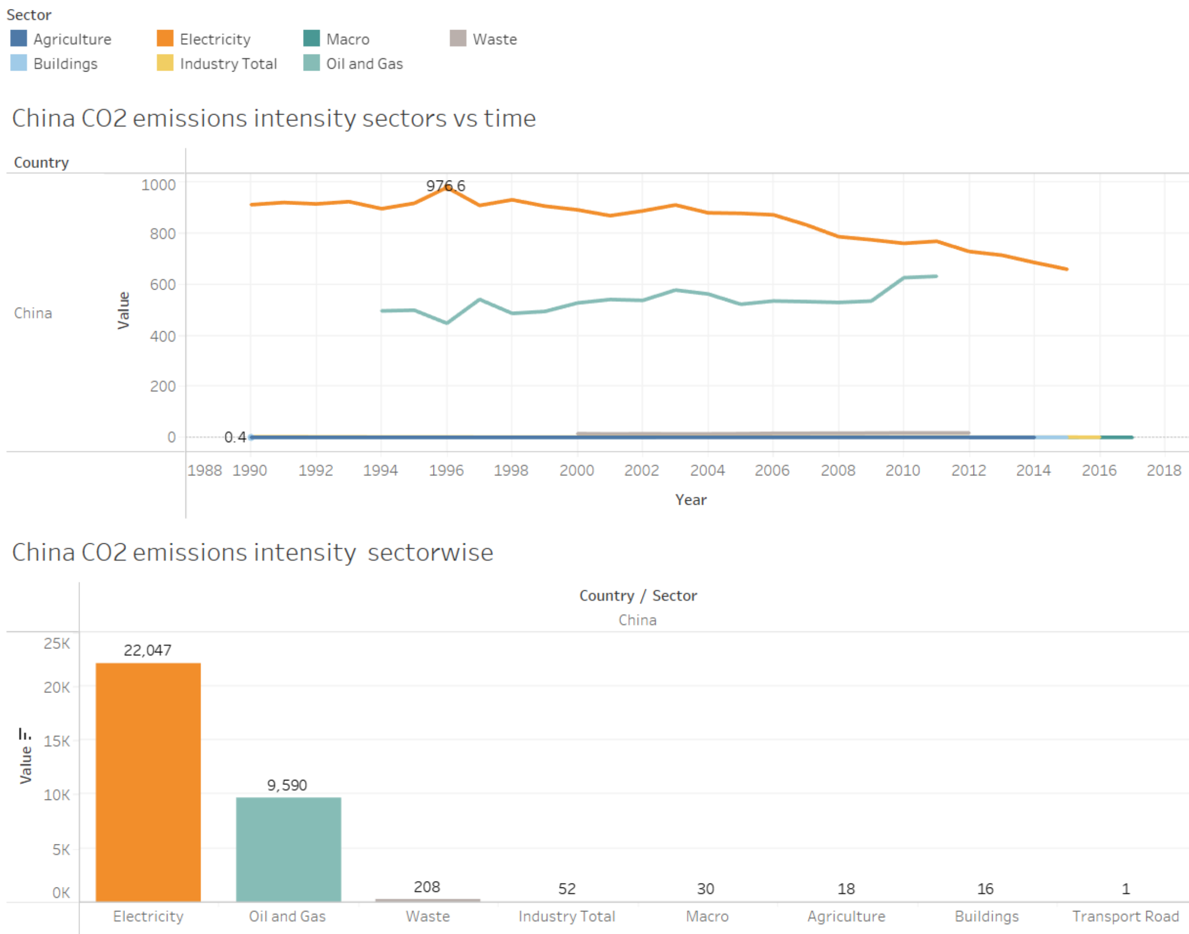


Figure 19: China's CO_2 Emission Intensity

- This graph shows that China has a higher CO_2 emissions intensity Electricity sector than the Oil and Gas sector's CO_2 emissions intensity.
- The Oil and Gas sector's CO_2 emissions don't have a fixed trend.
- The electricity sector's CO_2 emissions intensity was fixed until 1993, then it started slightly decrease until 1994, then it started increasing until it peaked in 1996, after that, it was slightly after that year.

4. United States

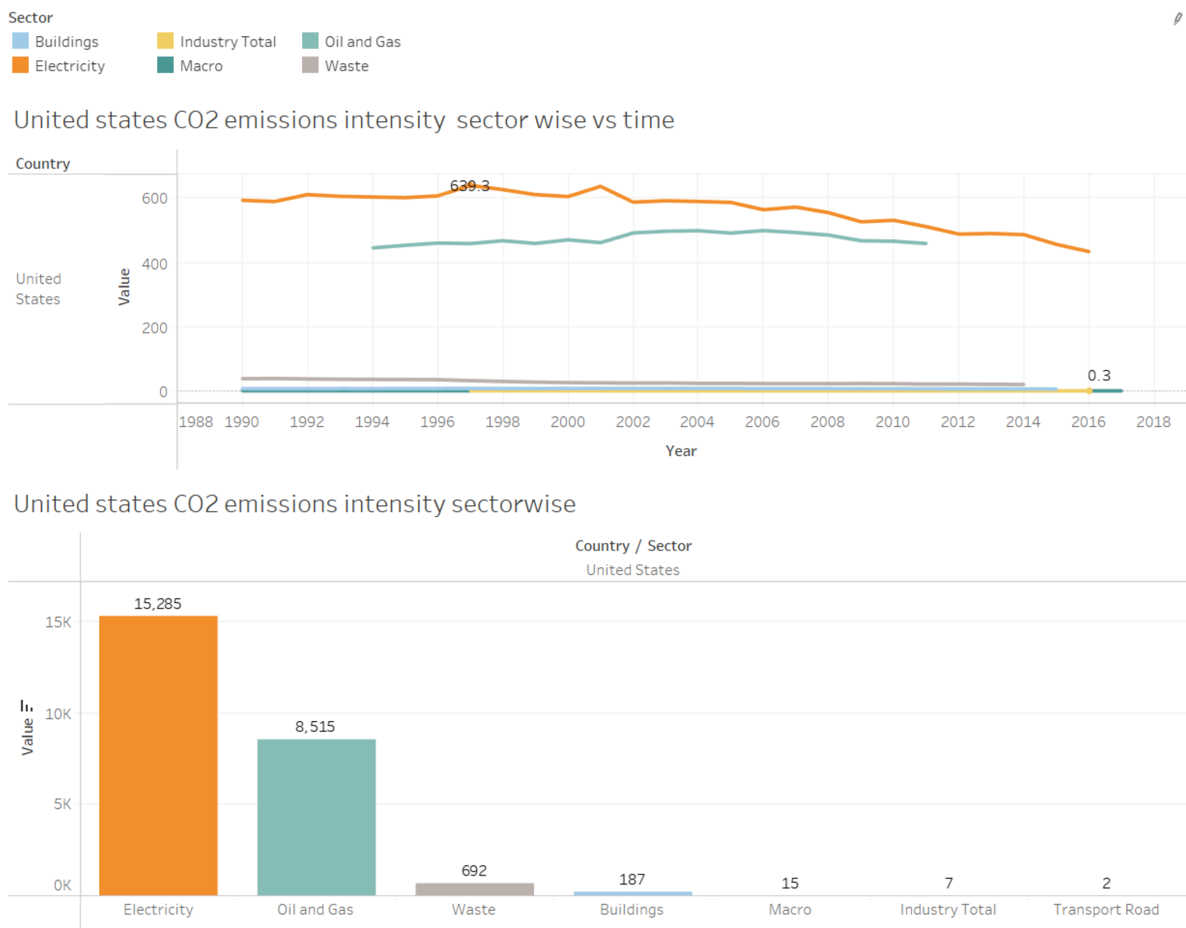


Figure 20: USA's CO_2 Emission Intensity

- This graph shows that United states has a higher CO_2 emissions intensity Electricity sector than the Oil and Gas sector's CO_2 emissions intensity.
- The Oil and Gas sector's CO_2 emissions slightly increased until 2001, then started increasing until 2002 then started slightly decreasing after that year.
- The electricity sector's CO_2 emissions intensity trend changed over time until it reached its peak in 1997 and then started decrease after that year.

5. Kingdom of Saudia Arabia

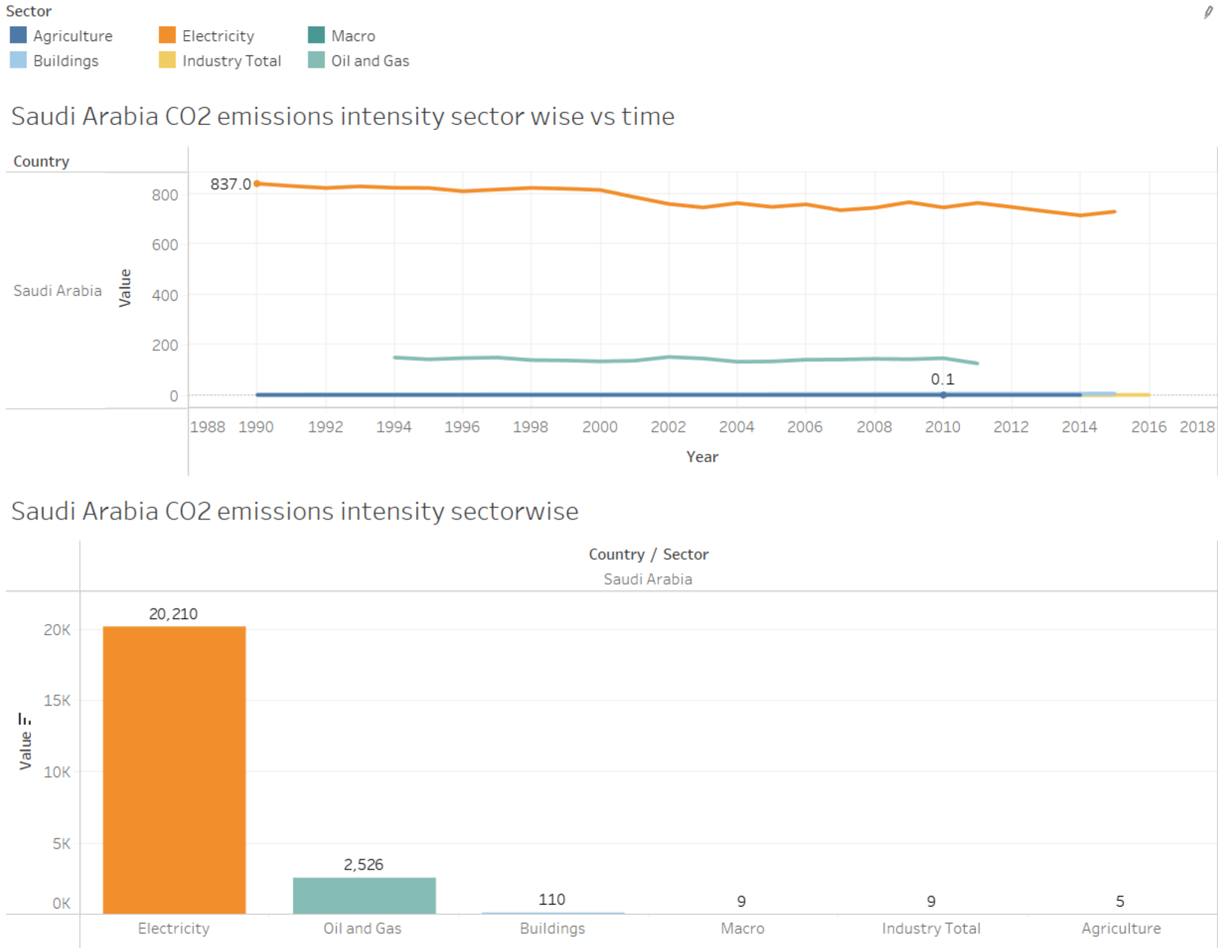


Figure 21: KSA's CO_2 Emission Intensity

- This graph shows that Saudi Arabia has a higher CO_2 emissions intensity Electricity sector than the Oil and Gas sector's CO_2 emissions intensity.
- The Oil and Gas sector's CO_2 emissions have a nearly steady trend.
- The electricity sector's CO_2 emissions intensity trend peaked in 1990 and then started slightly decreasing after that year.

6. UAE

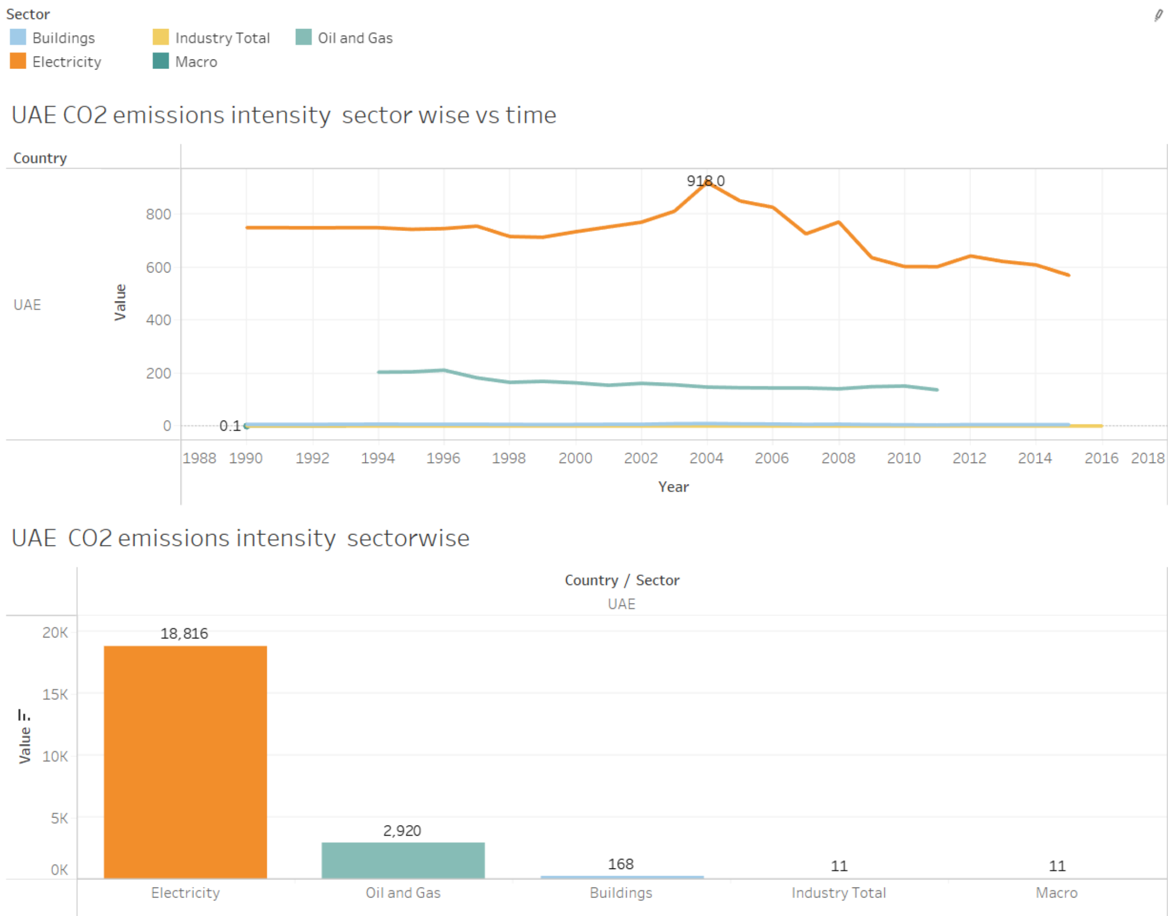


Figure 22: UAE's CO_2 Emission Intensity

- This graph shows that UAE has a higher CO_2 emissions intensity Electricity sector than the Oil and Gas sector's CO_2 emissions intensity.
- The Oil and Gas sector's CO_2 emissions have a slightly decreasing trend.
- The electricity sector's CO_2 emissions intensity trend was slightly increasing until 1997, then it slightly decreased in 1998, then increased until it peaked in 2004 and then started decreasing after that year.

7. South Africa

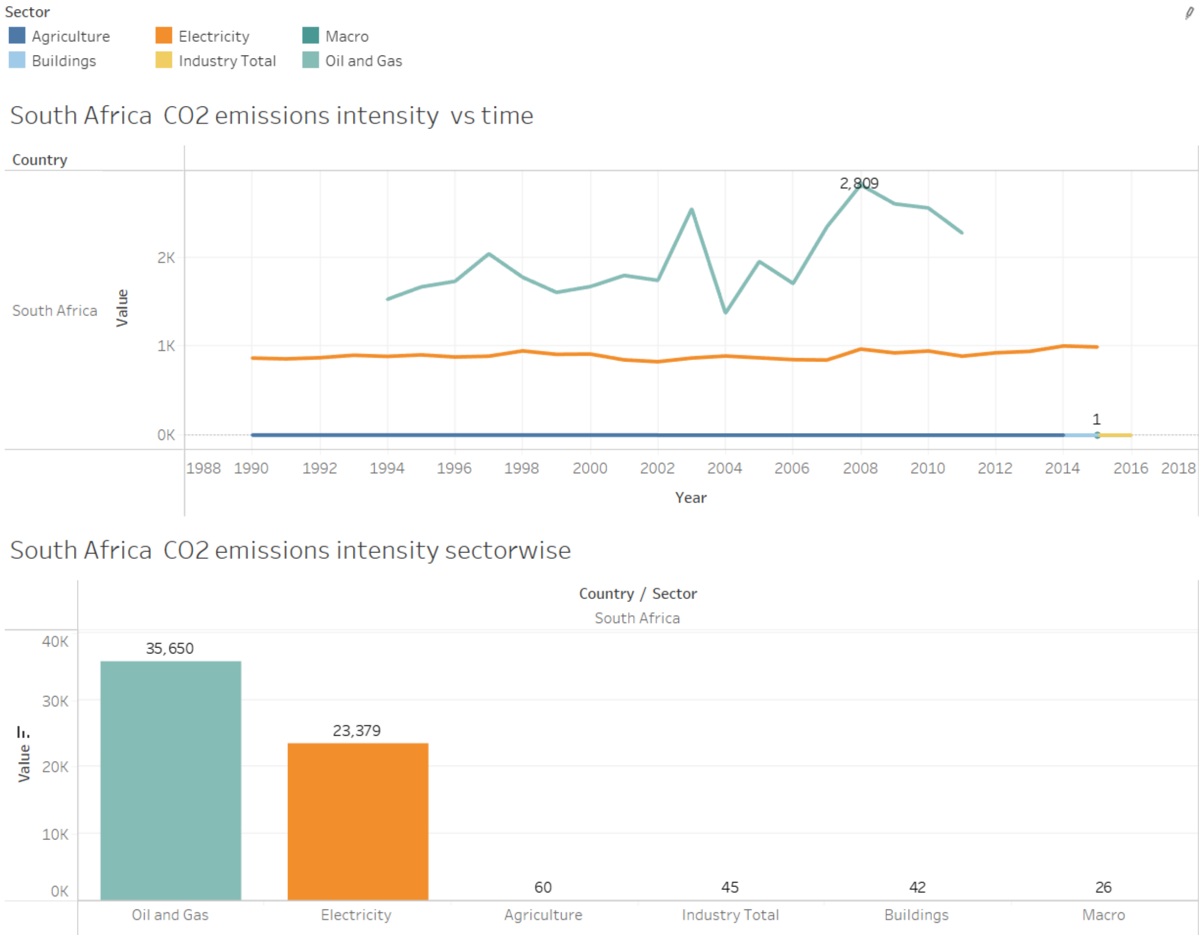


Figure 23: South Africa's CO_2 Emission Intensity

- This graph shows that South Africa has a higher Oil and Gas sector CO_2 emissions intensity than the Electricity sector CO_2 emissions intensity.
- The Oil and Gas sector's CO_2 emissions don't have a fixed trend; they peaked in 2008. Some years it increases, and some years it decreases, indicating no firm policies are enforced in this sector.
- The electricity sector's CO_2 emissions intensity decreased slightly until 2007, then increased slightly after that year over the time.

8. Chile

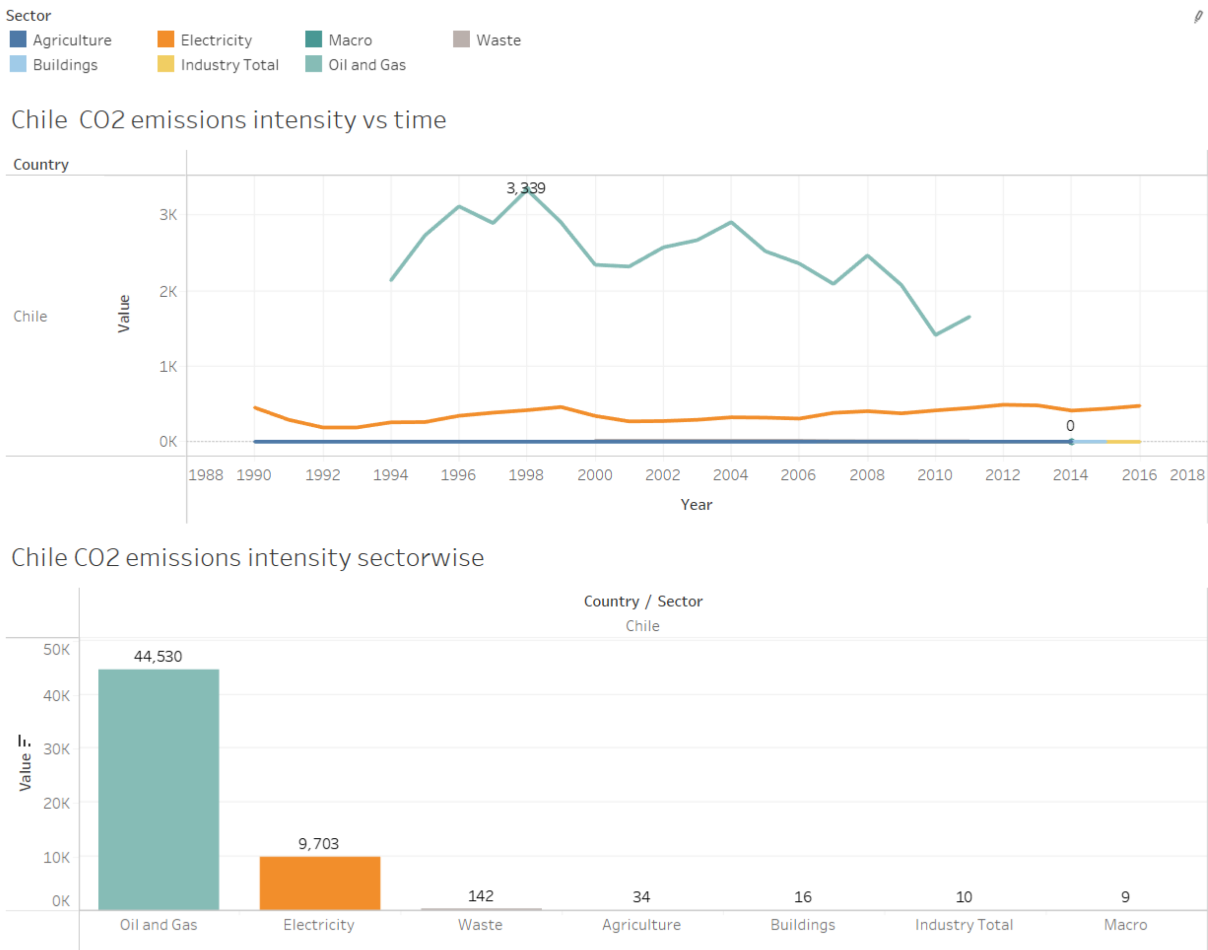


Figure 24: Chile's CO_2 Emission Intensity

- This graph shows that Chile has a higher Oil and Gas sector CO_2 emissions intensity than the Electricity sector CO_2 emissions intensity.
- The Oil and Gas sector's CO_2 emissions started a significant decrease after 1998; the peak was in the same year, perhaps due to some firm policies being enforced in this sector and increasing renewable energy adoption replacing the oil and gas.
- The electricity sector's CO_2 emissions intensity decreased slightly until 1999, then increased slightly after that year.

9. Australia

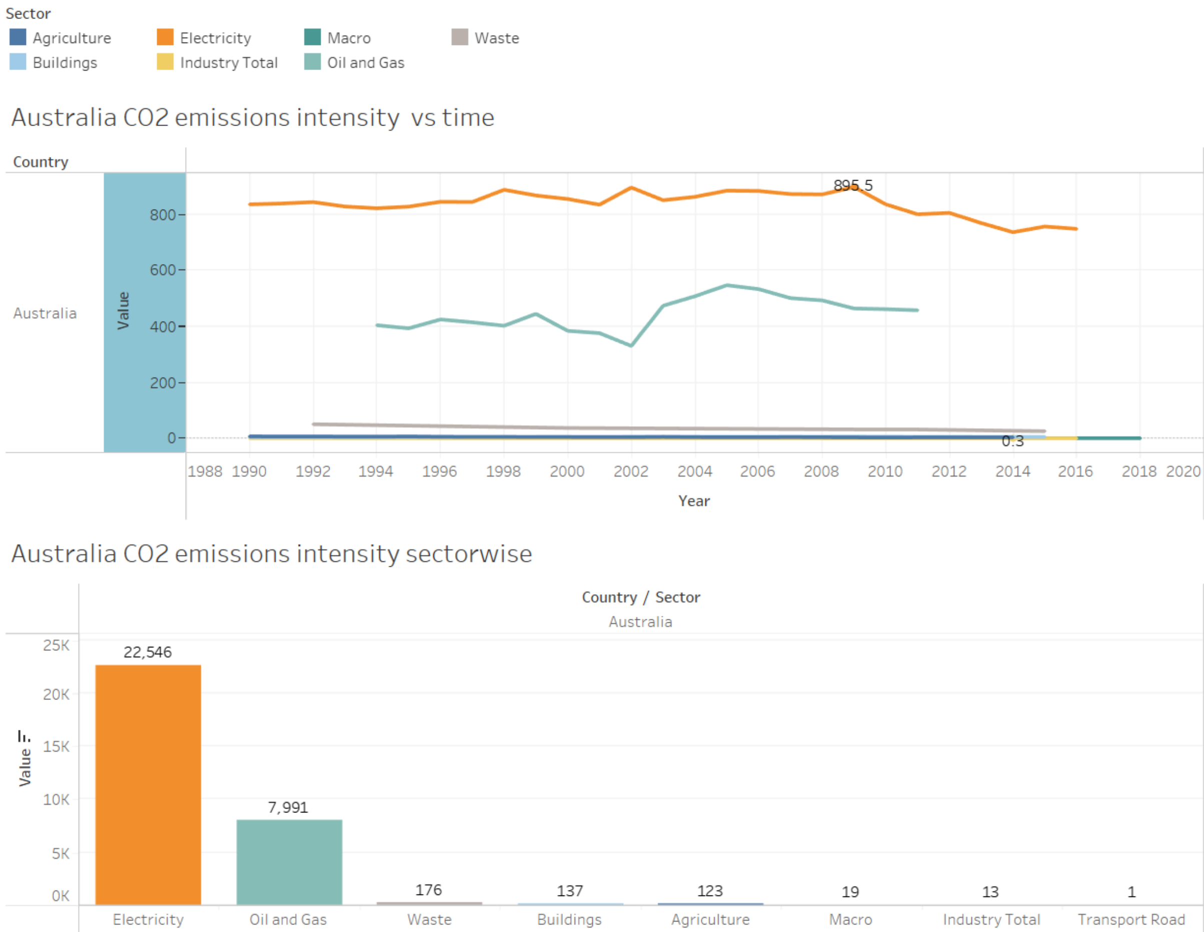


Figure 25: Australia's CO_2 Emission Intensity

- This graph shows that Australia has a higher CO_2 emissions intensity Electricity sector than the Oil and Gas sector's CO_2 emissions intensity.
- The Oil and Gas sector's CO_2 emissions reached their lowest value in 2002, then started increasing until 2005 then started slightly decreasing after that year.
- The electricity sector's CO_2 emissions intensity trend changed over time until it reached its peak in 2009 and then started slightly decrease after that year.

10. Italy

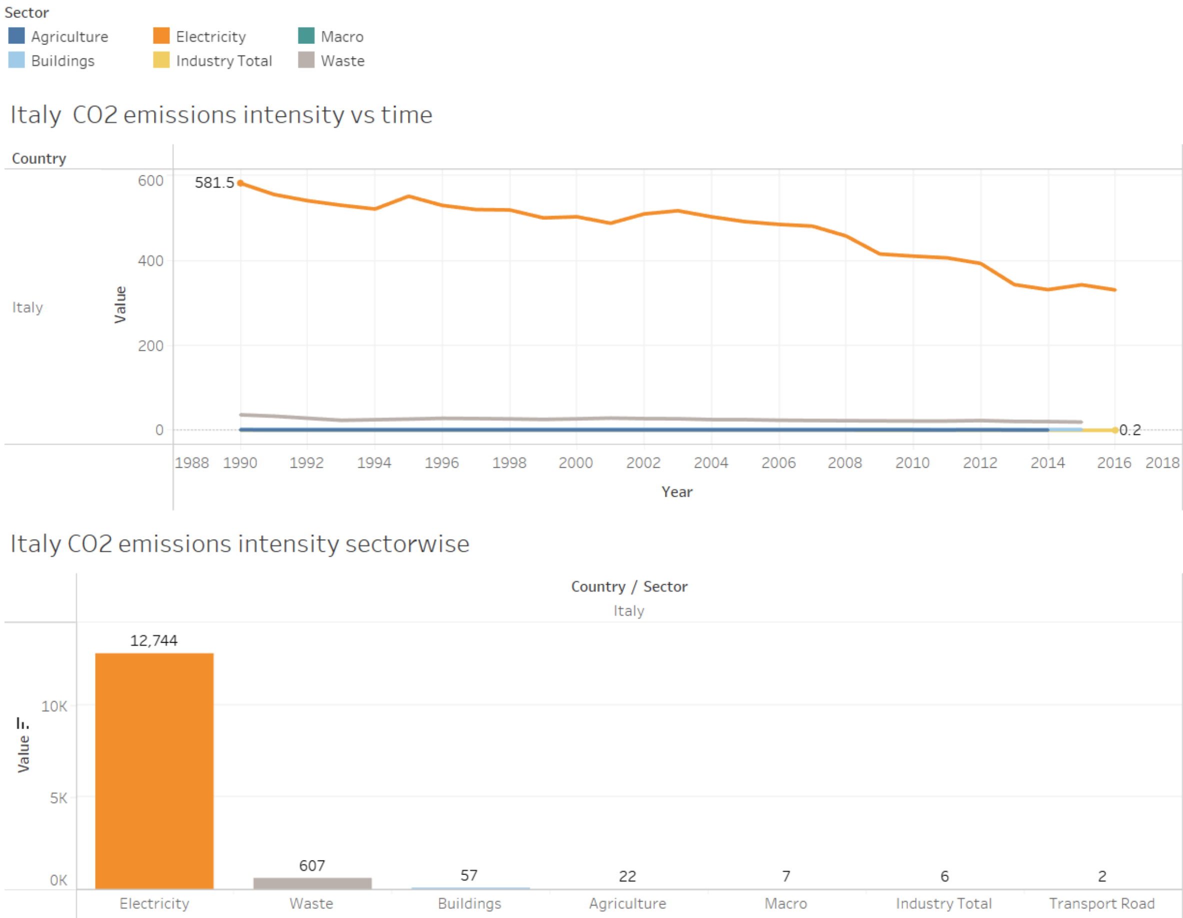


Figure 26: Italy's CO_2 Emission Intensity

- This graph shows that Italy has the highest CO_2 emissions intensity Electricity sector among all the remaining sectors.
- The Waste sector's CO_2 emissions are the second one.
- The electricity sector's CO_2 emissions intensity peaked in 1990, and the trend started decreasing after that year.

11. United Kingdom

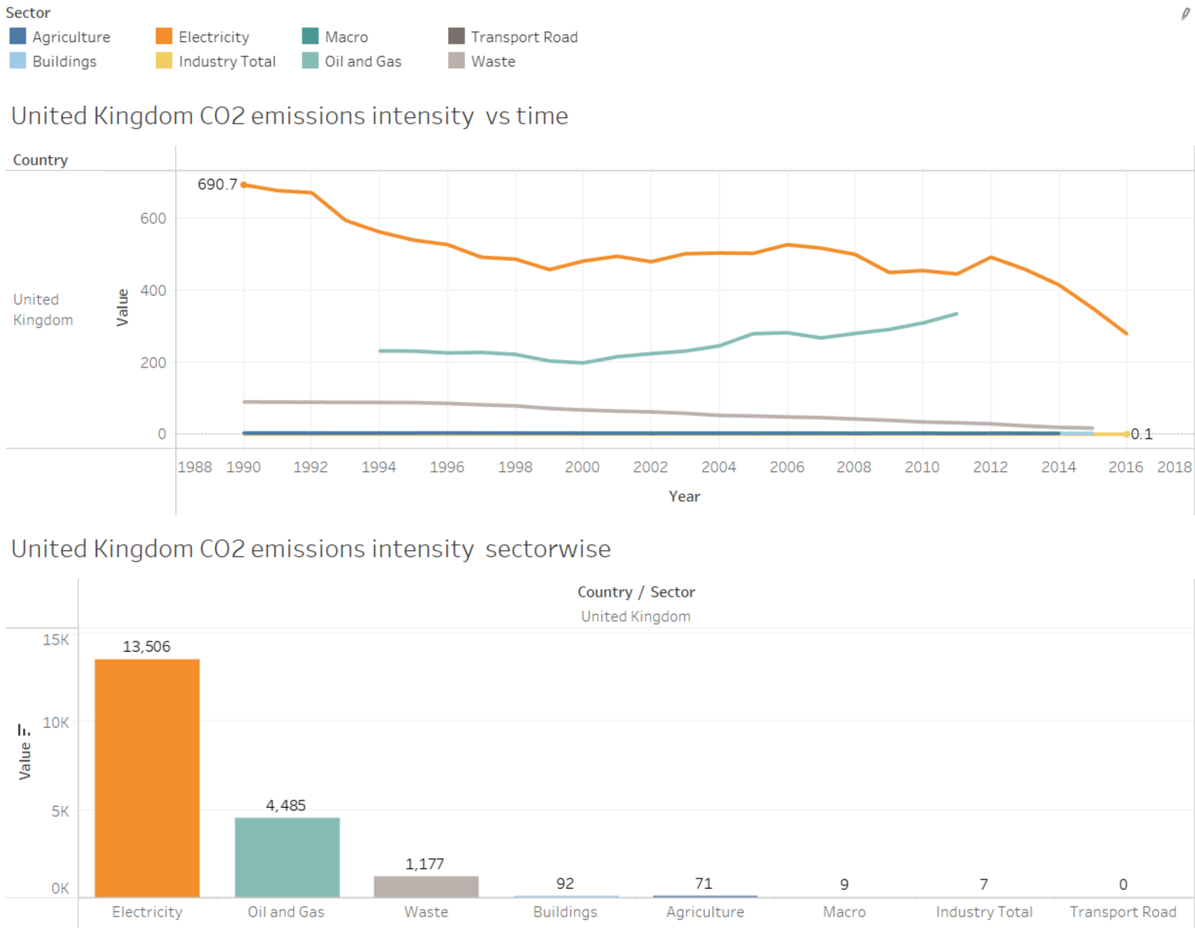


Figure 27: UK's CO_2 Emission Intensity

- This graph shows that United Kingdom has the highest CO_2 emissions intensity Electricity sector among all the remaining sectors.
- The Oil and Gas sector is second, and it has an increasing trend, followed by the Waste sector's CO_2 emissions which has a decreasing trend.
- The electricity sector's CO_2 emissions intensity peaked in 1990, and the trend started decreasing after that year.

3.1.1. Projected Current Policy Maximum

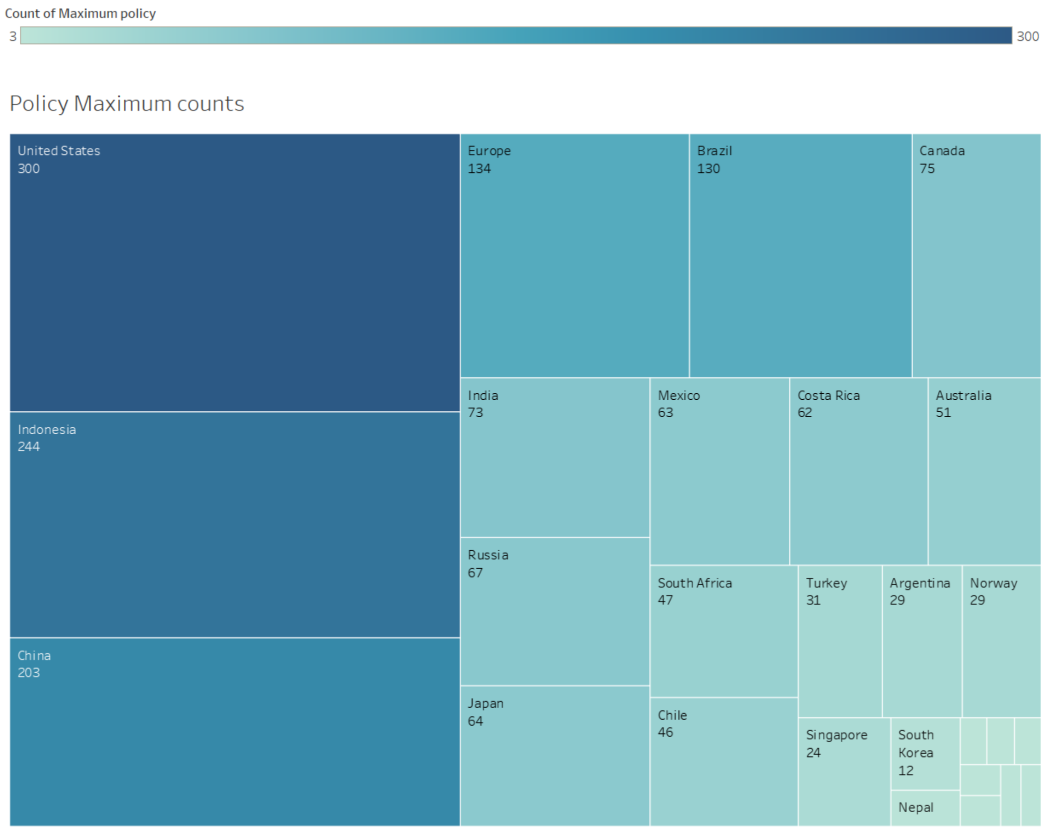


Figure 28: Policy Maximum Count

We have represented the countries' Policy Maximum counts as tree-map graph, and we found that the top five countries descending are the United States, Indonesia, China, Europe, and India; most likely, these countries are trying to combat climate change. They have opportunities for mitigation and adaptation.

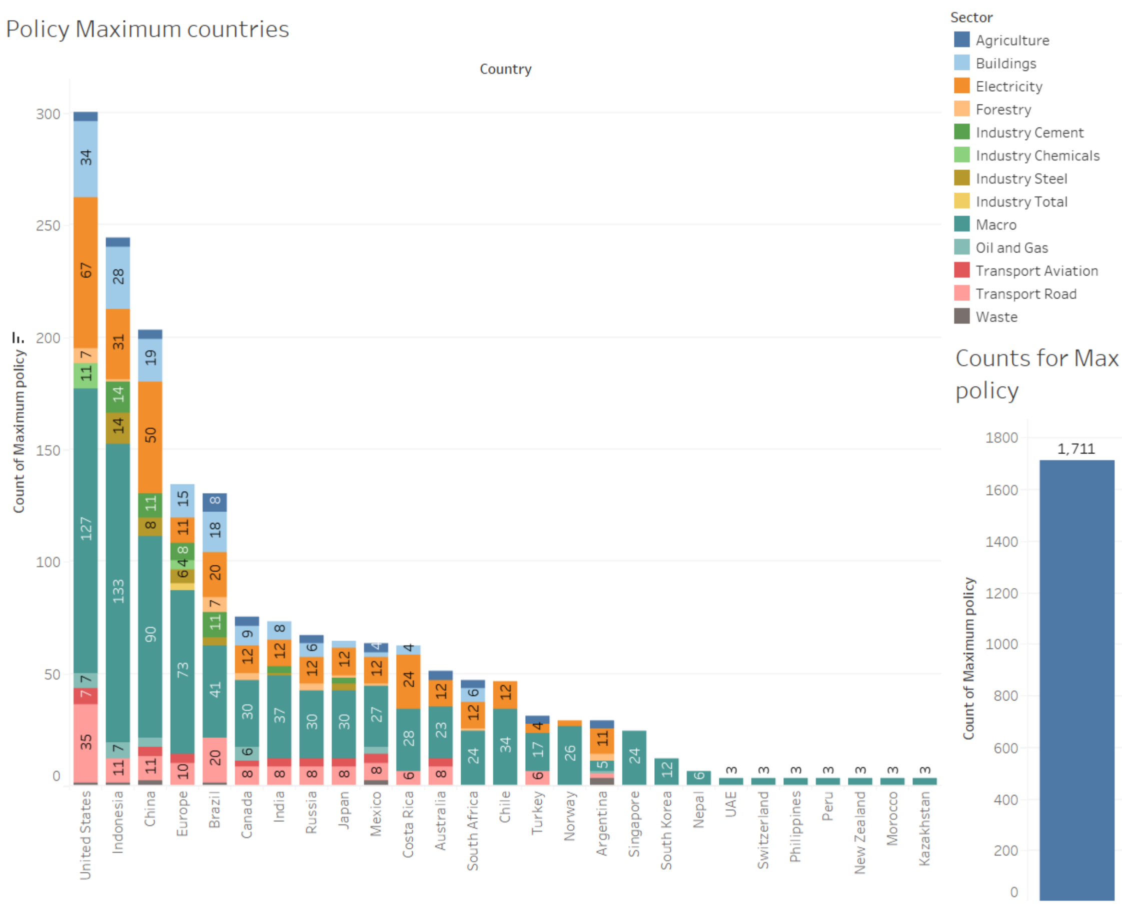


Figure 29: Policy Maximum Countries

1. We have represented the countries' Policy Maximum counts to see the distribution of the policies sectors, and we found that in the first country, the United States, the majority of policies are for the Macro sector, followed by the electricity sector, followed by transportation, followed by building sector, followed by industry sector, then Oil and Gas and forestry sectors.
2. Countries should target both the Electricity sector and the Oil & Gas sector more to reduce these sectors' CO_2 emission intensity.

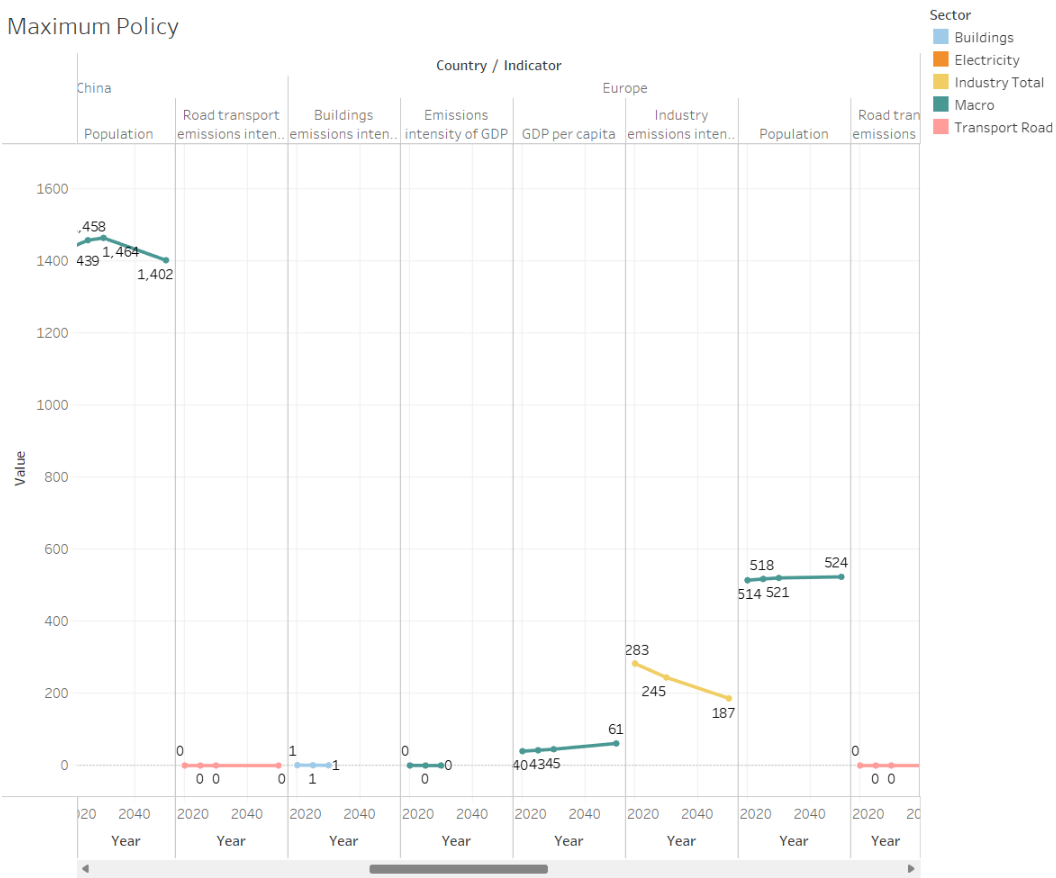


Figure 30: Maximum Policy

This graph shows that the Maximum policy decreased the CO_2 emissions intensity in the different sectors for Europe while some indicators are expected to increase, such as the GDP per capita.

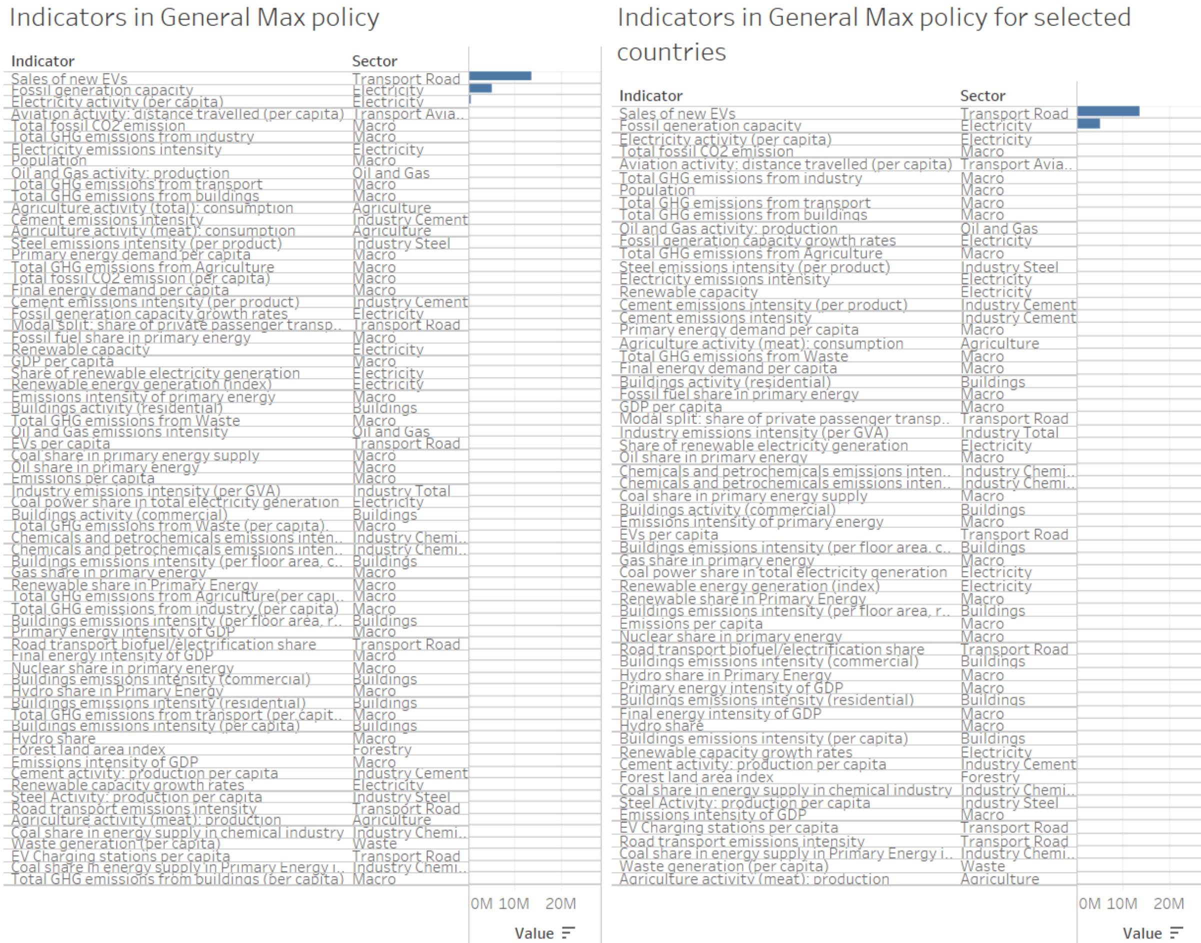


Figure 31: Indicators of General Max Policy

This graph shows the indicators for all countries and the indicators for the selected countries in the maximum policy scenario, and it's clear that the most correlated ones with CO_2 emission intensity are Sales of new EVs in the transportation sector and the fossil generation capacity in the electricity sector.

Maximum Policy for Greenhouse Gas

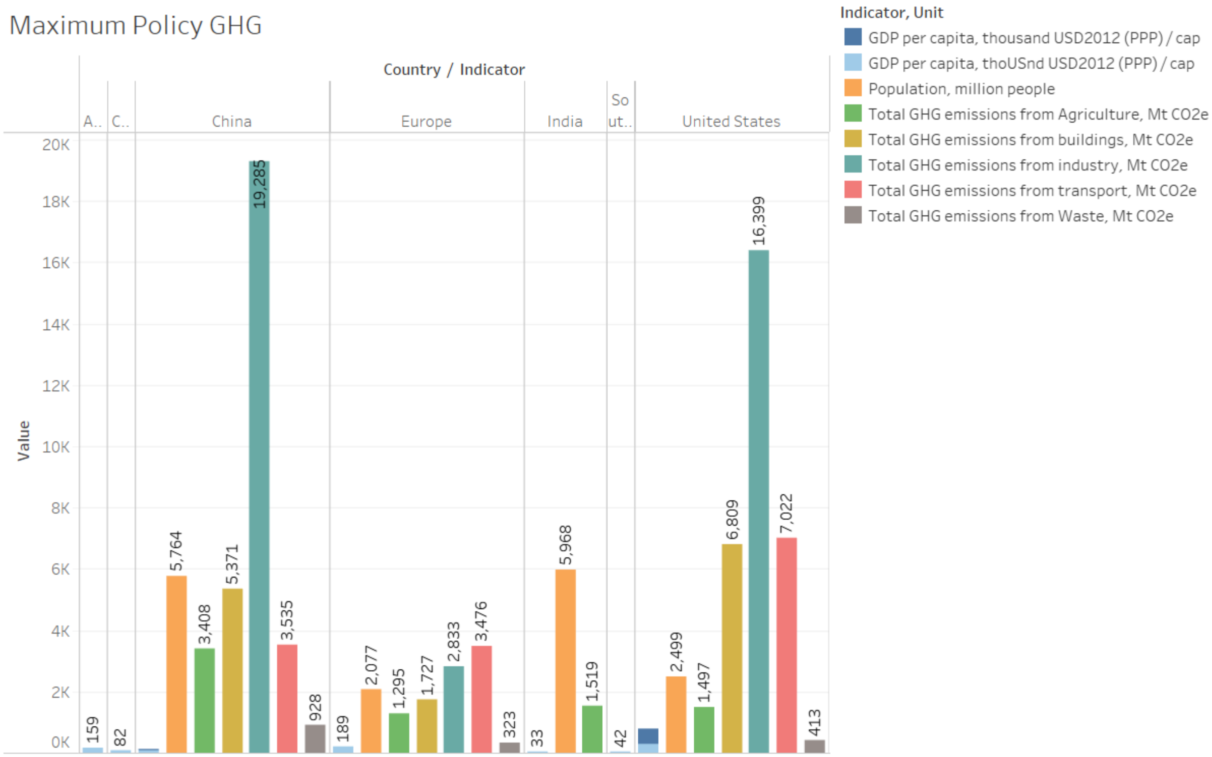


Figure 32: Maximum Policy GHG

This graph represents the GHG emissions in the maximum policy scenario in five countries that have available data as follows: China, Europe, India, South Africa, and the United States. The highest one is total GHG emissions from industry Mt CO_2e followed by Total GHG emissions from buildings Mt CO_2e and Total GHG emissions from transportation Mt CO_2e, so we recommend the policymakers focus more on these areas or the technology development to reduce the GHG emissions.

3.1.2. Projected Current Policy Minimum

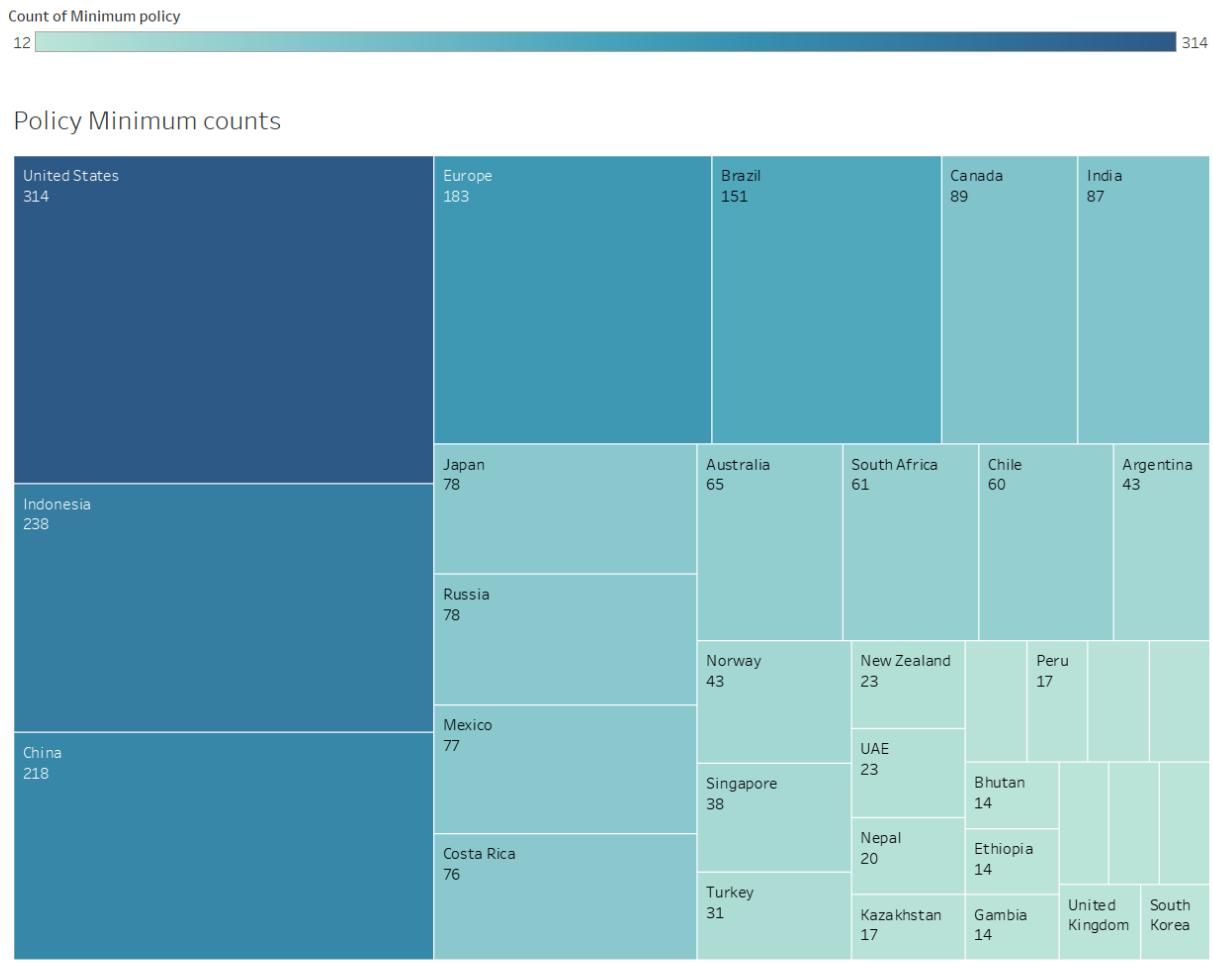


Figure 33: Policy Minimum Count

We have represented the countries' Policy Minimum counts tree maps graph, and we found that the top five countries descending are the United States, Indonesia, China, Europe, and Brazil; most likely, these countries are trying to combat climate change. They have opportunities for mitigation and adaptation.

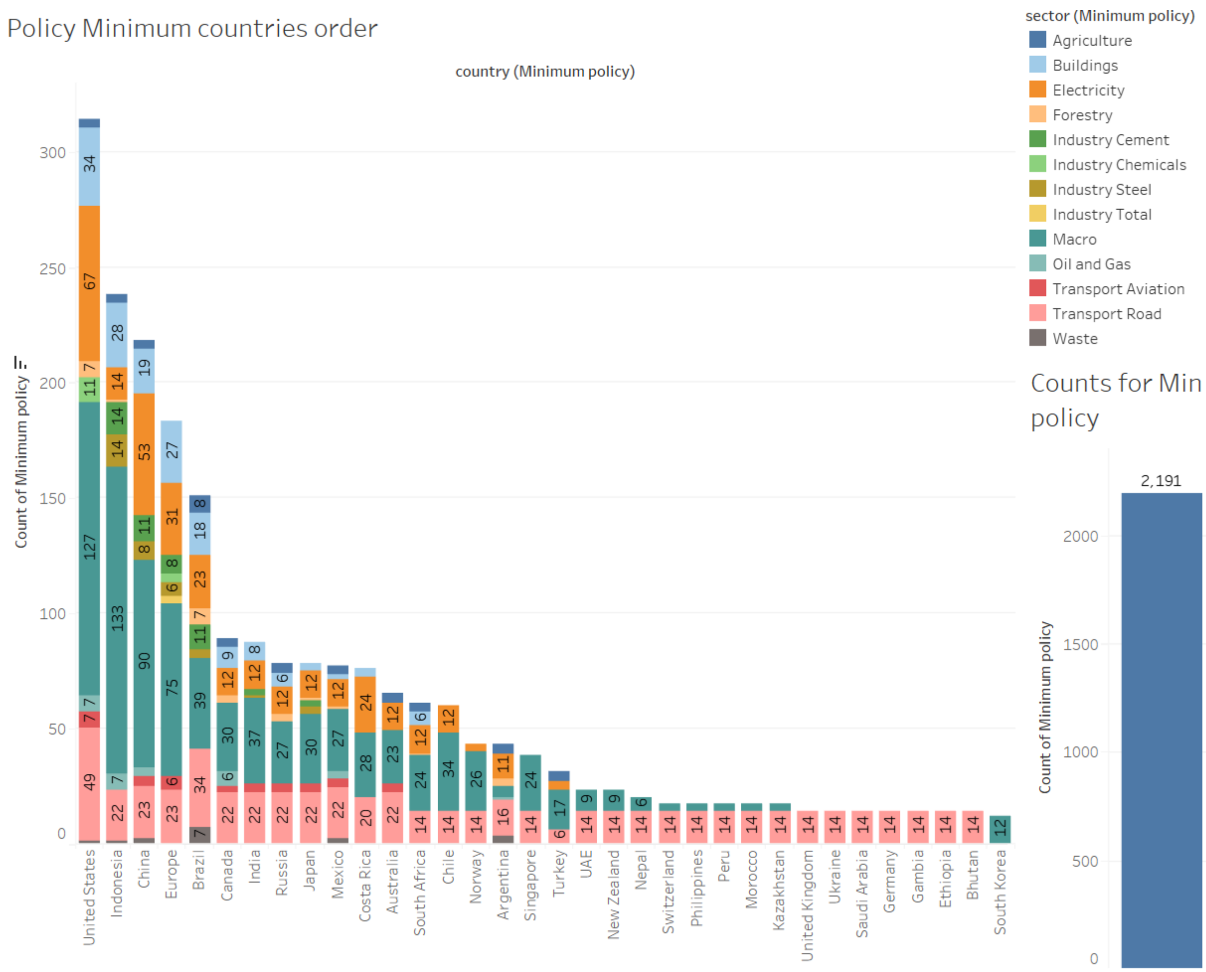


Figure 34: Policy Minimum Countries

1. We have represented the countries' Policy Minimum counts to see the distribution of the policies sectors, and we found that in the first country, the United States, most policies are for the Macro sector, followed by the electricity sector, followed by transportation, followed by building sector, followed by industry sector, then Oil and Gas and forestry sectors.
2. Countries should target both the Electricity sector and the Oil & Gas sector more to reduce these sectors' CO_2 emission intensity.

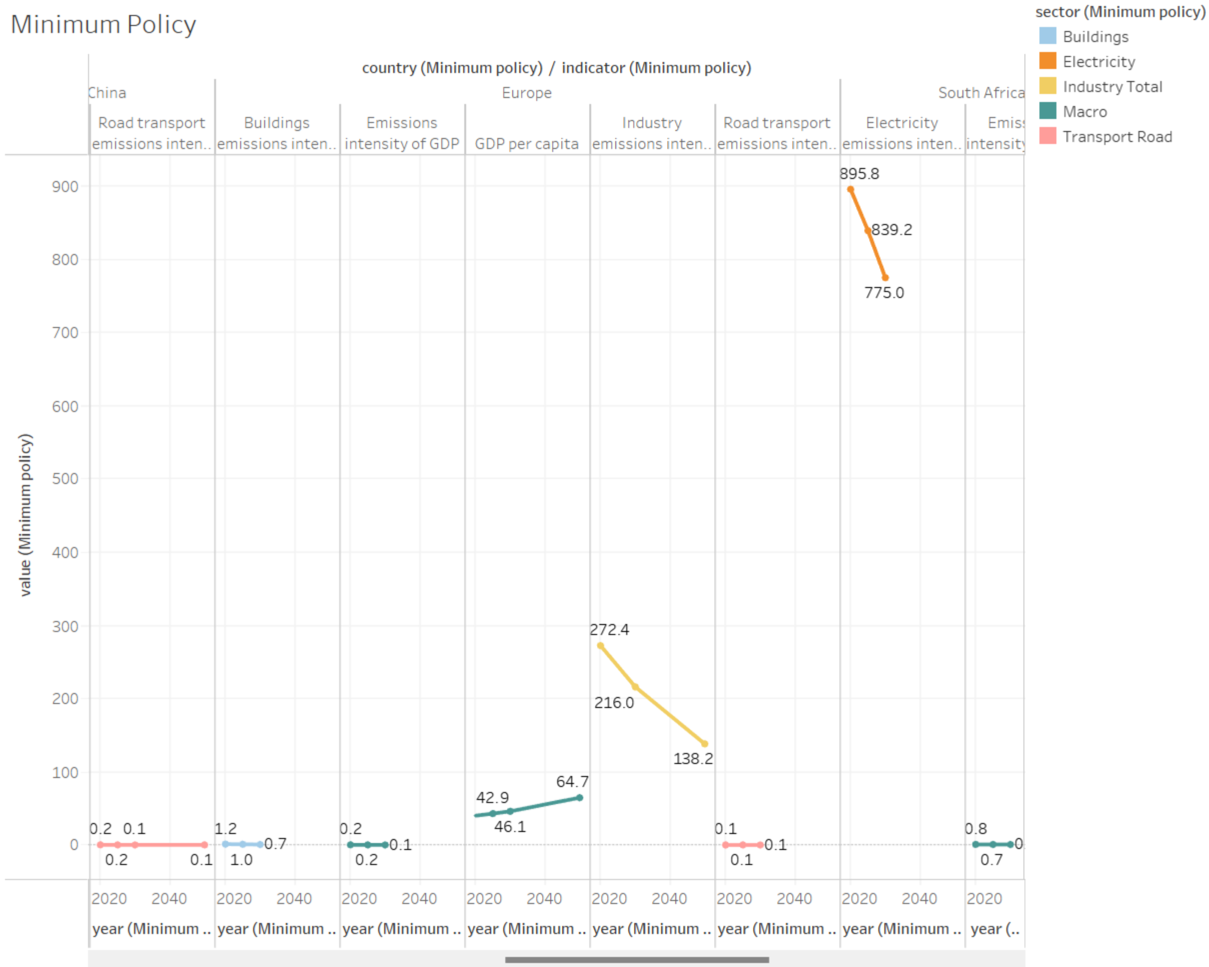


Figure 35: Minimum Policy

This graph shows:

1. The Minimum policy decreased the CO_2 emissions intensity in the different sectors of Europe. However, some of these CO_2 emissions will not be impacted in the minimum policy scenario like the building, so our recommendation to the policymakers is to consider if there will be an impact or not when developing or updating some policies in some sectors.
2. Some indicators are expected to increase, such as the GDP per capita.

Minimum Policy for Greenhouse Gas

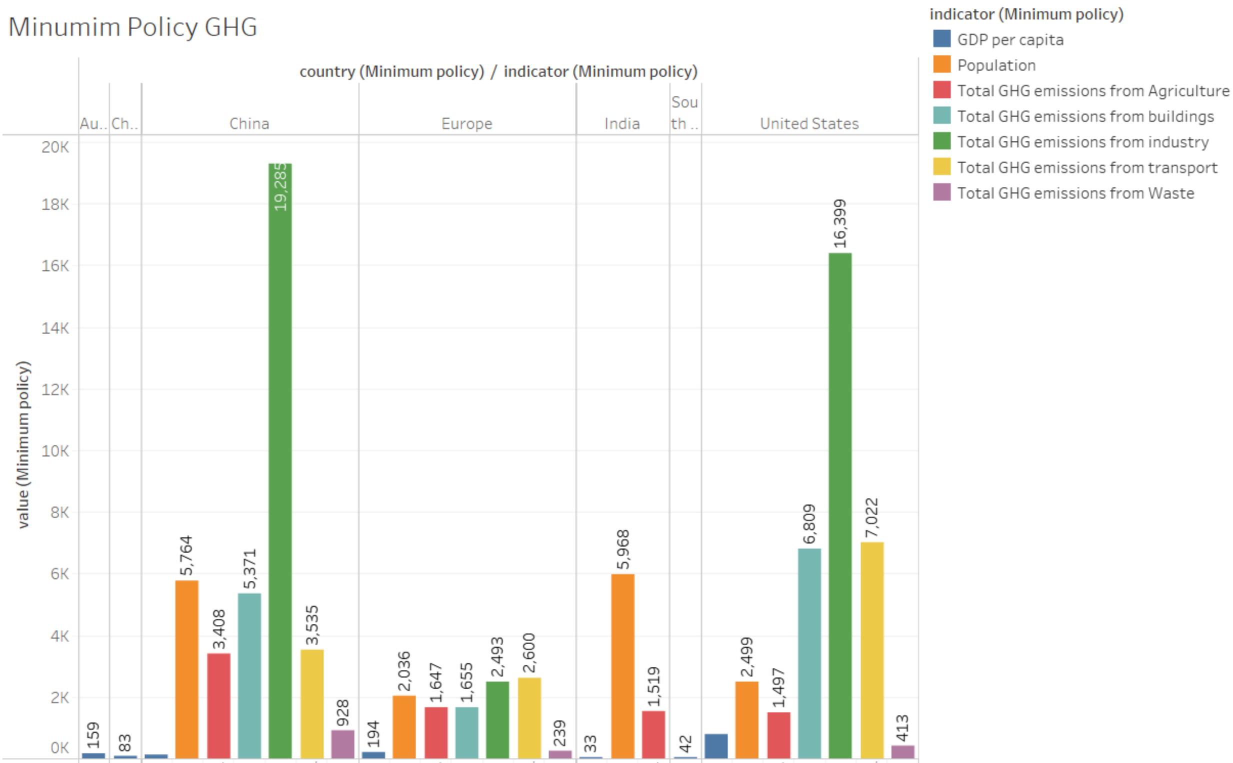


Figure 36: Minimum Policy GHG

This graph represents the GHG emissions in the minimum policy scenario in five countries that have available data as follows: China, Europe, India, South Africa, and the United States. The highest one is total GHG emissions from industry Mt CO2e followed by Total GHG emissions from buildings Mt CO_2e and Total GHG emissions from transportation Mt CO_2e, so we recommend the policymakers focus more on these areas or the technology development to reduce the GHG emissions.

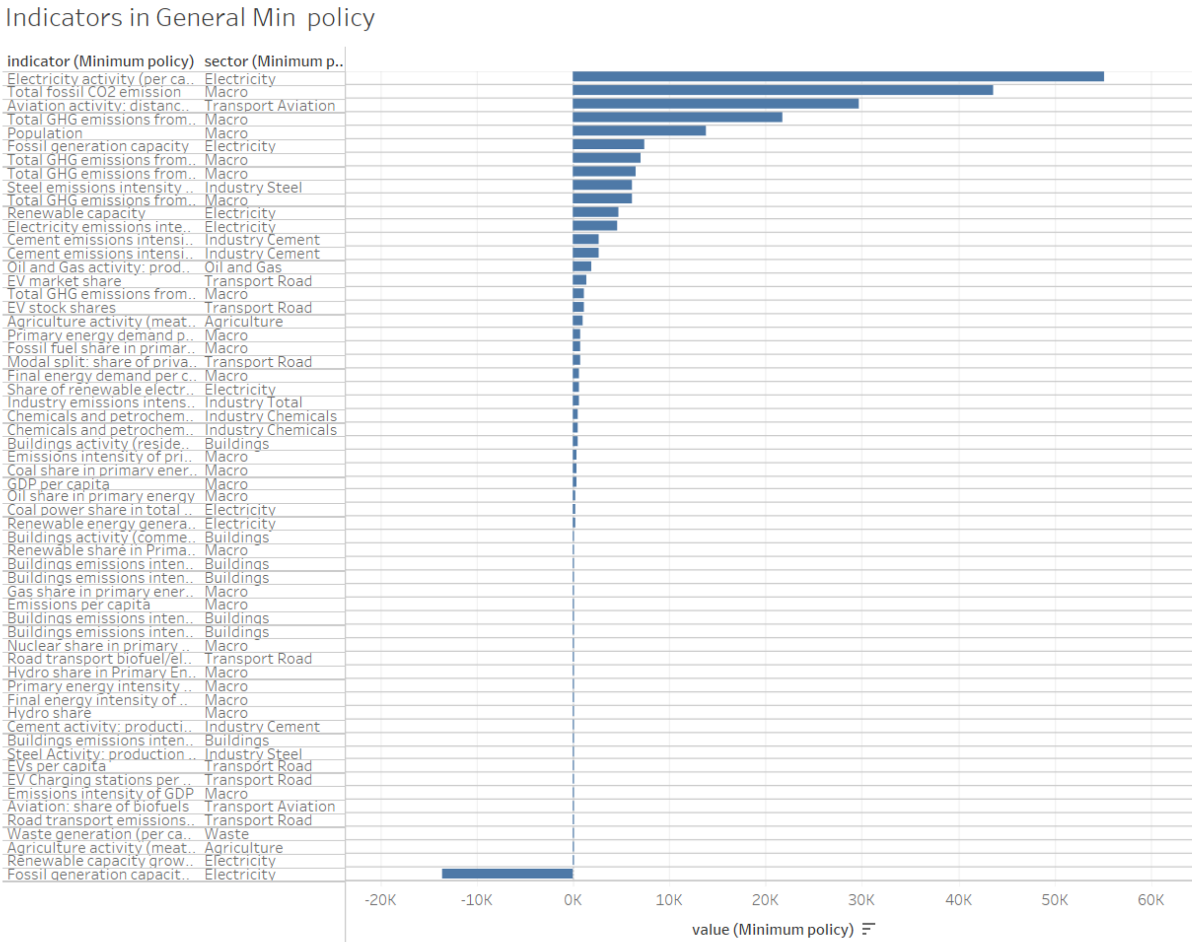


Figure 37: Indicators in General Min Policy

This graph shows the indicators for all countries in the minimum policy scenario, and the top five most correlated ones with CO_2 emission intensity are Electricity activity (per capita), Total fossil CO_2 emission, Aviation activity: distance travelled (per capita), Total GHG emissions from industry, population. However, Fossil generation capacity growth rates have a negative value which we should investigate.

3.2. Data Analytics Tools Used

3.2.1. R

R is a widely used open-source programming language for statistical computing and data analysis. This programming language's name, R, was partly inspired by the Bell Labs Language S and partly by the initial letter of the first names of the two R developers, Robert Gentleman, and Ross Ihaka. A convenient environment for statistical computing and design is provided by R, which offers a large variety of statistics-related libraries. Basic Statistics, Static Graphs, Probability Distributions, and Data Analysis are some of R's statistical features.

3.2.2. Tableau

Tableau is a business intelligence and data visualization tool used for big data analysis and report development. Users can use it to generate different graphs, charts, stories, dashboards, and maps to view and analyze data for business decisions. One of Tableau's advantages is the ability to link many data sources, as well as facilitate data exploration and discovery. Another feature is the ability to manage all published data sources in one area for an organization.

3.3. Time Series Algorithms

The time series algorithm is a machine learning algorithm used to understand how past data affects the future. It accomplishes this by analyzing historical data, identifying trends, and formulating small or long-term forecasts. It is a special form of regression, which is also known as autoregressive modelling. For each step in a time window—which can be up to 30 steps beyond the historical data, the time series model produces estimate of the desired value. As with other regression models, time series models produce numerous statistics to assess how well the historical data fits. In this project, 4-time series algorithms were used in this project to forecast the CO_2 emission – the drift method, the Holt linear method, the damped trend method and the ARIMA model.

Chapter 4: Data Analysis

4.1. Data Understanding

The dataset is from the Climate Action Tracker website: https://climateactiontracker.org/data-portal/. This website is an independent scientific approach that tracks government climate action and measures it against the globally agreed Paris agreement aim, which is "holding the warming well below 2°C". The selected dataset has values from 1990 - 2017 for historical data (35,000 observations) and 2020 -2050 for projected current policy min & max (5-year gap) (4000 observations). The data dictionary is as follows:

Table 1: Data Dictionary

Variable Name	Data Type	Description
sector	Character	Part of the economy
indicator	Character	Metrics are used to measure the growth or contraction of sectors within the economy.
country_code	Character	Two-letter country codes (ISO 3166-1 alpha-2 codes)
country	Character	Name of the country
year	Integer	Year
variable	Character	3 scenarios: ● Historic Data ● Projected Current Policy Min ● Projected Current Policy Max
value	Double	CO_2 emission value
unit	Character	Unit of measurement

4.2. Data Preparation

In this phase, the data preprocessing steps are considered to improve the data quality, and these data are used in the exploratory data analysis phase and the modeling phase.

Data Cleaning

Data cleaning involves correcting or eliminating incorrect, corrupted, improperly formatted, duplicate, or incomplete data in a dataset. The selected dataset contains many missing values because the dataset contains values for a specific period. The missing values were replaced with the mean values. Some of the countries and sectors were not selected because they had different units. The final preprocessed data are used for the analysis and models.

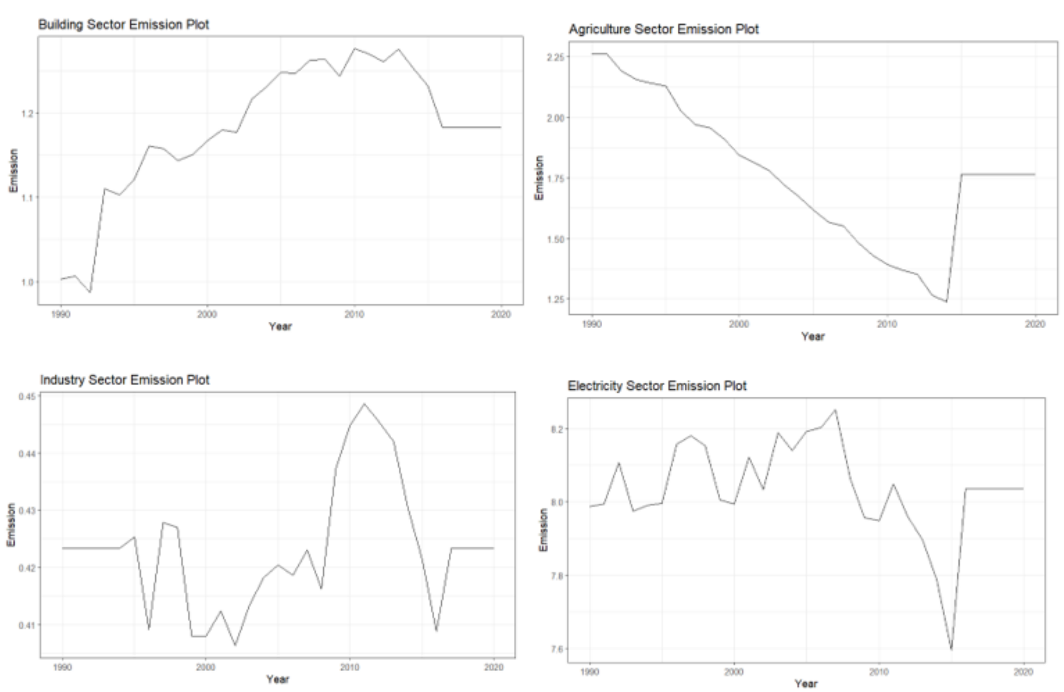
4.3. Data Exploration

Exploratory Data Analysis (EDA) is a crucial process in which initial examinations of data are conducted to find patterns, identify anomalies, test hypotheses, and validate assumptions using summary statistics and graphical representations.

The analysis focuses on 2016, as the historic historical values from 1990 – 2017.

1. **Contribution of Sectors to CO_2 emission**

   Six sectors are considered, Building, Agriculture, Industry, Electricity, Transport and Oil & Gas. The emission plots of the six sectors are shown in Figure 38.



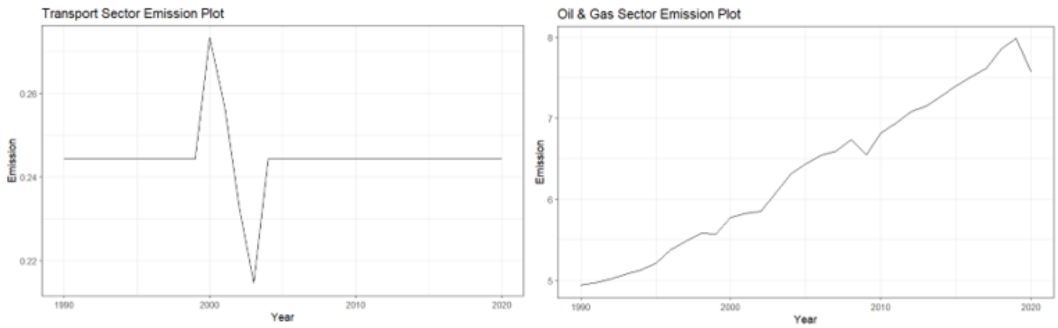


Figure 38: Emission Plots of the Sectors

From the emission graph, we can see that CO_2 emissions from some sectors, such as agriculture etc., are decreasing over the year; while CO_2 emissions are increasing in sectors such as electricity, industry, oil & gas etc.

2. Top CO_2 emitting sectors in 2016.

We found that for the year 2016, the Electricity sector had the highest CO_2 emission followed by Oil and Gas sector and Agriculture sector (shown in Figure 39).

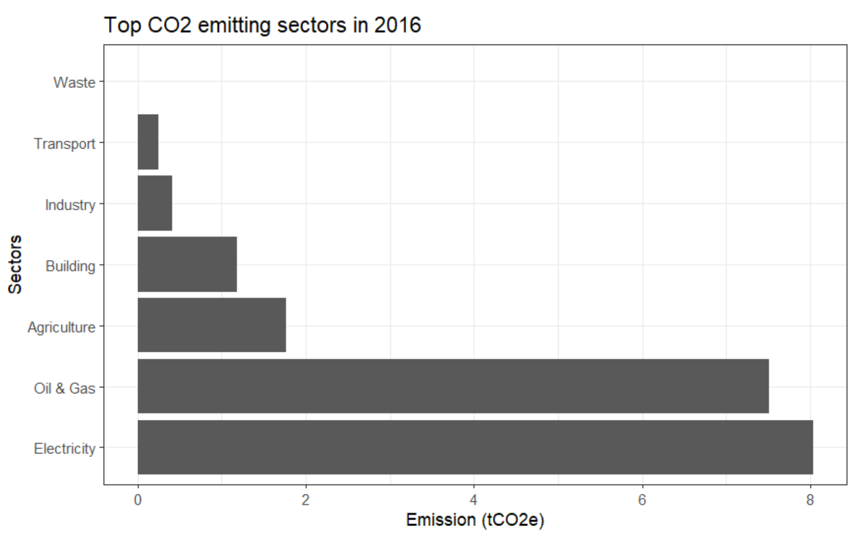


Figure 39: Top CO2 emitting sectors in 2016.

3. **Contribution of Countries to CO_2 emission (Top 10)**

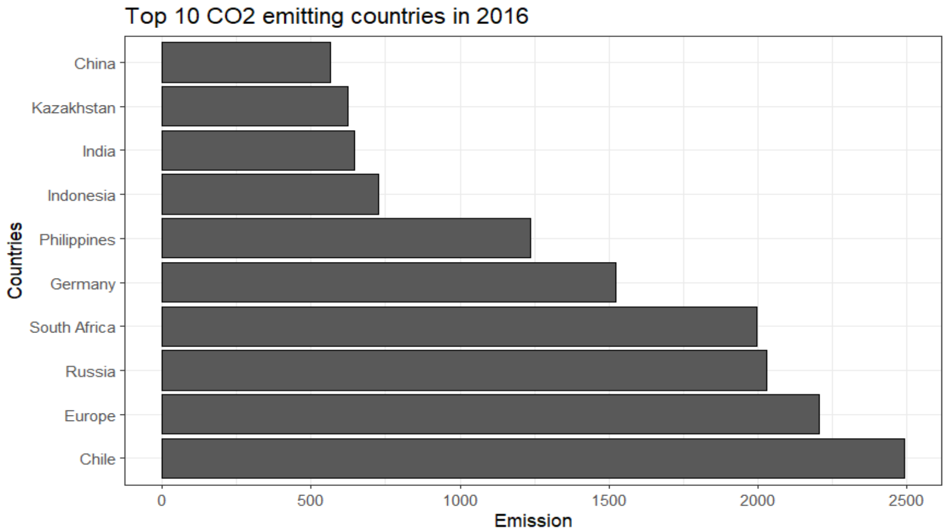


Figure 40: Top CO_2 emitting countries in 2016.

Based on the graph, we can see that among our selected countries for trend analysis, India, China, and Europe comes under Top 10 CO_2 emitting countries for the year 2016.

4. **Contribution of Countries to CO_2 emission Sector-wise**

The countries mentioned for each sector are the Top 5 countries that emit CO_2 the most for that sector.

a. **Electricity Sector**

Table 2:Top 5 Countries of Electricity Sector

Electricity Sector	
Countries	**Emission**
South Africa	13.48760
China	12.71954
India	11.88329
KSA	11.65973
Australia	11.19600

b. **Oil & Gas Sector**

Table 3:Top 5 Countries of Oil & Gas Sector

Oil & Gas Sector	
Countries	**Emission**
Chile	2473.874
Europe	2194.034
Russia	1980.554
South Africa	1980.554
Germany	1491.306
Philippines	1227.257

Here, Russia and South Africa were ranked 3rd for the Oil & Gas sector.

c. Agriculture Sector

Table 4: Top 5 Countries of Agriculture Sector

Agriculture Sector	
Countries	**Emission**
Australia	4.920397
Brazil	4.259074
New Zealand	2.991417
Canada	2.863348
UK	2.843594

d. Building Sector

Table 5: Top 5 Countries of Building Sector

Building Sector	
Countries	**Emission**
USA	7.204255
UAE	6.451584
Australia	5.250462
Canada	4.463941
Germany	4.366968

e. Industry Sector

Table 6: Top 5 Countries of Industry Sector

Industry Sector	
Countries	**Emission**
South Africa	1.0054631
Kazakhstan	0.6939792
China	0.6791654
UAE	0.5690333
Ukraine	0.4927477

f. Transport Sector

Table 7: Top 5 Countries of Transport Sector

Transport Sector	
Countries	**Emission**
Italy	0.9307206
France	0.4934719
Canada	0.2558546
China	0.2515764
Mexico	0.2472761

5. Macro Indicators

From the dataset, 5 macro indicators were selected based on their unit (tCO2e) and the GDP per capita indicator was also considered for the analysis. The top 5 countries were considered to determine which macro indicators are most correlated and the following result was obtained – Primary energy demand per capita followed by Emission intensity of primary energy and GDP per capita.

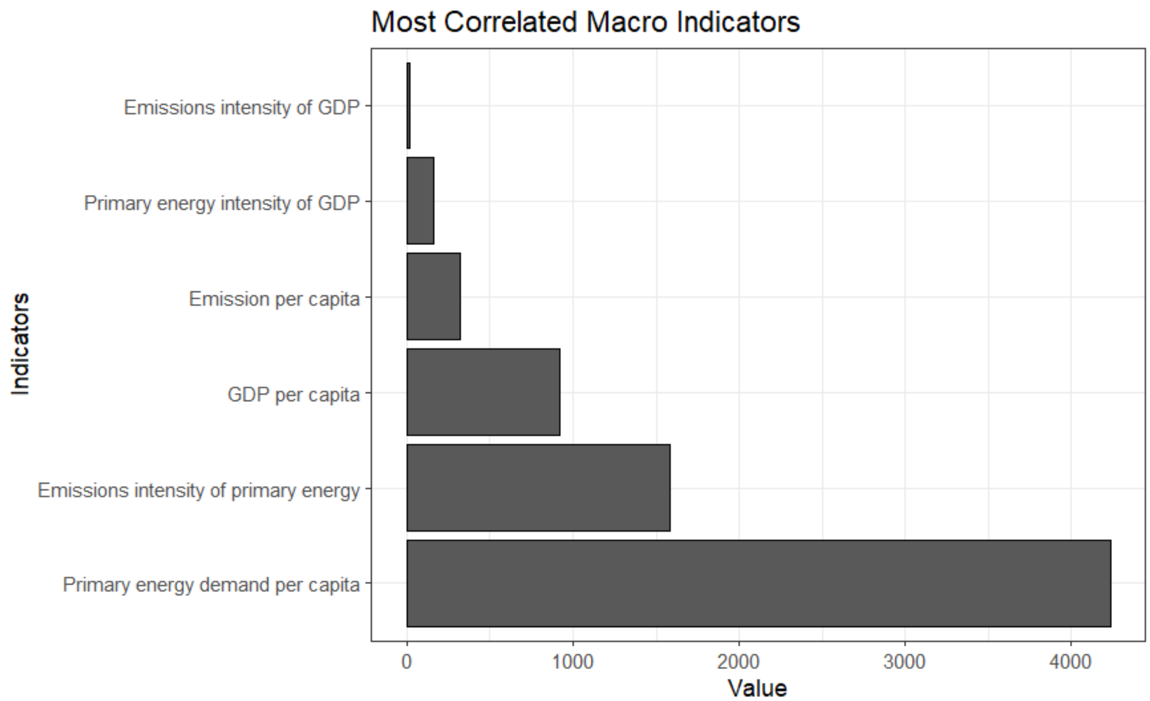


Figure 41: Most Correlated Macro Indicators

4.4. Modeling

The values in the historical data range from 1990 to 2017. The data is divided into a training set and a test set with a 70:30 ratios before being given to the model. Four models receive the data as input, and the best model is chosen based on performance metrics- RMSE, MSE, MAPE and MASE. The 4 models are as follows:

4.4.1. Drift Method

The drift method is a variation on the naive forecast that allows forecasts to increase or decrease over time with the amount of change over time (called the drift) being set to be the average change seen in the historical data. Unlike averages/naive methods, the drift method does not have a constant (flat) forecast. Thus, the forecast for time $T + h$ is given by.

$$\hat{y}_{T+h|T} = y_T + \frac{h}{T-1}\sum_{t=2}^{T}(y_t - y_{t-1}) = y_T + h(\frac{y_T - y_1}{T-1})$$

This is equivalent to drawing a line between the first and last observations and extrapolating it into the future.

4.4.2. Holt Linear Method

It is also known as double exponential smoothing or second-order exponential smoothing. When there is a linear trend in the data but no seasonal pattern, it is employed in time-series forecasting. It updates the components at each period using two weights, also known as smoothing parameters. The following are the double exponential smoothing equations, which includes a forecast equation and two smoothing equations (one for trend and one for level).

Forecast equation: $\hat{y}_{t+h|t} = l_t + hb_t$

Level equation: $l_t = \alpha y_t + (1-\alpha)(l_{t-1} + \ b_{t-1})$

Trend equation: $b_t = \beta^*(l_t - l_{t-1}) + (1+\beta^*)\ b_{t-1}$

Were,

l_t → level at time t,

b_t → slope (trend) at time t,

α → smoothing parameter for level, $0 \le \alpha \le 1$, and

β^* → smoothing parameter for trend, $0 \le \beta^* \le 1$

4.4.3. Damped Trend Method

It is a forecasting technique that employs double exponential smoothing, or exponential smoothing twice. But rather than being linear, the trend component curve is damped (flattens over time). This approach is thought to work well with data that have a trend but no seasonality. This approach incorporates a damping parameter $0 \le \varphi \le 1$ in addition to the smoothing parameters and (with values between 0 and 1 as in Holt's method).

$$\hat{y}_{t+h|t} = l_t + (\varphi + \varphi^2 + \cdots + \varphi^h)b_t$$
$$l_t = \alpha y_t + (1-\alpha)(l_{t-1} + \ \varphi b_{t-1})$$
$$b_t = \beta^*(l_t - l_{t-1}) + (1+\beta^*)\varphi\ b_{t-1}$$

The method is the same as Holt's linear method. For values ranging from 0 and 1, “dampens" the trend so that it eventually approaches a constant. Since φ < 0.8 is rarely considered during model construction due to its large effect on smaller values and a value of close to 1 indicates that the damped model cannot be distinguished from a non-damped model, the value of is constrained to a minimum of 0.8 and a maximum of 0.98. For our model, we consider φ = 0.9.

4.4.4. ARIMA Model

The statistical analysis technique known as Autoregressive Integrated Moving Average, or ARIMA, uses time series data to either better comprehend the data set or to forecast future trends based on the past values. ARIMA models can be used to model any "non-seasonal" time series that has patterns and isn't just random noise. The three terms p, d, and q that make up an ARIMA model are the order of the AR term, the order of the MA term, and the number of differencing respectively, which is necessary to render the time series stationary.

There were two factors to consider when developing an ARIMA model: The data should be stationary and univariate. The most typical method for achieving stationarity is to differentiate the data. The value of d determines how many differences are required to make a series of stationery. We chose d = 1 for our model because the time series data became stationary at this value.

The ACF and PACF plots are considered for the values of p and q respectively. In contrast to q, which is the order of the "Moving Average" (MA) term and refers to the number of lags of prediction errors, p is the order of the auto-regressive (AR) term and relates to the number of lags of Y to be used as predictors.

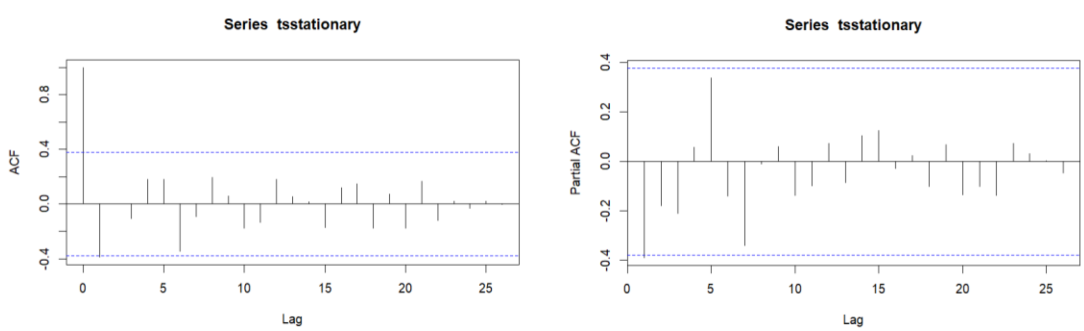


Figure 42: ACF and PACF plot of the stationary data

Based on the plots, we consider p=1, 2 and q=1. Therefore, we consider seven models – auto ARIMA, ARIMA (0,1,1), ARIMA (1,1,0), ARIMA (2,1,0), ARIMA (1,1,1), ARIMA (2,1,1) and ARIMA (0,1,0), and after further analysis, we consider ARIMA (0,1,1) as it has the lowest AIC value.

Table 8: AIC Values of the ARIMA models

ARIMA Models	AIC Values
auto.arima	155.99

ARIMA (0,1,1)	152.34
ARIMA (1,1,0)	159.44
ARIMA (2,1,0)	155.67
ARIMA (1,1,1)	154.13
ARIMA (2,1,1)	153.39
ARIMA (0,1,0)	160.33

4.5. Evaluation

The models are evaluated based on the 3-performance metrics – RMSE, MAE and MAPE.

4.5.1. Root Mean Square Error (RMSE)

Root Mean Square Error or RMSE, is one of the most used measures for evaluating the quality of the predictions. It illustrates the Euclidean distance between measured true values and forecasts.

$$RMSE = \frac{1}{n}\sqrt{\sum_{i=1}^{n}(x_i - \widehat{x_i})^2}$$

Where,

x_i → actual value

$\widehat{x_i}$ → estimated value.

i → variable i

n → total number of non-missing data points

4.5.2. Mean Absolute Error (MAE)

The mean absolute error, often known as MAE, is the average size of errors in a set of forecasts without considering their direction. It represents the model's prediction's absolute average distance.

$$MAE = \frac{1}{n}\left(\sum_{i=1}^{n}|y_i - x_i|\right)$$

Where,

x_i → actual value

y_i → predicted value.

i → variable i

n → total number of non-missing data points

4.5.3. Mean Absolute Percentage Error (MAPE)

Mean Absolute Percentage Error or MAPE, is one of the most used KPIs to measure forecast accuracy. It is the sum of the individual absolute errors divided by the demand (each period separately). It is the average of the percentage errors.

$$MAPE = \frac{1}{n}\left(\sum_{i=1}^{n} |\frac{y_i - x_i}{x_i}|\right)$$

Where,

x_i → actual value

y_i → predicted value.

i → variable i

n → total number of non-missing data points

The table below shows the forecast summary statistics of the 4 models considered in our project. Based on the 4-performance metrics (RMSE, MAE, and MAPE), the damped trend model (Holt Damped Model) is considered the best model for forecasting CO2 emissions.

Table 9: Forecast Summary Statistics of the Models

	RMSE	MAE	MAPE
DriftModel Training	22.1468	20.0339	2.5304
DriftModel Testing	28.1883	22.3588	2.8350
HoltModel Training	20.8938	19.3821	2.4547
HoltModel Testing	23.3189	20.2251	2.5390
HoltDampedModel Training	20.1047	17.6985	2.2451
HoltDampedModel Testing	22.1575	20.4121	2.5376
ArimaModel (0,1,1) Training	22.4675	18.4208	94.7259
ArimaModel (0,1,1) Testing	37.0034	36.2000	99.6149

4.6. Results

To meet the Paris Agreement and limit global warming to 1.5°C, CO_2 emissions must peak no later than 2025 and fall by 43% by 2030. In this section, we will forecast whether or not the selected countries are likely to reach their CO_2 emissions peak by 2025, and if not, we recommend the following:

1. Policymakers should develop and enforce strong mitigation policies and update their Nationally Determined Contributions (NDCs) and take this into account when formulating or updating their proposals for long-term low GHG development strategies (LT-LEDS).
2. All relevant stakeholders should work together to make some technological advances to reduce their country's CO_2 / GHG emissions.

In the evaluation phase, the Holt Damped model was selected as the best model for forecasting CO_2 emissions. In our initial analysis, we found that the energy sector (electricity sector and oil & gas sector) contributes the most to CO_2 emissions. Therefore, the energy sector is considered to analyze whether or not the sector will continue to increase its contribution to emissions for the following countries - India, United Arab Emirates (UAE), China, Kingdom of Saudi Arabia (KSA), United States of America (USA) and Europe.

4.6.1. Electricity Sector

1. India

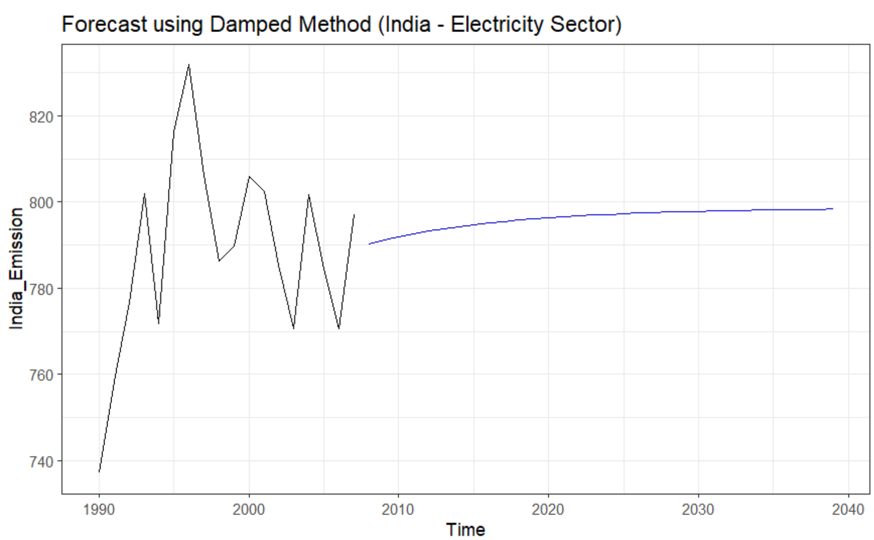


Figure 43: Forecasting India's CO_2 emission of Electricity Sector

From the plot (Figure 43), our model forecasts that the electricity sector of India most likely to won't reach its CO_2 emissions peak by 2025. Controversial, it will contribute more CO_2 emissions as the year goes by.

2. United Arab Emirates

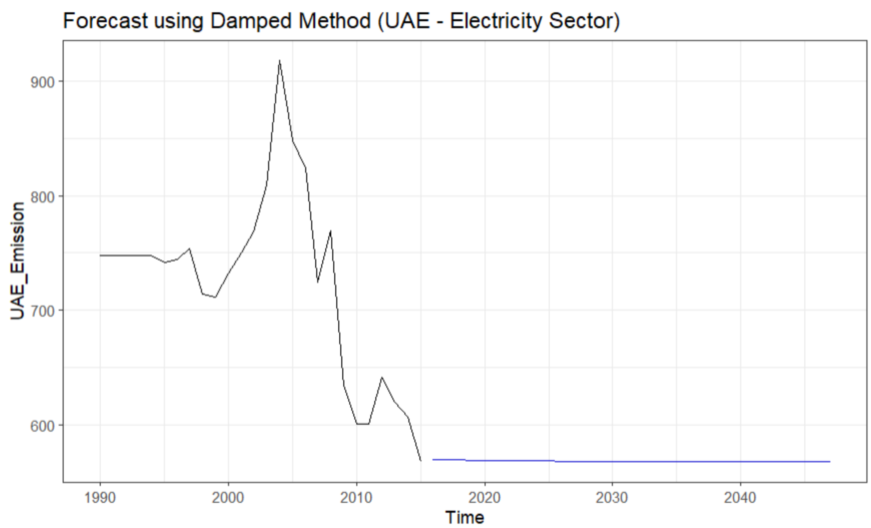


Figure 44: Forecasting UAE's CO_2 emission of Electricity Sector

From the plot, our model forecasts that the electricity sector of the UAE most likely reach its CO_2 emissions peak in 2025, as the emission peak was reached in 2005. Moreover, there is a slight decrease in the CO_2 emission from UAE's electricity sector as the year goes by.

3. Kingdom of Saudi Arabia

From the plot, our model forecasts that the electricity sector of KSA will be most likely to reach its CO_2 emissions peak in 2025, as the emission peak was reached around 1990. Moreover, there is a slight decrease in the CO_2 emission from KSA's electricity sector as the year goes by.

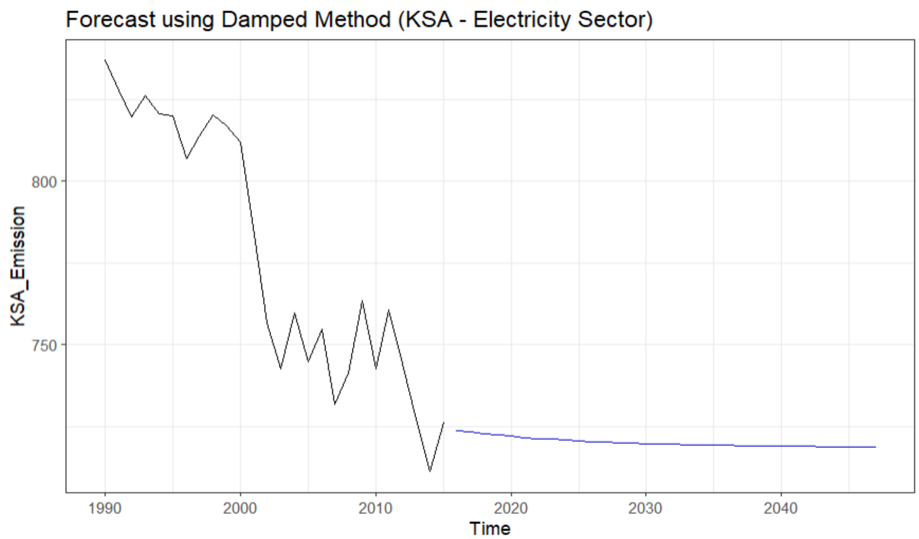


Figure 45: Forecasting KSA's CO_2 emission of Electricity Sector

4. China

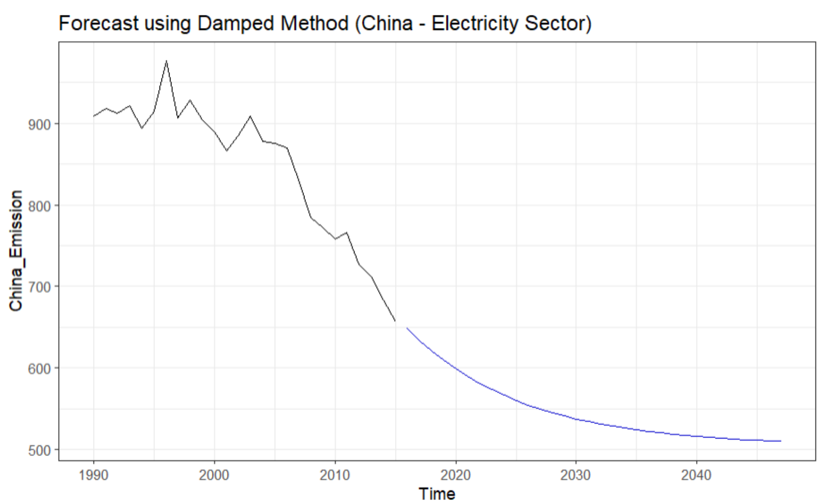


Figure 46: Forecasting China's CO_2 emission of Electricity Sector

From the plot, our model forecasts that the electricity sector of China will be most likely to reach its CO_2 emission peak in 2025, as the emission peak was reached around 1995. Moreover, there is a significant decrease in the CO_2 emission from China's electricity sector as the year goes by.

5. United States of America

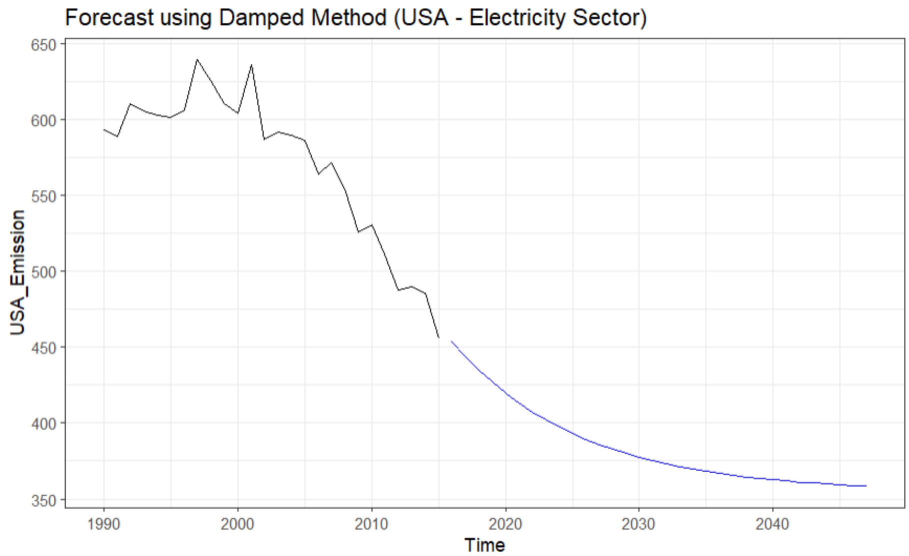


Figure 47: Forecasting USA's CO_2 emission of Electricity Sector

From the plot, our model forecasts that the electricity sector of USA will be most likely to reach its CO_2 emissions peak in 2025, as the emission peak was reached around 1998. Moreover, there is a significant decrease in the CO_2 emission from USA's electricity sector as the year goes by.

6. Europe

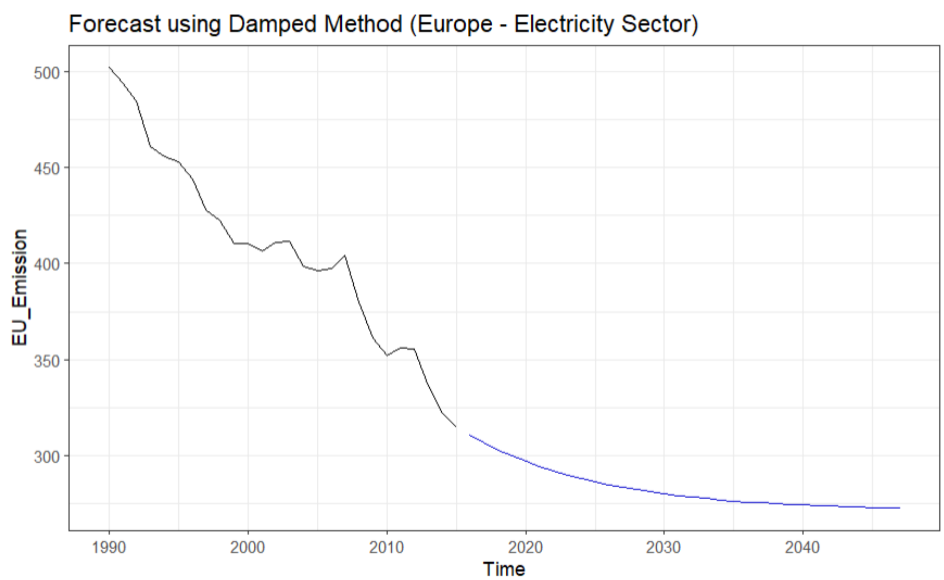


Figure 48: Forecasting Europe's CO_2 emission of Electricity Sector

From the plot, our model forecasts that the electricity sector of Europe is most likely to reach its CO_2 emissions peak in 2025, as the emission peak was reached around 1990. Moreover, there is a decrease in the CO_2 emission from Europe's electricity sector as the year goes by.

4.6.2. Oil & Gas Sector

1. India

   From the plot, our model forecasts that Oil & Gas sector of India will most likely won't reach its CO_2 emission peak by 2025. Controversially, it will contribute more CO_2 emissions as the year goes by.

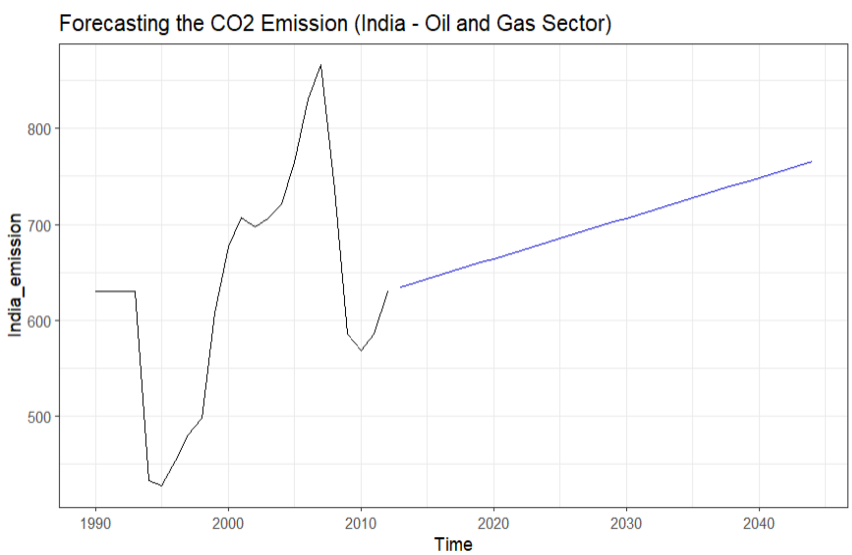


Figure 49: Forecasting India's CO_2 emission of Oil & Gas Sector

2. United Arab Emirates

   From the plot, our model forecasts that the Oil & Gas sector of UAE will most likely reach its CO_2 emissions peak in 2025, as the emission peak was reached around 1995. Moreover, there is a decrease in CO2 emission from the UAE's Oil & Gas sector as the year goes by.

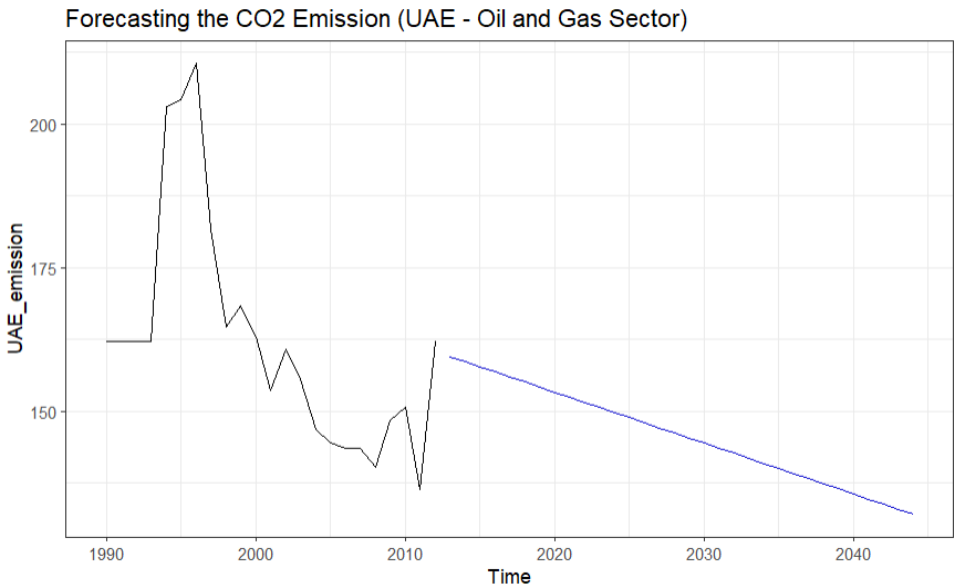


Figure 50: Forecasting UAE's CO_2 emission of Oil & Gas Sector

3. Kingdom of Saudi Arabia

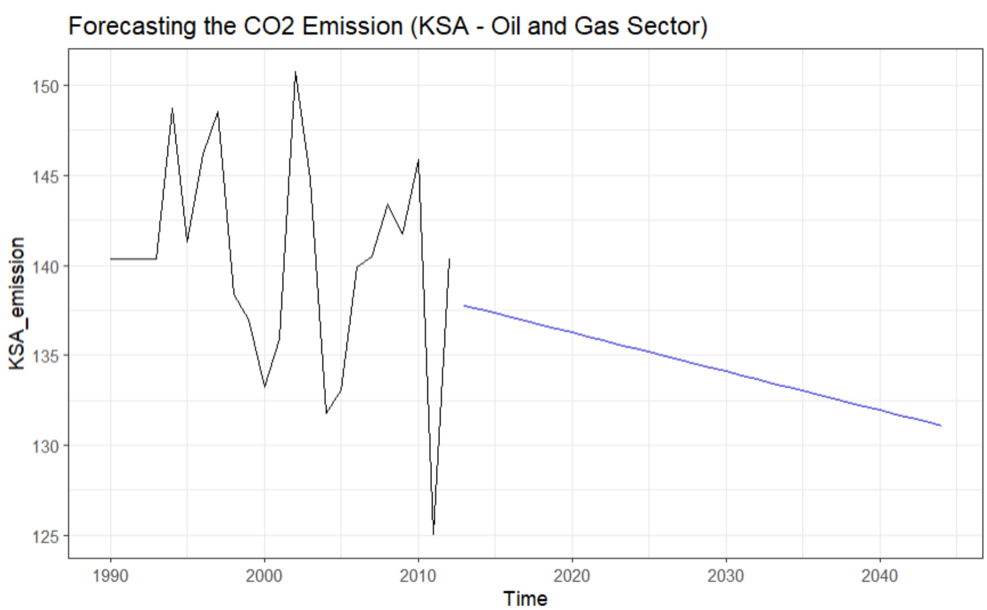


Figure 51: Forecasting KSA's CO_2 emission of Oil & Gas Sector

From the plot, our model forecasts that the Oil & Gas sector of KSA will most likely reach its CO_2 emissions peak in 2025, as the emission peak was reached around 2003. In addition, CO_2 emissions from KSA's Oil & Gas sector have been decreasing over the year.

4. China

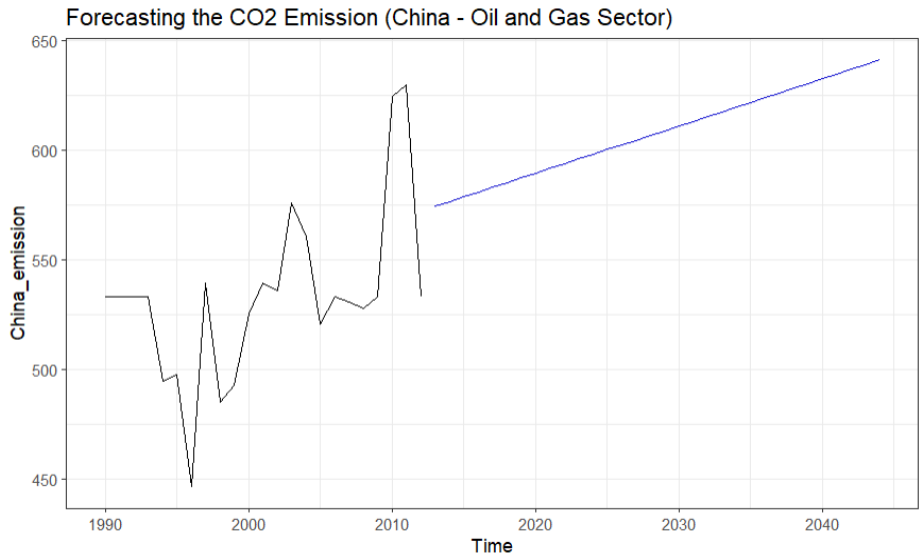


Figure 52: Forecasting China's CO_2 emission of Oil & Gas Sector

From the plot, our model forecasts that Oil & Gas sector of China will most likely won't reach its CO_2 emissions peak in 2025. Controversially, it will contribute more CO_2 emissions as the year goes by.

5. United States of America

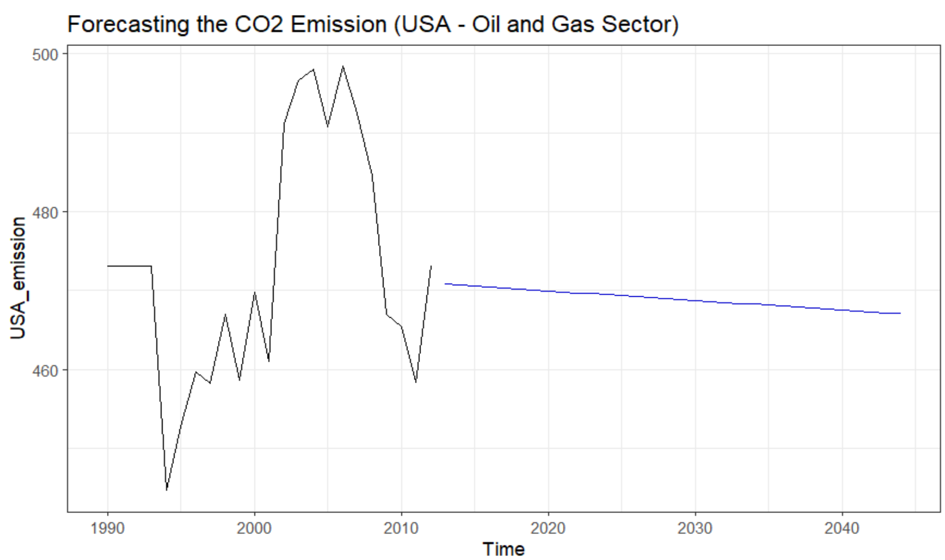


Figure 53: Forecasting USA's CO_2 emission of Oil & Gas Sector

From the plot, our model forecasts that the Oil & Gas sector of the USA will most likely reach its CO_2 emissions peak in 2025, as the emission peak reached around 2007. Moreover, there is a slight decrease in the CO_2 emission from USA's Oil & Gas sector as the year goes by.

6. Europe

From the plot, our model forecasts that the Oil & Gas sector of Europe will most likely reach its CO_2 emissions peak in 2025, as the emission peak was reached around 2011. Moreover, there is a significant decrease in CO2 emission from Europe's Oil & Gas sector as the year goes by.

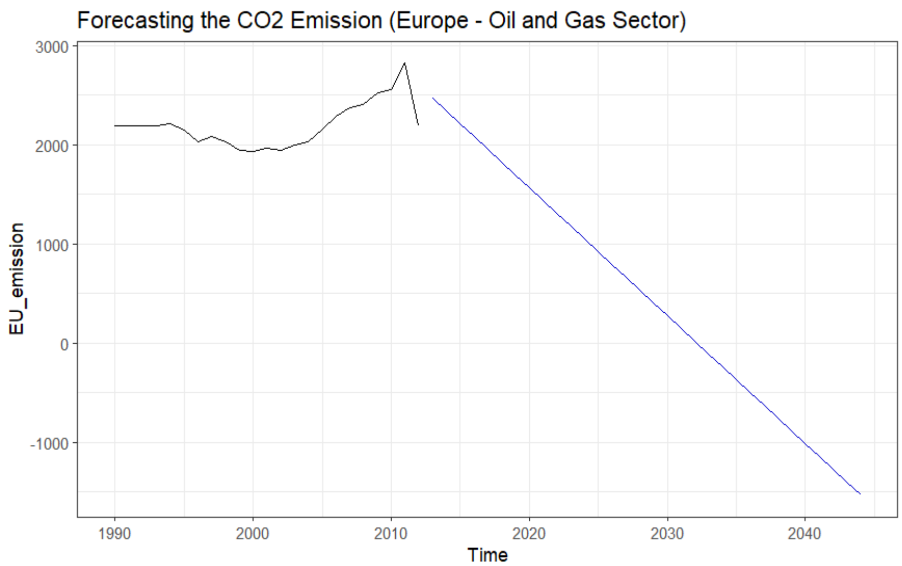


Figure 54: Forecasting Europe's CO_2 emission of Oil & Gas Sector

Chapter 7: Conclusion

7.1. Conclusion

Nations must act quickly to achieve the SDGs and make meaningful progress for the planet and people by 2030. However, the world must face some significant issues. One of these is climate change, the effects of which could make it more difficult for all nations to pursue sustainable development. Under the Paris Agreement, however, nations have committed to keeping global warming to 1.5°C above pre-industrial levels. Member nations have pledged to act quickly to combat climate change and halt global warming.

There is no doubt that climate change threatens human health and the future of our planet. Any further delay in concerted global action will miss a short and rapidly closing window to secure a livable future. We must urgently call for climate action. When countries pledged to limit global warming to 1.5°C above pre-industrial levels, we need to use data analysis techniques - to assess current and projected levels of CO_2 emissions on a sector-by-sector basis, with a focus on the energy sector, as three-quarters of greenhouse gas emissions now come from the energy sector; to study countries' effective adaptation and mitigation measures, including the National Determination Contribution (NDCs) and NetZero policies; to help policy-makers develop/ update better mitigation and adaptation measures to combat climate change.

In this project, we used a dataset from the Climate Action Tracker website and applied data analysis techniques and methodologies such as CRISP-DM and some machine learning algorithms such as time series; we have also used R and Tableau software to analyze CO_2 emissions in sectors and countries so the policy makers can use our insights and dashboards to better assess the impacts and implementation of their climate change mitigation policies and action. First, we identified the major sectors contributing to CO_2 emissions which we have found the highest CO_2 emission intensity sectors as follows: (Electricity, Oil and Gas, Waste, Buildings, Agriculture, and industry). Second, we created the Four-time series models drift method, Holt linear method, damped trend method, and ARIMA model. Then we select the best one based on the performance metrics – RMSE, MAE, and MAPE. We have selected the damped trend method for predicting CO_2 emissions for the selected countries to determine if they are going to meet the Paris Agreement and limit global warming to 1.5°C CO_2 emissions, as the IPCC AR6 report states countries must peak no later than 2025 and fall by 43% by 2030, our model forecasts that the electricity sector of India is probably won't reach its CO_2 emissions peak by 2025. Controversial, it will contribute more CO_2 emissions as the year goes by. At the same time, the United Arab Emirates, the Kingdom of Saudi Arabia, China, the United States of America, and Europe probably reached their CO_2 emissions peak earlier. On the other hand, our model forecasts that India and China's Oil & Gas sectors probably won't reach their CO_2 emission peak by 2025. Controversially, it will contribute more CO_2 emissions as the year goes by. At the same time, the United Arab Emirates, the Kingdom of Saudi Arabia, China, the United States of America, and Europe reached their CO_2 emissions peak earlier. Third, we identified the decarbonization indicators most correlated with CO_2 emissions at the sector level, and we found the top three are from the Transport sector is sales of new EV's with a unit of a number of EV's sold, from the electricity sector the indicator was the electricity activity (per capita) with a unit kWh/ capita. Lastly, for the agriculture sector, the indicator was Agriculture activity (total) consumption with a unit Kcal/cap/day. Fourth, we determined whether some selected countries meet their commitments in their NDCs, or NetZero policies based on the three trajectories (business as usual based on historical data, NetZero pathways -minimum policy and maximum policy CO_2 emissions); we observed that some countries like the United States, China, Europe, India Australia, South Africa, Chile are putting in place some policies that are targeting their higher CO_2 emissions intensity sectors while countries like UAE, KSA, United Kingdom, Ukraine they didn't put policies that are targeting their higher CO_2 emissions intensity sectors. Fifth, we investigated the social cost of carbon for the UAE, for the first time in the region, as this is currently a lively debate among policymakers. Our investigation for water and energy generation in UAE, SCC, is anticipated to be approximately 6.96 trillion dollars and 938.4 million dollars, respectively. By 2030, our investigation estimates that 1.5 trillion dollars can cut SCC by implementing mitigating methods.

As RIT students, we would like to contribute to the efforts of the UAE and the world to find solutions to climate change and raise awareness to accelerate the transition to clean energy. Furthermore, our project came when the UAE president, His Highness Sheikh Mohammad Bin Zayed, declared the Year of Sustainability this year, and the UAE will host the world its most significant event at COP28 at Expo City Dubai. However, there are some limitations -Some countries need mechanisms to collect the CO_2/GHG emissions or transparency reporting them, or they need an official CO_2/GHG emissions inventory. Therefore, the dataset for our project only includes annual data and does not include CO_2 emissions from all countries in the world; the time was another limitation; we tried in our project to have a holistic perspective and to study all sectors, then we decided to focus more on the energy sector and the Oil and Gas since they are the most CO_2 emissions contributors among all other sectors.

7.2. Recommendation

We believe our insightful analysis of the role of data analytics and machine learning in this regard will go a long way in inspiring more innovations and efforts toward mitigating the effects of climate change.

We recommend, firstly, expanding the research to focus on the other sectors as well, such as Waste, Buildings, Agriculture, industry, and transport. Secondly, to focus on the non- CO_2 gases the GHG emissions. For instance, methane is still an important greenhouse gas because of many human-caused sources. Methane today is responsible for about 0.5°C of total warming. Thirdly, explore the future work area.

7.3. Future work

For future work, first, we can investigate a better assessment methodology for some Gulf countries/small geographic areas, such as the UAE and Qatar, in terms of CO2 index per capita to explore other fair indices (considering that these countries are making great efforts to address climate change domestically and at their borders, they have small populations). Second, we can explore the Paris Agreement's second goal, adaptation.

The third future work is to investigate further the Social Cost of Carbon (SCC) for the UAE since, during our study, we have reviewed the current literature that examines the various energy production and water desalination methods employed in the United Arab Emirates and the resulting CO2 emissions and associated SCC. Two possibilities have been taken into consideration regarding energy generation. Scenario (1) presupposed that natural gas was the only resource used for electricity production and disregarded the adoption of mitigation measures. Adopting an energy mix strategy as part of the UAE Vision 2021 for sustainable development was a part of scenario number two. While the SCC is projected to be 6.96 trillion USD by 2030, Scenario 1's first resulted in 139.2 billion tons of CO2e emissions. By 2030, 109.23 billion tons of CO2e emissions were predicted by Scenario 2, with an estimated SCC of 5.46 trillion dollars. Around 30 billion tons of CO2e and 1.5 trillion dollars in SCC were thought to have been saved. We also looked at several water desalination methods and predicted that by 2030, CO2 emissions would amount to 18.8 million tons and SCC would be 938.4 million USD. Meeting the rising resource demand is becoming increasingly difficult because of the close relationship between water and energy. This analysis showed that CO2 emissions are rising along with their associated SCC. Therefore, it is imperative to reduce CO2 emissions to manage its detrimental effects on the environment and the economy.

Bibliography

1. UN DESA. 2022. The Sustainable Development Goals Report 2022 - July 2022. New York, USA: UN DESA. © UN DESA. https://unstats.un.org/sdgs/report/2022/
2. Paris Agreement (All language versions) | UNFCCC. (2015). Unfccc.int. https://unfccc.int/process/conferences/pastconferences/paris-climate-change-conference-november-2015/paris-agreement
3. IPCC. (2023). SYNTHESIS REPORT OF THE IPCC SIXTH ASSESSMENT REPORT (AR6) Summary for Policymakers. https://www.ipcc.ch/report/ar6/syr/downloads/report/IPCC_AR6_SYR_SPM.pdf
4. International Energy Agency. (2021, May). Net Zero by 2050 – Analysis. IEA. https://www.iea.org/reports/net-zero-by-2050
5. Stern, N., & Stiglitz, J. E. (2021). The Social Cost of Carbon, Risk, Distribution, Market Failures: An Alternative Approach. SSRN Electronic Journal. https://doi.org/10.2139/ssrn.3785806
6. The White House. (2021, January 21). Executive Order on Protecting Public Health and the Environment and Restoring Science to Tackle the Climate Crisis. The White House. https://www.whitehouse.gov/briefing-room/presidential-actions/2021/01/20/executive-order-protecting-public-health-and-environment-and-restoring-science-to-tackle-climate-crisis/
7. Saleh, L., Zaabi, M. al, & Mezher, T. (2019). Estimating the social carbon costs from power and desalination productions in UAE. Renewable and Sustainable Energy Reviews, 114, 109284. https://doi.org/10.1016/j.rser.2019.109284
8. (2021). Reducing Greenhouse Gases in the United States: A 2030 Emissions Target [Review of Reducing Greenhouse Gases in the United States: A 2030 Emissions Target].
9. (2021). The Long-Term Strategy of the United States: Pathways to Net-Zero Greenhouse Gas Emissions by 2050. [Review of The Long-Term Strategy of the United States: Pathways to Net-Zero Greenhouse Gas Emissions by 2050.]. the United States Department of State and the United States Executive Office of the President, Washington DC. November 2021.
10. (2021). China's Achievements, New Goals and New Measures for Nationally Determined Contributions [Review of China's Achievements, New Goals and New Measures for Nationally Determined Contributions].
11. (2021). China's Mid-Century Long-Term Low Greenhouse Gas Emission Development Strategy [Review of China's Mid-Century Long-Term Low Greenhouse Gas Emission Development Strategy]. China.

12. (2020). Update of the NDC of the European Union and its Member States [Review of Update of the NDC of the European Union and its Member States].
13. European Commission. (2019). A European Green Deal. European Commission. https://commission.europa.eu/strategy-and-policy/priorities-2019-2024/european-green-deal_en
14. (2022). India's Updated First Nationally Determined Contribution Under Paris Agreement [Review of India's Updated First Nationally Determined Contribution Under Paris Agreement]. India.
15. MoEFCC. (2022). India's long-term low-carbon development strategy. Ministry of Environment, Forest and Climate Change, Government of India
16. (2021). UPDATED FIRST NATIONALLY DETERMINED CONTRIBUTION [Review of UPDATED FIRST NATIONALLY DETERMINED CONTRIBUTION]. KINGDOM OF SAUDI ARABIA.
17. WORLD ENERGY COUNCIL COUNTRY COMMENTARIES M ARCH 2022 MEGS. (2022). Retrieved May 1, 2023, from https://www.worldenergy.org/assets/downloads/Issues_Monitor_2022_Saudi_Arabia_commentary.pdf
18. MOCCAE. (2022). A Bridge to Greater Climate Ambition [Review of A Bridge to Greater Climate Ambition]. Ministry of Climate Change and Environment.
19. (n.d.). National Climate Change Plan of the United Arab Emirates 2017-2050 [Review of National Climate Change Plan of the United Arab Emirates 2017-2050]. Ministry of Climate Change & Environment.
20. Tudor, C. (2016). Predicting the evolution of CO2 emissions in Bahrain with automated forecasting methods. Sustainability (Basel, Switzerland), 8(9), 923-923. https://doi.org/10.3390/su8090923
21. Malik, A., Hussain, E., Baig, S., & Khokhar, M. F. (2020). Forecasting CO2 emissions from energy consumption in Pakistan under different scenarios: The China–Pakistan economic corridor. Greenhouse Gases: Science and Technology, 10(2), 380-389. https://doi.org/10.1002/ghg.1968
22. Tudor, C., & Sova, R. (2022). EU Net-Zero Policy Achievement Assessment in Selected Members through Automated Forecasting Algorithms. ISPRS International Journal of Geo-Information, 11(4), 232. https://doi.org/10.3390/ijgi11040232
23. Kunda, D., & Phiri, H. (2017). An Approach for Predicting CO2 Emissions using Data Mining Techniques. International Journal of Computer Applications, 172(3), 7–10. https://doi.org/10.5120/ijca2017915098

24. Tudor, C., & Sova, R. (2021). Benchmarking GHG Emissions Forecasting Models for Global Climate Policy. Electronics, 10(24), 3149. https://doi.org/10.3390/electronics10243149
25. Qader, M. R., Khan, S., Kamal, M., Usman, M., & Haseeb, M. (2021). Forecasting carbon emissions due to electricity power generation in Bahrain. Environmental Science and Pollution Research. https://doi.org/10.1007/s11356-021-16960-2
26. Wei, S., Yuwei, W., & Chongchong, Z. (2018). Forecasting CO2 emissions in Hebei, China, through moth-flame optimization based on the random forest and extreme learning machine. Environmental Science and Pollution Research, 25(29), 28985–28997. https://doi.org/10.1007/s11356-018-2738-z
27. Kumari, S., & Singh, S. K. (2022). Machine learning-based time series models for effective CO2 emission prediction in India. Environmental Science and Pollution Research. https://doi.org/10.1007/s11356-022-21723-8
28. Ma, N., Shum, W. Y., Han, T., & Lai, F. (2021). Can machine learning be applied to carbon emissions analysis: An application to the CO2 emissions analysis using gaussian process regression. Frontiers in Energy Research, 9https://doi.org/10.3389/fenrg.2021.756311
29. Li, X., Ren, A., & Li, Q. (2022). Exploring Patterns of Transportation-Related CO2 Emissions Using Machine Learning Methods. Sustainability, 14(8), 4588. https://doi.org/10.3390/su14084588
30. Yang, H., & O'Connell, J. F. (2020). Short-term carbon emissions forecast for aviation industry in Shanghai. *Journal of Cleaner Production*, *275*, 122734. https://doi.org/10.1016/j.jclepro.2020.122734