University for the Creative Arts

BERLIN SCHOOL OF BUSINESS & INNOVATION

Dissertation Title: Exploratory analysis and interpretation of Global Renewable Energy Trends

Master title:

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Year: 2023

ABSTRACT

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ACKNOWLEDGEMENTS

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INTRODUCTION

The energy consumption has been constantly increasing throughout the years. Since the time production of energy has been in process, we have been using non-renewable energy sources. These include all different kinds of sources for production, such as Coal, Fossil fuels, Natural Gases or Nuclear fuels. But the problem with using this method is, as the name suggests, they are non-renewable. Moreover, they have adverse effects on the environment. They contribute towards more greenhouse gas emissions, and contribute towards different kinds of pollutions. They also result in less energy sources left with the increased use of these sources. On the other hand, renewable energy helps in tackling most of these issues by being more environmentally friendly and not exploiting the resources. The use of renewable sources of energy has been in use since the ancient times. Use of renewable energy has impacted the global worldwide energy consumption as well as helped in reducing the use of other kinds of sources. Renewable sources have limitations as well as they depend on the weather conditions. Installation of the machines to extract this energy is quite expensive. The output rate from these types of energy extractors is also low compared to non-renewable sources of energy.

GDP or Gross Domestic Product is an indicator which is used to measure the country’s economic stature. It is the total market value of all finished products and services produced inside the boundaries of a nation during a certain time. A country's GDP is frequently used as a broad indicator of the size and health of its economy. When a country can produce goods within itself, it can decrease its imports and if that service/good is in surplus, that can be used to increase their exports as well (Wikipedia contributors, 2023b). With the production of renewable energy production, the need for importing more energy from other potential sellers can be reduced. We will be trying to find out if there is any correlation between GDP and the production of renewable energy for the countries.

In this research, we will be able to visualize the global trends of consumption as well as production of renewable energy. We will then be analyzing the growth and usage of all the different types of renewable energy sources under production and how the production has increased over time. These trends will be then used to relate on whether this factor has had an impact on the economic growth of different countries or vice versa.

Correlation is the mathematical property that determines the causality between two different variables over a course of time. This study aims to check whether there is a correlation between GDP growth and energy consumption over a period of 30 years. We will be trying to figure out if the causality is bi directional or unidirectional.

Most of the previous studies which were conducted on this research topic have neglected the renewable energy consumption and production. The previous studies on Renewable, non-renewable energy consumption and income in top ten renewable energy-consuming countries: Advanced Fourier based panel data approaches states that there is a positive relationship for some countries and for some not which used data from 1970 to 2019 (Fareed and Pata, 2022). We will be trying to bridge this gap by conducting Pearson's correlation test on the data for a much broader number of countries.

Previous studies have also stated that even though there might be a bi directional or unidirectional relationship between these two factors, production of non-renewable energy cannot be neglected or reduced by a large factor compared to renewable sources of energy. (Salari et al., 2021)

We will be doing the research with the limitations that the data might not be accurate till date. The data that we will be using is till 2020 for the GDP for performing the calculations. Additionally, there will be some data gaps as well, since the data which is old cannot be accounted for to be 100% accurate. Other factors such as impact of natural disasters, economic shifts and geopolitical events can also affect the GDP of the countries, which are not being considered. There might also be changes to the renewable energy production policies of different countries or on a global scale, which are also not being considered. There is also a language and cultural barrier between different countries which can introduce bias or limitations to understanding the global landscape.

All the data that is used in this research is secondary as they have been taken from Kaggle and other Government sites. These data will then be manipulated using tools such as R, SQL as well as Tableau for finding relations as well for exploring the trends visually. We will be discussing the methods and tools used in detail in further chapters.

1.1 Aim

- The study analyses the global use of renewable energy and tries to find out if there is any relation between this data and the GDP of each country.

1.2 Objectives

- Examined different datasets related to the case study and tried to find a relationship between them.

- Calculated total utilization and production of different types of energy on a global scale.

- Determined the top standing producers of different types of energies and visualized their growth.

- Utilized this data to check whether there is any correlation between this and the economic growth of these countries.

1.3 Research Questions

- How has the consumption and production of renewable energy transitioned over the years?
- Which type of renewable energy source has seen an increase in the last 5 decades and how has this increase affected the global renewable energy production?
- Is there a correlation between the production of renewable sources of energy with the GDP of the country?

1.3 Research Overview

The importance of renewable energy and how this differs from largely commercialized non-renewable energy has been explained in the introduction. The factors such as GDP, which will be used for supporting the analysis as well as the mathematical property of correlation have been defined in the introduction. Background of Energy and types of energy vs GDP will be explained later in Literature review I. Followed by Specific types of renewable energy and their relation with the GDP of the countries will be researched and explained in literature review II. The methods used for supporting my research and my findings will be explained in detail later in chapters Methodology and Findings.

Currently, there are four major sources of renewable energy which has been commercialized to an extent. These include solar, wind, hydro and biofuel. We will be analyzing on these four renewable sources as well the total electricity consumption and generation on the global scale for a better perspective. We will investigate similar papers as well as their findings in the following chapters. This will include papers where energy consumption and trends have been analyzed as well as how they are connected to country's economic growth.

CHAPTER ONE – LITERATURE REVIEW I

1.1 Global renewable energy transition

The Global demand for investment into production of Renewable energy per country basis has seen a major increase in the past decades. In the studies conducted by Stern in 2006, it states that it would be too costly to tackle climate change challenge if the world keeps procrastinating in taking actions (Stern, 2006). It is suggested that renewables could provide as much as world's half energy needs by the year 2050. (Krewitt et al., 2007). The use of fossil fuels over the time known since the production of energy has been contributing towards an increase in GHG emissions, especially towards CO_2. It has been also stated that the average annual rate of primary energy consumption in emerging economies will be increasing at an annual average rate of 3.2 percent until 2025 (ASIF and Muneer, 2007). The consumption is increasing on average by 1.1 percent for OECD countries per year. It has been proved with numerous studies that; energy consumption can result in country growth. But as per the current scenario, energy consumption mainly includes of fossil fuels energy which contributes to energy growth, has a negative due to increase in carbon dioxide emissions and additional environmental degradation (Fareed and Pata, 2022b).

These factors, in turn, show the importance to rely on new energy sources which can compensate for reduced use of fossil fuels and can also help the economy grow without damaging the environment (Saidi and Omri, 2020). In the recent energy economics literature, it has been argued that renewable energy is a factor of sustainability which has the potential to rebalance the Sustainable Development Goals (Swain and Karimu, 2020). The hypothesis stated by Grossman and Krueger (1991) states that the level of environmental degradation increases with the growth of a country, and will start to decrease as the income exceeds a turning point. This has been confirmed by the many empirical researches (e.g., Grossman and Krueger, 1991; Ozturk and Acaravci, 2010; Ben Youssef et al., 2016; Tiwari et al., 2013; Bernard et al., 2015; Congregado et al., 2016; Sugiawan and Managi, 2016; Balaguer and Cantavella, 2016; Ali et al., 2017; Sinha and Bhattacharya, 2017; Yao et al., 2019; Chen and Taylor, 2020; Kacprzyk and Kuchta, 2020). Over the past few decades, the relationship between energy consumption and economic growth has been a subject of intense studies.

1.2 Critical Discoveries in the Field of Renewable Energy Research

As we all know, the energy system has transformed dramatically over the Industrial revolution. As a country gets richer as well as when the population increases, the demand for the energy increases. The increasing demand for energy year-to-year is making the transition towards more carbon friendly from traditional fossil fuel sources harder. The global energy consumption is growing at an average of 1% to 2% per year.

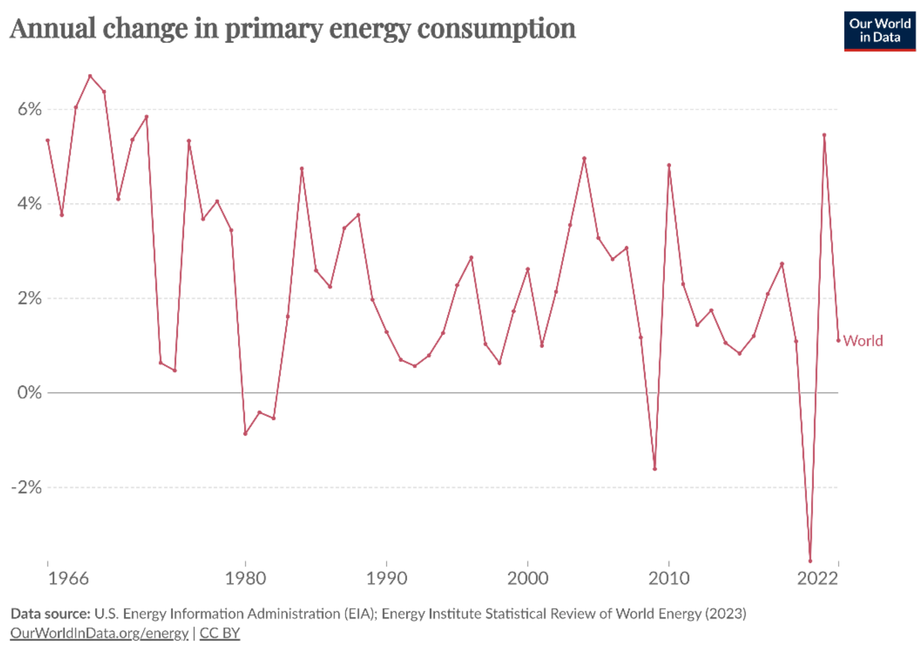

Fig 1.1 Annual Change in primary energy consumption (Annual change in primary energy consumption, 2023)

The energy consumption per country usually depends on the population of each country. But that does not give an idea on how the energy is consumed. When we check the energy consumed per capita, we can find that Iceland, Norway, Canada, The United States, and other wealthy nations of Middle East such as Oman, Saudi Arabia, and Qatar. This gives us the context that on an average a person from these countries consumes as much as 100 times more than an average person from some poor countries. This difference can be even greater as we do not have high quality data on energy consumption in some poor countries.

Even though, the energy consumption has been increasing on a global scale, this is not the case everywhere in the world. In countries, where the income is increasing along with the population, the consumption has been increasing compared to some rich countries, which have been trying to increase energy efficiency, where there has been a fall in the total energy consumption per year.

In the paper on examining previous energy crisis and reforms in the world by Qureshi, Rasli, and Zaman (2016) beginning from 1975 to 2012, the use of Granger causality method showed that there is causality between electric shortage and economic factors. We are currently moving through the global era of energy transformation, which includes low-carbon approaches and an increase in energy requirements across the globe which is set to begin a double-speed demand for load. One of the most important countries in world's energy market is Russia (Proskuryakova and Filippov, 2015). They are investing heavily in innovation and research in the energy sector to understand the global energy outlook. A brief analysis and citation are provided regarding the historical demand for US oil (Greene et al., 1998). The changes in commercial energy consumption as well as the connection between energy economic growth and energy consumption in the Association of Southeast Asian Nations (ASEAN) from 1960 to 1986 were given and examined by B. Ang (Ang, 1989). Numerous initiatives have been undertaken to lower energy usage both nationally (Román-Collado et al., 2018) and internationally (Csereklyei and Stern, 2015, Bithas and Kalimeris, 2013), as well as at sub-national (Dong et al., 2016, Zhang and Bai, 2018).

The primary energy generation can be used to estimate the number of primary energy resources produced or extracted. These include oil, coal, electricity, gas, biomass, and heat generation (Ahmad and Zhang, 2020). For other types of energy products, it includes external trade, primary production, marine containers, and stock exchanges.

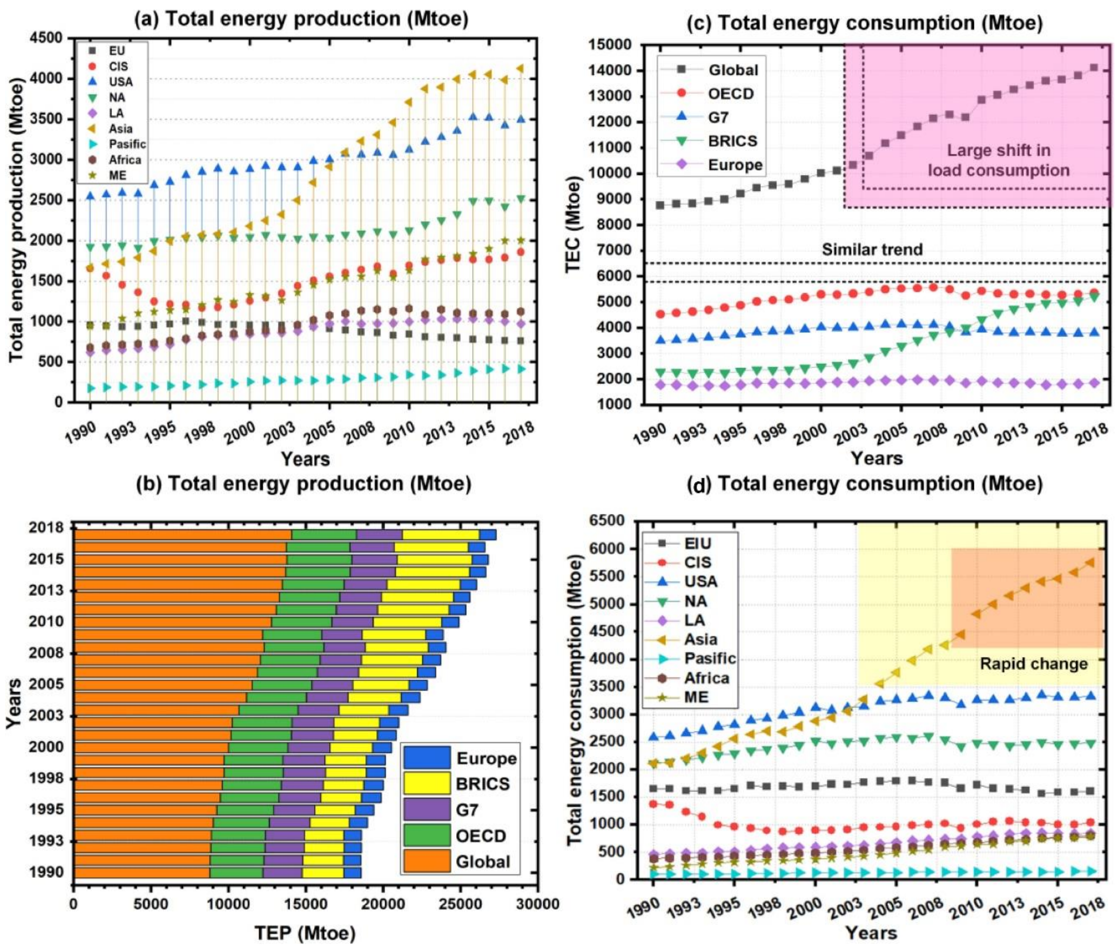

Fig 1.2 Total energy production and consumption in different regios from 1990 to 2017 (Ahmad and Zhang, 2020)

Figure 1.2 depicts the total energy production and consumption in different regions from 1990 to 2017. As can be seen from the image, the total production in USA is gradually increasing whereas in Asia, there is a rapid change in every production. Over the last decades there has been a major shift in energy production. There has been a large demand for energy production after the year 2000 in the BRICS[1] countries. To investigate various viewpoints for energy transformation and development, the global future energy demand study looks at a range of alternative tendencies. The models share some common traits, such a large rise in energy needs and a shift to a low-carbon blend of fossil fuels, but they also differ in terms of technological presumptions or policy. There has been a major shift in energy generation and consumption after 2000. This can be accounted to factors such as the global era of Industrialization, technological advancement, and rapid evolution of the world’s leading countries such as the USA, the European Union, China, Japan, and others. There has also been a 40% increase in energy consumption from the year 1990 to 2017.

There has been recent studies conducted to find the relationship between energy consumption and growth in 22 OECD countries over a period from 1960 to 2001 (Lee et al, 2008).. The examination was able to show that there is a bi-directional causality between economic growth and energy consumption. This research was done by employing a multivariate panel VECM[2] specification with output, energy consumption and fixed brut capital formation inside. (Matei, 2018).

On the other hand, there have been two studies which were able to find a unidirectional causality running from output growth and capital formation to energy use: Non-renewable sources of energy (Coers and Sanders,2013) and renewable sources of energy (Chang and al., 2009). In the first paper, panel unit root and cointegration techniques were used and an appropriate vector error correction model was specified to analyze the nexus between energy use and income. Over a very-short-run, there was evidence of bi-causality. The second research used a non-linear panel data technique for 30 OECD nations for the 1997–2006 period, and it focused on the link between economic growth and renewable energy usage in relation to energy costs. The findings demonstrate that while nations with low rates of economic growth are unable to adjust their levels of renewable energy in response to fluctuations in energy prices, those with high rates of economic growth can increase their consumption of renewable energy. Giraud et Kahraman [2014], studying with 15 OECD nations during the period 1970-2011, discovered that energy consumption unquestionably Granger causes growth, supporting the growth theory. Overall, the results of the literature indicate that, except for the very short term, measures intended to improve energy efficiency do not negatively impact GDP growth. They are also very susceptible to model misspecification. (Matei, 2018).

In his paper on Analysis of the development of global energy production and consumption by fuel type in various regions of the world by D S Shalaeva, it has been mentioned that all the energy used by humans does not exceed 0.3% of the photosynthetic energy that supports life on Earth (Shalaeva et al., 2020). But, the growth rate of human energy consumption is more important than the energy level. Global energy consumption has been growing exponentially over the past century, which has the potential to upset the planet's thermal equilibrium and cause catastrophic climate change (Halova G O 2017).

By the end of the 19th century, the amount of anthropogenic energy used by humans had grown to 1 billion tons of fuel, the highest level in human history of development. Additionally, it has increased about 17 times in the last century, reaching 16.5 billion tons of fuel in 2006. Put differently, from the time of the Bible, the average amount of energy consumed has grown by several orders of magnitude.

Due to persistent economic growth and rising demand in China, which has been the world's top energy user since 2009, worldwide energy consumption surged dramatically in 2018.

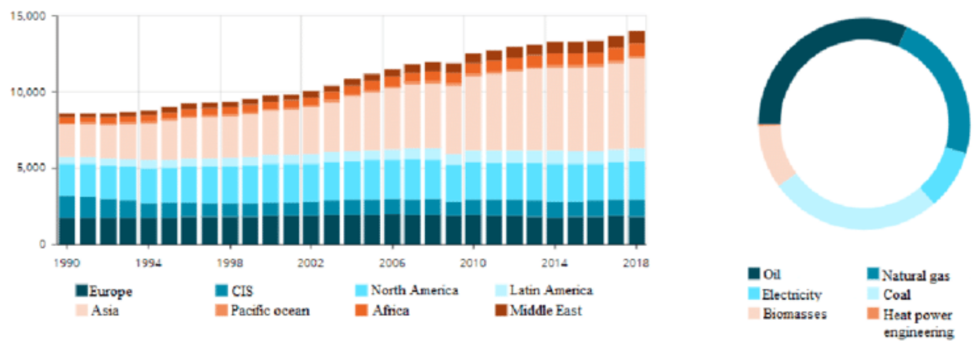

Fig 1.3 Different energy consumption over the years (Parhamfar, Mohammad & Adeli, Amir, 2022).

There was an increase in energy consumption in China from the year 2012, caused by electricity production, strong industrial demand, and an increase in fuel consumption in the transport sector. Compared to 2017, the total energy consumption in United States reached a record 2.3 Gtoe in 2018, which is more by 3.5%. However, energy consumption decreased by 1% in the European Union, and by 3.5% in Germany specifically. This decline was partially attributed to decreased power usage, a mild winter, lower consumption, and increased energy efficiency (Shalaeva et al., 2020).

The first two decades of the twenty-first century have seen an average 4% yearly rise in global economic growth due to the fast expansion of several emerging nations, headed by China and then India. Energy supply and demand increased by 2% yearly between 2000 and 2020, for a compound rise of over 50% over the previous 20 years. This suggests that the electricity sector is growing extremely healthily and that energy efficiency is continuing to rise. The global economy is expected to develop much more in the upcoming years. The poorer people who do not yet have access to electricity will gain most from this expansion, since their numbers have decreased from almost 2 billion in 2000 to just over 1 billion in 2020. By the year 2040, electricity may even reach every person on the earth. A 4% global GDP growth rate is being felt in even more impoverished regions of the world because of China's and India's ongoing progress. The quantity of energy needed to generate one dollar (or euro, or pound, or ruble, or rupee, or yen, or yuan) of GDP also continues to decrease. Put differently, energy efficiency is rising and producing more requires less energy, especially as so many countries transition from industrial to post-industrial civilizations. Moreover, the growth of impoverished nations has outpaced that of affluent nations, and global economic stability is creating the conditions for ongoing growth. Even if fossil fuels still account for more than 80% of the world's energy supply in 2020, there is a definite trend in the future toward alternative energy sources. The output of coal has mostly been constant from 2000 and 2020. Even though China has been the world's greatest producer and user of coal for nearly 200 years, projections point to a future in which power plants will become less common. Today's globe is moving away from fossil fuels and toward alternative energy (Khandakar Akhter Hossain, 2012).

One of the most significant features of renewable energy is its availability in abundance. It is infinite. Compared to fossil fuel technologies, renewable sources of energy are hygienic sources of energy which produce much lesser negative environmental impact. It is the need of the hour. All over the world, scientists and Engineers are researching in this domain (Umair Shahzad, 2015).

It is possible that the importance of energy in the context of economic growth, financial development, social and political strata in every nation is understated. This is because energy is essential to the operation of many systems, including those related to communication, transportation, education, health, finance, and industry, and its use is necessary for these systems to function fully. Aside from these, improvements in the standard of living are evident in the rise in food production, increased industrial output, housing accessibility, improved healthcare, and the development of alternative human amenities; all of these require the use of energy to progress (Rafindadi, 2016).

Many writers have tackled the question of whether energy use and economic development are causally related. For instance, the research by Caraiani et al. (Caraiani, Lungu and Dascălu, 2015) verifies the relationship between gross domestic product for Bulgaria, Poland, Romania, Hungary, and Turkey between 1980 and 2012/2013 and primary energy consumption from various sources. After examining the link between economic growth and energy consumption in India between 1950 and 1996, Paul and Bhattacharya (Paul and Bhattacharya, 2004) discovered that there is both same- and bidirectional causation between the two variables.

Regression analysis was used in some previous research by Pachuri (1977) and Tyner (1978) to find a high correlation between India's economic development and energy usage. In his search for causation, Cheng (1999) discovered a unidirectional causal relationship between energy use and economic development. Asafu-Adjaye (2000), on the other hand, calculated a unidirectional Granger causation between energy usage and income. Asafu-Adjaye's (2000) findings contradict Cheng's (1999) findings. Our empirical findings demonstrate a two-way causal relationship between economic growth and energy use. This study aims to explain how our results differ from those of Cheng (1999) and Asafu-Adjaye (2000).

1.3 Exploring the Surge in Research Papers on Renewable Energy

There has been a long-attracted attention at policy making level in the energy sector by complex economic process of energy consumption to achieve the established European targets. This relationship has been a great subject of interest in literature. The series of researches for determining the relationship between energy consumption and economic growth was opened by Kraft and Kraft in their paper “On the Relationship Between Energy and GDP” back in 1978. This research was carried out using a panel of US data from 1947 to 1974. This research concluded that the Gross National Product (GNP) leads to energy consumption. Numerous investigations on the same topic were conducted after this groundbreaking breakthrough. Most empirical investigations examined the direction of causation between these two variables or tested the function of energy in promoting economic growth. Regarding the link between energy consumption and growth, several research have employed various econometric techniques, different time periods, proxy variables, and countries of interest. On the relationship between different sources of energy consumption and GDP growth, however, not much study has been published. As noted by Ohler and Fetter, the nation's difficulties in figuring out the best combination of energy usage encourages future study to take individual sources into account (Caraiani, Lungu and Dascălu, 2015b).

Figure below illustrates how interest in this subject has grown in recent years. The first article was published in 1994, and up until 2010, less than eight articles were published annually—just 8.64% of the total. The number of articles peaked in 2017 with 110 papers and in 2018 with 128 articles, having reached 26 in 2010. There have already been 55 articles published on this topic of interest in 2019 as of May. The necessity to find better ways to live and the increased strain caused by the existing consumption pattern, in addition to the various renewable energy solutions that the researchers have offered, may be the reasons for the notable growth in interest in this field (Zaharia et al., 2019).

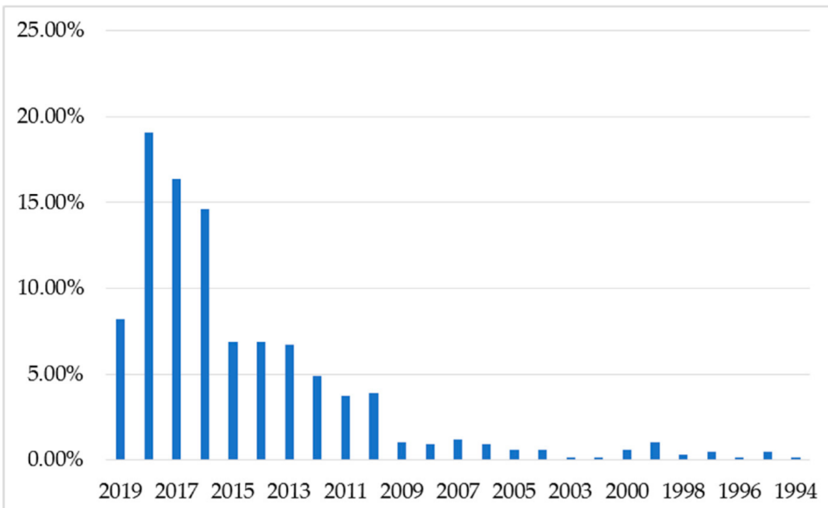

Fig 1.4 Percent share of research papers on the specific topic, Zaharia et al., 2019.

Compared to Çoban and Topcu's study, which found mixed relationships between energy use and economic growth at the EU27 level between 1990 and 2011, the results of the current study on the impact of economic growth on primary energy consumption in the EU28 between 1995 and 2014 only point to linear relationships of endogenous variable intensification (Çoban and Topçu, 2013). Nonetheless, the results are comparable to this study if we consider the distinct findings of Çoban and Topcu in the cases of the new and old member nations. However, given that the study by Çoban and Topcu related the variables to the number of residents attaining increases in energy usage per person of 0.03–0.04% over a different time, the amount of the change caused by economic growth cannot be compared with that study (Çoban and Topçu, 2013). Furthermore, the findings align with the research conducted by Saidi and Hammami, which highlights the correlation between GDP per capita and rising energy consumption (Saidi and Hammami, 2015).

According to correlations with specialized research, studying aggregates in a variable produces a clear, positive relationship with a high negative impact, increasing consumption as a state develops economically. This is evident in the case of the EU28's economic growth about primary energy consumption (Zaharia et al., 2019).

Researchers worldwide are very interested in the relationship between economic, social, and environmental factors as a holistic system and the consumption of energy (both primary and final). Chinese and Turkish researchers have made significant contributions to this field, and the UN has designated reducing the consumption of non-renewable energy as one of its sustainable development goals. Furthermore, as the impacts of climate change become more apparent, there has been a rise in scholarly publications in this topic in recent years (Zaharia et al., 2019).

1.4 A Deeper Dive: Intensive Exploration

In the upcoming chapter we will be reviewing extensively on how our specified modes of energy and the economic growth is dependent. The studies which are related to the similar topics will be explored and reviewed while keeping in mind to check for key insights and findings from previous works of different researches. We will be exploring how the GDP and energy is related and how this relates to the growth of the country.

CHAPTER TWO – LITERATURE REVIEW II

Introduction

The literature on global renewable energy development has become a vital and vibrant area of study considering the urgent global concerns related to climate change and the necessity of moving towards sustainable energy systems. It is critical to comprehend the many facets of adopting renewable energy as countries work to fulfil climate objectives and lessen their reliance on fossil fuels. The goal of this evaluation of the literature is to thoroughly examine and evaluate the corpus of current research on the growth of renewable energy worldwide. The study will delve into the various aspects of this global shift, including technical developments, legislative frameworks, economic ramifications, and sociological issues that influence the course of renewable energy globally.

Even though the conventional energy sources based on oil, coal and natural gas have proven to be highly effective drivers of economic progress, they have been damaging the environment as well as for the human health. Because of the impacts of oligopoly in production and distribution, they are often cyclical in character. Numerous environmental fronts are putting growing pressure on these conventional fossil fuel-based energy sources, with possibly the most significant one being addressing the greenhouse gas (GHG) reduction objectives of the Kyoto Protocol while considering the usage of coal in the future. It is now evident that, absent drastic carbon sequestration measures, any attempt to keep atmospheric CO_2 levels below even 550 ppm cannot be primarily based on a global economy driven by coal and oil (Cock, 2011).

Renewable energy sources have a higher potential as they can meet more than the world's energy demands in principle.

2.1 Renewable Energy Sources across the world

Sustainable energy can be provided by different renewable energy sources such as biomass, wind, solar, hydropower, and geothermal. With the reduction of costs of solar and wind power systems over the past 30 years, the transition towards renewable energy sources is looking more in favor. Currently, renewable energy sources provide around 15 – 20% of total energy demand in which biomass is the leading source towards this contribution (Antonio, 2011). There has been an increase in the renewable energy share in gross final energy consumption from 8.5% in 2004 to 17.0% in 2016 (Sadorsky, 2011). In Europe, 11 countries had already surpassed their target for 2020 (Anton and Nucu, 2020). Various geographic sources play crucial role in the production of renewable sources. These factors include precipitation levels, forested territories, etc. The targets set by different countries as well as other policies passed on global levels all contribute towards increasing the use of renewable energy and reducing the greenhouse gas emissions throughout the world (Anton and Nucu, 2020). The assumption of unidirectional causation from income to emissions underlies this conventional characterization of an inverted U-shaped relationship between emissions and income. Several studies on the relationship between income and emissions have questioned the assumption of unidirectional causality from income to emissions (Apergis and Payne, 2010). It is anticipated that the percentage of renewable energy sources would rise dramatically (to 30–80% in 2100) (Friðleifsson, 2001). While the "new" renewables only account for roughly 2% of the world's current primary energy usage, hydropower and conventional biomass are already significant contributors to the energy mix, accounting for about 18% of global energy demand. Solar energy, which has the potential to be the biggest single contributor to the "new" renewables, is still not economically competitive with traditional energy sources when it comes to producing electricity. Geothermal, wind, and "modern" biomass energy are all competitive in the market and developing rather quickly (Friðleifsson, 2001). As of today, renewable energy sources provide 14% of the world’s total demand (Panwar, Kaushik and Kothari, 2011). Dependency on non-renewable energy sources has decreased recently because of growing environmental consciousness and an emphasis on energy production from renewable sources, which resulted in increased renewable energy generation in both developed and developing countries in the recent years.

2.1.1 Solar Energy

"More energy from the sun falls on the earth in one hour than is used by everyone in the world in one year," claims the National Renewable Energy Laboratory (Solar Energy Basics, no date). We now use the sun's beams for a variety of purposes, including powering gadgets, heating buildings and houses, and warming water (Renewable Energy: The Clean Facts, 2022). Distributed solar systems use rooftop panels or neighborhood-wide community initiatives to provide electricity locally for homes and businesses. Solar farms, which use mirrors to focus sunlight over acres of solar cells, may produce enough electricity to power thousands of homes.

The installed capacity of power production from solar energy has raised from 130 MW to 110 GW in the 20th century (Madsen and Hansen, 2019). There has been an average growth rate of around 50% per year from 2006 to 2016 and a growth rate of 37% in 2017 (Madsen and Hansen, 2019). Early indications of a slowed global solar power growth rate were recently highlighted (Hansen, Narbel and Aksnes, 2017). At the regional level, this image becomes more evident since, for example, the start-up durations of large-scale deployment in Asia and Europe differ by several years. Since 2015, China's growth rate has increased significantly—an average of 66% annually—while in some European nations, the growth rate peaked between 2010 and 2012 (Höök et al., 2011). There exists a logistic growth pattern with national saturation levels proportional to the GDP for the three leading countries, which produces two thirds of the European solar power (Höök et al., 2011). Of all the renewable energy sources, solar thermal power has the most potential, but its commercial growth has lagged since the 1980s due to market opposition to big plant capacities and inadequate financial and political backing from incentive programs. Nonetheless, fundamental technology and market strategy are now developing quickly, and innovative approaches seem to have a very bright future ahead of them (Mills, 2004).

2.1.2 Wind Energy

Over the past few years, there has been significant evolution in onshore as well as offshore technologies for generation of wind electricity so that the production can be maximized (United Nations, no date). It is one of the most common renewable sources of energy. The yearly market was 52.6 GW in 2017, a little decline from the 54 GW in 2016. In 2017, China installed 37 percent of the world's new capacity (2016: 43%), with the EU at 30 percent (2016: 23%), the US at 13 percent (2016: 15%), and India at 8 percent (2016: 6%) (see Fig.2.1) (Lacal-Arántegui, 2019b).

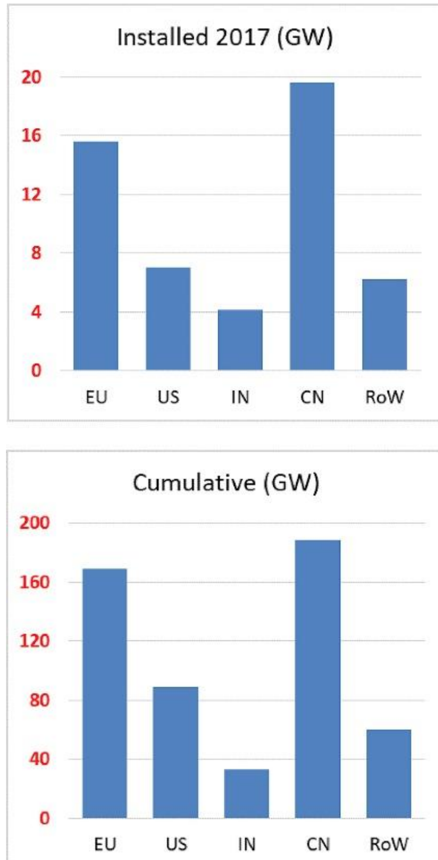

Fig 2.1 World wind energy deployment (or market) in gigawatts (GW) of installed capacity, both new installations in 2017 and cumulative at the end of that year (The Palgrave Handbook of International Energy Economics, 2022).

Asia has been dominating the global wind energy market since 2014, when they overtook Europe. Asia currently has 41% of the installed capacity. In the early 2000s, Europe accounted for around 75% of the global capacity (Eicke, Eicke and Häfner, 2022).

Since wind energy makes up a small percentage of the world's electricity supply, realizing all the benefits of wind energy depends on how feasible it is to switch the electricity sector from using other energy sources—particularly nuclear and fossil fuels—to wind energy. For example, about 16.9 petawatt-hours, or 63% of global electric power produced in 2019, came from fossil fuel sources, whereas 2.8 petawatt-hours, or 10% of global electric power produced in 2019, came from nuclear energy. Wind energy produced just 1.4 petawatt-hours, or 5% of the total electric power (British Petroleum, 2020).

2.1.3 Hydro Power

Hydroelectricity plays a crucial role in the agricultural sector and hence its relation with GDP is undeniable. Hydropower is the second most sustainable renewable energy after wind energy. It has many advantages as well as some drawbacks for the people as well as the environment. It also has the highest energy conversion efficiencies about 90% (Scherer and Pfister, 2016). There has been results of long run bidirectional causality between hydroelectricity consumption and economic growth in Argentina and Venezuela (Solarin and Öztürk, 2015). There exists a unidirectional causality running from GDP to hydropower energy consumption for Germany and a unidirectional causality running from hydropower energy consumption to GDP for Austria (Bildirici and Kayikçi, 2012). Economic expansion and hydropower energy use go hand in hand; rising energy consumption encourages rising economic growth and vice versa (Bildirici, 2016). Hydropower has been demonstrated to be the main domestic electricity source in several countries, including Canada (60%), Brazil (84%), Switzerland (55%), Iceland (80%), and Norway (98%). Regrettably, the world's hydropower potential is not evenly dispersed (Darmawi et al., 2013). Other vital water services like irrigation, flood control, and drinking water supply are frequently supported by hydropower. It makes it easier for everyone to fairly share a crucial resource.

2.1.4 Biofuel Energy

The reserves which are being used currently for petroleum reserves are limited reserves. As per various studies conducted, it has been estimated that the oil production would be at a global peak between 1996 and 2035 (Demirbaş, 2008). Biomass resources may be used to create a wide range of fuels, including gaseous fuels like hydrogen and methane and liquid fuels like ethanol, methanol, biodiesel, and Fischer-Tropsch diesel. The developing as well as industrialized countries consider biofuel as relevant technologies due to several reasons. These include energy security reasons, environmental concerns, foreign exchange savings, and socioeconomic issues related to the rural sector.

Carbon emissions play a crucial role in the increased demand for biofuel renewable energy globally. Jiand Zhang for China, Olanrewaju et al. for Africa, Sadorsky for the G7 nations, Jaforullah and King for the United States, Papiez et al. for the European nations, da Silva et al. for Sub-Saharan Africa, and Gozgor et al. for OECD demonstrates that carbon emissions and renewable energy have a positive correlation (Subramaniam and Masron, 2021b). Countries can improve the demand for renewable energies by rising technology, increasing the energy sources productivity and by lowering the energy costs by means of Economic Globalization. Demand for renewable energy is impacted by economic globalization through trade openness, FDI inflows, and technological advancements. There exists a positive correlation between biofuel consumption and agricultural production as well as a positive correlation between biofuel production and income (Subramaniam and Masron, 2021b). Countries which have a higher degree of economic globalization has the capacity to promote more utilization and production of biofuels. This shows that by promoting the development of biofuels, economic globalization will aid in preventing harmful environmental effects that stem mostly from the use of fossil fuels as an energy source (Subramaniam and Masron, 2021b).

With the increase in production and consumption of biofuel renewable energy, there is an increase in the GDP as well as more Agricultural Production and Economic Globalization with reduced Carbon Emission as can be seen from the graphs below.

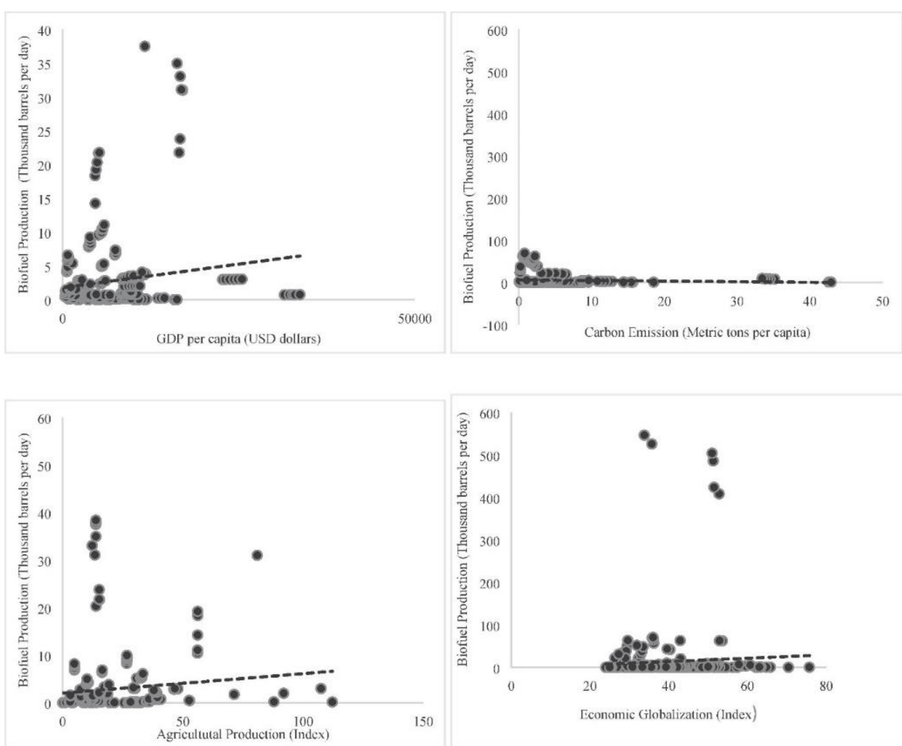

Fig 2.3 The relationship between biofuel and different independent variables, (Subramaniam and Masron, 2021b

2.1.5 Geothermal Energy

Natural steam and hot water, which is used to produce geothermal energy has been exploited for decades. They have been in use to generate electricity as well as for space heating and industrial processes. In 2000, geothermal energy generated 49.3 billion kWh annually, or 0.3% of the world's total electrical energy of 15,342 billion kWh. The installed capacity of geothermal energy worldwide was 7974 MWe (Barbier, 2002). Geothermal energy has the potential to play an important role in total energy production in the developing countries: In the Philippines, geothermal steam provides 21% of power; in El Salvador, 20%; in Nicaragua, 17%; in Costa Rica, 10%; and in Kenya, 8%. The efficiency of electricity production ranges from 10% to 17%. There was evidence of a one-way causal relationship between geothermal energy use and foreign direct investment, as well as a one-way relationship between economic growth and geothermal energy. However, in the situations of Portugal and Mexico, the link between geothermal energy use and foreign direct investment is one-way. For Mexico and Italy, there was evidence of a unidirectional causal relationship between economic development and the use of geothermal energy. In addition, Germany, Japan, and the USA all showed a direct relationship between economic development and geothermal energy usage (Zeren et al., 2023).

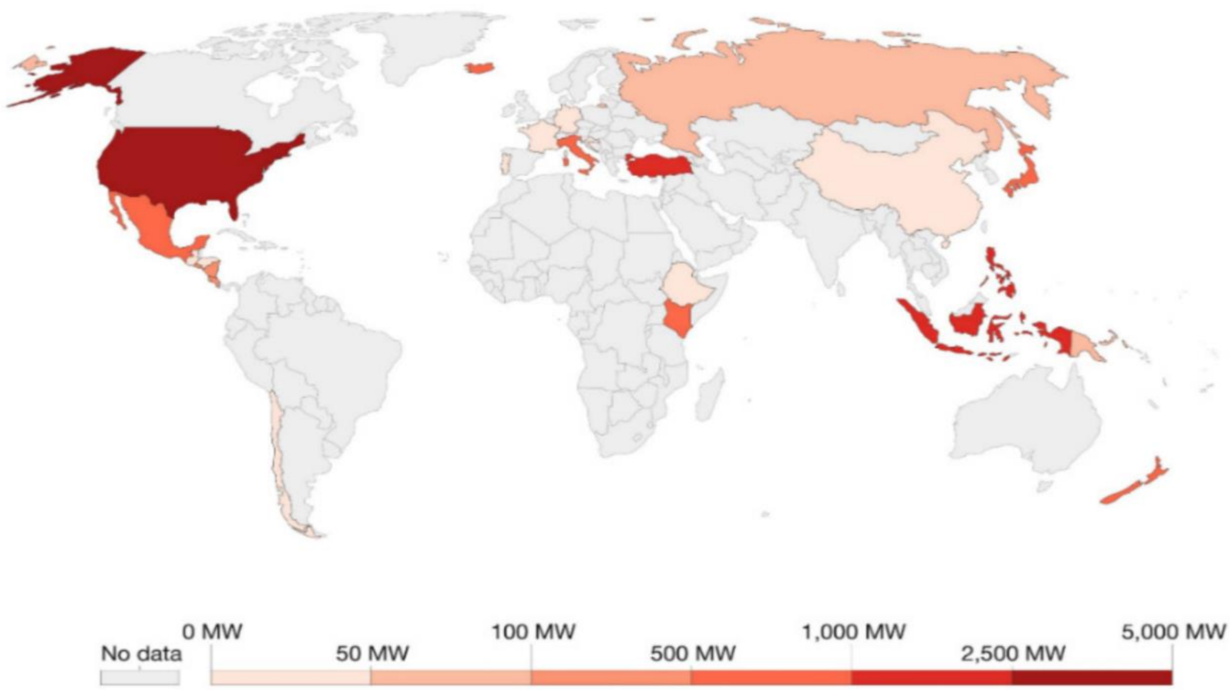

Fig 2.4 Geothermal energy capacity in 2020, Zeren et al., 2023.

2.2 Challenges and Barriers

As we have already stated that most of the expansion in the renewable energy has been taking place in solar and wind in the past few decades. The Distribution Network (DN) has evolved from a radial network to a mesh network because of the emergence of renewable energy resources (Sunderland et al., 2016). As a result, the network now contains several Distribution Generators (DG) and is more complicated. Because of its complexity, studying distribution power flow has become a difficult undertaking (Ghasemi et al., 2016). It is difficult to trace the distribution power flow, and it is even more difficult to price it. In the 21st century, the addition of Renewable Energy Resources (RES) to the DN paved the way for the development of Smart Grids and Micro Grids (Degefa et al., 2014).

The lack of sound policies as well as high costs are some of the main barriers for the developing countries (Kochtcheeva, 2020). Start-up costs, the absence of strategies to equalize the price differences between fossil fuels and renewables, and general structural barriers like the energy industry's centralization hinder the adoption and execution of new projects, discourage investment in renewables, and thwart more localized methods of obtaining energy. Notably, inequality is a problem with the deployment of renewables. The issue lies in the unequal pace of technological dissemination, financial availability, and policy execution both inside and between national borders. Furthermore, even while renewable energy is now one of the energy sources with the greatest rate of development in the world, expanding about 2.5% annually (REN21, 2014), it has not been able to keep up with the effects of the rapidly rising global energy demand.

2.3 Gross Domestic Product

The Genuine Progress Indicator (GPI) estimates that economic wellbeing has declined since 1978, even though the global Gross Domestic Product (GDP) has expanded by more than three times since 1950 (Kubiszewski et al., 2013).

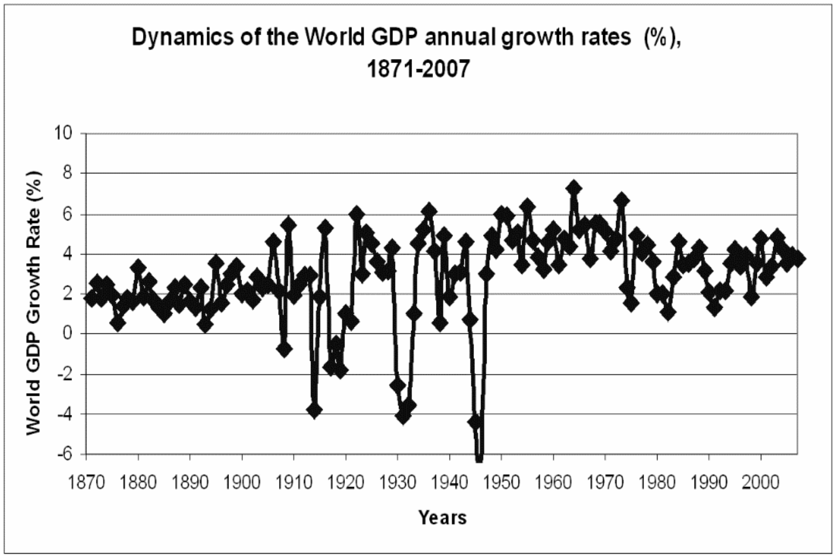

Fig 2.5 Dynamics of the World GDP Annual Growth Rates (%), 1871-2007, Kubiszewski et al., 2013.

On the one hand, the world GDP annual rates of change throughout these decades have been the lowest (for the years 1871–2007). However, the global GDP annual growth rates during the booms of the mid-20s and mid-30s reached record highs; they were only surpassed during the K-wave 4 Phase A, which occurred in the 1950s and 1960s, and they were typically greater than during the pre-World War 1 and current [1990s and 2000s] upswings. Naturally, this makes it more difficult to identify the long-wave pattern during the years 1914–1946 (Korotayev and Tsirel, 2010).

In low- and middle-income nations, the rise in energy demand has closely tracked the growth in per capita income, but high-income economies may maintain GDP growth with little to no increase in energy consumption.

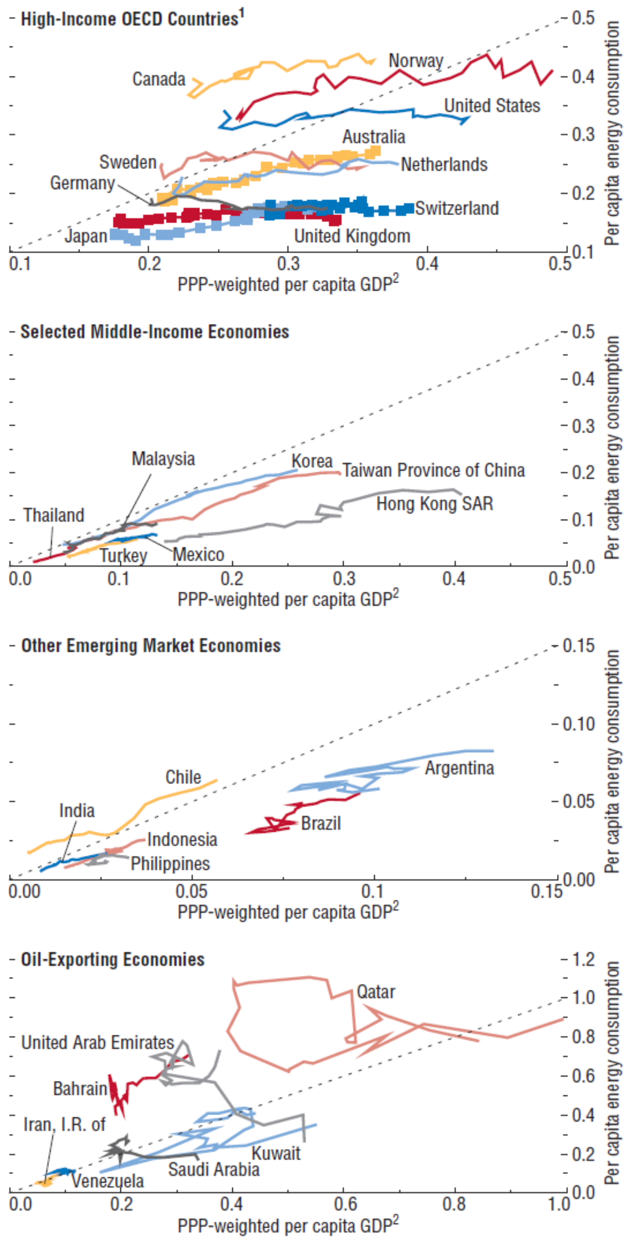

Fig 2.6 Relationship between per Capita Energy Consumption and GDP Growth, Yang, 2000.

A bi-directional causality between GDP and aggregate energy consumption has been found in Taiwan (Yang, 2000). When energy sources are broken down, there is a unidirectional causal relationship between GDP and natural gas and oil consumption, but a bidirectional causal relationship between GDP and coal, GDP and electricity consumption, and GDP and overall energy consumption (Tiwari, 2011). Waste had the biggest initial influence in 2004, followed by oil; nevertheless, over a three-year period, waste, oil, and hydropower collectively accounted a greater portion of the GDP variance among energy sources (Sari and Soytas, 2004). Additionally, there is no causal relationship between oil and real GDP, but there is a unidirectional Granger causal relationship between coal, coke, electricity, and total energy use and real GDP (Wolde-Rufael, 2004). There are arguments that bioenergy should contribute to the macroeconomic efficiency of economies by generating jobs and other benefits. Additionally, RES has been shown to positively impact economic growth by mitigating the adverse effects of oil price volatility, whether through energy supply security or some other means (Domac et al., 2005). The impact of shocks resulting from the use of non-renewable energy sources (NRES) such as coal, gas, and oil on production variation was greater than that of shocks resulting from the use of RES (Ewing et al., 2007). Effects of RES on GDP using Structural Equation Modeling (SEM) for 116 economies in 2003 (Chien and Hu, 2008). It was determined that while RES did not improve the trade balance and had no import substitution impact, it did have a positive indirect effect on GDP through an increase in capital creation.

2.4 Transition to Empirical Analysis

With all the above-mentioned literature review consisting of researches conducted by various people around the world, we try to analyze the data that we must find more evidence as well as to try to find any discrepancies in any previous research conducted by others. We have discussed the results obtained by previous researchers regarding how renewable energy has evolved as well as how this growth in consumption and production has affected the economy of various countries. We have also learned and reviewed how GDP of a country relates to the growth and economic wellness of the country. With the analysis we aim to bridge several gaps that exists between the previous researches as well as try to visualize how the energy curve has changed over time. By completing this analysis, we aim to contribute substantively to the ongoing global importance of renewable energy and its economic implications. By making this shift, we set out on a voyage from the theoretical foundation to the empirical investigation, deepening our comprehension of the intricate processes at the nexus of GDP and renewable energy.

2.5 Existing gaps and intentions.

Current scenario of the research as mentioned has a very large scope on a theoretical basis. There has been more interest on the topic during the last decade and the interest has been growing globally. With the help of the research, there is intention to strengthen and support other researchers with their findings in producing a positive result about the relation between economic factors and energy production/consumption. We also intend to explore the energy trends globally to understand the shift towards the renewable energy sector, with intention to understanding how the transition is taking place, the pace, and observing other interesting trends.

CHAPTER THREE – METHODOLOGY

As we have stated that our primary target for our research is to find how the renewable energy consumption and production has been changing for the past 50 years as well as how this growth relates to the country's economic stature. We will be trying to justify the presence of a causal relation between both energy and GDP of countries.

The research that we are carrying out will be both qualitative as well as quantitative during different analysis stages. We will be carrying out quantitative analysis during the first part of the research. During this stage we will find out the metrics involved with the production and consumption of energy on the global basis and try to visualize the changes that occurred during the research period. We will try to calculate what percent of each kind of energy was produced from different parts of the world. With this new quantitative data in our hand, we will be finding out how GDP of these nations as well as for other nations where less energy is produced or consumed has played a role in this sector. This will be done with the help of correlation metrics. The correlation metrics will provide us with a more in-depth view of our analysis, which can be then used for our second part of the analysis.

In the second part, we will be justifying our hypothesis that GDP has a causal relationship with GDP growth with graphs and tables which can support our findings. This will help in qualitative research as we will be able to qualitatively justify our statement.

There has been no reference to current papers which have made use of the following papers to analyze and research on the topic that we are exploring. On a much wider scale, the current datasets that we are using to correlate the topic has not been found to have been used for previous papers for similar studies.

3.1 Data Collection

For the specific research, we have collected datasets which are publicly available in the open repository of Kaggle. The data provides energy consumption and growth of 35 countries including global as well as continental data (Renewable Energy world Wide : 1965~2022, 2023b). Since the data has been obtained from a public repository, there are issues in the genuineness of the data.

We will be working under the assumption that the data we have is exact up to the date that we have. Similarly, the data for the economic stature of different countries has been collected from another public website, data world bank. The above-mentioned issues with data integrity exists for the same as well.

The data is available at the following sites:

Renewable Energy complete data: https://www.kaggle.com/datasets/belayethossainds/renewable-energy-world-wide-19652022

GDP data: https://data.worldbank.org/indicator/NY.GDP.MKTP.KD.ZG

These data have been structured primarily before we start the analysis (World Bank Open Data, no date c). We will be manipulating the dataset as well as extracting and only keeping the data that we only require for further exploration. This is because, not all the countries that has a GDP value measurement for signifying the country's growth, will be active in the renewable energy sector. The extracted data is then cleaned and sorted in a yearly order so that we will be able to recognize trends for different countries and visualize the growth of the major countries using different graphs. This method will also be implemented for visualizing the growth of these countries GDP values. The data can be merged to form one big csv file, which will be useful for analyzing the various aspects easily.

For the final part, which is the correlation calculation, we will be merging The GDP data of all the countries for which we have extracted from our main dataset, with different datasets containing the values of energy consumption as well as production in accordance to the year by keeping the year and country as keys. This will help us in getting a better view of our data as a whole and help us in carrying out our further analysis.

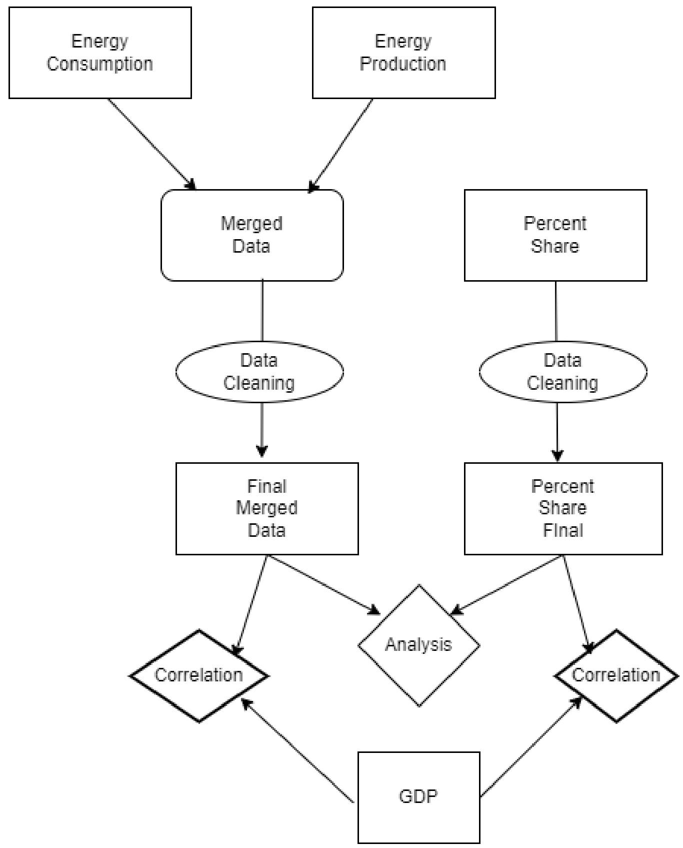

Fig 3.1 Process Flow Chart

Fig 3.1 depicts the complete flow chart of the analysis from the first stage to last stage. This shows how the dataset is being manipulated and how the process flows during the whole research stage.

3.2 How and Why?

For this research, we will be using R Studio for analyzing and visualizing the required tasks. The R programming language, which is intended primarily for statistical computation and data analysis, forms the foundation of R Studio. The language is flexible for a broad variety of statistical and data processing demands because to its rich ecosystem of packages designed for different purposes.

R provides strong capabilities for organizing and cleaning data with packages like dplyr and tidyr. These packages offer a standardized and effective vocabulary for operations including sorting, filtering, reshaping, and managing incomplete data.

R offers a wide range of functions and packages for statistical analysis, enabling researchers to do sophisticated multivariate studies in addition to simple descriptive statistics. Because of its adaptability, researchers from a variety of areas can use it.

R Studio shines when it comes to data visualization thanks to the ggplot2 package. Researchers may tweak and refine visual representations of their data with this package's robust mechanism for producing static and dynamic visualizations. Furthermore, tools like plotly and shine offer interactive visualizations.

Reproducible workflows are encouraged by R Studio. Researchers can increase openness and facilitate the replication of their findings by using scripts to record and distribute their code.

A further benefit is R Studio's incorporation with R Markdown. Scholars may easily include R code, findings, and graphics into papers, making it easier to create dynamic, repeatable reports or manuscripts that incorporate both narrative and code.

There are many of resources available, including tutorials, forums, and online help, thanks to the sizable and vibrant R community. The R ecosystem is constantly being developed and enhanced by the community, as seen by the frequent contributions of new packages and tools.

3.3 Calculations

In our study, there are a lot of calculations included of which correlation test is one of the main calculations. In the first part of our analysis, we will be trying to understand how the countries have changed the production and consumption over the years and will try to find the percentage change and overall growth in various sectors. We will also be trying to understand the total values of energy produced and consumed by these countries and order and visualize them using graphs and charts. This can in turn help us in understanding how different sectors have grown. Also, as our data provides us information regarding the same with respect to continents, we cam use this to enhance our analysis to find more about the growth on a continental basis.

For the last part of our analysis, we will correlate both the datasets using yearly data for GDP and the corresponding energy production and consumption using various sources. We will be using the basic correlation test using the built-in correlation function available with R. This function carries out Pearson correlation test on two variables. For achieving the same, we will be using merged datasets which contains all the yearly data of different countries which we need to correlate.

The Pearson Correlation test is carried out by the below formula

$$r = \frac{\sum(x - m_x)(y - m_y)}{\sqrt{\sum(x - m_x)^2 \sum(y - m_y)^2}}$$

Equation 3.1 Pearson Correlation coefficient

m_x and m_y are the means of x and y variables.

The test statistic that quantifies the statistical link, or association, between two continuous variables is called Pearson's correlation coefficient. Because it is based on the concept of covariance, it is regarded as the best way to measure the relationship between variables of interest. It provides details on the direction of the link as well as the strength of the association, or correlation.

We will be carrying out this test intensively on different sources of energy for every ranked country and try find if there exists a unidirectional or a bidirectional causality for the test cases.

The results obtained with this test will be used for further examination of our hypothesis. We will be creating graphs to visualize our findings and to show the relationship between the two sectors.

While there are other correlation tests such as Spearman Rank, Kendall Tau Rank, Point-Biserial etc., we have selected Pearson Correlation test due to the following reasons.

- Pearson correlation is more efficient in measuring linear relationships between variables.
- As Pearson correlation is much more familiar and easier to understand.
- For huge datasets, Pearson correlation calculation is more feasible since it requires less computing power than certain other correlation techniques.
- A perfect negative linear relationship is represented by a Pearson correlation value of -1, a perfect positive linear relationship by a value of 1, and no linear relationship is represented by a value of 0. It is simple to grasp because of its intuitive interpretation and simplicity.

- The normal distribution of the variables is assumed by Pearson correlation. Data often near normality, therefore departures from normalcy may not have a major impact on the outcomes.

3.4 Limitations

There exist few limitations while carrying out the study. We cannot fully consider the data integrity into account as all the data acquired for this research is from public datasets. There might be inaccurate values in our data. Since the accuracy and reliability of our research will depend on the quality of the data, we cannot account for miscalculations or missed out values while conducting the research. Since, the data has been organized in yearly manner, we will not be able to do in depth analysis as changes in renewable energy sector can take in a short time span.

Because various locations have distinct legislative contexts, different resources are available, and different socioeconomic conditions influence the adoption of renewable energy in different ways. Strict attention on global issues might obscure subtle localized tendencies, and the study's capacity to offer in-depth understanding of certain regions might be hampered by data shortages in the regions. It might be difficult to guarantee a homogenous and consistent dataset across several geographic locations. Different approaches to data collecting, different reporting requirements, and different levels of data accessibility may cause biases or restrict the comparability of findings.

In the field of renewable energy, technical innovation is happening quickly. The study could find it difficult to stay up to date with new developments, which could lead to an underrepresentation of cutting-edge trends or technology. It is possible that since not all renewable energy technologies are fully covered by the analysis, the correctness of the interpretation may be impacted by the omission of technology or the shallowness of the investigation of some developments.

Political, economic, and societal factors can cause changes in policies pertaining to renewable energy. Unexpected policy changes throughout the study period may have an impact on the validity of the findings, and the research may have difficulties capturing the complex consequences of changing policies. Policies may not be implemented as effectively even if they seem good on paper due to issues with political will, regulatory ability, and enforcement. The research might not be able to fully capture how policies really affect people on the ground.

Emergencies like natural catastrophes or worldwide pandemics have the potential to cause havoc in the renewable energy industry. It could be difficult for the research to discern between underlying systemic changes and trends impacted by these exogenous shocks. Geopolitical developments that are unpredictable, including trade disputes or hostilities, can have an influence on the world energy scene. It is possible that the study underrepresents the scope of these occurrences or their effects on trends in renewable energy.

3.4 Insights

The practical implications of this research extend beyond a theoretical understanding of global renewable energy development. By providing insights into the growth trajectories of different countries and highlighting areas requiring improvement, the review becomes a valuable tool for policymakers and practitioners worldwide. Countries with robust renewable energy policies and successful implementation strategies can serve as exemplars, offering valuable lessons for others looking to enhance their sustainable energy transition. Conversely, the identification of challenges faced by certain nations becomes a catalyst for knowledge-sharing and collaboration. The review, therefore, acts as a catalyst for international cooperation, allowing countries to learn from both successes and shortcomings. Policymakers can draw upon this knowledge to tailor strategies that align with their unique contexts, fostering a more efficient and effective global transition to renewable energy.

3.5 Chapter Summary

In this chapter, we have made the statement regarding our research on being qualitative and quantitative. We have also discussed how our research will be conducted. The collection and preparation of the data which is being used has been discussed as well as the genuineness of our data. Later we have explained the process flow of our research. We have explained the tools used for the research and what kind of outputs we are expecting. The mathematical aspects of our data have also been explained. This chapter also explains the limitations of our research from different perspectives. This includes the genuineness, political impacts, natural affects, and other external factors that can affect the problem statement.

CHAPTER FOUR – FINDINGS / ANALYSIS / DISCUSSION

Renewable energy and the trends have been a topic of analysis for so long. The economic growth of the countries and how they relate to the energy composition of countries has been another topic of analysis and discussion. The datasets which have been selected for this purpose has been thoroughly studied and analyzed to bring out some major relations and findings into the light. We will be discussing and analyzing the visuals that has been achieved using these plots.

4.1 FINDINGS

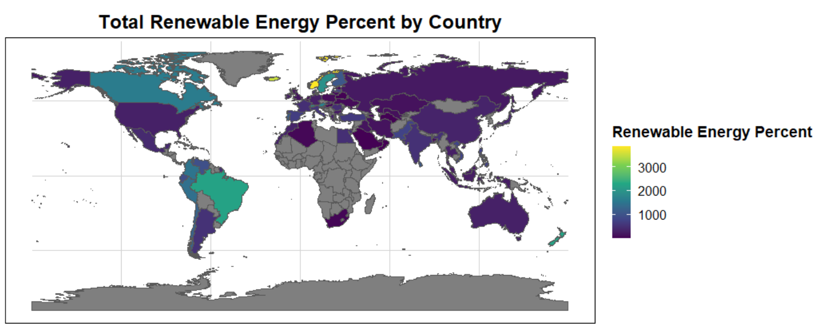

Fig 4.1 Share of total renewable energy share till 2021 global scale.

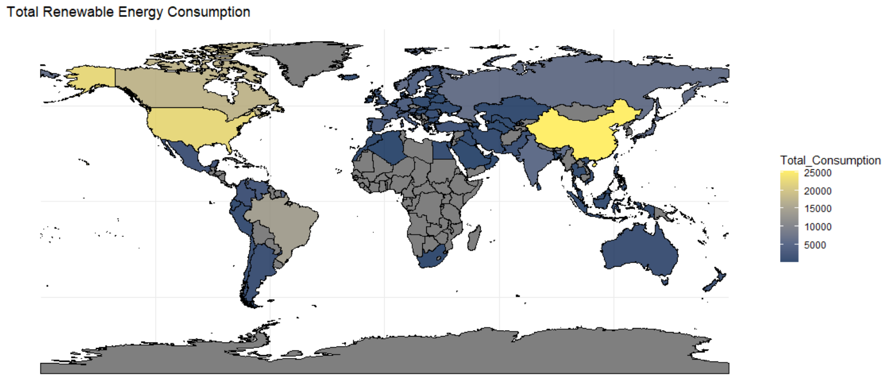

Fig 4.2 Distribution of total renewable energy consumption globally

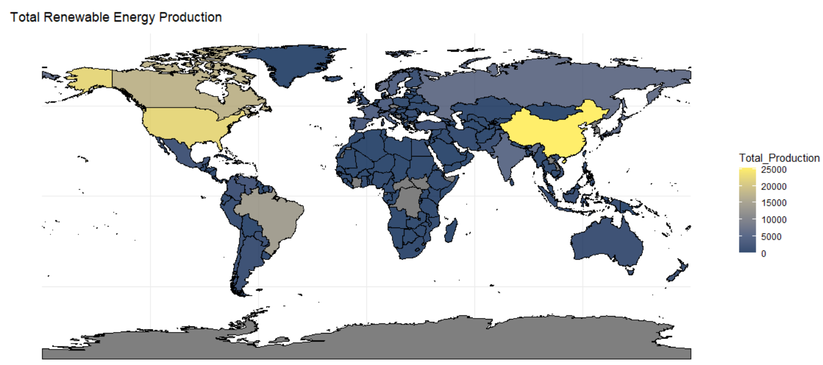

Fig 4.3 Distribution of total renewable energy production globally

Figure 4.1 displays the global renewable energy share percent aggregated and spread out. From the above figure Africa is the country with lowest share in this category. But on further exploration we were able to find out that there are other small factors and group of countries which has contributed to their share when the continent has been taken as a whole. We were able to aggregate those values and the values for the countries in each continent for which we have data for and has arrived at the following table, Table 4.1.

The following figures displays the distribution of how the consumption and production of renewable energy is split globally. In the figures, it is evident that Africa is a continent that has low values when it comes to production compared to other continents. It also depicts the fact that Africa do consume evenly among all its countries split equally.

Entity	Total Renewable energy percent share aggregate
Europe	23629.20697
South America	11713.35854
Asia	8033.62357
Africa	5785.61925
North America	2917.1203

Table 4.1 Continental data of primary energy share over the whole duration

This data includes the share from groups of countries in continents such as the Africa (BP), Eastern Asia, Western Africa and many more. We find that Europe has had the most share in the total renewable energy share for the duration and North America has had the least. When we analyze the country wise data to find the top performing countries listed in table 4.2, we can find that out of the top five, three of them are from Europe. This is in accordance to our findings from the first table.

Entity	Total Renewable energy percent share aggregate
Norway	3877.094
Iceland	3537.631
New Zealand	2252.164
Brazil	2235.130
Sweden	1936.339

Table 4.2 Top 5 countries and their total percent share accumulation

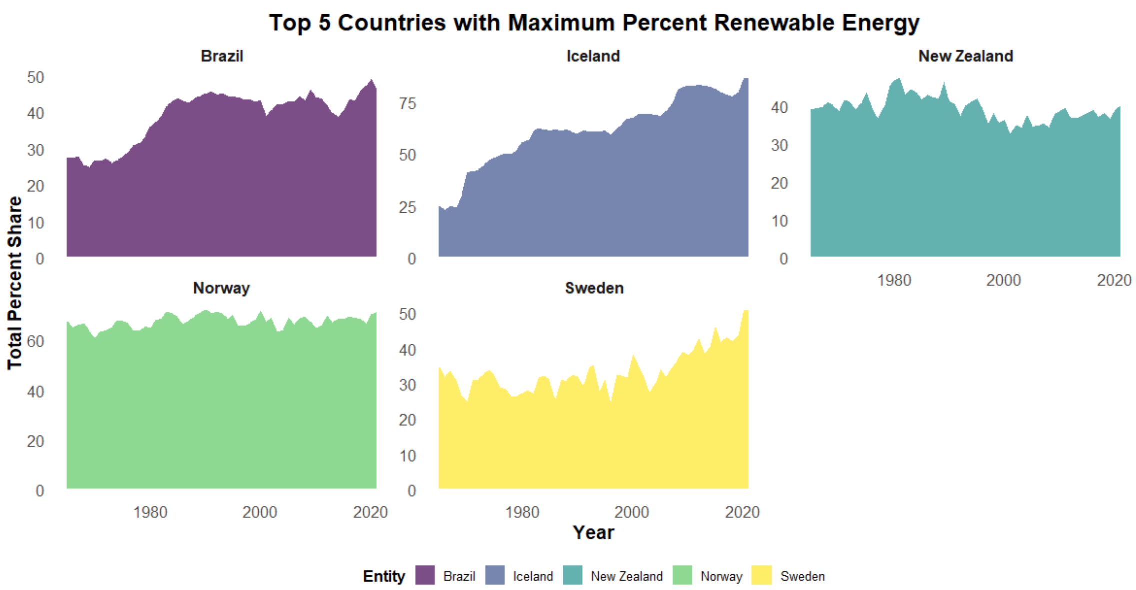

Fig 4.4 The top 5 countries with highest gross percent share in renewable energy

From figure 4.4, it can be found that Norway, Sweden, and Brazil have had not too much of a drastic change in their percent share over the years. On the other hand, Iceland has had a drastic change in their percent growth throughout the time. This is evident as the slope has been growing at a steady pace compared to other countries. We will be taking these findings into account while conducting further analysis later.

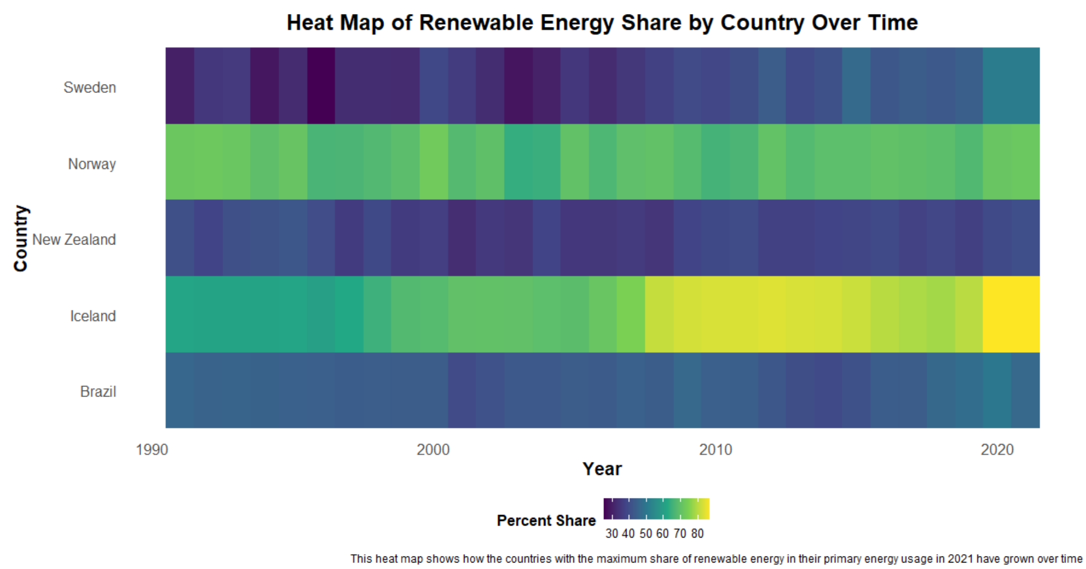

Figure 4.5 Heat map for the top countries

Entity	Total Renewable energy percent share aggregate
Norway	3877.094
Iceland	3537.631
New Zealand	2252.164
Brazil	2235.130
Sweden	1936.34
Qatar	0.74
Oman	0.27

Turkmenistan	0.25
Kuwait	0.18
Saudi Arabia	0.08

Table 4.3 Top 5 and bottom 5 Countries.

Table 4.3 provides us with the difference in the top 5 and bottom 5 countries along with their aggregate of total renewable energy share as primary energy over the years. This table has been created to bring out the contrast between both the ends. This can be accounted to the fact that these countries are among the ones that have high fossil fuel reserves and leading producers and consumers of non-renewable sources of energy. This huge difference can be found to be around 10000 times.

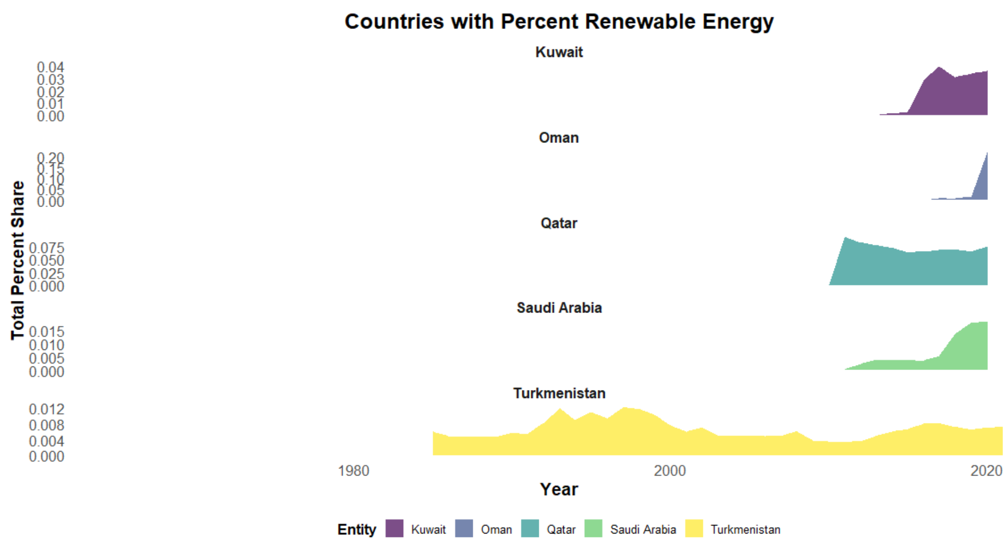

Fig 4.6 The bottom 5 countries percent share in renewable energy

The above figure depicts the growth of the countries in the bottom five places. It can be inferred that all these countries have entered the renewable energy market recently. Also, the percent share is low, which shows that they are not much significant when doing the analysis.

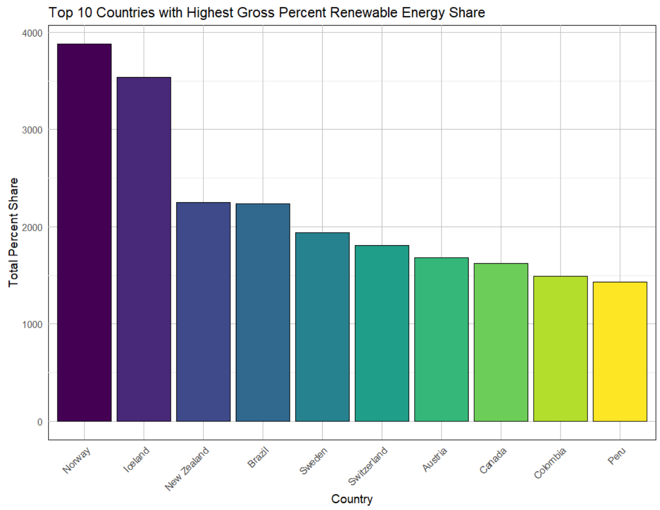

Fig 4.7 Top 10 countries arranged in descending order of their gross percent share in primary energy

After the first four entities in the bar graph, the total is almost a constant from there on. Also, apart from Canada, there is no other North American country. Also, there is no presence of Asian or African countries in the list. We will be discussing the same as to why these countries might have higher contributions later in the discussions part.

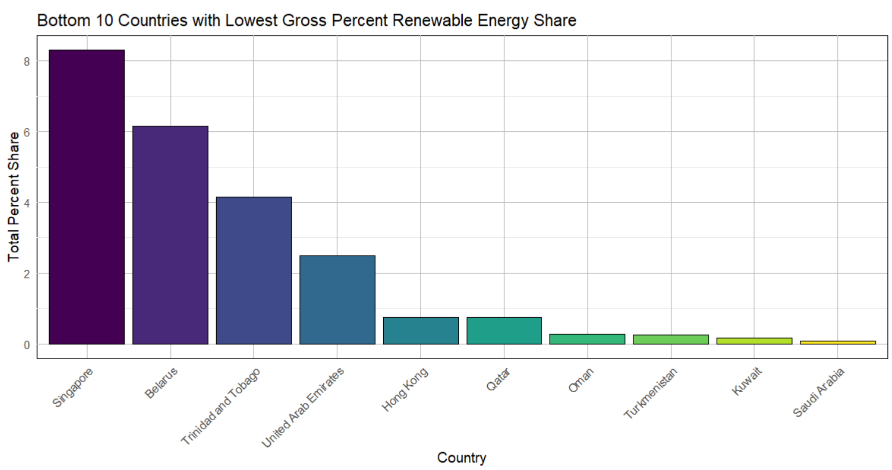

Fig 4.8 Bottom 10 countries arranged in descending order of their gross percent share in primary energy

The figures 4.7 and 4.8 provide us with how the numbers stack up at the top side and bottom side of the data. Norway and Iceland have been found to have a better number statistically in this type of energy share. This is almost double that of any other single country. Followed by New Zealand which is an astonishing finding in our analysis when we take the size of the country into account.

Types of Renewable Energy and their yearly changes

As we have mentioned in earlier chapters, the main types of renewable energy sources which is in use in our world comprises mostly of Solar, Wind, Hydro, Geothermal and other sources. We will be analyzing these in detail in the next steps.

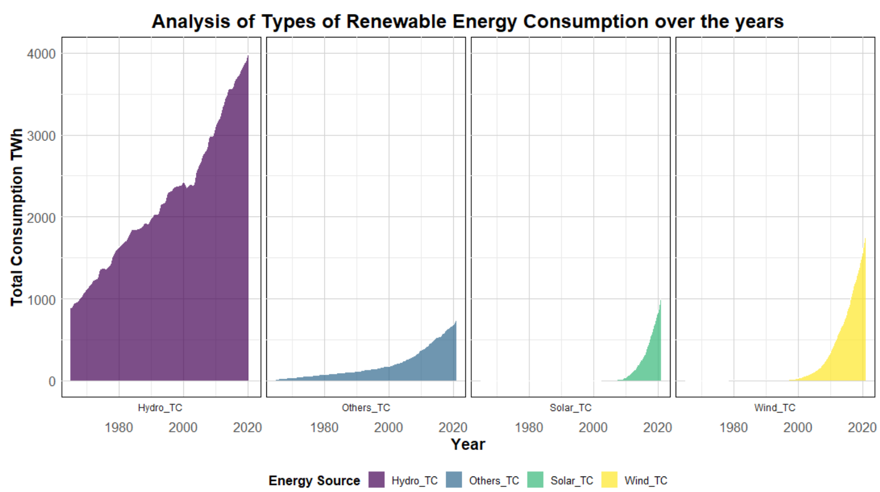

Fig 4.9 Renewable energy consumption split over the years.

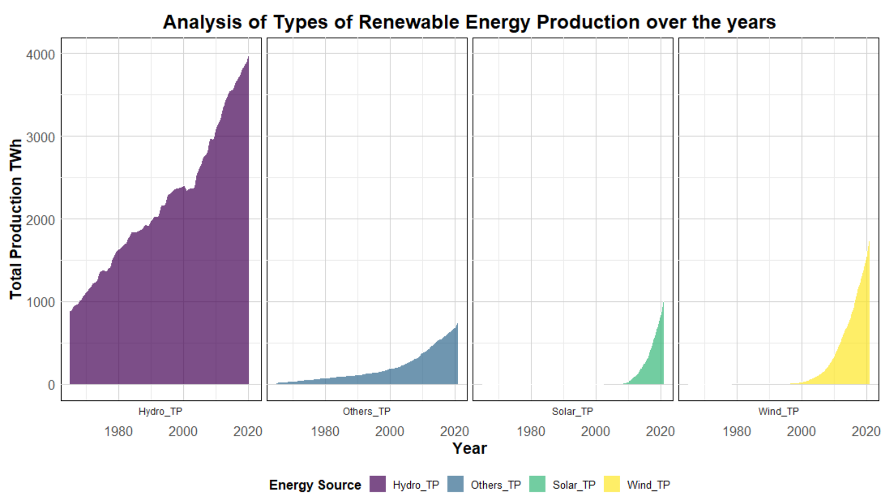

Fig 4.10 Renewable energy production split over the years.

The above area graphs above show us how the renewable energy consumption and production has been divided from the years 1960 till 2020. From the time being, it is evident that, till this day, maximum share has been from hydro energy. This is then followed by Wind, others, and solar energy.

We will be trying to analyze which countries have contributed towards this split.

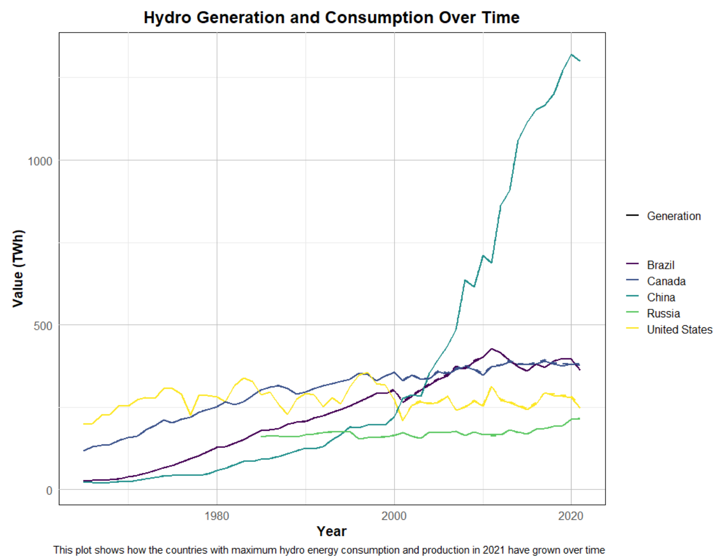

Fig 4.11 Top 5 Countries in Hydro Energy Generation and Consumption

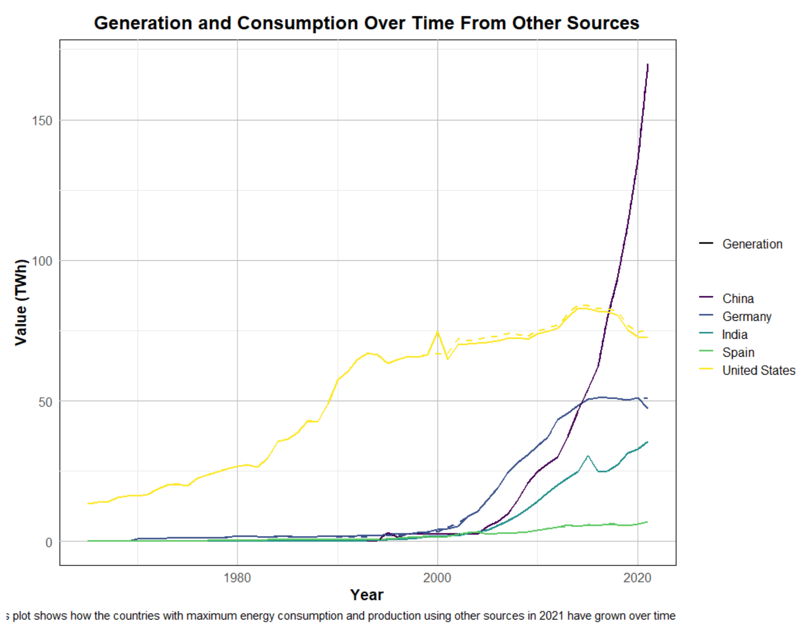

Fig 4.12 Top 5 Countries in Other Energy Generation and Consumption

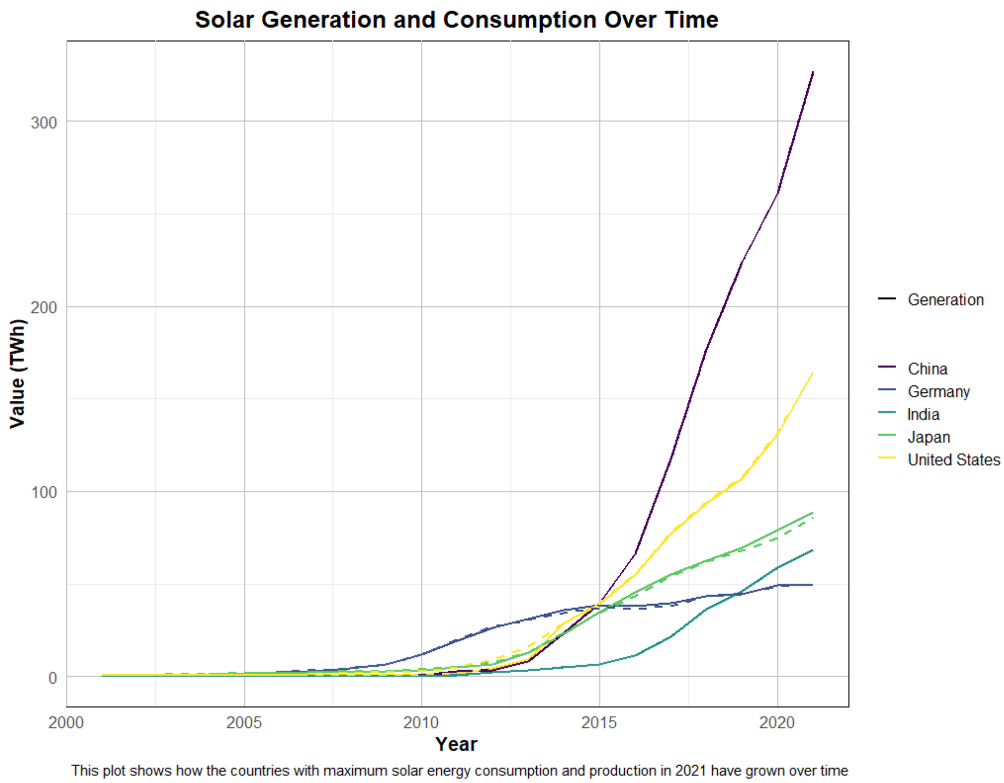

Fig 4.13 Top 5 Countries in Solar Energy Generation and Consumption

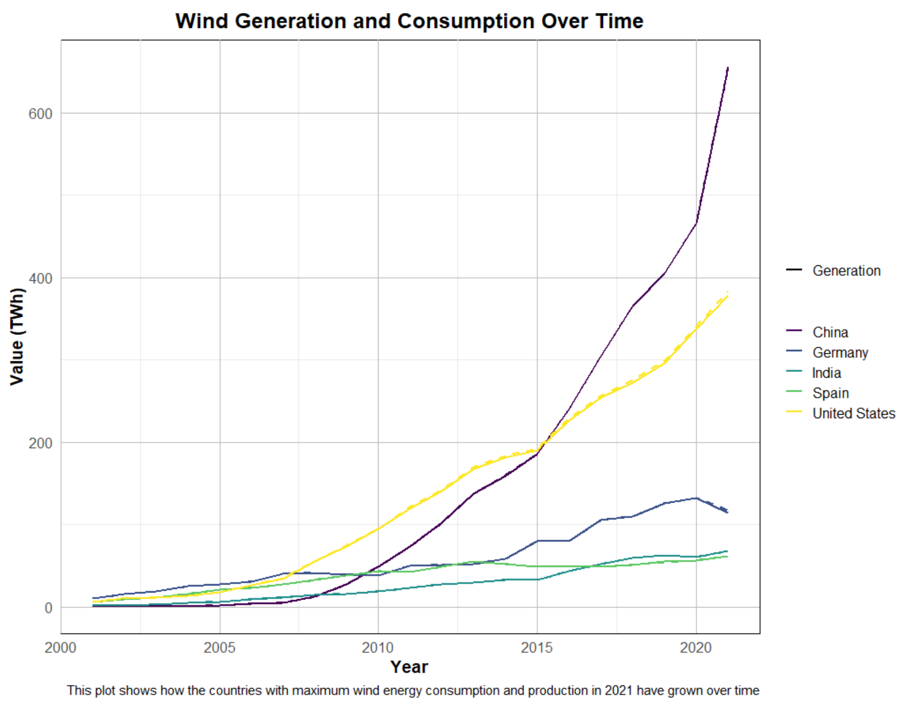

Fig 4.14 Top 5 Countries in Wind Energy Generation and Consumption

In every type of renewable energy, we have found the top five performers and plotted how they have grown over time. As we can see, China is a common country which has thrived in every sector. Also, there is at least one country in each sector which has found a sudden rise in their contribution. Also, there exits countries in each sector that has been active in a steady state throughout this time. We will be analyzing and discussing these same.

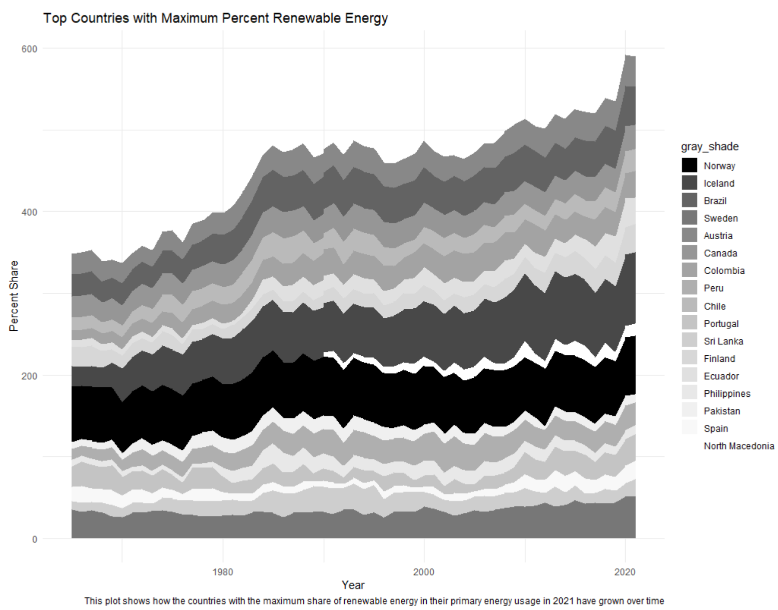

Fig 4.15 Top countries with maximum renewable energy share Area Chart

Fig 4.16 Top Countries with maximum renewable energy share individual analysis

Figure 4.15 displays a stacked area chart that exhibits the distribution of countries renewable energy percent share. The darkest color displays the one that has the maximum share and the lightest color displays the country with the least share in the list of top 10. This list includes only the countries that has more than 10% equivalent share of primary energy from renewable energy over the period of analysis.

These countries have been analyzed individually in the following figure 4.13. Each area graph corresponds to the country's percent share over the years.

Introduction of GDP

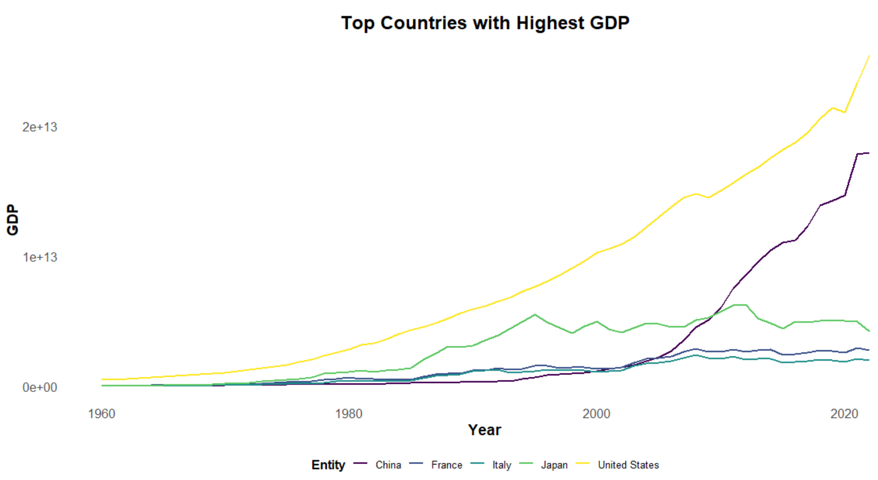

Fig 4.17 Countries with highest GDP aggregates

We want to try to find correlation between the countries GDP and their involvement in the renewable energy sector. Figure 4.17 shows the countries which has had high GDP over the time. The countries are selected based on the highest aggregate GDP scores for the countries. Current GDP statuses might be different as these are not based on current GDP value for each country.

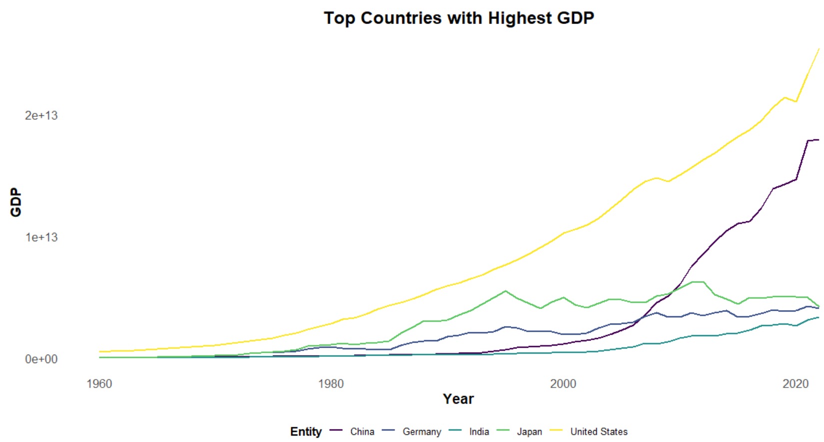

Fig 4.18 Countries with highest GDP as of now

Figure 4.18 displays the countries that has currently the highest GDP and their growth over the analysis period.

We will be analyzing this GDP dataset with our energy share dataset in further steps.

4.2 ANALYSIS

For the analysis, we will be correlating GDP values for the countries taken yearly and the yearly share of renewable energy in the primary energy. For the first part, we will consider the countries that has more than 10 % share of renewable energy in total energy share. This 10% is the aggregate sum over the years.

The countries in the picture are Norway, Iceland, Brazil, Sweden, Austria, Canada, Colombia, Peru, Chile, Portugal, Sri Lanka, Finland, Ecuador, Philippines, Pakistan, Spain, and North Macedonia.

The values for these countries after the correlation is as follows:

Entity	**Correlation**
Iceland	0.86
Austria	0.79
Sweden	0.75
Ecuador	0.73
Finland	0.64
Columbia	0.63
North Macedonia	0.62
Brazil	0.54
Canada	0.34
Peru	0.30
Norway	0.24
Spain	0.20

Philippines	0.07
Portugal	0.06
Chile	0.2

Table 4.4 Correlated values of the countries which has more than 10% aggregate share of renewable energy in total primary energy usage

We can see that there are much diversely scattered points in this table. We will visualize the correlation table using a scatter plot for easier understanding. The scatter plot is displayed in fig 4.19.

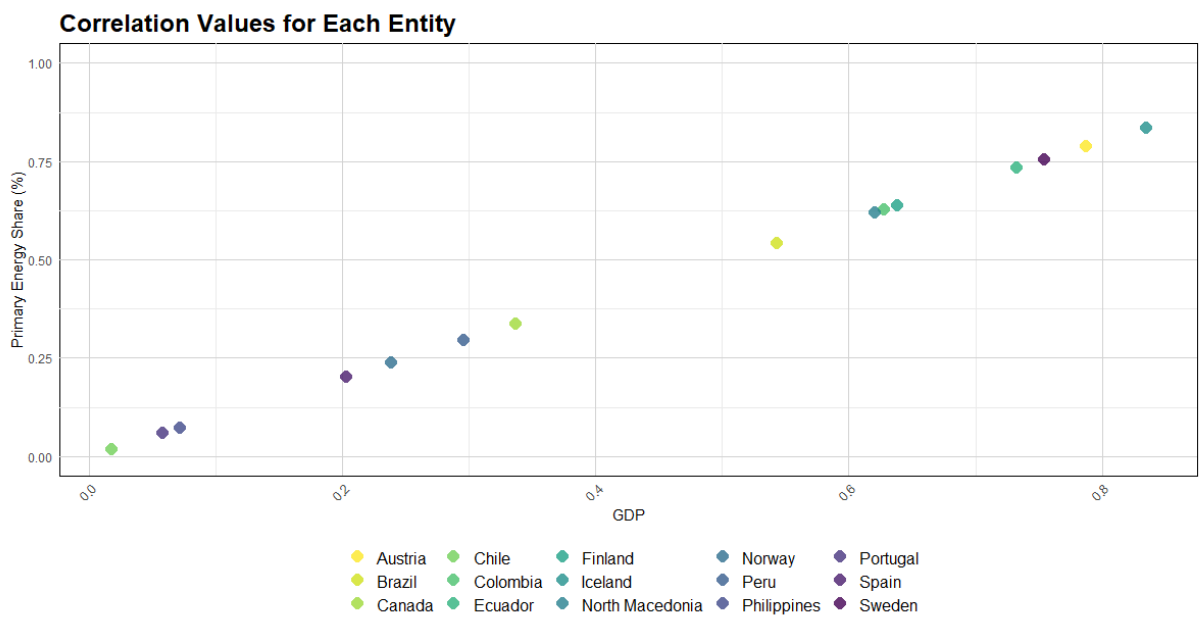

Fig 4.19 Scatter plot displaying the correlation values of the countries with more than 10% share of renewable energy in primary energy.

For the next part of the analysis, we will be finding out the list of countries which has had high change in the initial and final share percentage. This is calculated by taking the difference between the final and the initial percent share of the same and converting this value to percent change with respect to initial value. From these values, we will be filtering out only the ones for which there is a minimum of 50% change between initial and final values.

Table 4.5 lists out the Countries that satisfy this condition and their respective maximum, minimum and growth percentage.

Entity	**Maximum Percent Share**	**Minimum Percent Share**	**Percentage Growth**
Ecuador	36.04	5.35	573.55
Philippines	24.90	4.58	444.14
Spain	22.34	5.01	345.62
Pakistan	18.67	4.31	332.31
Portugal	32.70	7.97	310.54
North Macedonia	19.91	4.90	306.72
Iceland	86.87	23.20	274.46
Sri Lanka	32.77	9.41	248.08
Finland	34.61	11.42	203.20
Peru	36.60	12.18	200.67
Colombia	35.18	11.79	198.46
Chile	32.09	13.26	142.01
Sweden	51.06	25.27	102.09
Brazil	49.47	25.06	97.44
Austria	38.26	19.52	95.97

Table 4.5 Countries with more than 50% Growth in Primary Energy Share

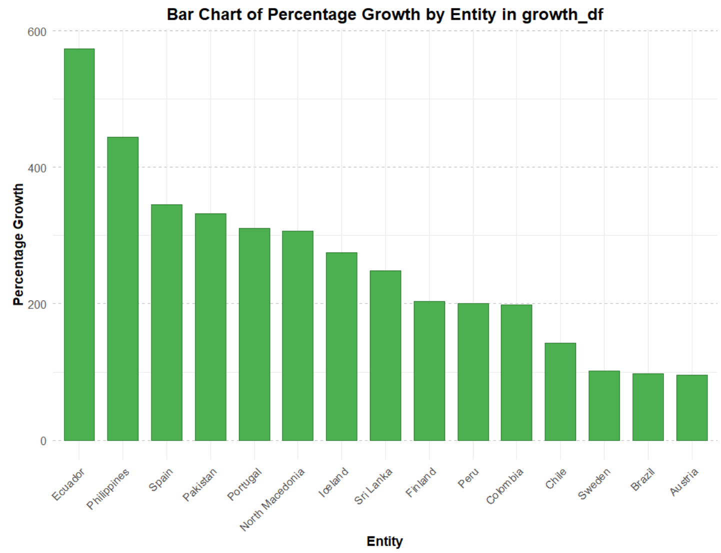

Fig 4.20 Bar Chart showing the percent growth of countries in reverse order

From this table, we can find that there are countries that have high percent change in their initial and final values. We will be trying to correlate the data for these countries and trying to find the correlation value.

We will first try to visualize how these countries stack up with their renewable energy share in primary energy. This will provide us with an overall picture on their distribution.

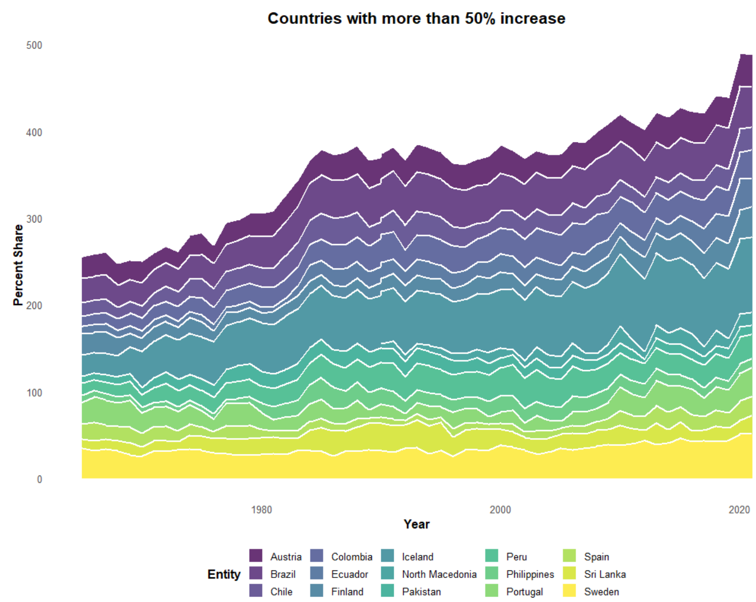

Fig 4.21 Stacked Area Graph to visualize the growth of all these countries

From the graph, we can easily decipher that the country with the highest share in each year has been Iceland among the selected countries, and Spain with the least share as total. We will find if there is high correlation for these countries with GDP.

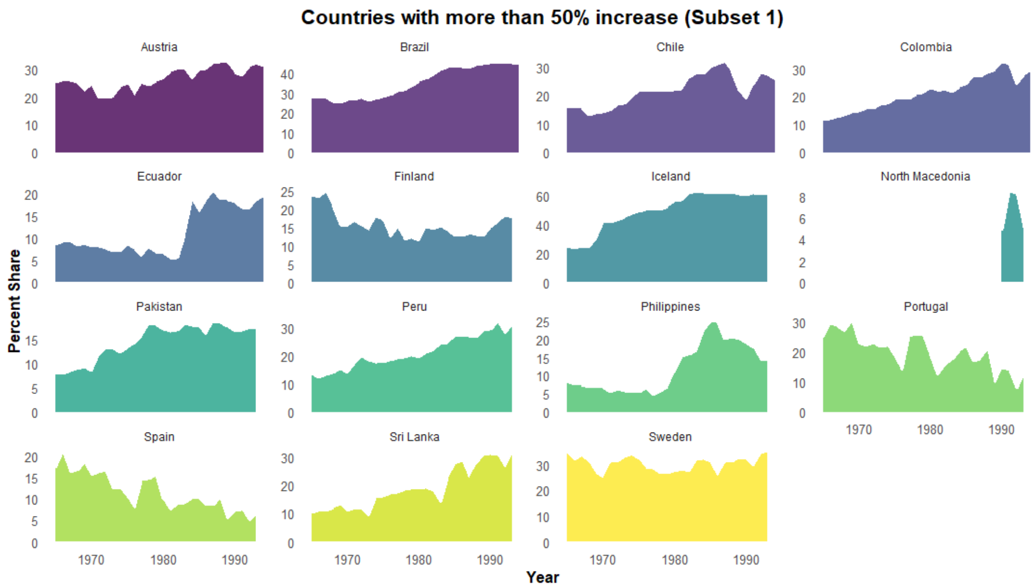

Fig 4.22 Yearly Primary Share Data of countries in the list (Part 1)

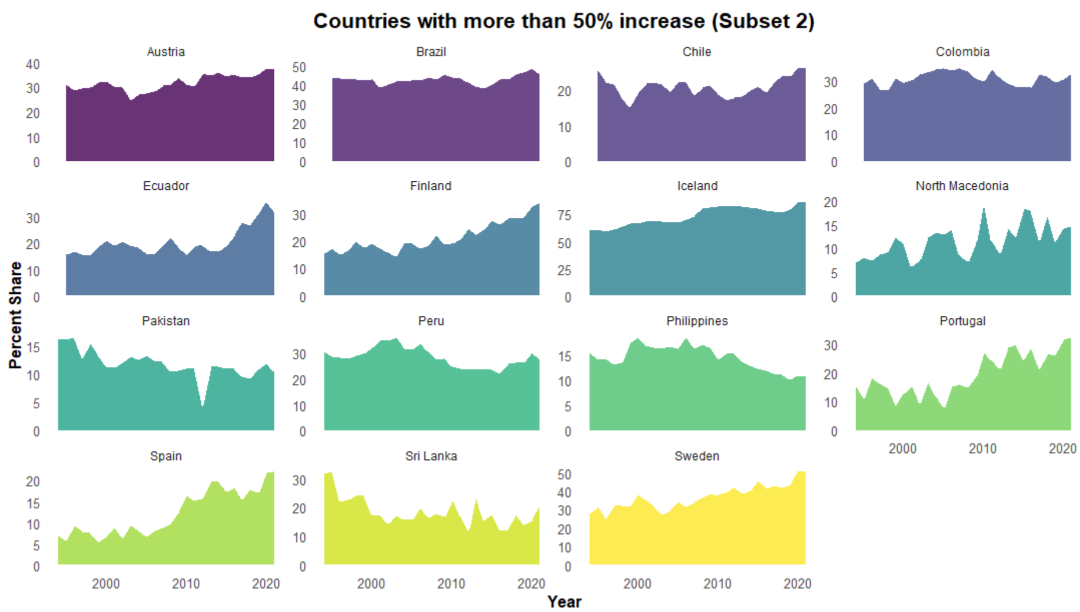

Fig 4.23 Yearly Primary Share Data of countries in the list (Part 2)

The figures 4.22 and 4.23 shows how these countries have changed in their primary share percent throughout the period. This has been split into two for better visualization. We can see that in the plots, there exists countries that have had a roller coaster type of graph, implying that they have gone down in their percent share compared to how much they had. There are multiple dips in the lines of these countries. Of all these, it is seen that Sri Lanka has had a huge decrease in their shares as they were in their 80s and 90s and gradually decreased from there on.

The most correlated countries

For this part, we will be finding the most correlated countries by directly correlating the GDP value with their percent share of renewable energy in primary energy. A filter for correlation above 0.8 will be applied to find the most correlated countries in the whole list. We will then review their distribution, growth and how they relate.

After correlating the whole dataset, there are sixteen entities for which we have achieved a correlation value of more than 0.8. These entities are listed out in Table 4.6.

Entity	Correlation
Qatar	0.98
China	0.97
Hungary	0.91
Poland	0.90
Denmark	0.89
Bulgaria	0.88
Ireland	0.87
Estonia	0.86
Czechia	0.86

Lithuania	0.84
Iceland	0.83
Germany	0.83
Israel	0.82
Luxembourg	0.81
Netherlands	0.80

Table 4.6 Entities with more than 0.8 Correlation.

We find that there is a correlation over each second decimal for one entity under this filtered condition. We can create a scatter plot to visualize this trend. Figure 4.24 displays the same. In the figure, each point represents an entity.

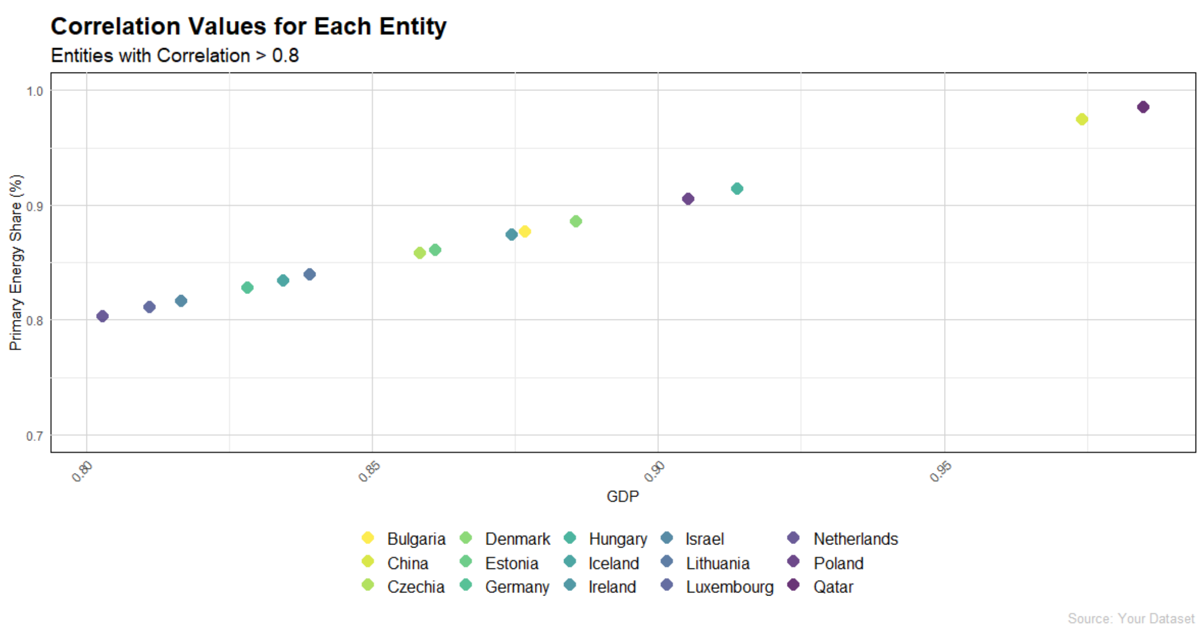

Fig 4.24 Scatter plot for the correlation data for Entities having more than 0.8 correlation.

We will now be exploring how the share of energy has been growing for these countries individually. This will help us to get a more in-depth picture of how these countries have transitioned.

The first graph that we will be plotting will be how their renewable energy share in primary energy have grown over time. These metrices are displayed in figures 4.25 and 4.26.

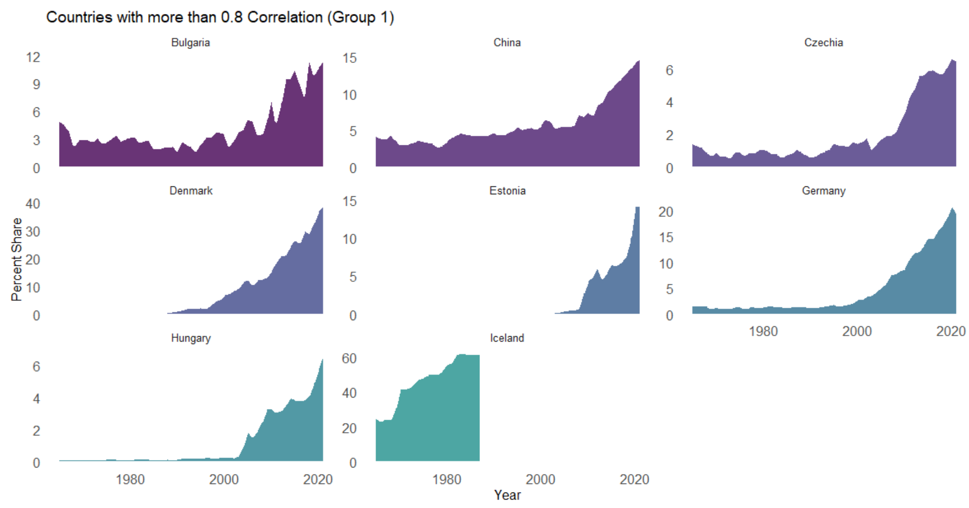

Figure 4.25 Primary Energy Share of countries with more than 0.8 correlation Set 1

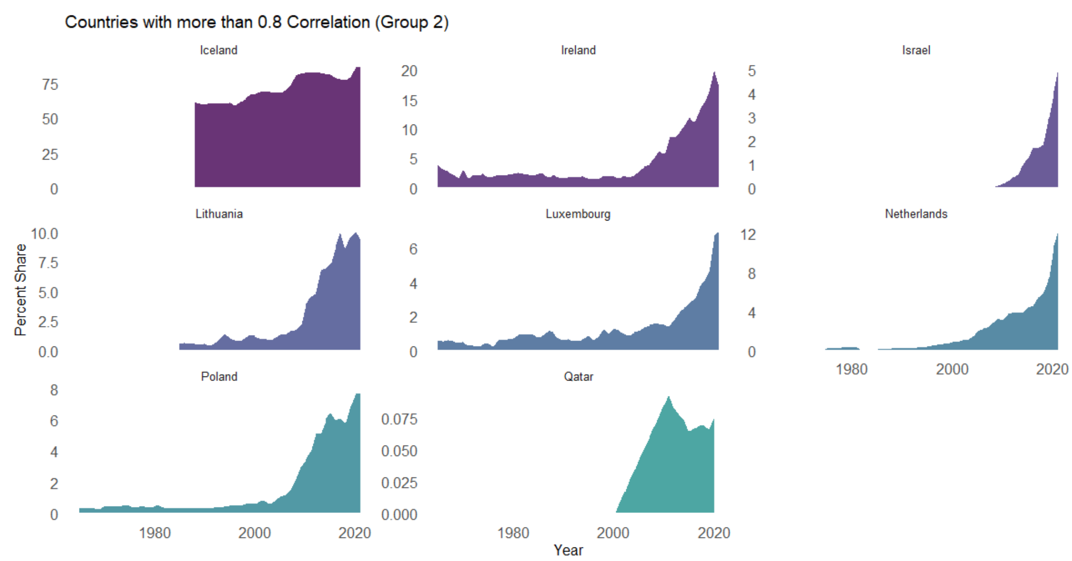

Figure 4.26 Primary Energy Share of countries with more than 0.8 correlation Set 2

Next, we can visualize on what type of energy source does these countries mainly depend on. For this we will be using our other dataset, which contains data regarding type of energy source and their consumption. These visuals can help us in understanding the variance in the type of energy each country is involved in more.

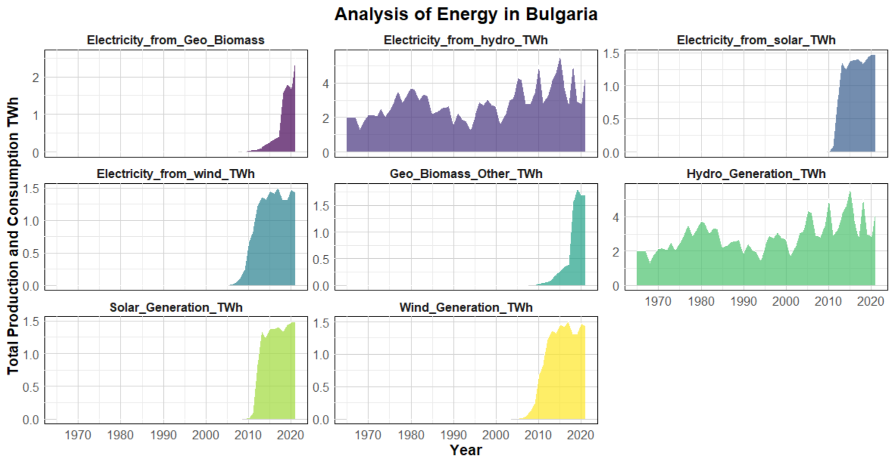

Figure 4.27 Energy Analysis of Bulgaria

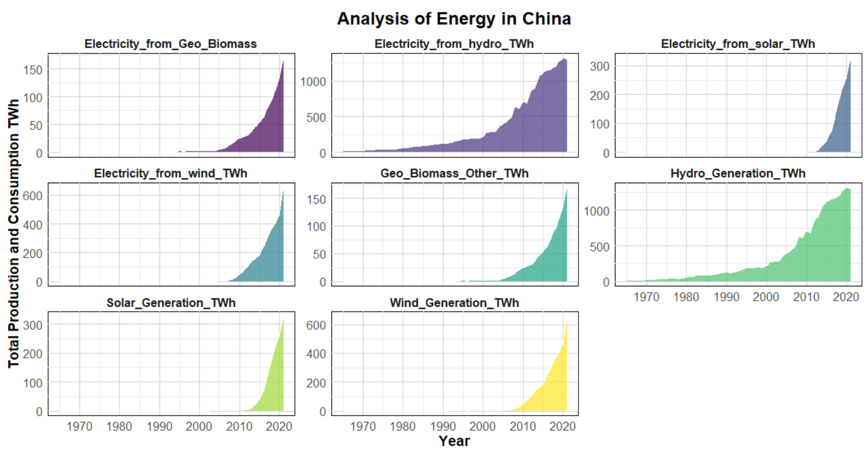

Figure 4.28 Energy Analysis of China

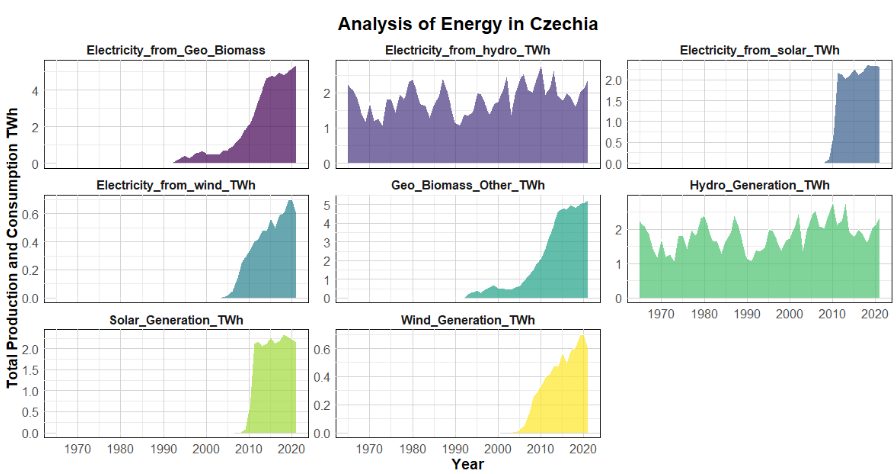

Figure 4.29 Energy Analysis of Czechia

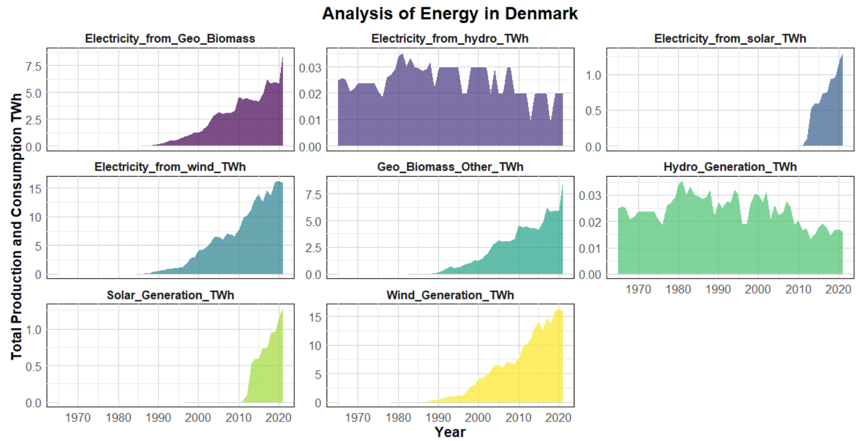

Figure 4.30 Energy Analysis of Denmark

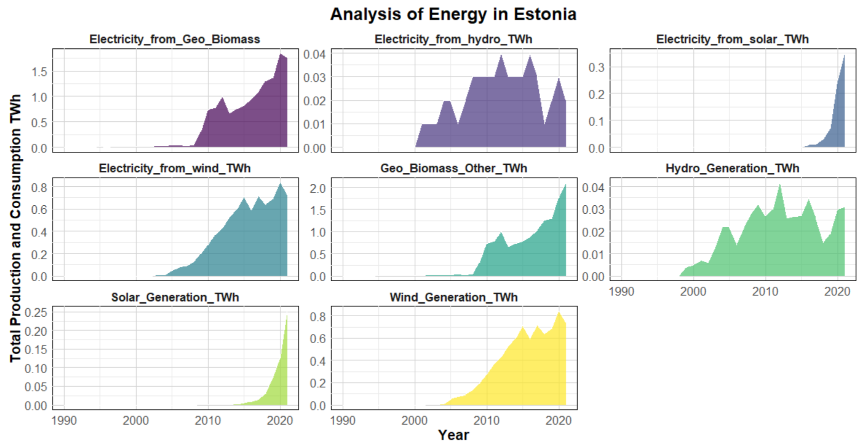

Figure 4.31 Energy Analysis of Estonia

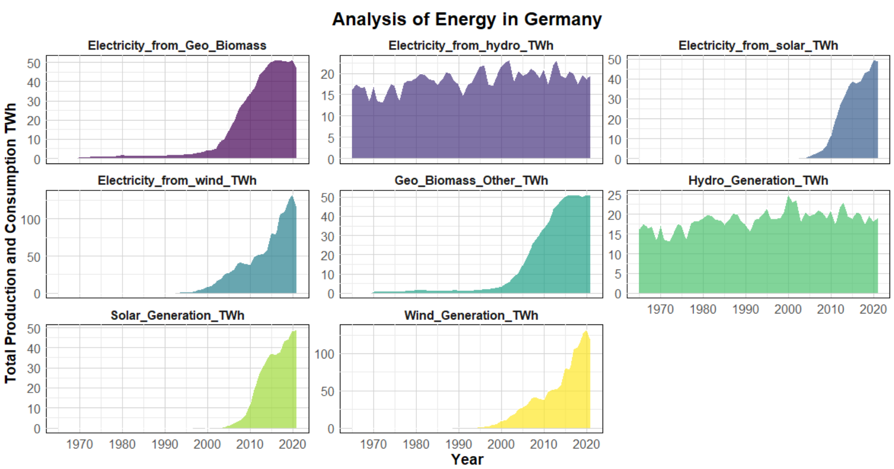

Figure 4.32 Energy Analysis of Germany

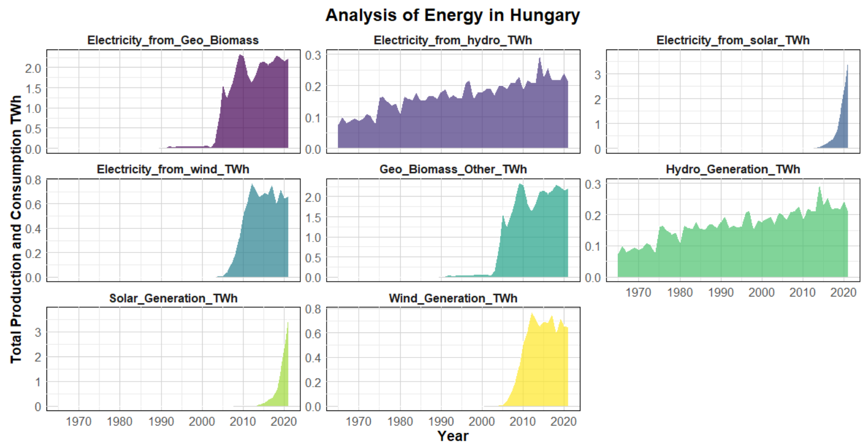

Figure 4.33 Energy Analysis of Hungary

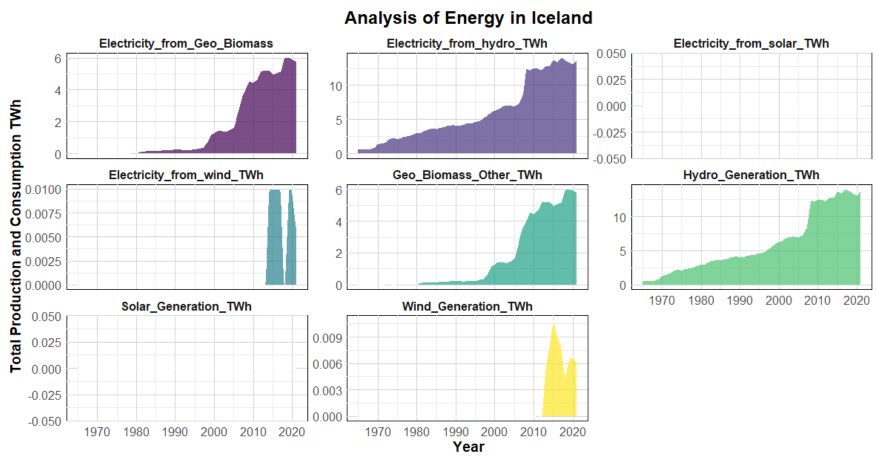

Figure 4.34 Energy Analysis of Iceland

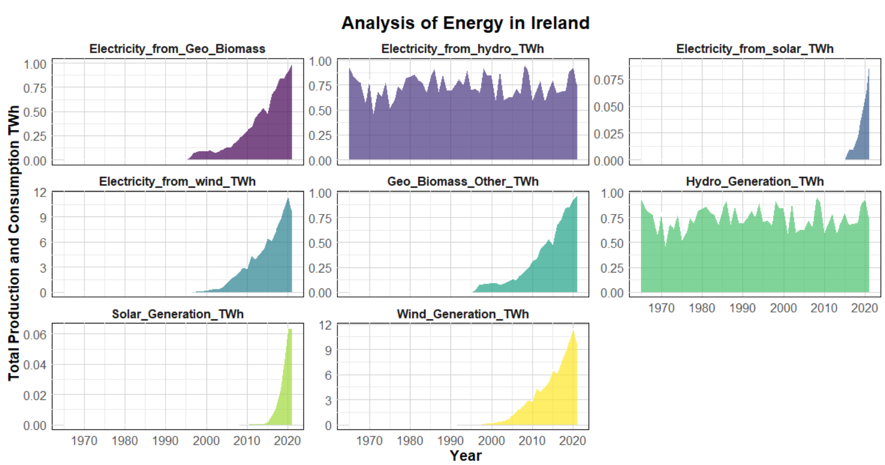

Figure 4.35 Energy Analysis of Ireland

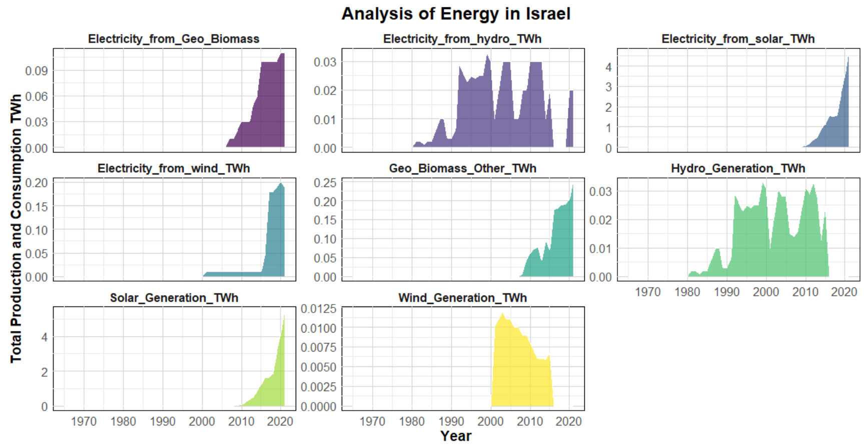

Figure 4.36 Energy Analysis of Israel

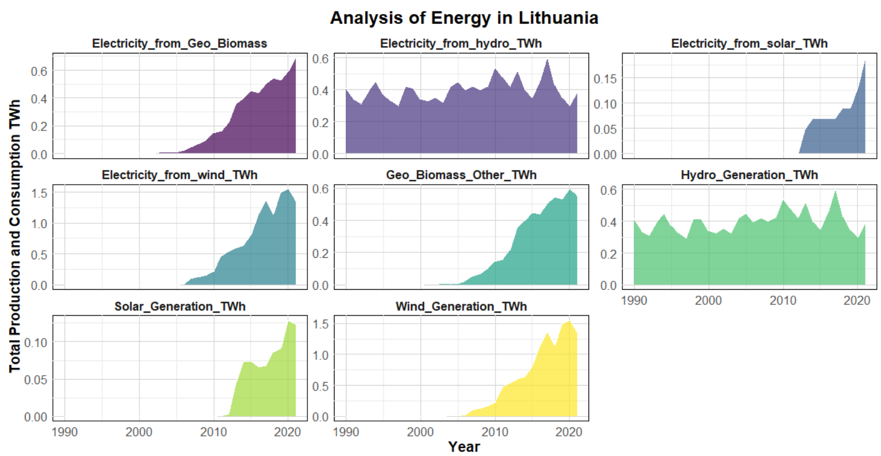

Figure 4.37 Energy Analysis of Lithuania

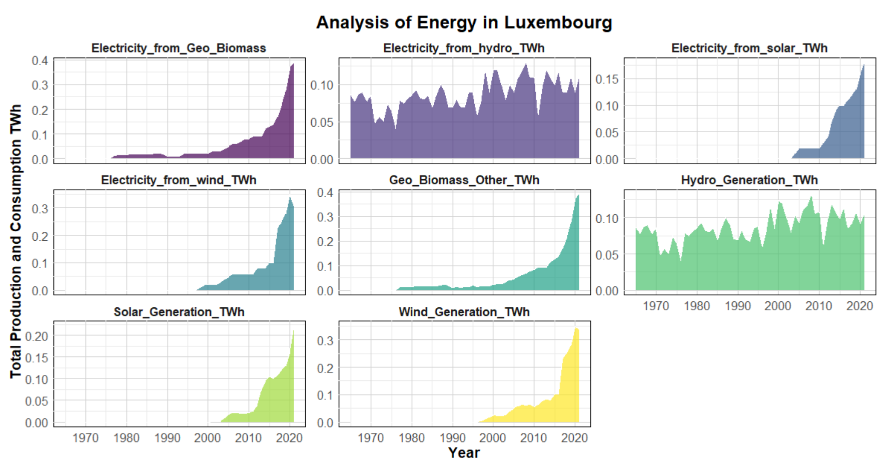

Figure 4.38 Energy Analysis of Luxembourg

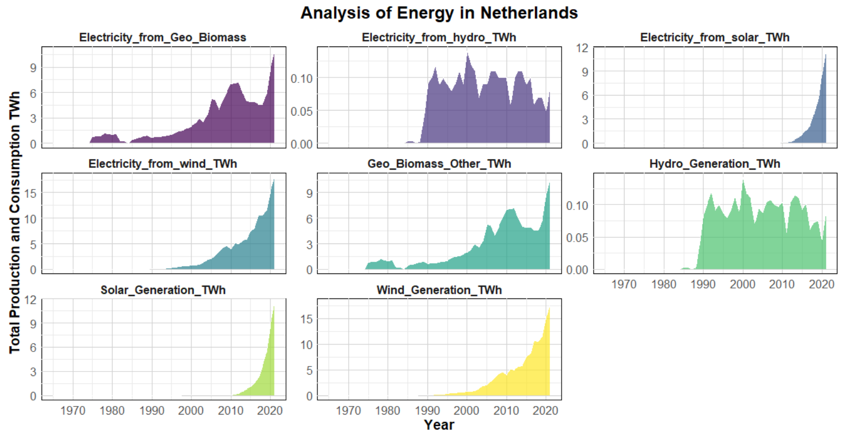

Figure 4.39 Energy Analysis of Netherlands

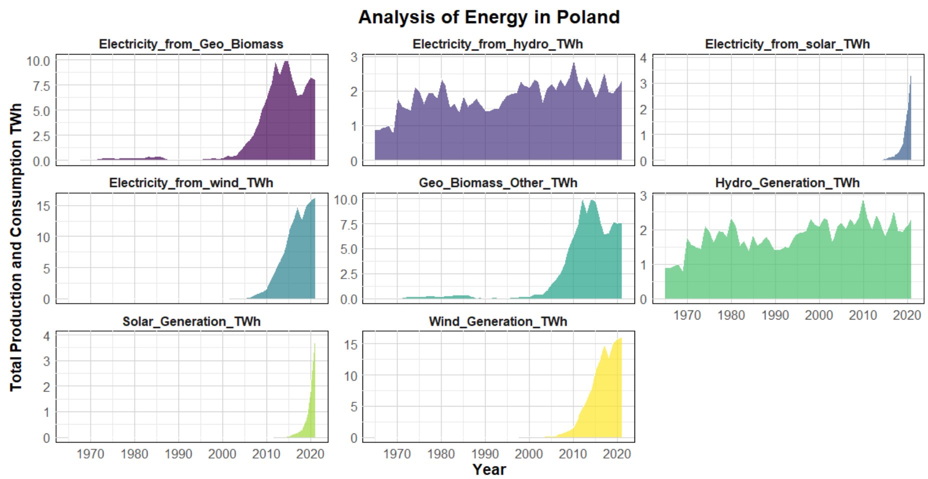

Figure 4.40 Energy Analysis of Poland

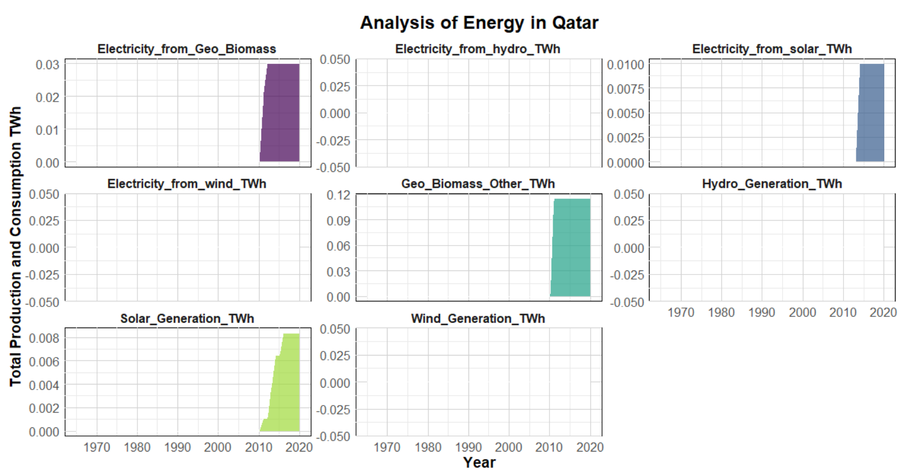

Figure 4.41 Energy Analysis of Qatar

Stacking up and comparing GDP visuals

For the final part, we will be stacking the graphs together and comparing them with the shape of the GDP curve for visualizing the correlation. For this, we will stack all types of energy sources, be their consumption or production, create the area chart and examine the shape of the curve.

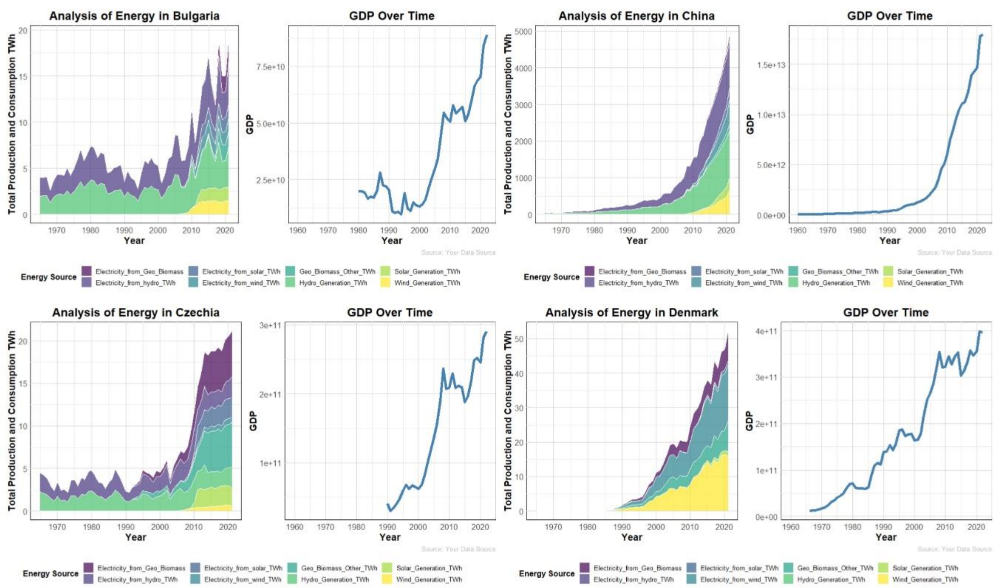

Fig 4.42 Graph comparison of selected countries group 1

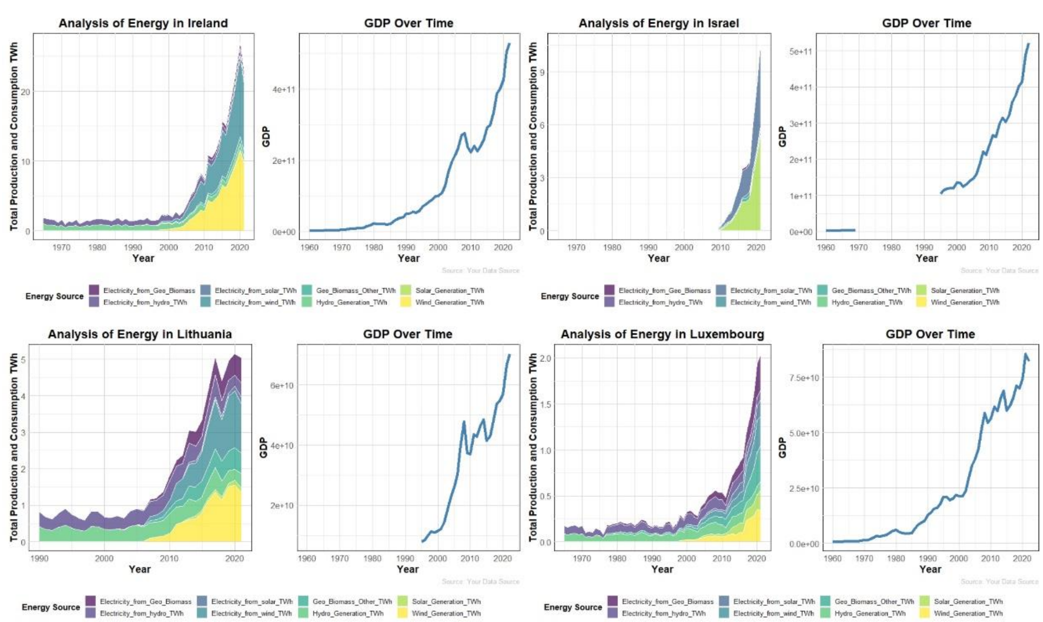

Fig 4.43 Graph comparison of selected countries group 2

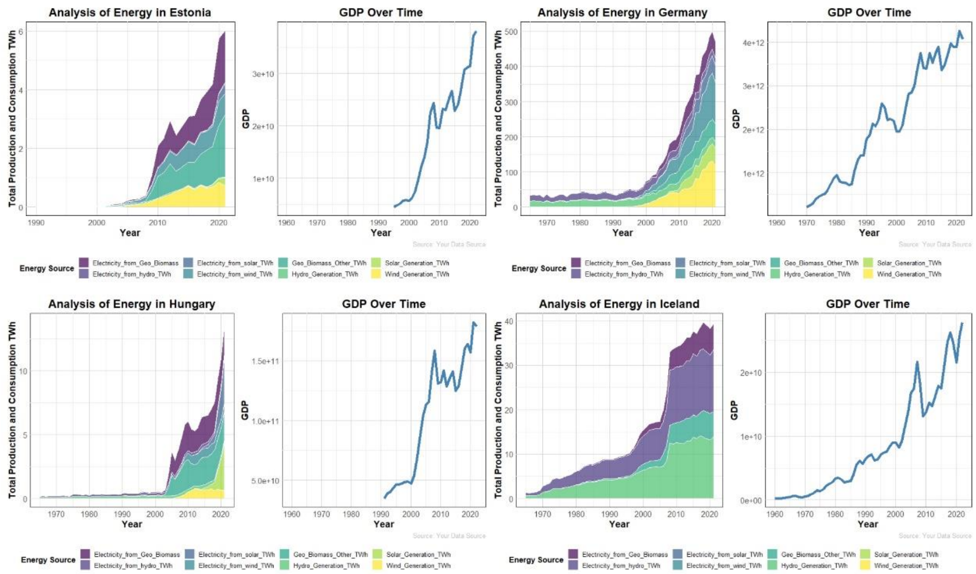

Fig 4.44 Graph comparison of selected countries group 3

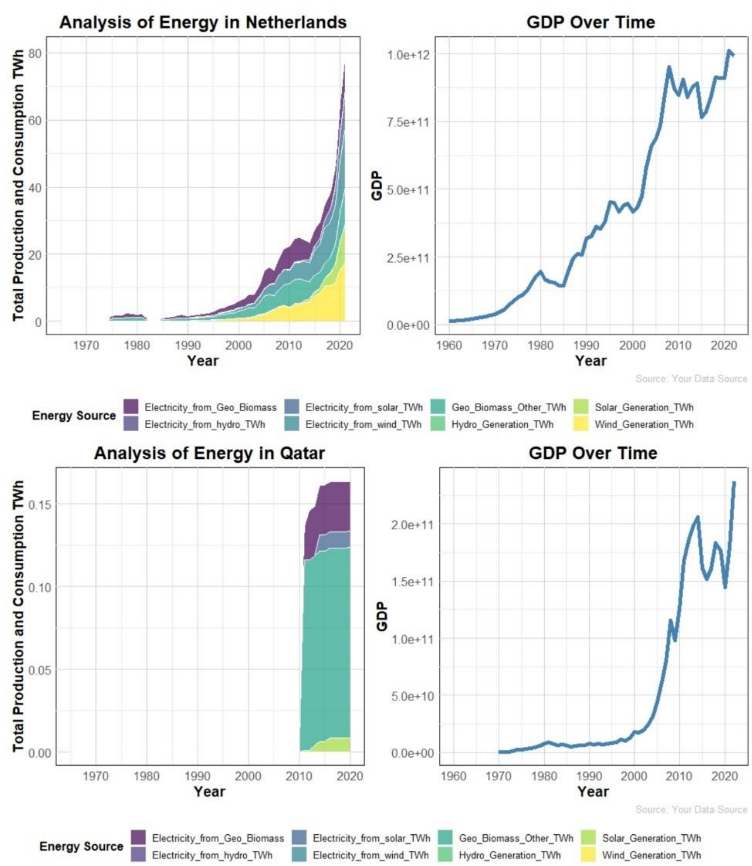

Fig 4.45 Graph comparison of selected countries group 4

These graphs provide us with how each of these countries has produced what type of renewable energy over the years and by how much. The plot nearby displays the GDP of the respective country over the years. We can find similar shape for the curve for both graphs. These findings inspired us to try a different approach for the analysis.

Correlating Total energy production with GDP

The previous analysis provided us with a significant result as the curves of the energy consumption and production of the country and the GDP has a similar curve.

To begin with this analysis, we first find the countries which have high numbers in production of renewable energy over the years.

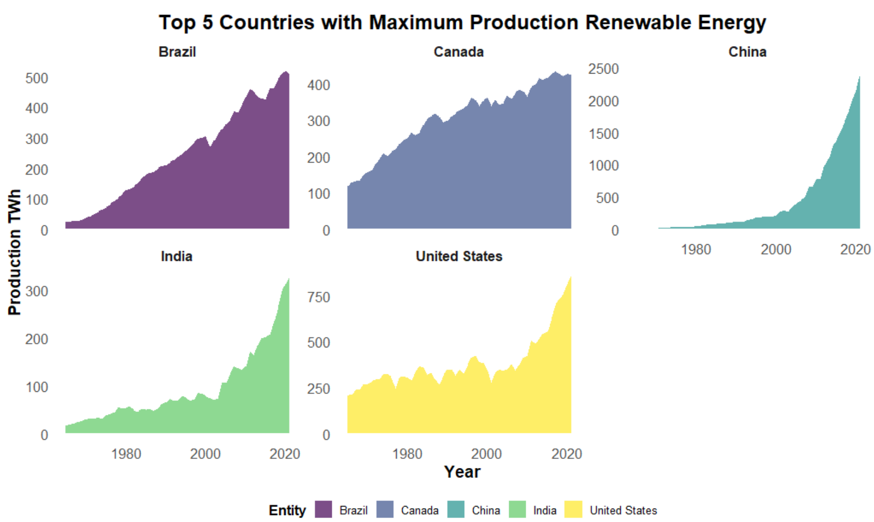

Figure 4.46 The countries with maximum aggregate production of all kinds of renewable sources of energy.

Figure 4.46 displays the countries which has produced the most energy from solar, wind, hydro and other sources of renewable sources of energy over the period of study.

Before we correlate this data, we will look how the GDP of the top countries in this category line up with the graphs of their respective production curve. Figure 4.41 depicts the GDP variation of the countries in highlight.

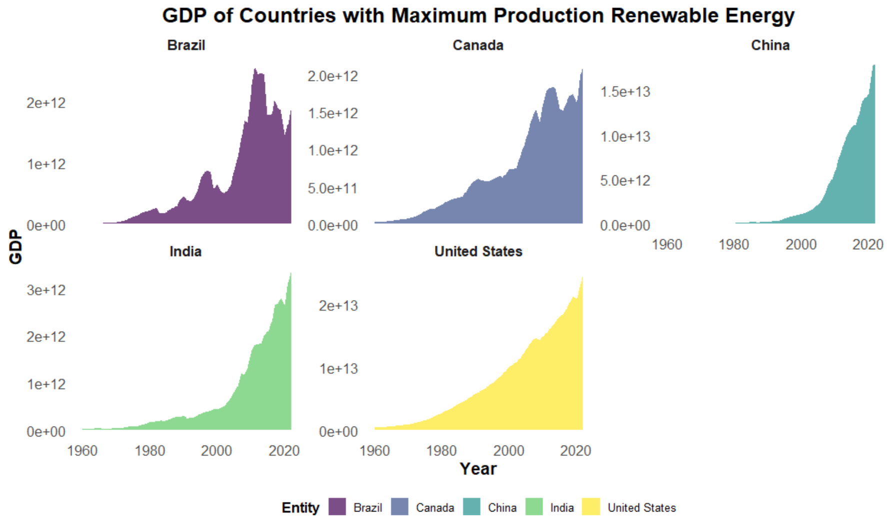

Fig 4.47 GDP area graph of the top 5 countries with highest aggregate renewable energy production over time.

We now proceed to correlate the sum of all productions and that with GDP of the Countries. The results of this correlation provide us with a very amusing finding as there exists around 29 countries with more than 0.9 correlation. The list of these files is available in the CSV file in the following link:

https://drive.google.com/file/d/100QcYgsvz7zBdCtt5WSDDy0gfscVE8N6/view?usp=drive_link

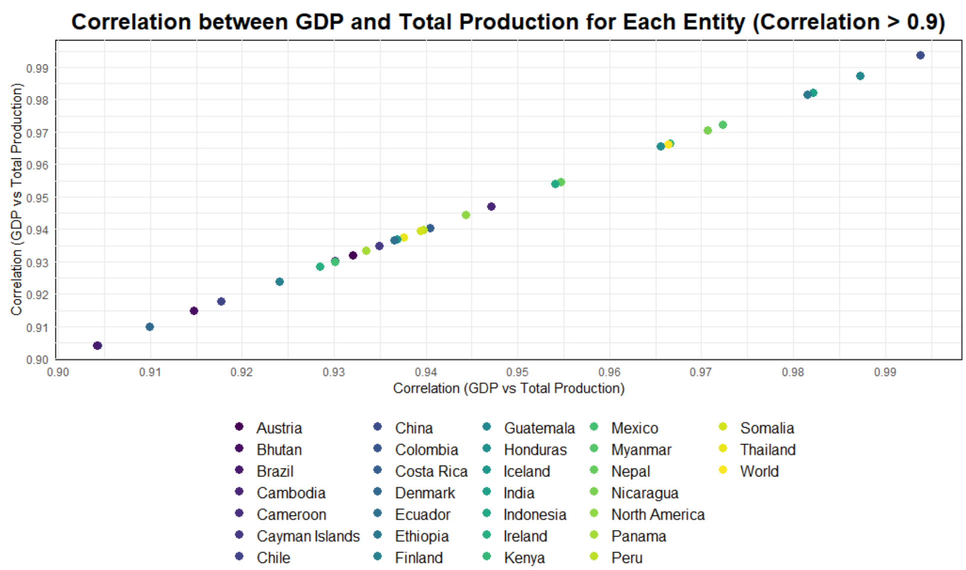

Fig 4.48 Scatterplot for countries with correlation above 0.9

This scatter plot shown in figure 4.48 depicts the arrangement of the correlation value of 29 countries with correlation between GDP and total renewable energy production having a value of more than 0.9. This plot provides us with positive conclusion to our research as we have achieved high correlation values while correlating the renewable energy production and GDP.

We have also achieved high correlation values for 5 countries while correlating GDP and the percent share of renewable energy in primary energy of countries. Both these results are in accordance to our research objective of correlating GDP and various measurements of renewable energy measurements.

4.3 DISCUSSION

From the findings and analysis conducted using the datasets that we considered; we have found that South America has been the leading continent when we take yearly percent share into account. We can see that the top 5 countries in South America have had almost constant share for the period, with Brazil leading the share. It should also be noted that all these countries have had an average of above 30% throughout the period, which is an important and serious number to consider. Refer figure 4.49.

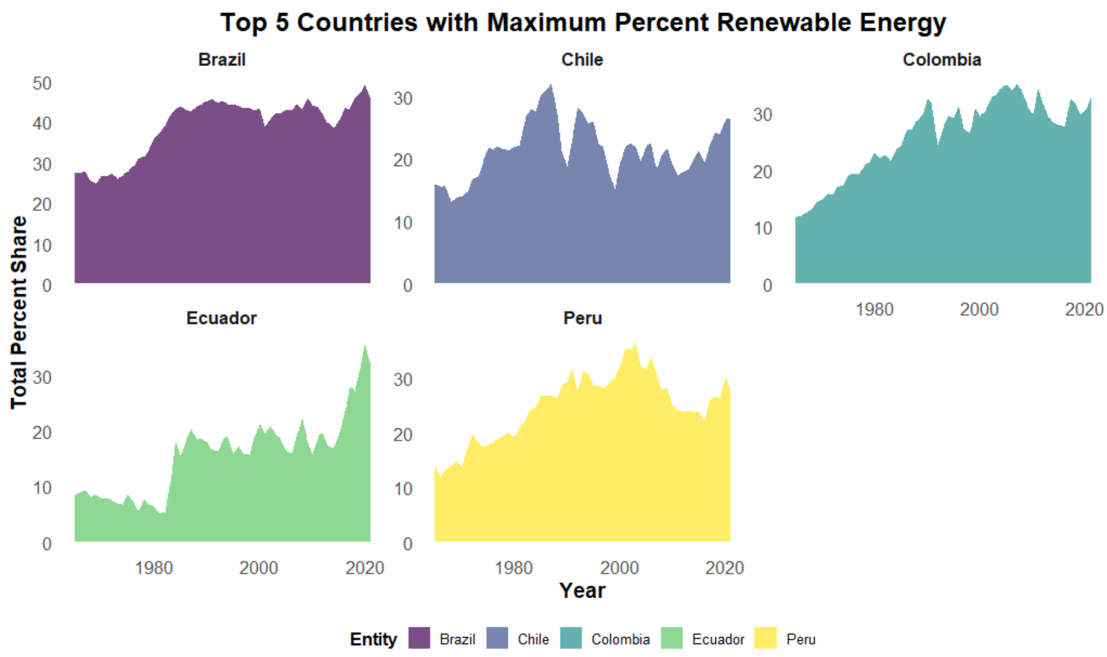

Fig 4.49 South American countries and their percent share.

This is followed by Oceanic countries, in which the main contributor has been New Zealand. This can be accounted for their low population also as less energy is consumed in this country. The primary energy share has as average of more than 30 throughout the period for New Zealand. Refer figure 4.50.

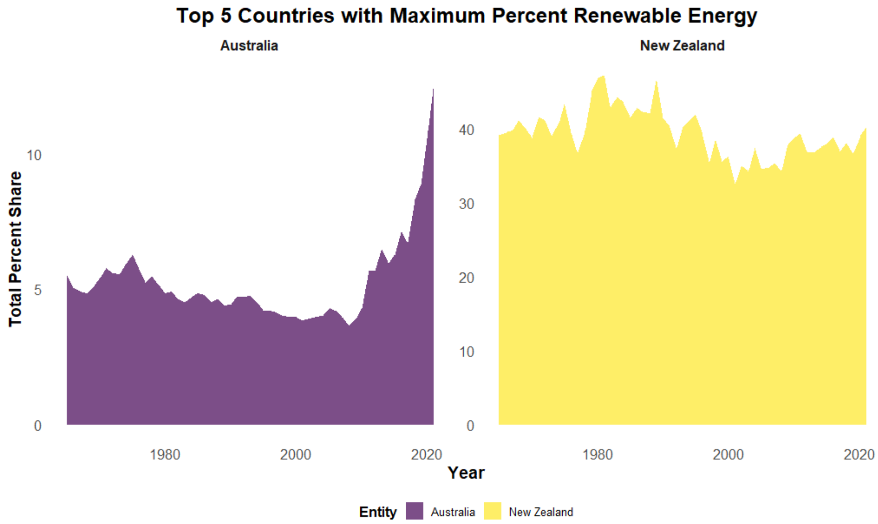

Fig 4.50 Oceanic countries and their percent shares.

After we found these two astounding results, we moved on to find the countries which had high percent share throughout the period and the result was the following countries arranged in descending orders of their shares: Norway, Iceland, New Zealand, Brazil, Sweden, Switzerland, Austria, Canada, Columbia, and Peru. Norway, Iceland, and Sweden are countries located towards the northern hemisphere, which helps them generate a lot of hydro energy and Wind energy due to their geographical conditions. The low population of these countries should also be considered.

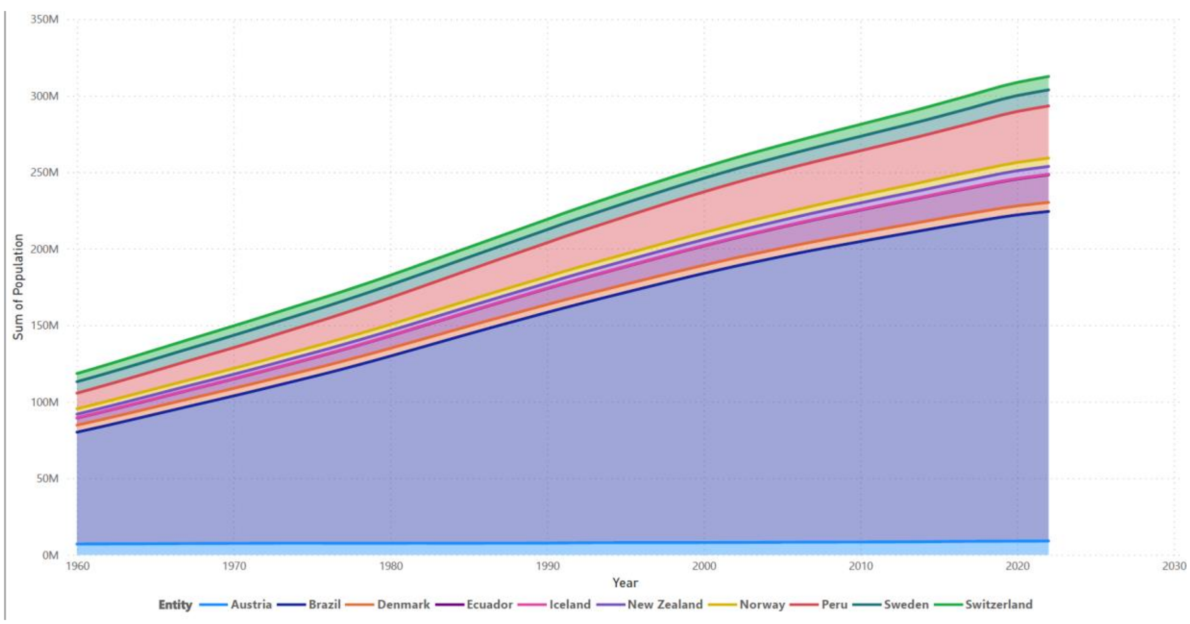

Fig 4.51 Population curve of the top 10 countries

From fig 4.51, it is evident that apart from Brazil, all other countries which has high percentage share of renewable energy in their total primary energy usage has low population.

The visualization of the countries at the bottom part of this graph, that is the countries that have low percent share aggregate over the period has helped us to conclude on some points.

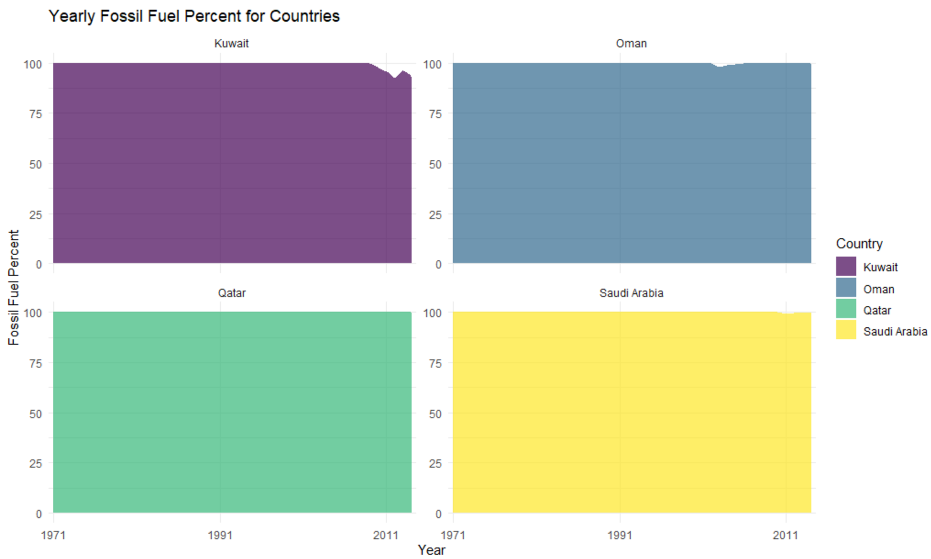

Fig 4.52 Fossil fuel consumption percent share of bottom 4 countries

The countries at the bottom of the list have nearly 100% consumption of fossil fuels during this period, which justifies their low percent share in renewable energy. But, during the last decade, there has been an increase in their share of renewable energy. This share, even though low is a good movement towards the future and better for environmental regulations.

From table 4.3, we were able to conclude that the countries which has high share is around 2000 times more active in the renewable energy sector. This has a positive outcome towards the environment as they are consuming less non-renewable energy, resulting in betterment of the world.

Further analysis took place towards understanding what type of renewable energy is being consumed most globally and which had less share. The analysis pointed out the high usage of hydro energy. This can be accounted to the abundance of water bodies spread globally. Moreover, the hydro energy conversion rate is much higher than any other source of energy. Water can also be stored and be can serve as a reservoir of energy storage. This can also be accounted to the fact that hydro turbines can achieve an energy efficiency of more than 90% compared to between 15% and 50% for other sources of renewable energy.

Another important point that we can find from this plot is the usage of solar energy started to increase in late 1980s.This is since commercialization of solar energy took place during this era and the increase in its share over this small period has been exceptional. Wind energy also increased its percent share some years prior to the commercialization of solar energy. We can see much increased applications of these energy sources in the years to come.

The further exploration took place in understanding and identifying the countries which has production and consumption in these different sources of renewable energy.

China, India, Japan, United States and Germany are the leading countries in wind energy generation and consumption. These are the same countries which resulted in having highest values in Solar energy consumption and production. This can be accounted to their geographical reasons such as being coastal countries and better economic stature as they can create more wind plants, which are much more expensive than solar or hydro energy plants.

Geothermal energy and other sources of renewable energy purely depend on the country's availability of such kind of environmental conditions.

Upon introduction of GDP factor

Our next task was to introduce the factor of GDP to find how all this relates to the country's economic performance. We summarized the countries with highest gross GDP over time and were able to find the same five countries in the list; China, Germany, India, Japan, and United States, with United States having the highest gross GDP till 2020.

This value reflects on why these countries have been able to perform well in production of renewable energy over time. Their high economic value helps them financially to fund government programs to set up more of such energy plants. This action in turn helps them in producing more energy and the loop goes on.

The first correlation problem we tried to encounter was by filtering out the countries which had at least an aggregate of more than 10% share of renewable energy over the period. The countries which satisfied the conditions were; Norway, Iceland, Brazil, Sweden, Austria, Canada, Colombia, Peru, Chile, Portugal, Sri Lanka, Finland, Ecuador, Philippines, Pakistan, Spain, and North Macedonia.

After correlation, we were able to achieve the table 4.4. In this table, we were able to get only one country which had high correlation. The country was Iceland with a correlation value of 0.83. This value was achieved by correlating the percent share of renewable energy in primary energy and the GDP value of the country. There were three countries with correlation values between 0.8 and 0.7, which are, Austria, Sweden, and Ecuador. The top three countries were European followed by a South American country. Chile and Portugal had a correlation value of 0.06 and 0.02, which are low values.

Our next topic of interest was to find the countries which had high changes in their percent share of renewable energy in primary energy. We calculated the percent change for each country and filtered out the countries which had more than 50% growth. This result has been displayed in Table 4.5. The list was almost like a few new countries added to the previous list. Ecuador had more than 500% growth in their share in renewable energy. The countries of interest were as follows: Ecuador, Philippines, Spain, Pakistan, Portugal, North Macedonia, Iceland, Sri Lanka, Finland, Peru, Columbia, Chile, Sweden, Brazil, and Austria.

It was astonishing to find that there were this much countries which have seen such an increase in their renewable energy usage over time. Upon further investigation it was found that North Macedonia even though had high percent increase over time, had only been active in this sector from early 1990s. Every other country in the list has been active from the initial period under study.

Correlation on all Countries primary share percent

After analyzing the countries with their percent growth and having maximum share, we moved on to correlating the primary share for all countries and the GDP value to see if there exists any relation between these two factors.

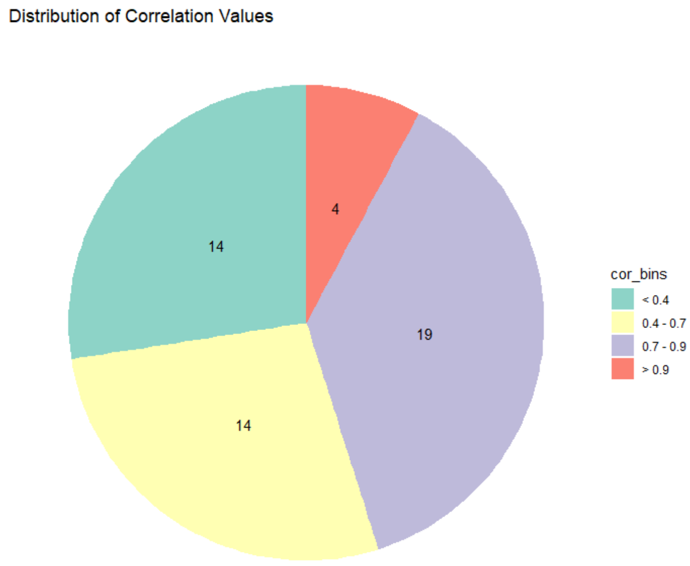

Fig 4.53 Correlation on GDP vs Renewable Energy Share in Primary Energy Distribution

Figure 4.53 demonstrates the split of our correlation function. We achieved a value more than 0.9 for four countries, 19 countries had correlation between 0.7 and 0.8, 14 of them had a value between 0.4 and 0.7 and 14 had low values below 0.4.

We moved on to analyze the countries which had correlation of more than 0.8. There were 15 countries which satisfied this condition. They were Qatar, China, Hungary, Poland, Denmark, Bulgaria, Ireland, Estonia, Czechia, Lithuania, Iceland, Germany, Israel, Luxembourg, and Netherlands.

The country with the highest correlation was Qatar, which was a country which had high percentage of non-renewable energy consumption. We then plotted which type of energy source and how much TWh of this energy has been consumed by each country and their GDP curve to find how the curves ended up looking.

The two curves for each curves appeared to be similar. The curve for Qatar appeared to be similar too. It was found that Qatar, even though being an Arab Country, had low GDP till 2000s. their GDP started to rise after 2000, coinciding with the period during which they started to increase their share of renewable energy. But the highest consumption of renewable energy of Qatar is 0.16

TWh which is low and this high correlation value is a contradiction as many other factors could have played a role in their GDP increase during this period.

Another curious case arises when analyzing Israel's energy share and GDP curve as they have a similar trend to that of Qatar. Israel too entered the renewable energy sector in late 2000s. But, the have around 10 TWh consumption compared to 0.16 TWh of Qatar in their renewable energy share. This can be found to have had an impact in increasing the country's economy as this increase is substantial in a short period of time.

Hungary also showed a sudden increase in their renewable energy consumption and production share in mid 2000s, which is like their sudden increase in GDP during this period. But, apart from Qatar and Israel, Hungary has always had a small consumption of renewable energy from the initial period of study.

For every other country, the curve of the graphs is perfectly overlapping apart from some year. There are dips in both the graphs of GDP as well for the aggregate TWh value of consumption and production.

The interesting part that we could not from these observations was that, even though we correlated the percentage share of renewable energy in primary share with GDP, we were able to get similar graph shapes when plotting the total production and consumption of different types of renewable energy sources and the GDP of each of these countries. With this finding, we moved on to correlating each countries total production and consumption over time with the GDP to see if we could get better results.

GDP and Energy Production over time

Further analysis of summing the production of solar, wind, hydro and other sources of renewable energy was carried out. The top countries were Brazil, Canada, United States, India, and China. As we have mentioned earlier, Brazil is one of the countries with highest share of renewable energy. No other country from that list has made to the list when it comes to the production in consumption. This is because population plays a crucial role in percent share as all these countries are highly populated. As population increases, the percent share decreases as other types of energy should be taken for fulfilling the needs of the whole country. On the other hand, all these countries have high GDP, which also indicates that with increase in economical stature of the country, more energy can be produced as these projects can be funded easily.

We move on to the next part of the analysis of correlating these values with the GDP. The carried-out correlation returned with the following distribution for all the countries. Check figure 4.46.

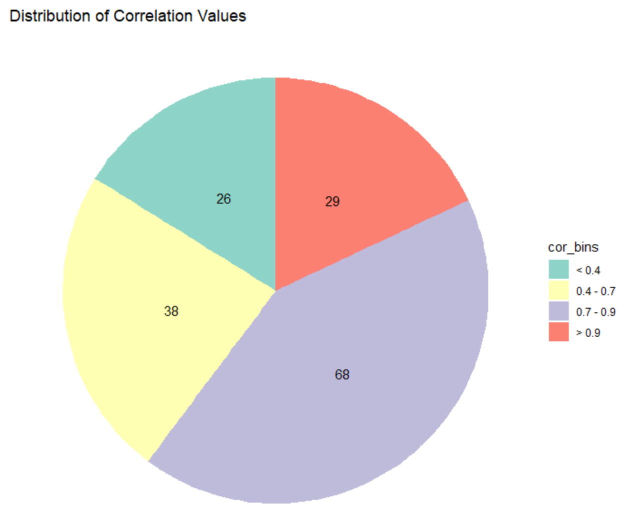

Fig 4.54 Correlation on GDP vs total production Distribution

The above pie chart shows how the correlation value output has been split. As can be seen, there are 29 countries which resulted in more than 0.9 value for correlation, followed by 68 countries which has a correlation value between 0.7 and 0.9. 26 countries have returned a value less than 0.4 and the rest 38 has a value between 0.4 and 0.7.

The high number of countries that has high correlation values, that is above 0.7 shows us that there exists some sort of relation between a country's economic value and the consumption and production of renewable sources of energy. The countries with higher GDP have implemented many policies to increase the production of renewable energy sources which in turn helps again in increasing the country's GDP value. Turning to such sources of energy also helps the countries to reduce expenses on fossil fuel energies and other non-renewable sources of energies which are far more expensive than this. The use of renewable energy also helps in the betterment of the environment of the country, thus helping in reducing costs to save environmental and other natural damages.

CONCLUDING REMARKS

The exploration of global renewable energy trends has revealed crucial insights into the dynamics of percentage share of renewable energy in primary energy usage, total energy production and consumption and which sources of renewable energy is being used most and produced more and at which locations. Their correlation with economic indicator Gross Domestic Product (GDP) was also studied and we were able to shed light on the interplay between renewable energy adoption, economic development, and energy production patterns across the countries.

Primary Energy Share: A thorough picture of the worldwide shift to renewable energy sources was given by analyzing the primary energy share across national boundaries. Among the noteworthy discoveries are the wide variations in the rates of adoption of renewable energy, with certain countries setting the standard for the transition to sustainable energy. It is apparent that several nations have achieved noteworthy progress in decreasing their dependence on non-renewable energy sources, so augmenting the sustainability of the global energy terrain.

Total Energy Production and Consumption: Determining the economic effects of energy generation requires an understanding of the relationship between GDP and total energy production. The study found trends that demonstrate the differing levels of dependence on energy production as a catalyst for economic growth. To maintain long-term environmental and economic stability, nations where the GDP and total energy output are highly correlated may need to investigate ways to balance economic expansion with sustainable energy practices.

The findings and discussions that we have done, help us to answer the objectives posed during the introduction of the paper. We were able to find the transition of renewable energy during the last five decades and were able to find the growing trends for increased percent share of renewable energy in the total primary energy usage globally. This change is for the betterment of the environment as well as good for the growth of the individual countries.

The countries which still has low share of renewable energy in their primary should initiate new policies to increase the use of renewable energy as this will help them reduce the carbon footprint. The countries which are leading can support other countries with sharing the technologies.

We have also visualized the type of energy which has been produced most in the last 5 decades and found which type of renewable energy has had a great increase during this period. Hydro energy, which has been in existence and commercialized for so long is still the leading source of renewable energy globally. But with the commercialization of photovoltaic cells and increased creation of large wind energy plants, these two sectors are increasing at a pace which is far more than that of hydro energy. It can be concluded that these two sources of renewable energy will be the leading producers by the year 2050 due to the high abundance of these resources.

Correlation Analysis: This study's correlation analysis yielded insightful information on the connections between several variables. The identification of 15 nations where the primary energy share and GDP have a correlation higher than 0.8 highlights the relationship between economic growth and the uptake of renewable energy. Similarly, the discovery of 29 nations where the GDP and total energy output have a correlation higher than 0.9 emphasizes the contribution of energy-intensive industries to economic expansion. This correlation poses a doubt whether the correlation is unidirectional or bi directional and this can be another research topic as well. As we have seen that the countries with higher GDPs have more energy production throughout this period and these countries are also growing their economic factors with the help of this energy production and consumption.

Research gaps and challenges faced

While conducting this research, we have faced various limitations as the data does not provide us with the data for all the countries in existence. And there has been some gaps in the data for some countries which is evident from the graphs of GDP in some cases.

Extension to Non-Renewable Sources: The research can be extended to combining the datasets of non-renewable sources of energy and exploring them more to get a better idea as to the decreased production of these type of energy and how this has influenced other nations to adopt the same.

Influence of External Factors: There is also the impact from other factors on the performance of these countries, such as the population, economic regulations, geographic limitations etc. For instance, population growth poses a unique challenge as it escalates the demand for energy, potentially impeding the transition to alternative sources. Future research should delve deeper into these factors to unravel their complex interactions and implications for sustainable energy transitions.

Comparative Analysis: Comparative studies of nations with comparable economic metrics but differing adoption rates of renewable energy might yield insightful results. Comprehending the reasons for the disparate adoption patterns of renewable energy in some countries with similar economic characteristics might aid policymakers in crafting focused measures. This comparison method may make clear contextual subtleties and hidden variables that either help or impede the successful adoption of renewable energy measures.

Longitudinal Studies: Longitudinal studies can be carried out to capture the dynamic character of the link between GDP and primary energy share. It is possible to gain a more sophisticated picture of the causal links and the effects of policy interventions by looking at how these variables change over time. Additionally, longitudinal research would offer a foundation for forecasting future trends and identifying any roadblocks that could appear in the way of the adoption of sustainable energy.

To sum up, although the existing research provides insightful information about global trends in renewable energy, filling in the gaps and exploring these new avenues will improve our comprehension of the intricate relationships that exist between sustainability, energy production, and economic development. Researchers can help create more focused and efficient plans for accelerating the world's shift to renewable and sustainable energy sources by expanding the scope and improving the analysis.

Conclusion

In summary, this preliminary examination of worldwide patterns in renewable energy has shed light on the advancements achieved by nations in adopting sustainable energy resources. Policymakers and stakeholders can benefit from knowing the relationships between GDP and primary energy share and GDP and total energy production. The results of this study highlight the significance of coordinating economic growth with ecologically responsible energy practices as the world works toward a more sustainable future. The world can work together to create a more resilient and sustainable energy future by taking note of other countries' issues and learning from their triumphs.

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APPENDIX