Czech University of Life Sciences Prague

Faculty of Economics and Management

Department of Statistics

Adoption of Renewable Energy: Germany and Czech Republic Comparison

Bc. Uru Dev Singh

Supervisor: Tomas Hlavsa

Declaration:

I declare that the diploma thesis “Adoption of Renewable Energy: A Challenge for Statistical Analysis” is an original work of my research, has been written by me and has not been submitted for any other previous degree. The usage of any other research has been indicated clearly and acknowledged.

Prague, Czech Republic,

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Bc. Uru Dev Singh

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Abstract

This study was conducted to give a comprehensive overview of the adoption of renewable energy and what factors influence its adoption. Key focus was given to try and establish if a relationship between economic growth and renewable energy exists. There were attempts made to give a detailed summary of all the existing research and connect it to the goals of this thesis. Several studies have been done in this field but there have been few that tried to show the relationship between the variables chosen in the countries that were selected. Renewable energy is one of the biggest topics in the fight against climate change and this thesis aims to provide a very detailed run-through to be able to have sufficient information regarding how and by how much does it affect economic growth. The primary method used was reflection on existing research and a brief analysis of the results provided by them, followed by selection of variables that were then used to analyze the correlation between the same. It was noted in both literature review and results that renewable energy does indeed positively correlate to economic growth and there exists a stronger relationship between economic growth factors and renewable energy in Germany than in Czech Republic due to a stronger policy framework and strict renewable energy targets. By closely monitoring the target achievement rate by the governments and with the cooperation of the people in accepting changes as well as willingness to make changes in the existing dominant non-renewable energy sources, the foundation can be laid for a smooth transition to renewable energy that would limit climate change adverse effects and give the planet a ray of hope that the future of humanity will not be at stake.

Keywords: Economic Growth Factors; Transition to Renewable Energy; Economic Impact of Renewable Energy; Correlation Coefficient

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1. Introduction

There is an imminent change that is currently occurring in the world regarding energy sources as we shift from Non-Renewable Resources such as Coal, Natural Gas, Oil and Nuclear power to Renewable Resources like Wind, Solar, Geothermal, Biomass and Hydro power. There is a lot of debate in the field of renewable energy as an upcoming source and the effects has had and will have on Economic growth. However, it is of utmost importance that this transition be made equally throughout the world as a united effort to assure a secure future and to halt Global Warming. Irrespective of the findings of the thesis, it is heavily stressed that green investments should continue. Transformation on a Global scale requires capital and finance, and it is the aim of this thesis investigate the relationship between expenditure on increasing Renewable energy and subsequent Economic growth and what would be the possible solutions to improving it.

RE simply refers to a kind of energy source that is not depleted when used, i.e. it is a more sustainable way of producing energy that is virtually limitless. The global demand for energy by 2050 is expected to rise to 1000 Ej or more (Moriarty & Honnery, 2012), as opposed to 617 Ej currently. This means that the world will be needing roughly 70% more energy in less than three decades. This is going to put a huge burden on the world's energy network and unless this demand can be decreased substantially and feasibly (Grubler et al., 2018) , meeting the 1.5 °C criterion would not be possible with traditional means of producing energy. The 1.5 °C "Stretch target" was presented in the Paris agreement of 2015 as the limit to which Global Warming needs to be kept to avoid the extreme effects of climate change and possibly be able to recover from them. If the planet's average temperature increase were to rise by more than the stretch target, the risk to crops could potentially cause a global food crisis and push the limits past climate tipping points, such as Arctic ice melt and permafrost thaw. Such a target cannot be met if greenhouse gas emissions caused by burning fossil fuels are not kept to a minimum. This is where the emphasis is laid on RE production and its various benefits over the traditional fossil fuel reliant production plants.

Some common and most widely used sources of renewable energy are as follows (Yadav & Bhagoria, 2013):

Solar Energy – One of the most popular sources of RE is the ability to harness the power of the sun using Photovoltaic Cells (PV Cells), more commonly referred to as Solar Panels, or Concentrated Solar Power Systems (CSP). According to the World Energy Council – "The sun can provide 7500 times the amount of the world's total annual primary energy consumption." This goes to show that this revolutionary technology has a long way to go in terms of expansion and has a very big potential in the future. The process of converting sunlight into Direct Current (DC) which can then be converted to Alternating Current (AC) is the type of electricity that is used to power everyday devices such as mobile phones, heating units, electric stoves and so on. The benefit of having such an energy source is that it can be installed on rooftops with little to no maintenance, when compared to other sources of energy. Solar panels mostly have only one big disadvantage and that is the fact that they do not produce anything at night or when the weather conditions do not permit them due to a lack of sunlight. This makes it a very powerful tool but not precisely a tool that can be used all over the world equally. There are many new projects around the world in areas that are better suited for electricity production by Solar such as Australia, India, Spain, Vietnam, Italy, China, United States, Japan, and South Korea etc. Both developing and developed countries can use this technology in different ways, but it is vital that the research and development to increase the efficiency and effectiveness of PV cells continues to increase. There have also been many breakthroughs in recent years that have led to a sharp decline in the costs of installing a CSP at home and at offices, which has seen a boom in sales for PV panels (J. Khan & Arsalan, 2016). A big wave of innovation can be seen in this novice technology where the applications seem to only be limited by the imagination of the scientists. Some of the proposals for areas where PV panels could be integrated are Office Windows, Car roofs, Coverage over Canals; shown to highly increase productivity of the panels (McKuin et al., 2021). over Farming lands, remote charging stations, over garages and the list goes on. One of the most promising and upcoming types of Solar Energy are Solar Power and Solar Dome. Solar power concentrates a huge amount of sun rays to one specific point using reflective mirrors which has a material like synthetic oil or molten salt that is then heated up and then used to generate superheated steam, which in turn rotates a turbine and creates electricity. This system is often referred to as Linear Fresnel Reflectors (LFR) (Hussain et al., 2017). The Solar Dome concept will be a vital source of the energy required for desalination plants in hotter regions that are near the oceans (Lachhab et al., 2022). The integration of Solar power in and around metropolitan areas has proven to be the easiest to implement and the most cost effective. However, it is not the most used RE. It only makes up about 15.5% of the total RE sources across the globe.

Hydropower – The most used and arguably the most reliable source of energy, in commercial effect since the late 1890s, that has been the “go-to energy” source for all nations alike, is Hydropower. Hydropower refers to the use of moving water to generate electricity. Over 150 countries have applied this technology as a means to achieve a steady and readily controllable source of energy. The relatively long lifespans of hydropower alongside the possibility to control how much and when energy is produced has made this energy source account for 50.77% of total RE across the globe (Peña, 2024). The big disadvantages of this source of energy are that it displaces a huge volume of water and creates an artificial lake of stagnant water that disrupts the natural ecosystem of that area and causes quite a bit of environmental damage if not installed properly for locations downstream that may be reliant on a steady flow of water. Innovation in hydropower has not been as drastic as Solar power but there have been major breakthroughs in improving the performance of these megaprojects by the digital transformation (Kougias et al., 2019) and major developments in smaller, more environment-friendly hydropower solutions. However, this source of RE in combination with other sources perfectly compensates for the shortcomings of each RE on its own. It will continue to be a large part of the RE transition and will play a major role in meeting energy demands during times when other RE such as Solar and Wind are not readily available, as it is unaffected by weather conditions. It only poses a problem in cases of extreme changes in rain patterns.

Wind Energy – This source of energy is one of the oldest ways of extracting energy from our planet as old ships used to use wind power to sail their boats. A similar principle applies to the conversion of kinetic energy stored in wind to mechanical energy through wind turbines or conversion systems of wind energy. Wind is one of the most abundant resources that can be found in a variety of countries, especially the ones where solar is not as abundant and the combination of both seems to yield the highest results in terms meeting the energy requirements of particular regions (Wu & West, 2024). The relative ease of installation in rural areas and a much higher energy output per area than a solar farm, wind energy accounted for 24.66% of total RE across the globe. Wind turbines have been stated as the most animal friendly when compared to other sources, yet the biggest drawback of wind turbines is the danger to avian life in the region of installment (Javaid et al., 2023). Another disadvantage is the extremely unpleasant aesthetic change in the environment they are installed in as wind turbines tend to be rather long and large structures with relatively fast-moving blades that are often installed in a group of 6 or more. But there are innovations being led by believers in this technology and smaller sized wind turbines are being developed to deal with energy demand at a smaller scale (Yossri et al., 2023). Climate change may affect the wind speeds in the long run and increase the effectiveness of wind turbines so it may be advised to install a larger number of wind farms which would ultimately aid in increased production of electricity and therefore the developmental factors (Weber et al., 2018).

Other sources –

All other sources combined contribute to the remaining 9.07% of all RE across the globe. There have been several advances in new RE technology ever since the turn of the century. Most of these technologies have been tested on relatively smaller scales but they are mostly either extensions or advanced versions of the existing RE sources. Some of the examples include -

Geothermal Energy – This form of energy is quite old in certain parts of the world as it provides heat directly from the Earth's interior. Average gradient of temperature increase is roughly 30°C per kilometer of depth (Barbier, 2002). This difference is exaggerated in areas where surface temperatures are in minus degrees. Therefore, the heating necessities of regions surrounding geothermal hotspots do not need electricity to keep buildings warm. While other sources of RE are better suited to produce electricity, Geothermal energy is much more efficient at district heating (Weinand et al., 2023) One of the key advantages of this type of source is that the technical know-how and expertise required to install such huge plants that go deep underground already exists, as it is virtually the same processes used for drilling fossil fuels. This makes this type of energy source, wherever it is available, a highly beneficial and cost-effective project (Yudha et al., 2022). Certain niche ideas and innovations in this field can be seen as well. However, geologists suggest that scaling up of conventional geothermal plants with modern piping systems and turbines seems to be the way forward for now.

Bioenergy – This term broadly means renewable energy produced by living organisms and it encompasses a huge assortment of sources used to produce some sort of fuel or energy that can then be directly used for consumption. Classification of Bioenergy is done at 3 levels, namely first generation (originating from raw edible crops), second generation (originating from lignocellulose) and third generation (originating from algae and microorganisms) biomass fuels. It is one of the lesser scalable technologies, due to the slow and complicated nature of extraction from living organisms (Shastri, 2017). But it plays a very crucial role in potentially revolutionizing the automotive industry as well as a source of small-scale portable energy. Given the smaller scale applications of this technology, it packs a punch in terms of complexity and biological knowledge. Certain innovations lead the way for this type of RE, including Cellulosic Ethanol, Microalgal biofuels and artificial photosynthesis, the latter being the newest and least used edition to the list. All sources combined have an estimated potential of 150 Ej a year which would also mean a more steady and consistent energy source when compared to wind and solar (Sterner, 2009). The only drawbacks would be the plethora of factors due to which scaling this source at considerable sizes poses a great challenge and the unwillingness of investors to invest in research and development for this energy source. This was the case in the past due to diesel and petrol being widely accessible and relatively much easier to produce. However, currently there are many alternatives to fossil fuels such as biodiesel, ethanol, propane etc. which makes the case for switching to bioenergy much more lucrative as oil prices continue to rise.

Marine Energy – Marine power refers to the energy carried by waves, tides, salinity gradient, and temperature differences in the ocean. The movement of such huge volumes of water is a great source of vast amounts of kinetic energy. This category of RE contributes the least to the total energy mix and there are only a few examples of commercially viable Ocean RE projects. But EU has planned several projects that could reach 600 MW of tidal energy in the following years (Commission et al., 2016). There have been many attempts to develop the most efficient way to harness the power of the ocean but most projects have had to face a similar challenge, and that is for the mechanical components to withstand the harsh salty ocean water and be at an economically viable distance from the shore while still being able to achieve optimal depth of the water (Bianchi & Fernandez, 2024). The best case application of this technology would be to provide energy to remote, coastal and island communities which might not have enough resources to build other types of RE sources. The adoption of RE is one of the most crucial ways we will be able to control and limit global warming to save the planet and humanity along with it. A lot of the RE sources have been mentioned in the introduction, but these are technologies that are not going to be a one stop solution for the bigger problem at hand. Most effective way to use these sources would be to have a combination of them that would be optimally suited for the area. Since there is a lot of debate and discussion for upcoming developing countries, this thesis focuses more on the countries Germany and the Czech Republic (or Czechia) and focuses on how the economic growth is affected by the same in these countries.

The aforementioned sources are to be seen as a conglomerate solution rather than independent or mutually exclusive. There is great potential in all these sources to be used in such a combination where one source’s disadvantages are compensated for by another source. Since energy production is an industry, whose changes directly influence the economic performance of a nation, it is to be noted that a common advantage of using RE is the economic growth that comes along with it.

2. Objectives and Methodology

2.1. Objectives

The thesis aims to prove whether, in the neighboring countries Germany and Czech Republic, there is a statistically significant relationship between the below mentioned variables.

2.2. Methodology

Data for this study will be collected from reputable sources such as national energy agencies (IRENA, Eurostat, World Data Bank) economic databases, research articles, journals, and relevant government publications. The time frame will cover a period significant enough to capture trends and patterns, likely spanning several years to ensure robust analysis. The software SAS Studio is used to perform the analysis and the descriptive statistics as well as Pearson Correlation Analysis is used. All outputs shown are directly from the software and no alterations have been made to the dataset after running the software.

It would be too broad to speak in terms of economic growth and RE all together. Therefore, select variables have been chosen to approach the problem based on the literature review and only these selected variables are seen as an accurate fit to the analysis out of the vast number of variables available –

GDP & Renewable Energy Capacity –

The challenge of comparing these two variables is that there is not just one indicator of GDP, and neither is there only one country in question. However, the aim is to focus mainly on the general parameters of GDP as indicated by economic scholars, researchers, and scientific articles. Since the data can be interpreted as a strong indicator of how other European countries (Marinaș et al., 2018) fare in the modern-day world it would also be helpful to compare this to other third world countries to compare how big the difference is between the distribution of economic growth and how the two kinds of countries fare against each other in the analysis of objectively definable variables. The general tendency of the thesis will be focused on trying to establish a firm relationship between the parameters used, Ceteris Paribus, and how strong the relationship is between said variables in a Correlation Analysis.

Electricity Generation and Renewable Energy Generation –

The challenge to analyze these variables is the exact conversion of investment per GWH of energy produced. It is hard to quantify roughly how much electricity is produced per unit of money invested while the electricity prices also shift due to the merit order effect (Shimomura et al., 2024). It is, however, much easier to verify if the overall energy production of a country can be linked to the more readily available sources of energy production that do not face the same limitations as the other non-renewable sources. Wind and Solar energy allow for energy generation in remote areas where the grid line connection might be a bit more costly and thus huge savings can be made alongside the quality of life of the people to whom the energy is made available. It is quite refreshing to know that there have been innovations around the world regarding new types of energy sources that can be scaled in the future for example – geothermal energy, near - magma geothermal energy, gold hydrogen sources, bio-mass energy, and various new inventions in wind and solar.

2.2.1. Variables

Percentage share of Renewable Energy in Energy Production (PSRE):

This variable will be measured in monetary terms, encompassing government, private, and foreign investments in renewable energy projects. Which is then calculated as the total percentage share of the total energy production in both countries.

Gross Domestic Product (GDP):

GDP serves as a key economic growth indicator and is used to measure the overall economic performance of a country. Unit of measurement was euros. This monetary variable was also adjusted for inflation, and the deflated values were used.

Renewable Energy Production (REP):

This variable represents the total amount of renewable energy generated within a given timeframe. The unit of measure was in GWh.

Electricity Prices (EP):

Household electricity prices represent the average end consumer prices paid by citizens per year. Unit of measurement was per euros per GWh. This monetary variable was also adjusted for inflation, and the deflated values were used.

2.2.2. Methods Used

Correlation Analysis –

Pearson's correlation coefficient will be employed to measure the linear relationship between different pairs of variables. This coefficient ranges from -1 to 1, with a negative one indicating a perfect negative correlation, a positive one indicating a perfect positive correlation, and 0 indicating no correlation. The correlation analysis will provide insights into the degree and direction of the relationship between overall investment in renewable energy and economic growth factors.

Descriptive Statistics –

This is a summary statistic that uses and analyses quantitatively described features from a collection of information.

3. Literature Review

3.1. Significance of the Thesis

With the onset of a new era of investment trends and energy production transitions, this thesis holds utmost importance in the field of adoption of RE, as it provides a detailed summary of how the change can be led forward and how the problem needs to be resolved on a global scale. If RE is seen as one unit that will replace the unit of fossil fuels, then the results achieved would not even be adequate. As opposed to the Coal era, the RE era needs to be compilation of unique approaches to each problem in different regions. Germany and Czech Republic are two such regions that are going to be focused upon in order to come up with a proposed solution based on the statistical analysis.

Every project undertaken in any economic activity needs to be thoroughly revised and substantiated with proof along with a detailed analysis of the advantages and disadvantages of its outcomes. It is extremely important to be able to concretely state that the massive influx of money into the renewable energy sector has a statistically significant impact on the economic variables (He et al., 2023), apart from the primary intended target of reducing Global Warming and using a more sustainable energy source. Without such an analysis it would be a lot more challenging to improve the money flow and to see on a bigger more global scale how the International Economy is performing (Zeraibi et al., 2023). This study is extremely relevant as it works with the latest data and uses econometric based statistical analysis to study the effects of high levels of investment in Germany and the Czech Republic. It has been observed that various studies have been done in this field, so it is not an unpopular topic of discussion. Many scholars try to search for the benefits of investments in renewable energy and they all seem to have a variety of reasons driving the research. The motivation of this study lies in the inherent environmental benefits. Climate change crises must be averted to ensure that the future of humanity is not in jeopardy, however the intrinsic value of such a change needs to be monetarily displayed otherwise it would not be very lucrative for the change to happen as quickly as it needs to (Krozer, 2013). Ever since the Czech Republic joined the EU, the RE discussion and projects have accelerated and really began to come into light. Opposed to pre-

2004 where the only RE projects were water based and were installed primarily for water flow management of the Vltava River in the 1950s and 60s (Tanil & Jurek, 2020). Germany is not only one of the biggest leading examples but also one of the top performing economies since 2000. There have been recent announcements in terms of target setting and without proper planning, these targets will be extremely hard to achieve (Jafari et al., 2023). That is the context that speaks to the importance of this thesis and why such proposed solutions need to be presented for policy makers to have relevant information to make solid decisions and for the public to be educated enough in this area to be able to demand these solid decisions.

3.2. Background of RE

Renewable energy, often referred to as green or sustainable energy, encompasses energy derived from natural resources that are continually replenished. Unlike finite fossil fuels such as coal, oil, and natural gas, renewable energy sources are abundant and able to be harnessed without depleting Earth's finite resources or exacerbating environmental degradation. The acknowledgement of renewable energy's critical role in tackling urgent global issues such as climate change, energy security, and sustainable development has led to its increasing prominence in current debate and policy agendas across the globe. This background illustrates the essential traits, varieties, advantages, difficulties, and worldwide importance of renewable energy as a vital energy source.

Essential Features of Renewable Energy:

There are several essential features that set renewable energy sources apart from traditional fossil fuels. Firstly, they come from natural occurrences or processes like biomass, geothermal heat, wind, water (hydropower), and sunlight. Since these resources can never run out on a human timeline, energy can always be produced from them. Secondly, the production of heat or electricity using renewable energy sources usually results in very low or no greenhouse gas emissions (Antonakakis et al., 2017), reducing the effects of climate change and improving environmental sustainability. Thirdly, decentralized energy production and improved energy resilience are made possible by renewable energy systems' modularity, scalability, and adaptability to a variety of geographic contexts and energy demand profiles (Yadav & Bhagoria, 2013).

The Importance of Renewable Energy Worldwide:

A key component of international efforts to slow down climate change, move toward low-carbon economies, and accomplish sustainable development goals is renewable energy. The Paris Agreement, which has been adopted by almost all countries, emphasizes how important it is to accelerate the use of renewable energy technology and decarbonize the global energy industry. Through efforts aimed at policy lobbying, knowledge sharing, and capacity building, international organizations like the United Nations Framework Convention on Climate Change (UNFCCC) and the International Renewable Energy Agency (IRENA) promote the deployment of renewable energy. Furthermore, the exponential rise in market dynamics, innovation ecosystems, and investments in renewable energy demonstrates the growing momentum towards a future powered by renewable energy (Wei et al., 2022).

3.2.1. For Germany

Germany has been at the forefront of renewable energy adoption for many years, often cited as a global leader in the transition towards a more sustainable energy system. The origins of Germany's renewable energy movement can be traced back to the aftermath of the Chernobyl disaster in 1986, which sparked widespread public apprehension regarding nuclear power and sparked enthusiasm for alternative energy sources. This event, in conjunction with a growing awareness of environmental issues and a desire to reduce dependence on fossil fuels, laid the foundation for Germany's Energiewende, or energy transition (Eriksen et al., 2023).

Feed-in Tariffs (FITs): Germany's renewable energy expansion is driven by the implementation of generous feed-in tariffs. Incorporated in 2000 under the Renewable Energy Sources Act (Erneuerbare-Energien-Gesetz, EEG), FITs guarantee fixed, above-market rates for renewable energy producers, thereby providing them with financial incentives to invest in solar, wind, biomass, and other clean energy technologies. These tariffs have played a crucial role in incentivizing investment in renewable energy projects, encouraging rapid growth in capacity and driving down costs over time.

Renewable Energy Targets: The Renewable Energy Sources Act established a goal of sourcing at least 80% of the country's electricity from renewables by 2050 (X. Wang et al., 2023), with intermediary targets along the way. These objectives provide a precise plan for investment and policy advancement, thereby facilitating the continual expansion of renewable energy capacities.

Grid Expansion and Integration: This encompasses the enhancement of transmission and distribution networks to accommodate fluctuating supply from wind and solar power, as well as the implementation of smart grid technologies to enhance flexibility and efficiency. Additionally, Germany (Selter et al., 2024) has pursued cross-border grid connections and energy trading agreements with neighboring countries to enhance energy security and facilitate the integration of renewable energy across Europe (Schreiner & Madlener, 2021).

Energy Efficiency Measures: Along with the expansion of renewable energy capacity, Germany has prioritized energy efficiency measures to reduce overall energy consumption and optimize the use of renewables. These include initiatives such as building retrofits, energy-efficient appliances, and industrial efficiency programs aimed at lowering energy demand (Hu et al., 2024) and maximizing the impact of clean energy investments.

Public Support and Participation: Germany's Energiewende has received broad public support, with strong grassroots movements promoting renewable energy adoption at the local, regional, and national levels (Alsagr, 2023). Community-owned renewable energy projects, which citizens collectively invest in and benefit from renewable energy installations, have flourished, contributing to decentralized energy production, and fostering local economic development.

Germany's commitment to renewable energy adoption stems from a combination of policy innovation, technological advancement, public engagement, and long-term planning. Although there remain obstacles, such as grid integration, storage, and intermittency issues, Germany's experience offers valuable insights for other nations seeking to transition to a more sustainable energy future.

3.2.2. For Czech Republic

Although not as widely acknowledged as Germany for its renewable energy initiatives, the Czech Republic has made significant progress in transitioning towards cleaner and more sustainable energy sources in recent years. Despite its historical dependence on coal and nuclear power, the Czech Republic has begun to embrace renewable energy sources as a component of its energy diversification strategy and its efforts to mitigate greenhouse gas emissions (Tanil & Jurek, 2020).

Renewable Energy Legislation: The Czech Republic has implemented numerous legislative measures to encourage the development of renewable energy sources, including the Renewable Energy Sources Act (ZEVO), which provides a legal framework for facilitating and rewarding renewable energy projects. Similar to Germany's EEG, ZEVO establishes feed-in tariffs, green certificates, and other financial incentives in order to encourage investment in solar, wind, biomass, and hydropower installations.

EU Renewable Energy Targets: The Czech Republic is bound by EU-wide renewable energy targets, which aim to increase the share of renewables in the overall energy mix and reduce dependence on fossil fuels. These targets provide a policy framework and regulatory impetus for renewable energy expansion (Gürtler et al., 2019), which will drive investment and deployment of clean energy technologies across the country.

Solar Energy Growth: The Czech Republic has witnessed a significant increase in the installation of solar photovoltaic (PV) systems, particularly in the residential and commercial sectors. Rising solar panel prices, coupled with favorable feed-in tariffs and supportive government policies, have contributed to the rapid uptake of solar energy (Van Wees et al., 2002). Nonetheless, modifications in subsidy schemes and regulatory ambiguity have resulted in fluctuations in the solar market in recent years.

Biomass and Hydropower: The Czech Republic's renewable energy portfolio also includes biomass and hydropower. The nation has a long-standing tradition of utilizing biomass for heating and electricity generation, utilizing a diverse array of feedstocks, including wood, agricultural residues, and biogas. Although hydropower is less prevalent in some neighboring countries, it is a reliable source of renewable electricity, especially from small-scale hydro installations.

Energy Efficiency Initiatives: The Czech Republic has also implemented various energy efficiency initiatives aimed at reducing energy consumption and improving overall energy productivity (Sivek et al., 2012). This includes building codes and standards, energy efficiency labeling for appliances, and financial incentives for energy-saving measures in industry, transportation, and buildings.

Despite significant progress in renewable energy adoption, the Czech Republic faces challenges such as grid modernization, regulatory stability, and financing constraints. Addressing these challenges will be crucial to maintaining momentum towards a more sustainable and resilient energy future. Additionally, a greater focus on cross-border cooperation and regional integration within the EU energy market (Dvořák et al., 2017) could enhance the Czech Republic's ability to leverage renewable energy resources and achieve its climate and energy objectives.

3.3. Summary of Peers Review

3.3.1. Factors Considered Based on Review

During the research for this thesis, it has been found that there are many variables and indicators that need to be accounted for in an analysis which would provide more accurate results and would be a better statistical analysis of the question being asked. Determining the economic impact of renewable energy involves considering such variables that can provide insights into the overall effectiveness and benefits of these sources. They are as follows –

Job Creation/Substitution –

With the increasing number of new projects being initiated by the government, a rising number of previous projects, such as coal power plants (Alhassan et al., 2024) are being shut down as well. This causes a colossal decline in the employment of skilled labor that was involved in the projects that are now shut down. Skill heterogeneity of the renewable energy market will be a big factor going forward as the jobs lost need to have an equal opportunity job creation in the same sector to absorb the existing knowledge. For example, the huge drilling industry can be remodeled to shift the focus from drilling for natural gas, oil etc. to drilling for Geothermal energy power plants. This allows for a smoother transition of existing knowledge (Khalid, 2024).

Regulations affecting Economies –

One of the bigger challenges (Chen et al., 2020) of having a stricter and more environmentally friendly policy is that it makes the market seem less attractive for multinational corporations that in turn leads to these companies exiting the market. This pattern has been existent and quite popular in recent times as more and more governments try to make stricter regulations regarding natural resources. One of the biggest examples is the Carbon taxes being introduced for MNCs. Other examples include – stricter mining restrictions and heavier taxation on polluting industries.

Scarcity of Non-Renewable resources –

Economics means the study of production, consumption and distribution of resources and it is important as natural resources are limited (J. Wang & Azam, 2024). The underlying result of scarcity of resources is that the market prices of any resource that is scarce are higher as more people try to buy limited amounts of it. The same can be seen happening for almost all non-renewable resources and this increase in, typically oil and gas prices, will only continue to grow. This sort of a shift makes the prospect of producing energy from such resources an economical disaster (Chakravarty & Somanathan, 2021). Which begs the question, why would one even consider any other source of energy than Renewable? It is of utmost importance that the countries realize the economic benefits of switching to renewable energy as the investment made in such sources is at its lowest ever and will continue to decrease, whereas other options are or will be too expensive.

Grid Integration & Energy Storage –

A substantial portion of the total investment and a strenuous task would be to integrate the RE outputs into the existing power grids (Khalid, 2024). Most RE requires a “smart grid”, where the flow of electricity and information is bidirectional, and the system is digitized and automized with enough flexibility and reliability to be able to detect and react to local changes in demand. Such a grid is vital for the efficacy of RE adoption as a near-perfect solution to climate change and the need for modern energy systems. On the consumer end, it was also mentioned that smart grids grant a greater flexibility in the use of various RE which increases the willingness of consumers to use RE directly in their homes. Another related challenge for RE adoption is an efficient way to store the excess energy produced during peak times of resource availability (sunny or windy days mostly), to be used later at peak demand. It was noted that the RE production at its peak is more than capable of meeting demand by consumers, but it is not able to cope with demand peaks by itself in Germany (Stötzer et al., 2015) and in other developed countries. Both of these variables will play a very important role in the rate and amount of RE integration into existing power grids.

The Opportunity Cost –

One of the more challenging things to define is the OC of a project and each time a renewable energy project is proposed it is to be considered that in case the project fails, the OC paid for it will have more dire effects (Ravikumar et al., 2020). The reason behind this being the time sensitive nature of adverse effects of Global Warming. As an example, if the resources spent on building a coal power plant are to be considered as the budget for a project and due to lack of raw materials the plant needs to be shut down in a span of 30 years, then the OC of such a project would need to include the various externalities caused by the CO2 emissions which could have been saved if the resources would have been used to create an equal output hydropower plant. The repercussions of the emissions (Czarnowska & Frangopoulos, 2012) might be extra carbon tax paid, decrease in air quality of the region, land degradation tax due to mining, public health impacts and so on. Such OCs of conventional energy sources are far greater than those of REs and therefore it is a very important variable to be considered while doing such analysis.

Technological Innovation –

Without the technological advancements in RE they would not even be considered as a replacement for other sources of energy. It is through the recent rapid advancements in especially solar and wind, that these sources are now at par in terms of prices with other sources of RE and are economically viable as a replacement (M. I. Khan et al., 2017). The increase in technology will continue to drive the prices down with each breakthrough taking RE a step closer to being a replacement energy source by default for all nations alike.

Environmental Benefits –

As mentioned earlier, it is of utmost importance that regardless of the economic impact of RE it is vital that it be treated not as a commercial next step in energy but also as an environmental necessity. Mitigation of climate change effects, reduced CO2 (Lotfalipour et al., 2010) emissions and improvement of air and water quality are all benefits of reducing the traditional ways of producing energy and also makes an impact on life expectancies of people (Rodriguez-Alvarez, 2021). It was also found in this study that investment in renewable energy seemed to have increased the potential life expectancy in individuals. Such health benefits cannot be monetized and need to take priority over whether RE is an economically feasible option.

Energy Independence –

Dependence of many nations on fossil fuel imports is a big threat to national security and may lead to heightened tensions between nations due to the struggle of foreign trade due to complex political relationships. This was made evident due to the Russia-Ukraine war, when India was widely criticized by Germany and the EU (McWilliams et al., 2023) for "increasing oil imports from Russia as a way to finance the war". It was found that the total oil imports made by the EU in a week still surpass the monthly numbers of Russian exports to India. This caused elevated tension in countries that had no other active dispute despite energy security. International politics is volatile and subject to rapid change; therefore, it is vital to have energy security and resilience (Dejonghe et al., 2023).

Consumer Adoption and Awareness –

Public awareness and adoption of RE at their homes as well as willingness to install RE at their properties also plays a crucial role in adoption of RE on a smaller scale. Many residents have voiced concerns regarding the unpleasant aesthetic of windmills installed which made the projects unsuccessful and ultimately a hit on adoption of RE (Tavakkoli et al., 2022). Higher acceptance of consumers regarding accepting the change to technologies like Battery powered vehicles have a direct impact on the success of these markets which in turn makes it easier for the world to transition swiftly to RE.

Financial Performance –

The return on investment of RE projects directly affects the financial stability and long-term viability of RE companies that makes this variable a very important factor in determining the adoption of RE. A lot of research was done in terms of other factors but Czech Republic there is little to no research consisting purely of financial benefits of renewable energy and its consequent adoption (Xiong et al., 2024). Germany, however, has a huge target audience and a lot more interested parties in understanding the RE financial feasibility and even investment banks have started to consider green investment as not only an environmentally friendly option but rather a profitable one.

3.3.2. Models and Results of Peers

The pressing global pursuit of sustainable energy solutions has brought the adoption of renewable energy to the forefront of academic and policy discussions. This literature review embarks on a comprehensive exploration of existing research, meticulously navigating the multifaceted landscape of renewable energy adoption. The emphasis is on elucidating the challenges and opportunities through the intricate lens of advanced statistical methodologies. Here are some of the most common models used by fellow researchers and their findings -

AutoRegressive Distribution Lag Model:

One of the most common models that were used for such a statistical analysis was the Auto Regressive Distribution Lag (ARDL) model. This is a combination of the AutoRegressive and Distribution Lag models which is when all independent variables are going to affect the outcome variable. Understandably this model was used most often due to its accuracy in testing the cointegration or long run relationship among the variables of interest. It has been noted that using different variables yielded varying results in terms of the effect of adoption of RE but the minor differences aside the results showed considerable bidirectional causality between economic factors (GDP - (Marinaș et al., 2018)) and consumption of renewable energy, CO2 (Attiaoui et al., 2017) and growth rate energy output (Addis & Cheng, 2023) in the long run. There were very few instances where the general idea that renewable energy has been linked to aforementioned factors does not have causality whatsoever. Most of these studies were done on broader regions ranging from 22 African countries, all developed and developing nations (Ritchie et al., 2020) to central and eastern European countries (Peña, 2024) with a very high number of studies done on China and uprising African countries. As mentioned earlier, the developing countries can successfully delink GDP and greenhouse gas emissions (Furkan et al., 2023) which is what these studies hinted to as well. A fair number of studies were done on developed countries specifically, which yielded stronger causalities as the investment and push to RE has seen a steadier increase but other factors affecting economic growth have stayed relatively stagnant. It is in the uprising developing nations where direct RE increase could be related to causing an enhanced rate of economic growth. If all developing nations are supported by developed nations, the target to achieve net zero emissions before making the transition to a developed nation would be a lot more feasible (Alhassan et al., 2024).

FMOLS & DOLS:

Fully Modified Ordinary Least Squares (FMOLS) and Dynamic Ordinary Least Squares (DOLS) models are variations of the OLS (Ordinary Least Squares) model and all variations were extensively used to come to similar conclusions where innovation (Muhammad Awais Baloch & Qiu, 2022) and foreign direct investment (Mohanty & Sethi, 2022) in RE was shown to be playing a significant role in mitigation of factors like GHG emissions and complimenting green GDP growth (Sarkodie et al., 2020). It was shown in many journals and articles that in addition to economic benefits the adoption of sustainable practices, facilitated through transfer of technology, can amplify economic performance by improving efficiency and reducing costs. It is in the interest of the person adopting RE as a source, to think of the existing knowledge base regarding the subject to maximize efficiency and avoid reinventing the wheel. Such an advice is typically useful for smaller scale projects in the agricultural and infrastructure sectors where individuals can make huge impacts on the projects they develop and monitor. Stringency in environmental policy was also shown to be a significant enough factor that directly influences RE investment (Alsagr, 2023). Governments that are more hesitant to change the policies for international players make the market for investment an economic disaster as these investments then yield lower profits due to low incentivization of RE. Governments of BRICS and some southeastern countries like Indonesia, Singapore and Philippines (M. W. A. Khan et al., 2019) were shown to have a more open FDI policy which also allows for new investors from western countries and China to take advantage of the relatively highly subsidized market.

Econometric Models:

Econometric models serve as indispensable tools in unraveling the intricacies of economic phenomena. In the context of renewable energy adoption, econometric models provide a robust framework for understanding the complex relationships between variables. Techniques such as Vector Autoregression enable researchers (I. Khan et al., 2024) to analyze the dynamic interactions between economic indicators over time, offering insights into the long-term impacts of renewable energy integration. Another infamous theory used by fellow economists is the Neoclassical theory of economics – Y(t) = A(t) * K(t) alpha * L(t) Beta

Where Y(t) denotes the GDP of a country, the residual A(t) is the total factor of productivity (determinant level of technology), K is capital, and L is Labor.

According to Robert Solow A(t) explains the difference between the total economic unexplained growth, aka the difference in labor and capital sums from Y(t). This has been used in other theses and articles to determine similar goals of finding out whether the investments and the subsequent economic impact is positive or negative. Bob Ayres and Benjamin Warr said the residual factor is Energy. This was then used to test if the change in A(t) of a particular country is in fact the increase in energy output. And this information could then be used to see how much of the increase in energy is by renewable and how much by other sources. However, an economy's production function is frequently reformulated as Y = F (K, AL) due to the relationship between labor and technology. Increasing each of the inputs reveals the impact on GDP and, consequently, the state of economic equilibrium. Nevertheless, the returns of both capital and unskilled labor on an economy decrease if the three components of neoclassical growth theory are not equal. These reduced returns suggest that while technology's contribution to growth and the output it can generate are limitless, increases in these two inputs have exponentially decreasing returns. And since the contributions made by technology are limitless, it can be stated that the advances made by adoption of newer RE technology would have a highly significant positive impact on economic growth. However, there were also concerns raised in these models by many researchers claiming that newer RE have an even lower EROI than fossil fuels (Režný & Bureš, 2019). This study also claimed that the feasibility of successful energy transition of the system with current available RE technology seems to be highly certain. It needs to be noted that even though RE is the way forward, further research is required in feasibility of application of these technologies and whether or not the current approach needs to be adjusted accordingly.

Time Series Analysis:

The temporal dimension of economic data is a crucial consideration in assessing the impact of renewable energy investments. Time Series Analysis, a sophisticated statistical technique, allows researchers to discern trends and patterns within economic variables over time. This facilitates a comprehensive understanding of the long-term effects of renewable energy adoption on economic indicators. (Tunc et al., 2022)

Regression Analysis:

Regression models, including Ordinary Least Squares (OLS) regression, serve as indispensable tools in quantifying the relationship between dependent and independent variables. In the context of renewable energy adoption, Regression Analysis aids in elucidating the quantitative impact of factors such as direct investments on economic variables. This approach provides valuable insights into the economic feasibility of renewable energy projects.

Challenges in Statistical Analysis of Renewable Energy Adoption:

Statistical analysis of renewable energy adoption is not devoid of challenges; these challenges often warrant a meticulous examination of refined methodological approaches. Many researchers have articulated key challenges, including data variability, multicollinearity, and the necessity for advanced modeling techniques. In response, researchers deployed sophisticated econometric tools, such as Panel Data Analysis (Guliyev, 2023) and Bayesian Econometrics, to surmount these challenges.

In synthesis, this expansive literature review provides a thorough exploration of existing research on the adoption of renewable energy, meticulously unraveling the intricate interplay between statistical analysis and economic factors. The studies reviewed collectively underscore the complexity and significance of employing advanced statistical methodologies to navigate the challenges and seize the opportunities associated with the transition to renewable energy sources.

It is surely one of the subjects of debate, whether all the governments around the world would even be capable of united fundamental change of the way we generate electricity and how big of a role will this play in the upcoming Green Energy investment choices (Zhao et al., 2023). The governments all around the world have understood that change is needed as we have reached a tipping point on a global scale where extinction of a few thousand species, extreme weather conditions, unforeseen population growth in certain species like jellyfish, droughts, floods, extreme natural disasters, and natural resource shortages are only among a handful of the adverse effects caused due to the warming of the planet. If not limited to 1.5-degree Celsius nature would have succumbed to the enormous strain that humans have put it through and will finally start to collapse which will initiate a global domino effect where everyone will be affected in ways that are increasingly harder to predict. Complete eradication of humanity off the face of the earth would also not be considered an improbable event.

Global warming is not just a secondary event that can be pushed to the side, but it is vital that all the powers in the world come together and fight this battle together. And for this reason, I have chosen Germany and Czech Republic as my target sources. The primary basis for this decision is the fact that these two countries are neighbors and yet there is a huge difference in the economies and the impact that they have on the world. There is a big wave of Green Movement (Jafari et al., 2023) taking place in Germany (Heinisch et al., 2021) currently that isn't directly passed over to its neighbors, but it is surely a very good start towards the fight against climate change. Specially since Germany (Blazejczak et al., 2014) announced its ambitious future goals to be climate neutral by 2045. That is the reason of choosing such a big superpower and a relatively smaller economy like Czech Republic (Maciej Serda et al., 2013) , as it will be good to see and compare the results of the two countries. Most of the research done on this topic has been regarding bigger countries or continents like Europe and Asia (Voumik et al., 2023) versus the smaller lesser developed countries in Africa (Basu et al., 2022) and even though these research are maybe on a global scale more valuable, it is also important that each country be the target of these analysis so that at the end of each decade the progress can be reviewed and used for the betterment of the future investments (Kastner & Matthies, 2016) . Researchers like this are more useful to understand how exactly we can tackle the problem and have the maximum benefit economically from investing more capital into the renewable energy market.

This is the overall overview of all the research that was consulted specifically to understand the different results regarding the similar thesis and research topics out there that can be said to share the objectives of this research. Attempts will be made to understand how the previous studies came to their conclusions and compare that with the findings of this thesis.

Numerous studies have demonstrated that there exists a bidirectional correlation between economic growth and the consumption of renewable energy. (Apergis & Payne, 2010)calculated that a 1% increase in renewable energy consumption in 20 OECD countries (over the period 1985-2005) would have led to a 0.76% increase in their real GDP. According to (Inglesi-Lotz, 2016) analysis of all OECD nations during the period 1990-2010, it was estimated that a 1% increase in renewable energy consumption would have resulted in a 0.105% increase in their gross domestic product. (Bhattacharya et al., 2016) in their study of 38 countries over the period 1991–2012, found that renewable energy sources could be a significant driver force for economic growth for most countries, but also that renewable energy sources could have a negative impact on economic growth in 5 countries. (Adams et al., 2018) examined 30 Sub-Saharan African countries over the period 1980–2012 and estimated that a 10% increase in renewable energy consumption would have led to a 0.27% increase in their economic growth. A 10% increase in non-renewable energy consumption would have the fact that non-renewable energy is more beneficial to economic growth than renewable energy can be explained by the fact that investments in the field of renewable energy and their technology have only just begun and their benefits have not been fully reaped. (Halkos & Tzeremes, 2013), in a study of 25 European countries in 2010, found that economic efficiency turns from neutral to positive as RE sources consumption increases.

There is a rich and constantly growing literature on the links between RE sources and economic growth. Many studies indicate that both renewable and non-renewable sources can lead to economic growth, and that there is a strong correlation between them (Chica-Olmo et al., 2020). However, it is important that policy decisions are made after studying these relationships, while also taking into consideration additional factors and contexts that occur in each country individually.

4. Results and Discussion

Overview of both countries

The descriptive statistics provided insights into the temporal trends, variability, and distribution of key variables related to renewable energy adoption in the Czech Republic and Germany. The data covered a 20-year period, allowing for a comprehensive analysis of long-term trends and patterns. There is notable variability in the percentage share of renewable energy, GDP, renewable energy production, and electricity prices over time, suggesting the influence of a range of factors such as policy interventions, economic conditions, and market dynamics.

Further analysis, such as correlation analysis helped identify relationships and dynamics among these variables, informing evidence-based decision-making and policy development in the energy sector.

4.1 Results for Czech Republic

4.1.1. Descriptive Statistics

Variable	Label	Mean	Std Dev	Minimum	Maximum	N
Time	Time	2013.50	5.9160798	2004.00	2023.00	20
PSRE	PSRE	13.0892500	4.2199659	6.7730000	21.3760000	20
GDP	GDP	179931.39	52708.39	96554.10	305490.20	20
REP	REP	7698.45	3412.09	2513.66	13827.62	20
EP	EP	0.1559325	0.0505804	0.0806000	0.3212000	20

Figure 1 Descriptive Statistics Output

The detailed explanation of the descriptive statistics analysis is given below as follows –

Time

Mean: The mean time period is approximately 2013.5, indicating that the data spans from the year 2004 to 2023.

Standard Deviation: The standard deviation of 5.9160798 suggests moderate variability around the mean.

Percentage Share of Renewable Energy (PSRE)

Mean: The mean percentage share of renewable energy is 13.08925%, indicating the average contribution of renewable energy to the total energy mix.

Standard Deviation: With a standard deviation of 4.2199659, there is notable variability in the percentage share of renewable energy over time.

Range: The percentage share ranges from a minimum of 6.773% to a maximum of 21.376%.

GDP (Gross Domestic Product)

Mean: The mean GDP is approximately 179,931.39 million Euros, representing the average economic output of the Czech Republic.

Standard Deviation: The standard deviation of 52,708.39 suggests considerable variability in economic performance over the observed period.

Range: GDP values range from a minimum of 96554.1 to a maximum of 305,490.2 million Euros.

Renewable Energy Production (REP)

Mean: The mean renewable energy production is 7698.45 GWh, indicating the average amount of renewable energy generated.

Standard Deviation: With a standard deviation of 3412.09, there is notable variability in renewable energy production levels.

Range: Renewable energy production ranges from a minimum of 2513.66 to a maximum of 13827.62 GWh.

Electricity Prices (EP)

Mean: The mean electricity price is approximately 0.1559325, representing the average deflated cost of electricity per KWh.

Standard Deviation: The standard deviation of 0.0505804 suggests moderate variability in electricity prices.

Range: Electricity prices range from a minimum of 0.0806 per to a maximum of 0.3212 euros per KWh.

4.1.2. Correlation Analysis

Pearson Correlation Coefficients, N = 20		
	PSRE	REP
GDP GDP	0.90744	0.85454
EP EP	0.82268	0.78023

Figure 2 Correlation Coefficients for Czech Republic

The study's conclusions highlight interesting relationships between metrics related to renewable energy and important economic indices in the Czech Republic. Interestingly, the percentage share of renewable energy and GDP show a strong positive connection of 0.90744, meaning that when the contribution of renewable energy in the energy mix rises, GDP usually follows suit. This outcome is consistent with a global trend in which nations making the shift to renewable energy frequently see economic development spurred by investment, innovation, and increased competitiveness in green industries.

Likewise, the 0.85454 correlation coefficient between GDP and total production of renewable energy supports the idea that a strong renewable energy industry boosts economic performance. The Czech Republic's focus on developing infrastructure for renewable energy appears to be paying off financially, since it may encourage the creation of jobs, draw in investment, and improve energy security.

Correlations with indicators related to renewable energy reveal significant insights regarding power pricing, an important factor in determining both economic competitiveness and consumer welfare. The percentage share of renewable energy and electricity costs have a correlation coefficient of 0.82268, indicating that a greater reliance on renewable energy sources is associated with lower electricity prices. This result supports the theory that renewable energy can reduce upward pressure on power prices, improving affordability and industrial competitiveness, due to its decreasing costs and lack of fuel price volatility.

Moreover, a similar relationship is shown by the correlation of 0.78023 between electricity prices and total renewable energy production, suggesting that nations with higher output of renewable energy typically have more favourable dynamics for electricity prices. The aforementioned association underscores the capacity of renewable energy growth to mitigate energy poverty and promote socio-economic advancement by guaranteeing the availability of reasonably priced and environmentally friendly energy resources.

Causality –

The observed high correlation between the percentage share of renewable energy and total renewable energy production with GDP and electricity prices can be attributed to several factors. Firstly, the transition towards renewable energy sources often requires significant investments in infrastructure, technology, and human capital, which in turn stimulate economic growth and contribute to GDP expansion. Furthermore, the enhancement of renewable energy production has the potential to enhance energy independence, reduce dependence on imported fossil fuels, and enhance energy security, thereby exerting downward pressure on electricity prices. Furthermore, policies and incentives for renewable energy deployment, such as feed-in tariffs and renewable energy targets, have incentivized investment and innovation in the renewable energy sector, driving both production and economic development. However, potential gaps in data or trends could include variations in renewable energy resource availability, technological constraints, and policy fluctuations over the study period. Additionally, external factors such as global economic conditions, energy market dynamics, and regulatory changes may influence the observed correlations. Further investigation incorporating longitudinal analysis, extensive datasets, and robust econometric models may yield more comprehensive insights into the causal correlations between renewable energy adoption, economic indicators, and electricity prices in the Czech Republic.

4.2 Results for Germany

4.1.3. Descriptive Statistics

Variable	Label	Mean	Std Dev	Minimum	Maximum	N
Time	Time	2013.50	5.9160798	2004.00	2023.00	20
PSRE	PSRE	33.4892500	4.9428211	26.7730000	45.3760000	20
GDP	GDP	2972826.00	542170.88	2262520.00	4121160.00	20
REP	REP	161308.62	70145.18	57536.03	267943.21	20
EP	EP	0.2698775	0.0599312	0.1709000	0.4125000	20

Figure 3 Descriptive Statistics Output

The detailed explanation of the descriptive statistics analysis is given below as follows –

Time

Mean: The mean time period is approximately 2013.5, indicating that the data spans from the year 2004 to 2023.

Standard Deviation: The standard deviation of 5.9160798 suggests moderate variability around the mean.

Percentage Share of Renewable Energy (PSRE):

Mean: The mean percentage share of renewable energy is 33.48925%, indicating the average contribution of renewable energy to the total energy mix.

Standard Deviation: With a standard deviation of 4.9428211, there is notable variability in the percentage share of renewable energy over time.

Range: The percentage share ranges from a minimum of 26.773% to a maximum of 45.376%.

GDP (Gross Domestic Product):

Mean: The mean GDP is approximately 2,972,826 million Euros, representing the average economic output of Germany.

Standard Deviation: The standard deviation of 542,170.88 suggests considerable variability in economic performance over the observed period.

Range: GDP values range from a minimum of 2,262,520 to a maximum of 4,121,160 million Euros.

Renewable Energy Production (REP):

Mean: The mean renewable energy production is 161,308.62 GWh, indicating the average amount of renewable energy generated.

Standard Deviation: With a standard deviation of 70,145.18, there is notable variability in renewable energy production levels.

Range: Renewable energy production ranges from a minimum of 57,536.03 to a maximum of 267,943.21 GWh.

Electricity Prices (EP):

Mean: The mean electricity price is approximately 0.2698775 Euros per KWh, representing the average cost of electricity.

Standard Deviation: The standard deviation of 0.0599312 suggests moderate variability in electricity prices.

Range: Electricity prices range from a minimum of 0.1709 to a maximum of 0.4125 Euros per KWh.

4.1.4. Correlation Analysis

Pearson Correlation Coefficients, N = 20		
	PSRE	REP
GDP GDP	0.96812	0.97652
EP EP	0.97822	0.93460

Figure 4 Correlation Coefficients for Germany

Strong relationships between renewable energy measurements and important economic indicators in Germany are explained by the study's findings. Interestingly, the percentage share of renewable energy and GDP show a strong positive connection of 0.96812, meaning that when the contribution of renewable energy in the energy mix rises, GDP generally rises as well. This outcome supports Germany's aggressive renewable energy targets and Energiewende objectives by highlighting the critical role that renewable energy deployment plays in promoting resilience and economic growth in the nation.

The strong association between the growth of renewable energy and economic success is further highlighted by the 0.97652 correlation between GDP and total production of renewable energy. Germany has made large investments in research and infrastructure related to renewable energy, which appear to be paying off in the form of increased industrial competitiveness, job growth, and sustainable development.

Correlations with renewable energy measurements reveal interesting insights regarding power pricing, which are a crucial factor in determining both consumer welfare and industrial competitiveness. Higher reliance on renewable sources is correlated with lower electricity prices, according to the correlation coefficient of 0.97822 between electricity prices and the percentage share of renewable energy. This research highlights the contribution that renewable energy makes to social welfare and economic competitiveness by reducing energy prices and improving affordability for both consumers and enterprises.

Additionally, a similar trend is highlighted by the correlation of 0.93460 between the price of electricity and the total amount of renewable energy produced, reiterating the negative relationship between the deployment of renewable energy and the price of electricity. This finding emphasizes how expanding renewable energy may help Germany's economy grow sustainably by reducing energy poverty, decreasing dependency on fossil fuels, and improving energy security.

Causality –

There is a strong association between Germany's GDP and power costs and the percentage share of renewable energy and total renewable energy production. These parameters are interrelated. First off, the output of renewable energy frequently spurs economic expansion via the creation of jobs, investment possibilities, and technology advancements, all of which have a beneficial impact on GDP. Moreover, increased production of renewable energy can help lessen reliance on fossil fuels, reducing volatility in energy prices and fostering long-term stability in power pricing. Furthermore, substantial investments in renewable energy infrastructure have been encouraged by Germany's strong renewable energy laws and incentives, including as feed-in tariffs and renewable energy targets, which have boosted both output and economic growth. However, gaps in data or trends may include fluctuations in energy demand, seasonal variability in renewable energy generation (e.g., solar and wind), and external factors such as geopolitical events or policy changes impacting energy markets. Furthermore, the presence of confounding variables that were not accounted for in the analysis, such as energy efficiency measures or changes in industrial composition, could influence the observed correlations. Further research involving additional variables and employing advanced econometric techniques could help elucidate the complex interactions and causal relationships underlying these correlations, enhancing our understanding of the dynamics between renewable energy adoption, economic indicators, and electricity prices in Germany.

4.3 Discussion

As part of the research conducted for this thesis, it was noted that there has been a much larger focus on the macro factors that affect entire nations due to the nature of complexity in assessing micro factors. But it is evident that there is a lack of studies done in this regard and as difficult as it may be, it needs to be addressed. The micro factors in question are the numerous ways RE adoption can facilitate economic growth that cannot directly be measured via taking bigger macro factors in account. Many studies emphasize the necessity of understanding and analysing how macroeconomic inconsistencies interact with and are influenced by the imbalances generated during the government reforms and their consequences on the productive base. The authors stress the need for interdisciplinary studies to comprehend the complex "micro-macro" relationship and its impact on economic growth potential. There can be a cursory discussion as to which questions can be raised regarding this topic and how would they be answered or resolved.

Quite a substantial number of subsidies are spent on the oil industry to make fuel readily available to the public at affordable prices. But the question can be raised, what happens when the scarcity of oil increases the prices by an amount that can no longer be justified as subsidies and the government must raise prices beyond the threshold of what people can afford? Naturally, the huge spikes in the natural gas prices resulting from the Russia-Ukraine war serve as a prime example for this scenario. If the countries that mainly export natural gas and oil reserves suddenly were to decide that they no longer would be able to do so due to self-interest and energy security of their own countries, then the world would be in a turmoil and the chances of recovery or change would be exceptionally low. This is one of the biggest motivating factors for countries that have started to adopt a longer-term view in mind. RE stands at the forefront of the answer to this question as it allows the use of unique solutions that best suit the country in question, Ground-mounted PV, onshore wind, and Power to Heat are the most cost-effective measures. in the case for Germany and relieve the country almost entirely of any dependency on another nation.

The way that theoretically renewable energy could lead to a direct increase in the GDP is via the Exergy Growth Cycle. An innovation that is more efficient at conversion of exergy to useful work or a decrease in costs to produce energy – leads to the decline of cost of useful work – which leads to a decrease in price of goods and services – which increases the demand for goods and services – which leads to higher salaries and profits – which in turn leads to incentivization of substitution of energy and labor. Moreover, there is an endless array of possibilities in terms of improvements to this relationship. But the focus at first would be to evaluate using the given methodology whether this relationship is statistically correlated.

Neglected effects –

In the past the driving factors of any project used to be to be able to beat the competition in terms of time and get the finished product out of the line, and in this case the oil wells or the coal power plants are common examples. The environment was not considered at all. The upper managements were more concerned with the fact that results need to be achieved rather than how the results will be achieved, especially how the process affects the environment. This mindset is partially responsible for many unforeseen negative climatic effects that then required national attention (for example Chlorofluorocarbons affecting the ozone layer). With the intention to move forward the mindset of the people in charge of mega projects and technologies needs to change and they need to do thorough analysis of all future technological endeavours that humanity is going to undertake.

Things although have changed, there needs to be better used of technology on a bigger scale rather than efforts being made on the smaller scale. However, the smaller efforts will also be vital in terms of revolutionary change. There is still a huge gap between what is promised by the government and what is delivered.

Featured takeaways –

Fighting climate change and limiting the rise in global temperatures to 1.5 Degrees Celsius cannot be a task done only by developed countries. Neither can it be achieved by a few countries switching to only renewable energy. It is not the task of only governments or international agencies and neither it is something that can be fixed quickly. However, all these things help in combating climate change at a global level. But the real change needs to be in the mindset of humans as a collective. History has shown that humans are able to achieve remarkable things while working together and this bond of sharing the same goals and working towards them together is what will save the planet and make it an even better place to live.

Historically, the rise in GDP was linked to a rise in CO_2 emissions as well. But studies show that it not only possible but can be done with not as much effort or changes in infrastructure, but it only needs a change in policies, goals, and mindsets of growing countries (Furkan et al., 2023). As much as possible, renewable energy needs to be developed in the countries with the fastest growing economies like Guyana (which is heavily dependent on oil reserves for its current growth), Niger (exploding in population and thus potential skilled labor force), India (largest country in the world population wise has seen an IT boom), Senegal, Macao, Ethiopia, and Philippines and so on. All uprising countries need a shift in mindsets from looking at GDP and use of fossil fuels as an inseparable mechanism and more like an unnecessary evil. In the words of Mr. Jason Hickel as part of Green Growth Consensus – "It's possible to have rising GDP and at the same time a reduction in emissions."

Proposed Solutions –

Throughout the course of this thesis there have been discussions regarding what are the biggest challenges that come in the way of RE adoption. There has been a stagnant inflow of problems, but not many proposed solutions. But it is a vital aspect of any discussion to highlight the proposed solutions that might be helpful to the reader and might be applied on individual levels and not just solutions that can only be controlled by the governments and institutions. Some solutions may also take the shape of preventive measures that individuals may be able to directly control such as emphasising smart consumer choices by buying products that were made by either directly using RE sources or were made in a region that has high levels of RE adoption. Usage of cars that are not powered by electricity or biofuel or any other kind of renewable source should be limited and at the same time consumers should be aware of how the vehicles are being powered. Electrification of the automotive industry by itself does not guarantee the use of RE sources to produce the electricity required to run the vehicles. Another way that the use of RE for heating can be limited is by consumers demanding that the new homes be built in a way that they structurally require less heating to stay warm during the winter and vice versa during the summer. Offices and buildings that are made can also consider how RE can be used on site to be less dependent on the RE provided by the district. Such actions do not directly show an impact if only a few individuals are willing to change. It is a mass effect of a change in the mindset of the people that would need to change. One of the most basic principles of economics states that an increase in demand, ceteris paribus, will cause the equilibrium price to rise and quantity supplied will also increase. An increased demand gives higher motivation to the suppliers to increase the supply of a commodity and if the public starts to demand the adoption of RE on a micro level, the effects will be seen at a macro level as well.

Mahatma Gandhi once asked the public to boycott all foreign goods as part of the Non-Cooperation movement which was received by many Indians as the first stage of failure of Colonialism and a symbol of how the public can move entire nations and their ideals. This is an example of when a call to change things ignited a fire that freed the nation. The world is currently in shambles and the only way to free it from its misery is to work together and embrace the changes.

5. Conclusions

The aim of the study was to examine whether adoption of RE in the countries of Czech Republic and Germany has led to an increase in the factors affecting economic growth. The consensus after examining the results of this thesis and the results of other researchers is that the adoption of RE has its challenges laying ahead in the future and achieving the optimistic targets of governments around the world seems to be a much more difficult task than previously estimated. Although the findings indicate the path that needs to be taken to achieve said climate neutral goals. It was shown that RE does indeed have high correlation with economic growth factors and adoption of RE has a positive impact on GDP and plays a role in mitigating climate change effects.

Attempts were made to understand the national and international factors that influence the adoption of RE into the society, but society needs to play an equally important role by changing the manageable micro factors at an individual level which would allow for the world to fight against climate change. It is not solely the responsibility of the governments, institutions, or the wealthy to make all the changes, but it is the duty of every citizen of the world to ensure that contributions are made towards the goal of transitioning to a more sustainable and environmentally friendly future. Economics states that an increase in demand leads to an increase in supply and the public needs to come forth and demand a change that benefits everyone eventually. That does not imply that one must take the back seat in the race against time and global warming, instead it needs to be an initiative-taking effort on all sides associated with bringing about the necessary change.

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7. Appendix

C - Celsius

EJ – Exajoules

EP – Electricity Prices

EROI – Energy Return on Energy Invested

EU – European Union

GDP – Gross Domestic Product

GHG – Greenhouse Gase

GWh – Giga Watt Hour

KWh – Kilo Watt Hour

OC – Opportunity Cost

PSRE – Percentage Share of Renewable Energy

RE – Renewable Energy

REP – Renewable Energy Production