Czech University of Life Sciences Prague

Faculty of Economics and Management

Department of Economics

Interrelationships between sectoral growth and greenhouse gas emissions in Central Europe.

Ing. Ahmed Altouma

© 2023 CZU Prague

Declaration

I declare that I have worked on my Ph.D.'s dissertation titled "Interrelationships between sectoral growth and greenhouse gas emissions in Central Europe" by myself and I have used only the sources mentioned at the end of the dissertation. As the author of the Ph.D.'s dissertation, I declare that the dissertation does not break any copyrights.

In Prague on 15/04/2023 ____________________________

Supervisor:

doc. Ing. Vladimír Krepl, CSc.

Interrelationships between sectoral growth and greenhouse gas emissions in Central Europe

Abstract

Central European countries are among the developed countries with good investment potential with suitable infrastructure, which own almost forty percent of the GDP of the countries of the European region.

To achieve this, these countries have diversified their economic activities, causing an additional ten percent of the total greenhouse gas emissions compared to the average they should contribute compared to other European countries.

Agriculture, forestry, and other land uses contribute negatively to the environment in about one-fifth of the annual carbon dioxide emissions that negatively contribute to global climate change. Deforestation is the main cause of a high percentage of emissions.

Central European countries have different industrial levels, anyway, they consider the industrial sector as one of the vital sectors to ensure the continuity of the industrial level. Different types of energy are used, both renewable and non-renewable.

And since energy is the number one cause of industrial emissions, the use of non-renewable energy leads to increased emissions that will negatively impact the environment. The movement of people and the transportation of products in various ways is the main cause of carbon dioxide and methane emissions in the service sector. Households are also a significant contributor to gas emissions. These countries participate in agreements guaranteeing environmental protection and are an essential part of the European Green Deal.

Central European countries have provided different solutions to keep pace with economic development, considering sustainable development and its applications in agriculture, industry, and services. To solve this problem, governments are trying to implement the provisions of the European Green Deal, a rapid transition to the production and use of renewable energy, a ban or limitation of deforestation, and in addition, an acceleration of the transition to circular economy applications.

explore and evaluate the impact of the major sectors that make up the economy on the environment, represented by greenhouse gas emissions. Providing achievable proposals that suit the situation of each country according to its situation and priorities. The research will discuss the whole economy sectors in order to find out which sector contributes the most emissions and has the greatest environmental impact on the environment. The results of this research should show experts, politicians, and laypeople which industries and technologies have the greatest impact on the environment.

This dissertation was analyzed using panel data from 1995 to 2018. Using two main types of analysis. The first is the panel VAR and the second is the panel ARDL. Granger causality analysis was also used as a companion step to panel VAR analysis.

The null hypothesis of this dissertation was rejected in three places, namely that "economic growth is important and a significant contributor to (greenhouse gas, carbon dioxide, methane) emissions in Central Europe", and therefore the alternative hypothesis was accepted that "economic growth is not significant and does not significantly contribute to emissions (greenhouse gases, carbon dioxide, methane) in Central Europe. Unfortunately, in reality, the null hypothesis was temporarily accepted in the EU.

These results confirm that the countries of Central Europe are, from a theoretical point of view and perspective, on the right track when it comes to the transition to a green economy through the production and use of renewable energies. Likewise, the results confirm that these countries need a qualitative shift in the field of agriculture in order to reduce nitrogen oxide emissions and thus greenhouse gas emissions. This is achieved by many methods, mainly by reducing deforestation, manure management, and agricultural land. Likewise, the appropriate use of mechanization for precise feed preparation, the use of environmentally friendly fertilizers, and the promotion of the use of renewable energies in agricultural areas. These new methods will lead to the acceleration of the employment of qualified staff and thus to the solution of the above-mentioned objectives.

Keywords: Economic growth; Greenhouse gases; Emissions, Agriculture; Industry; energy; ARDL Panel; VAR panel; Central Europe

Vzájemné vztahy mezi sektorovým růstem a emisemi skleníkových plynů ve střední Evropě

Abstrakt

Středoevropské země patří mezi vyspělé země s dobrým investičním potenciálem s vhodnou infrastrukturou, které vlastní téměř čtyřicet procent HDP zemí Evropské unie.

Aby toho dosáhly, tyto země diverzifikovaly své ekonomické aktivity a způsobily dalších deset procent celkových emisí skleníkových plynů ve srovnání s průměrem, kterým by měly přispívat ve srovnání s ostatními zeměmi Evropské unie.

Zemědělství, lesnictví a další využití půdy negativně přispívá k životnímu prostředí asi jednou pětinou ročních emisí oxidu uhličitého, které negativně přispívají ke globální změně klimatu. Odlesňování je hlavní příčinou vysokého procenta emisí.

Středoevropské země mají různou průmyslovou úroveň, každopádně průmyslový sektor považují za jeden z životně důležitých odvětví pro zajištění kontinuity průmyslové úrovně. Používají se různé druhy energie, obnovitelné i neobnovitelné.

Protože energie je hlavní příčinou průmyslových emisí, používání neobnovitelné energie vede ke zvýšeným emisím, které mají negativní dopad na životní prostředí. Přeprava osob a přeprava produktů různými způsoby je hlavní příčinou emisí oxidu uhličitého a metanu v sektoru služeb. K emisím plynů významně přispívají také domácnosti. Tyto země se účastní dohod zaručujících ochranu životního prostředí a jsou nezbytnou součástí Evropské zelené dohody.

Středoevropské země poskytly různá řešení, aby udržely krok s ekonomickým rozvojem s ohledem na udržitelný rozvoj a jeho aplikace v zemědělství, průmyslu a službách. K vyřešení tohoto problému se vlády snaží implementovat ustanovení Evropského zeleného programu, rychlý přechod na výrobu a využívání obnovitelné energie, zákaz nebo omezení odlesňování, a navíc urychlení přechodu na aplikace oběhového hospodářství.

Hlavním cílem této disertační práce bylo zjistit roli skleníkových plynů a změřit dopad ekonomického růstu na emise skleníkových plynů ve střední Evropě.

To se neomezuje pouze na roli skleníkových plynů jako celku, ale cílem disertační práce je probrat každý ze tří hlavních plynů (oxid uhličitý, metan a oxid dusný), aby bylo možné zjistit, které odvětví se na emisích podílí nejvíce a má největší dopad na životní prostředí.

Výsledky tohoto výzkumu by měly ukázat odborníkům, politikům i laikům, která odvětví a technologie mají největší dopad na životní prostředí.
Tato disertační práce byla analyzována pomocí panelových dat z let 1995 až 2018. Pomocí dvou hlavních typů analýzy. První je panel VAR a druhý panel ARDL. Grangerova analýza kauzality byla také použita jako doprovodný krok k panelové analýze VAR.
Nulová hypotéza této disertační práce byla zamítnuta na třech místech, a sice že „ekonomický růst je důležitý a významně přispívá k emisím (skleníkového plynu, oxidu uhličitého, metanu) ve střední Evropě“, a proto byla přijata alternativní hypotéza, že „ekonomický růst není významný a významně se nepodílí na emisích (skleníkové plyny, oxid uhličitý, metan) ve střední Evropě, bohužel ve skutečnosti byla v EU dočasně přijata nulová hypotéza.
Tyto výsledky potvrzují, že země střední Evropy jsou z teoretického hlediska a perspektivy na správné cestě, pokud jde o přechod na zelenou ekonomiku prostřednictvím výroby a využívání obnovitelných energií. Stejně tak výsledky potvrzují, že tyto země potřebují kvalitativní posun v oblasti zemědělství, aby se snížily emise oxidů dusíku a tím i emise skleníkových plynů. Toho je dosaženo mnoha metodami, zejména omezením odlesňování, hospodařením s chlévskou mrvou a zemědělskou půdou. Stejně tak se doporučuje vhodné mechanizační zařízení pro přesnou přípravu krmiva, používání ekologických hnojiv a podpora využívání obnovitelných energií v zemědělských oblastech. Tyto nové metody povedou k urychlení zaměstnávání kvalifikovaných sil a tím k řešení výše uvedených cílů.
Klíčová slova: Ekonomický růst; Skleníkové plyny; Emise, Zemědělství; Průmysl; energie; Panel ARDL; panel VAR; Střední Evropa

Table of content

List of graphs, tables, and abbreviations

List of graphs

List of tables

List of abbreviations

ABSL: The Association of Business Service Leaders
ADF: Augmented Dickey–Fuller.
AGR: Agriculture.
ARDL: Autoregressive Distributive Lagged
AVA: Agriculture Value Added.
BRICS: Brazil, Russia, India, China and South Africa
CAP: Common Agricultural Policy.
CDM: Clean Development Mechanism.
CE: Circular Economy
CEAP: Circular Economic Action Plan
CEE: Central and Eastern Europe
CFCs: Chlorofluorocarbons
CH4: Methane
CO2: Carbon dioxide
EAPs: environment action programs.
EC: Energy Consumption
EC: Energy Consumption.
EEA: European Environment Agency
EF: Ecological Footprint
EG: Economic Growth
EGD: European Green Deal.
EIP: Environmental Integrity Project
EKC: Environmental Kuznets Curve
ENG: Energy.
EPA: United States Environmental Protection Agency
ETC/CME: European Topic Centre on Climate Change Mitigation and Energy.
ETS: Emissions Trading Program
EU: European Union.
FAO: Food and Agriculture Organization
FDI: Foreign Direct Investment
FMOLS: Fully Modified Ordinary Least Squares
GCI: global competitiveness index.
GDP: Gross Domestic Product
GFCF: Gross Fixed Capital Formation.
GHG: Greenhouse gases
GLS: Generalized Least Squares.
GMM: Generalized Method of Moments

HFCs: Hydrofluorocarbons.
IAEA: International Atomic Energy Agency
IEA: International Energy Agency
IEEP: Institute for European Environmental Policy
IMF: International Monetary Fund
IND: Industry.
IPBES: Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services
IPCC: Intergovernmental Panel on Climate Change.
IRF: Impulse Response Function (IRF)
ISO: International Organization for Standardization
IT: Information Technology.
ITA: International Trade Administration.
IVA: Industry Value Added.
JRC: European Commission Joint Research Centre.
LLC: Levin, Lin, Chu
MDGs: Millennium Development Goals.
MENA: Middle East and North Africa.
MVS: Material Values Scale.
N2O: Nitrous Oxide
NACE: North Atlantic and Central European region
NDCs: Nationally determined contributions.
NRDC: Natural Resources Defense Council
OECD: Organization for Economic Cooperation and Development
OLS: Ordinary Least Squares
PAICC: Paris Agreement Implementation and Compliance Committee.
PHH: Pollution Haven Hypothesis.
PP: Phillips–Perron.
PSTR: Advanced Panel Smooth Transition Regression.
PVAR: Panel Vector Autoregression.
R&D: Research and Development.
SDGs: Sustainable Development Goals.
SMEs: Small and Medium-Sized Enterprises Sectors
SO2: Sulfur Dioxide
SOC: Soil Organic Carbon
SPM: Suspended Particulate Matter.
STIRPAT: Regression on Population, Affluence, and Technology.
UN: United Nations
UNCTAD: United Nations Conference on Trade and Development
UNFCCC: United Nations Framework Convention on Climate Change
USA: United States of America.
USD: United State Dollar
V4: Visegrád Four 'European Quartet'
VAR: Vector autoregression
VECM: Vector Error Correction
VMT: Vehicle Miles of Travel
WHO: World Health Organization
WKC: waste Kuznets curve.

1. Introduction

1.1. Worldwide Economic Growth

The concept of the global economy is very dynamic and delicate that has been dealt with previously and is dealing with recent tumultuous events, namely the global coronavirus-19 pandemic and the geopolitical uncertainties, which have been taking the world by storm. According to the International Monetary Fund's (IMF) last three Annual Reports, the world is still working hard to achieve sustainable economic growth and prosperity. At the same time, it lies in the aftermath of the pandemic and the global financial crisis of 2007-2008 on the banking system and the financial markets (IMF, 2021; 2020; 2019). Global trade has assisted countries in nurturing their economic growth by enhancing incomes and living standards by enabling the flow of technology across the globe (IMF, 2019). However, the global trade engine that has worked for so many years must be updated to make the global financial system safer, especially in our current world (IMF, 2019). This is a work in progress to invest in people's futures, mainly because global trade and the regional/international trade integration processes are crucial to sustainable economic growth and prosperity. This economic development falls under Goal 8 from the ambitious sustainable development goals (SDGs) of the United Nations, 17 goals set to be achieved by 2030.

The international parties' determined efforts towards taking a holistic approach to solve the challenges facing sustainable global economic prosperity over the past years were faced with an unprecedented impediment in the form of a universal health crisis with detrimental economic consequences (IMF, 2020; World Bank, 2022a). In early 2020, when the COVID-19 pandemic reached the headlines, the global economy came to a standstill. Now, with the ongoing impact of this health predicament, the world's economy is facing a deep recession due to global, regional, and significant national declines in export earnings, massive job losses, extensive lockdowns, and minor business disruptions, among other drastic changes that no one was prepared to tackle (IMF, 2020). According to the IMF's World Economic Outlook, the annual global economic growth rate was subject to several revisions, mainly because of the pandemic's uncertainties (IMF, 2021b; 2022). In 2020, the economic world output was a -3.1 annual percent change. This data point means the pandemic has halted growth and reversed it. For example, the advanced economies such as Germany, United States, France, Spain, the United Kingdom, and other countries had an economic decrease of -4.5%, while the emerging market and developing economies such as China, India, Russia, Brazil, Mexico, and other countries suffered a decrease of -2.1% (IMF, 2021b; 2022).

These 2020 annual percentages were shaped significantly in 2021 when the economy seemed to recover from the coronavirus-inflicted recession (IMF, 2021b; 2022). The economic world output was estimated at 5.9%, a notable change from the 2020 percentages. Similarly, the aforementioned advanced economies experienced an estimated economic increase of 5.0%, whereas the emerging market and developing economies experienced an estimated economic increase of 6.5%. These optimistic percentages were not the case in the latest world economic outlook update of January 2022. The projections depressed to 4.4% for the world, 3.9% for the advanced economies, and 4.8% for the emerging economies. To make matters worse, the IMF's 2023 projections for economic growth only decline further because the current global inflation is expected to persist longer than anticipated and at a higher rate (IMF, 2022). This inflation persists because of the increased prices of goods and services, especially now with the political turmoil and conflict in different regions, most notably between Ukraine and Russia (O'Neill, 2022; Mbah & Wasum, 2022).

1.2. Economic Growth in the EU

With global growth projected to slow down through 2023 and the subsequent widening divergence in growth rates between advanced economies and emerging and developing economies (World Bank, 2022a), all countries are bound to face hardships in their pursuit to return their economies to pre-pandemic rates. Europe, amidst the pandemic and especially with the rising Russian-Ukrainian conflict, is facing head-on collisions with its economies. The World Bank forecasted Europe, a region of countries with advanced economies, to have the slowest economic growth at 2.9% in 2023. While, other regions, such as the Middle East and North Africa (MENA), Sub-Saharan Africa, and South Asia, which will face slow economic growth in 2023, will still be at a higher economic growth rate than Europe (World Bank, 2022a). For example, the MENA region's economic growth rate is 3.4% in 2023, and South Asia's growth is 6% in 2023 (World Bank, 2022a). These statistics result from a plethora of risks the region faces, most notably the pandemic, geopolitical turmoil, tight macroeconomic policies, increase in commodity prices, high debt, and inflationary pressures, among other weighing factors (World Bank, 2022b).

COVID-19 has infected at least one-tenth of Europe's population since the beginning of this year. Death surges, and cases owing to the COVID-19 pandemic and its variants are elevated in the region, where new daily cases in January 2022 reached an estimated 80,000 people (World Bank, 2022b). The pandemic is expected to disrupt further the region's road to economic recovery as international travel bans are to be reimposed, denting revenue from the tourism sector. Additionally, consumer and business confidence is weakening with the rising cases in the region, which leads to lingering supply chain bottlenecks and the softening of external demands (World Bank, 2022b). Alongside the pandemic, economies within the region have tightened their monetary accommodation policies, external financing conditions, and fiscal support measures by central banks. These measures taken by European countries have compounded the inflationary pressure, which is not expected to subside shortly because of the uncontrollable rise in prices, especially energy and oil prices due to the Russian-Ukrainian conflict, and growing wage pressures as a result of elevated expenditures and constant fragility in revenues (World Bank, 2022b). In addition to the rising inflation rates experienced by European economies, the political turmoil between Russia and Ukraine only further declined regional economic growth (Mbah & Wasum, 2022). After the Russian invasion of Ukraine, the U.S. imposed sanctions on the invading country, which served additional financial market pressures. Europe's economy has begun to feel the impact of this crisis, where sharp increases were witnessed in oil, natural gas, and food prices just a few days into this crisis (Mbah & Wasum, 2022). Negative impacts are expected on household consumption, unpredictable stock swings, supply chain disruptions, economic growth impediments, decreased investment due to political risks, and bulging utility bills (Mbah & Wasum, 2022).

1.3. Impact of Economic Growth on the Environment

Environmental degradation is an expanding challenge in our time. Often, fingers point to economic growth as one of the leading causes of this ongoing crime against the global environment (Cederborg, and Snöbohm, 2016). However, some studies indicate the beneficial aspects that economic growth can bring to the environmental table (Cederborg & Snöbohm, 2016). First, it is crucial to understand the relationship between the economy and the environment to tap into the advantages. Economic growth is crucial for human development, especially with the exponential increase in the global population. There is a need to constantly produce and improve current economies to engulf this increase in the global world. However, there are environmental consequences when this growth is uncontrolled, and economies become unsustainable. When the environmental aspect is not considered, economic growth becomes the primary pollutant, drastically affecting the lives of the global world (Cederborg & Snöbohm, 2016).

Economic growth in industrialized countries such as the ones in Europe has changed the dynamic of the environment around the region, releasing more pollutants in the form of emissions and, as such, disrupting the natural ecosystem upon which we depend to breathe clean air and provide food (Cederborg, and Snöbohm, 2016). As pollutants accumulate in our atmosphere, greenhouse gases, which are usually naturally present on our planet, increase and produce the so-called greenhouse gas effect (GHG), which in turn causes global warming. As the global temperature increases, the arctic ice melts more quicker, raising the sea level (McMichael, Woodruff, and Hales, 2006). However, this is not even the worst effect of rising global temperature; experts expect more floods, droughts, desertification, wildlife extinction, wildfires, among other effects, in the future and, which have recently been witnessed with the 2021/2022 fires that have consumed Australia, Lebanon and the United States of America (Browne, 2021; McMichael, Woodruff, and Hales, 2006).

A necessary puzzle piece, which explains why it is always important to factor in the environment when planning to improve economic indicators, is the notion that whatever negative impact the environment suffers from will circle back and affect human life (Frunkim, 2016). In other words, and as clearly stated by the World Health Organization (WHO), "Environmental Health comprises all aspects of human health and is determined by physical, chemical, biological, and psychological factors in the environment. It refers to the theory of practice of assessing, correcting, controlling, and preventing factors that can potentially adversely affect the health of present and future generations" (Frunkim, 2016). To put it in numeric terms, take, for example, the 2021-2022 wildfire that began in Denver, Colorado, in the United States. The estimated Cost of damages was $513,212,589 (Browne, 2021; McMichael, Woodruff, and Hales, 2006), a value that could otherwise have been invested to better the economy. In sum, this is a vicious and endless cycle of uncontrolled economic expansion, leading to environmental degradation, which hurts humans directly by causing sickness, including different types of cancers, inflammations, and heart diseases, as well as disastrous consequences on societies as a whole including poverty, starvation, unemployment, etc., and this in turn circles back to the economy, causing dents in its growth and plummeting its expansion (Cederborg, and Snöbohm, 2016; McMichael, Woodruff, and Hales, 2006). This negative feedback mechanism shows that to grow economically and prosper as global communities and societies, it is vital to incorporate the environment into our plans and frameworks. This deduction also feeds into the interconnectedness of the United Nation's Sustainable Development Goals (SDGs), which unites the environment (or biosphere), society, and economy under its 17 ambitious goals (Wahl, 2017). There are interlinkages between the goals, targets, and indicators, thus enjoining the environment with the economy and society as an indispensable component towards achieving the goals (Wahl, 2017). The following section discusses the SDGs, their interlinkages, and the importance of the environment-economy dyad in more detail.

1.4. World Development Goals and The Environment

The Sustainable Development Goals (SDGs) are 17 ambitious goals from 2015 to 2030 adopted by the United Nations after the era of the millennium development goals (MDGs). These 17 goals cover a wide range of areas the world needs to progress on to achieve a better and more sustainable future for all (Lee et al., 2016). We are halfway through the 15-year agenda as we passed the seventh year, and there have been differing points of view on whether the goals will be achievable on time. These points of view cover these goals' economic, social, health, and ecological dimensions. However, all perspectives indicate that if nations continue functioning as they are, the goals will not be accomplished by 2030. According to several studies, the SDGs will not be accomplished by 2030 because different evaluation criteria for the targets are being utilized, too many goals and targets exist, the targets are labeled as wrong or do not comprehensively represent the goals, or the targets included are poorly framed. More adequate data must be needed to track progress (Nicolai et al., 2015). This trend is worrisome because failing the global agenda equates to failing to improve human health, ecology, and universal social and economic development. Even though some SDGs have shown more progress than others, such as SDG 2 (no hunger) and the essential elements of SDG 3 (good health and well-being: maternal health and child mortality), some still need much work to reach an acceptable level of achievement such as SDG 6 (Clean water and sanitation) (Green, 2018).

Scholarly articles focused on some missing aspects from the SDGs; for example, Guevara & Pla-Julián (2018) focused on circular economy as a missing aspect from SDG 12 (sustainable consumption and production) being the key to reaching sustainable development with some challenges relating to strengthening the social dimension of the circular economy. Other articles focused on assessing challenges faced while trying to achieve goals. For example, Herrera (2019) assessed the governance challenges faced at the local level associated with SDG 6, which promises to ensure sustainable water and sanitation for all. Given that most developing countries provide services at the subnational level, the quality of the governance is a critical aspect in the progression of this water sector and vital for the improvement of SDG 6.

The aim here is to show the interconnectedness between all SDGs and that their limitations or lack of progress in their targets can be a severe hindering factor to the accomplishment of the new development agenda that has at its heart the three pillars of sustainability: Economic growth, social progress, and environmental protection (United Nations, 2012). The U.N. 2030 SDGs are cemented on these three pillars, whereby only some could be achieved if any of them is considered while aiming to achieve the ambitious targets. In other words, we can only hope to achieve the SDGs if the environmental factor is considered. After all, all 17 SDGs have environmental components as economic and social components (United Nations, 2012).

1.5. The Paris Agreement

After establishing the necessity and vitality of the environment as a precursor to achieving the 2030 goals, countries and their representatives began organizing, planning, and participating in international meetings, global symposiums, and conventions to see through the accomplishment of these goals. One famous accord is the Paris Agreement, a 2015 international treaty on climate change, which is a chief artificial factor in global environmental degradation. This agreement is legally binding to 196 countries after it entered into force on November 4th, 2016 (UNFCCC, n.d.). The main goal is to keep the global temperature below 2 degrees Celsius, at a target of 1.5 degrees Celsius. To achieve this, countries must decrease their greenhouse gas emissions (GHGs) and adapt to climate change's inevitable effects and consequences. This treaty is prominent because it is the first-ever agreement that brings together the globe to combat climate change, and it is essential to recognize that it was agreed upon within the same timeframe as the 2030 SDGs, solidifying it as the first global-scale intervention in realizing the SDGs (UNFCCC, n.d.).

1.6. Objectives

Economic growth is divided into three main pillars: agriculture, services including transportation, and industry including construction. The countries under study are industrialized countries that produce and consume energy for use in the three sectors. The combination of obtaining energy and using that energy in all its forms in various sectors, in addition to various practices in agriculture and services, including transportation, leads to the release of more pollutants in the form of emissions. As pollutants accumulate in our atmosphere, greenhouse gases, which normally exist naturally on our planet, increase (European Central Bank, 2022; European Environment Agency, 2020).

The general aim of the dissertation is to explore and evaluate the impact of the major sectors that make up the economy on the environment, represented by greenhouse gas emissions. Providing achievable proposals that suit the situation of each country according to its situation and priorities.

To achieve the general aim, the following points will be discussed:

- Providing a vision for the economic and environmental situation of Central European countries and explaining vocabulary, theories and general policies
- Analysis of the impact of the economy on greenhouse gas emissions and its three components (carbon dioxide, methane, and nitrous oxide) during the extended time period (1995 to 2018).
- Discussing and comparing the impact of the economy on the environment in each of the research countries and linking them to appropriate proposals.

This objective is broken down into specifics, which be addressed by answering the following fundamental questions namely:

- ➢ How does economic growth affect greenhouse gas emissions in Central Europe?
- ➢ What is the impact of economic growth on greenhouse gas emissions in Central Europe?
- ➢ What is the impact of economic growth on CO2 emissions in Central Europe?
- ➢ What is the impact of economic growth on methane emissions in Central Europe?
- ➢ What is the impact of economic growth on nitrous oxide emissions in Central Europe?
- ➢ Is there a negative trend in emissions of carbon dioxide, methane, nitrous oxide and greenhouse gases in the countries studied?
- ➢ What policy recommendations will help the region under study reach a climate-neutral bloc?

1.7. Hypothesis

In order to discuss the claim that greenhouse gas emissions have an impact on the economies of countries including but not limited to Austria, Czech Republic, Germany, Hungary, Poland, Slovakia, Slovenia, and Switzerland, this thesis focuses on determining where central European countries stand concerning the environmental Kuznets curve and providing the necessary assessment of the impact of greenhouse gas emissions on economic growth in Central Europe.

This dissertation emphasizes the importance of greenhouse gas emissions to economic growth and will be tested against the hypothesis below:

Null hypothesis: economic growth is important and significantly contributes to Greenhouse gas emissions in central Europe.

Alternative hypothesis: economic growth is unimportant and does not significantly contribute to Greenhouse gas emissions in central Europe.

Null sub-hypothesis: Economic growth is important and significantly contributes to Carbon dioxide emissions in central Europe.

Alternative hypothesis: economic growth is unimportant and does not significantly contribute to Carbon dioxide emissions in central Europe.

Null sub-hypothesis: economic growth is important and significantly contributes to Methane emissions in central Europe.

Alternative hypothesis: economic growth is unimportant and does not significantly contribute to Methane emissions in central Europe.

Null sub-hypothesis: economic growth is important and significantly contributes to Nitrous oxide emissions in central Europe.

Alternative hypothesis: economic growth is unimportant and does not significantly contribute to Nitrous oxide emissions in central Europe.

1.8. Significance and Structure of Paper

In principle, considering that the European Union contains 27 countries, the seven countries under study are supposed to have an average emission of 29 percent of the total greenhouse gas emissions, similar to the average gross domestic product. Since 1995, the seventh countries provided 40.06% of European emissions and continued to do so, with an increase or decrease of one to two percent annually until 2018, when it stabilized at 40.70%. Similarly, the eight countries under study achieved an average gross domestic product of 39 percent in 1995. It continued to fluctuate with an increase or decrease from 1 to 2 percent from 1995 to 2017 when it settled in 2018 at 40 percent (World Bank, n.d-a; n.d-b; n.d-c;n.d-d; n.d;e; Ritchie & Roser, 2020). Besides these 7 countries, we have Switzerland which is completing the puzzle of the central european countries. As it is known to everyone, the country of Switzerland is not one of the European Union's puzzle pieces. Despite this, it has been added as an important component of the research because the study first includes geographically central European countries and not only the European Union countries. Secondly, the countries of the European Union in general and the Central European region in particular have a close relationship with each other through trade and influence on each other, due to the fact that Switzerland is one of the important members of the European Free Trade Association and the Schengen Agreement. Switzerland shares with neighboring countries the same international environmental agreements, leading to the Paris Agreement. Let us not forget that the energy and electricity market is closely linked to the market of neighboring European Union countries during the period of preparation of the study (European Commission, 2023).

This economic progress of the Central European countries during the 23 years and the accompanying increase in emissions of greenhouse gases made it necessary to present a study that discusses what is happening in this geographical space for the first time.

Previous research in the section (Lapinskienė et al., 2015, 2017; A. Wang et al., 2022) has looked at general greenhouse gas emissions, their relationship to sectoral growth, and other factors influencing their emissions in different parts of the world, including Europe. According to the author's research and investigation, there is no empirical study on the impact of economic growth on greenhouse gases that includes industry, agriculture, and energy as additional factors to provide a more precise and more accurate picture of the results. The novelty of this study is that it determines the practical impact of each component of greenhouse gases independently, which will help to know which exact sector is doing well and following the Paris agreement and the European green deal and which sector needs more improvement to accelerate the efforts to reach the European target to reduce the emission. The dissertation will also concentrate on countries in Central Europe for a reason mentioned above. The study will make recommendations that will benefit the environment of Central European countries as well as the rest of the world.

1.9. Author’s motivation for topic selection

The post-communist time period witnessed many changes that affected the Central European region, which made the author desire to explore the research aim for the region as a whole. In the Central European region, an increase in economic growth was achieved, as many countries achieved a boom in GDP growth and increased confidence in increasing investment attractiveness. With the expansion of the real GDP per capita by more than hundreds of times in some of the study countries over the past twenty years. The Central European region of Europe is one of the best places for foreign direct investments. Given the relatively acceptable labor costs, favorable tax environment, and access to tax incentives, diversification of the economy is another feature of Central Europe. Besides, many industries are active in Central Europe, including the production, automotive, aerospace, information technology, agriculture, food processing, electricity and financial sectors. All the points mentioned, “in addition to the fact that no previous research has discussed these countries,” provide motivation for choosing the topic (European Central Bank, 2021).

2. Literature Review

2.1. An Overview of Greenhouse Gas Emissions

With the warming of the world, greenhouse gases become a central focus as they present the world's most pressing challenge. Even though CO2, CH4, and N2O, which are some examples of greenhouse gases and the most prominent ones, are not artificial, artificial emissions of these said gases have increased their concentration to the point that the global temperatures have increased beyond 1oC on average (Ritchie & Roser,2020). This matters in the grand scheme of things because these severe increases in global warming have quickened the pace of the climate change process, which is a critical driver of environmental damage and degradation (Ritchie & Roser, 2020). As mentioned before, the environment is a significant component of the SDGs and is one of the three pillars contingent on one another for world development (Lee et al., 2016). Therefore, artificial greenhouse gas emissions are the focus of this paper section.

Carbon Dioxide (CO2), a significant GHG inducing climate change, is usually emitted from burning fossil fuels such as coal, oil, and natural gas, which run our industrial world today. CO2 is one of the most significant contributors to GHGs, accounting for 74.4% of the total emissions (Ritchie & Roser, 2020). however, not entirely due to the burning of fossil fuel but also to deforestation, industrial waste, landfills, air pollution, and acidification of water bodies, among other factors. The latest emissions data indicate that the total greenhouse gas emission in kilotons reached around 45 million kt of CO2 equivalent, and CO2 emissions alone were driven up by over 2 billion tonnes in 2021 due to a rise in coal utilization (World Bank, 2018; IEA, 2022a). This increase in CO2 emissions offset the 2020 pandemic-induced decline, and this rise's effects are compounded by the emission estimates of Methane and nitrous oxide (IEA, 2022a). The upsurge in CO2 emissions speaks to the unsustainable nature of the global economic recovery, whereby the GHGs rose to their highest levels from energy combustion and industrial processes (IEA, 2022a).

Methane (CH4), a notable GHG contributing to environmental degradation and responsible for a 30% increase in global temperatures, has increased by 70% more than official figures have reported due to the amplified utilization of oil, gas, and coal (IEA, 2022b). Indeed, Methane dissipates faster than CO2. However, CH4 is more potent, and thus targeting the reduction of this gas will show a rapid effect in combating rising temperatures (IEA, 2022b). The international energy agency, which is comprised of several European member countries, estimates that in 2021 about 9 million tonnes (Mt) of methane emissions will come from bioenergy, 43.6 Mt of CH_4 comes from coal, 42.9 Mt comes from oil, and 39.6 Mt of Methane comes from natural gas (IEA, 2022b). These are perilous statistics given that CH_4 can lead to tropospheric ozone, a dangerous air pollutant, thus affecting air quality, and CH_4 leaks could pose explosion hazards (IEA, 2022b). This gas is even riskier due to the heavy uncertainty around its estimates, whereby various sources try to assess and approximate the proper level of Methane emitted from anthropogenic sources. Still, it is estimated that 60% of CH_4 present in the atmosphere is of human origin, while 40% comes from natural sources (IEA, 2022b).

Nitrous oxide (N_2O), a long-lived greenhouse gas resulting in stratospheric ozone depletion, steadily increases at 2% per decade (Tian et al., 2020). Like CH_4, national inventories and official reports do not fully represent nitrous oxide emissions from natural and anthropogenic sources (Tian et al., 2020). Natural sources of N_2O gas production are microbes that live in the soil, i.e., the most significant contributor to N_2O emissions are agricultural sources (Emissions et al., n.d.). However, with the growth in the global population, there is an intensification in land use due to amplified food production. This overproduction and utilization of land muddle with the natural processes of nitrification and denitrification, the two main ways microorganisms produce N_2O (Emissions et al., n.d.). N_2O production contributes almost 300 times more to climate change than a single carbon dioxide molecule, which is more potent in supporting environmental degradation (Emissions et al., n.d.). However, according to the U.N. Climate Change News, significant changes have been made to lower the agricultural sector's contribution to climate change through N_2O emissions (UNFCCC, 2021).

2.2. Structure of the Euro Area Economy

The euro area has a sizable and considerably more closed economy than any one of its individual members. It is the third-largest economy in the world in terms of its percentage of global GDP, behind China and the United States (European Union, n.d.). Similar to most highly developed economies, the service sector makes up the most considerable portion of overall output, followed by the industrial sector, with a comparatively small contribution from agriculture, forestry, and fishing. With about 340 million inhabitants, the Euro area has one of the most excellent populations in the world. (European Central Bank, 2022). Breaking down the economic structure into value added by sector.

Agriculture, sometimes known as farming, is the industry standard for the agricultural sector and refers to the process of generating food, feed, fiber, and other desired goods through cultivating particular plants and keeping domesticated animals (Merriam-Webster, n.d.).

Due to its impact and influence on other sectors of the economy as well as people's daily lives, the agriculture industry is one of the most crucial ones (Vásáry, 2005). There are many reasons why this sector is the backbone of an economy; for instance, the agriculture sector provides food and fodder to feed people and livestock, is a source of raw materials for production, is a source of employment and a means of subsistence for a sizable portion of the global population, contributes to national income and is a source of government income, and is a basis for economic development - locally and nationally - and is a contributor to a country's overarching prosperity. The agriculture industry significantly impacts economies at all levels, including local, regional, national, and even global levels (Food and Agriculture Organization, n.d.; Vásáry, 2005). Nevertheless, the agriculture industry is dealing with a number of issues, including population increase, food security, and climate change. The European Commission is committing significant research resources to the socioeconomic concerns of food security, sustainable agriculture, marine and maritime research, and bioeconomy through the Horizon 2020 initiative to address and combat these challenges. Embracing, successfully integrating, and combining digital technology related to Industry 4.0 is another strategy to assist the farm sector through these issues (European Commission, n.d.a).

Several agroecological conditions can be found in the Central European nations. As a result, they have different approaches to agricultural production, particularly in the area of plant production. The nations analyzed offer similar opportunities for livestock husbandry. Therefore the disparities between the countries under consideration regarding the directions of animal production are relatively less (Bański, 2008). The level of development of agriculture is where the disparities between the Central European nations are most noticeable. This results from various historical, political, economic, and social processes and phenomena. The Central European nations under consideration can be divided into two groups based on the production effects attained. Czechia is the first; agriculture achieves the relatively highest production impacts of all the countries analyzed. Hungary, Poland, and Slovakia make up the second group; in terms of the level of development, asset value, and productivity, it can typically be said that Central European agriculture lags behind that of the most economically developed nations in Western Europe (Food and Agriculture Organization, n.d). Czechia's agriculture is comparatively closest to the farming level in these nations. The average yields of wheat and barley in the Czech Republic during the economic transformation period of 2000–2005 were thus 4.8 tons and 4 tons, respectively, while the comparable statistics for the EU-15 countries were 5.8 and 4.6 tons (EUROPEA, 2019). The highest agricultural output is seen from Germany throughout the period. In contrast, alternately throughout the period, the lowest output is seen to be between Slovakia and Slovenia. The figure shows agricultural output data for central European countries between 1995 and 2018 (world Bank, n,d-a).

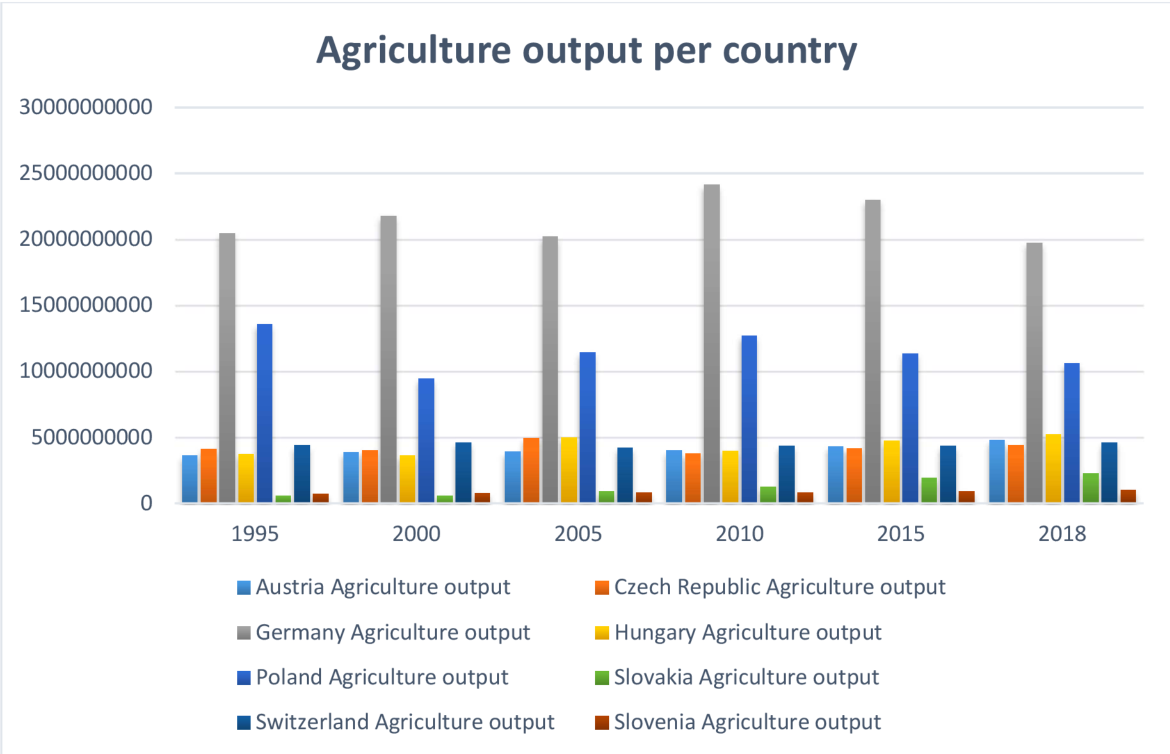

Figure. 2.1. Agriculture output for Central European countries throughout 1995–2018
Source: (World Bank, n,d-a)

The graphic below illustrates how the industrial sector in central European nations contributes to overall GDP, with numbers that consider essential contributors like mining and building. Given that the Czech Republic's GDP percentage has constantly outperformed that of other nations between 1995 and 2020, it is clear that its number is the highest. This is due to its highly valuable research and development (R&D) activities (World Bank, n.d-b).

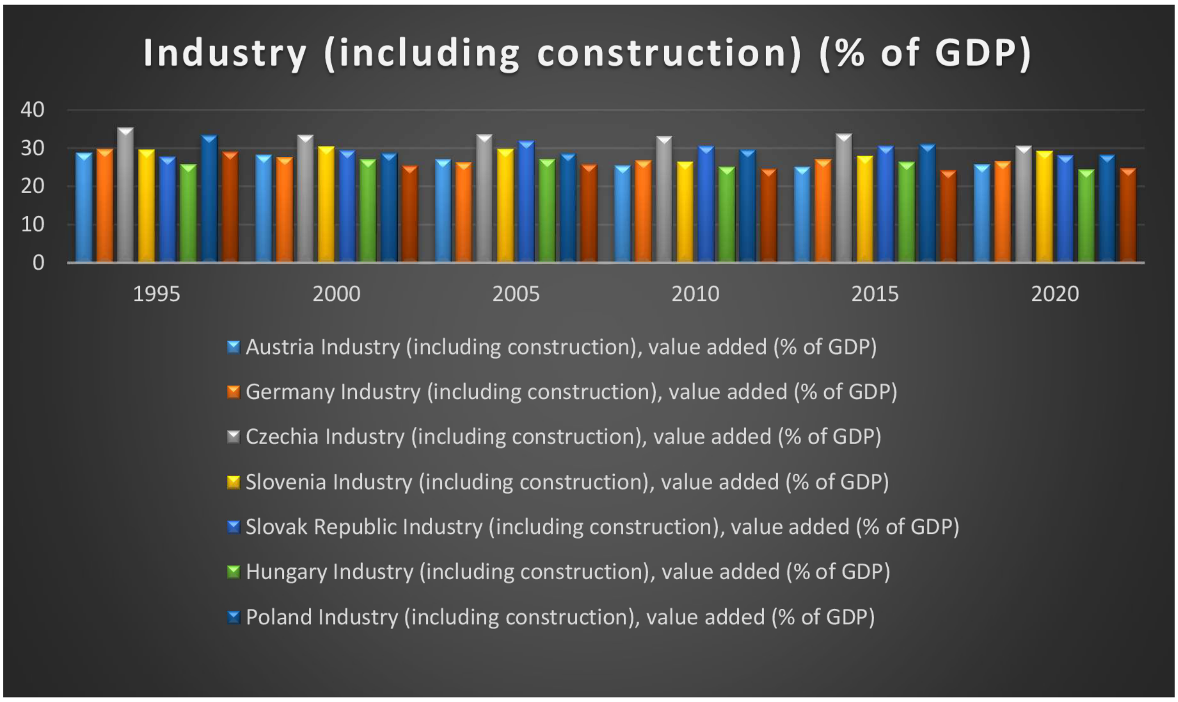

Figure. 2.2. Industry (including construction) value added (% of GDP) for Central European countries throughout 1995–2020

Source: (World Bank, n.d-b).

The below graph shows the annual growth of the manufacturing industries in the various central European nations. There was general agreement that growth would increase from 1995 to 2010. From 2010, there were indications of diminishing manufacturing growth, which persisted until negative growth rates were noticed in 2020. This resulted from the onset of the Covid-19 pandemic (World Bank, n.d-c).

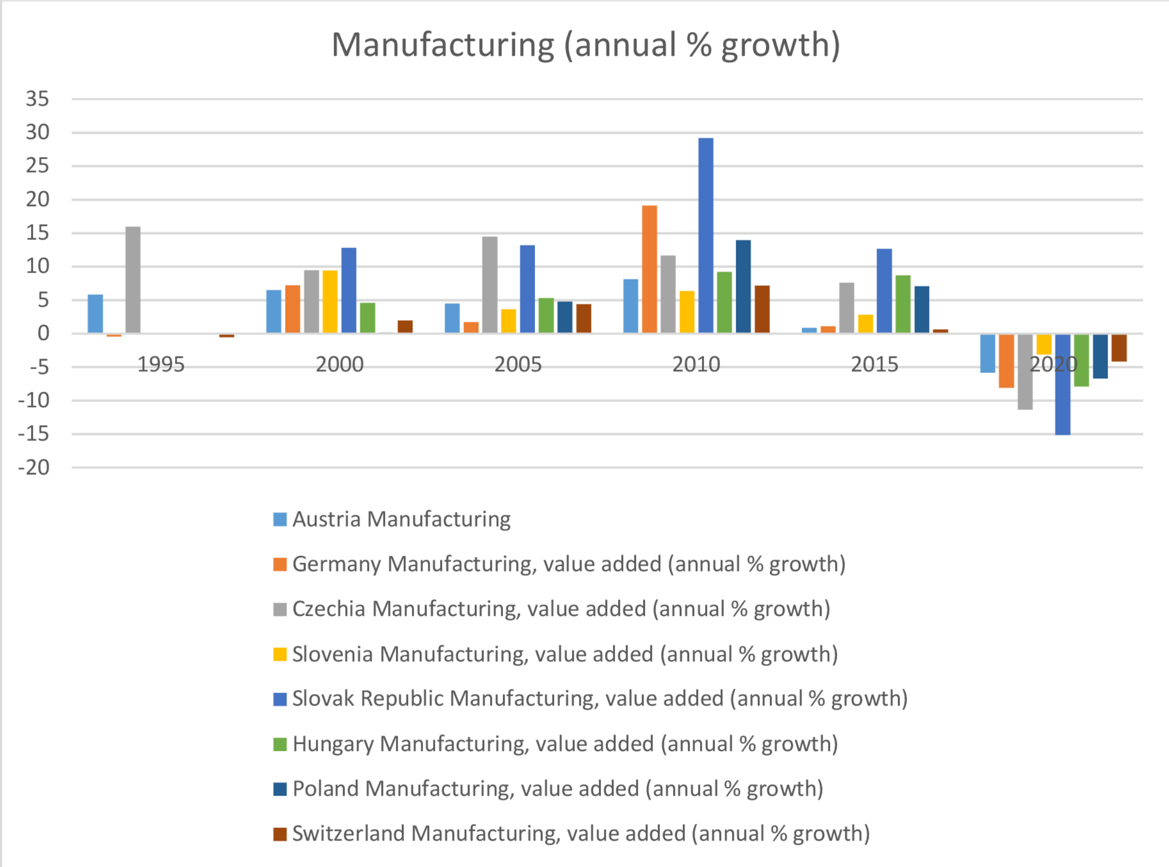

Figure. 2.3. Manufacturing Value added (% of annual % growth) for Central European countries throughout 1995–2020

Source: (World Bank, n.d-c).

The percentage of the services sector's overall contribution to GDP is shown in the graph below. Due to its stable labor market and the fact that more than 50% of its population works in the services sector, the data demonstrates that Switzerland continually had the most outstanding percentage contribution of the services sector to GDP. (European Central Bank, 2019; World Bank, n.d-d).

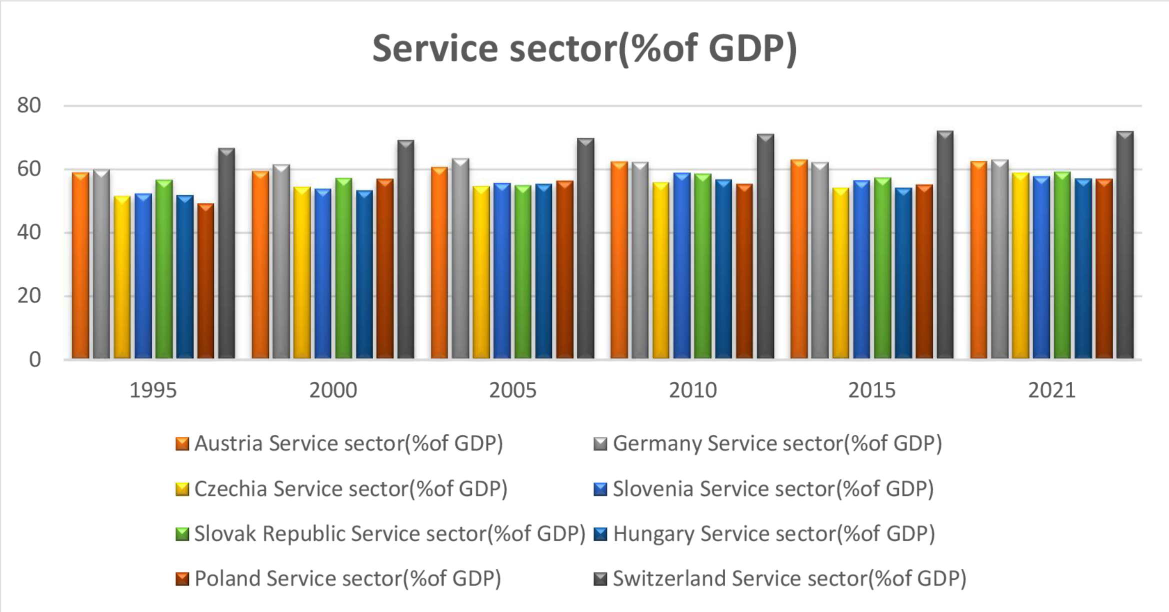

Figure. 2.4. Service Value added (% of GDP) for Central European countries throughout 1995–2021

Source: World Bank, n.d-d

However, the remainder of central Europe's nations has had nearly the same value addition in the services sector. The share of the services sector in the Czech Republic's gross value added has significantly changed during the past ten years, rising from 44% in 1990 to 49% in 1993 to 57% in 2000. After declining in 1992, the services sector rose until 1996, dropped in tandem with the broader economic downturn in the following years, and developed again in 1999. (European Central Bank, 2019). While social services in general and the health and educational sectors in particular stagnated or even decreased, growth was particularly outstanding in the trade and business services sectors of market economies. From 1993 until 1999, there was a gradual decline in employment in the education sector, with a loss of roughly 28 thousand workers (when the first Labour Force Survey was conducted). Nonetheless, employment in that sector increased significantly in 2000 (World Bank, n.d-d).

The Czech Republic's development sector is still relatively tiny and has a less favorable organizational structure than other countries. Traditional personal services, which rely on manipulating symbols and information, are outpacing modern market share (Vidovic, 2002). Employment is also lagging in areas like research and development, public and social services, public administration, and social welfare (Boersch, 2022).

Starting with the Company Law's introduction in 1989, Hungary's transition to a service-based economy started in the late 1980s. Since then, the number of businesses offering services has expanded by a factor of two more than the total number of businesses (Kovacs, 1999). In 2000, the services sector produced 62% of the nation's value-added and held close to 60% of all jobs. The cumulative increase of value added in the service sectors from 1994 to 2000 lagged that of industry. Transport and telecommunications (as one statistical item) grew at the fastest rates. When examining these two sectors separately, however, the telecommunications sector saw an extraordinary upward development after the privatization of the national telecom company and legislative changes coupled with intense investment activities value added in the services sectors. In contrast, the transport sector experienced a severe slump until the mid-1990s and only recovered in 1997 (Viszt & Borsi, 2001).

Poland's economy has undergone an extensive reorganization toward a service economy over the past ten years, more than doubling in size. The tertiary sector's contribution to gross value added increased from 50% in 1994 to 61.3% in 2000, while agriculture and industry's contributions decreased to 3.8% and 35%, respectively (ABSL,2023.; JLL,2020). Nevertheless, from 1994 to 2000, the value-added growth of the services sector fell much behind that of the general economy and the industrial sector. The value added of the tertiary sector's financial inter-hotels and restaurants was 84% more than in 1994, and the wholesale and retail trade was up 41% (World Bank, n.d-b; n.d.-d). These latter produce more than 20% of the nation's value-added, by far the most significant percentage in the entire region. With around 10-12% of the entire retail market in Poland under their control, retailing has been the third most crucial goal for foreign investors. Notable investors include IKEA (Sweden), French and Portuguese businesses, and Metro AG (Germany) (EBRD, 2001).

According to registration data, Poland's significant percentage of agricultural employment, which accounts for roughly 19% of the total or 26%, sets it apart from most other transitioning nations. Between 1994 and 2000, total employment stayed essentially constant, except for some temporary improvement (up to 1998), while value-added more than tripled from 1994 levels in 2000. During that time, employment increased in the services sector, compared to agriculture and industry, which reported job losses. While employment in community services stayed at the same level as in 1994, jobs were almost solely produced in the market services sector (O'Neill, 2023). The market services industry's real estate, rental, and business services sector, where the number of employed individuals more than doubled, registered the most outstanding growth rates. Compared to 1994, hotel and restaurant employment increased by over 50%. A 20% increase in employment was noted in the wholesale, retail, and financial intermediation sectors. The only community service sector with expanding employment is public Administration and defense (ABSL, 2023.)

Slovakia, which employed roughly 56% of the workforce overall in 2000, was the second nation after Hungary to generate more than 60% of its value added in the services sector. Actual output increased by more than 30% above 1995 and by as much as 44% in the community services sector (Michigan State University, 2023.).Within market services, which saw a 26% increase, value added in wholesale and retail trade, including hotels and restaurants, grew by more than 40%. Transport and telecommunications, real estate, and business activities grew next. Because of the significant changes the industry has undergone over the past ten years, the value-added level of financial intermediation was around one-third lower in 2015 than it was in 1995 (WorldAtlas, n.d.).Over that time, the market services sector saw growth of 8% while the tertiary sector's job growth was only 6%. The industries with the most job growth were financial intermediation, wholesale and retail trade, and hotels and restaurants. Real estate recorded a lower employment level in 2000 than in 1995 despite having extraordinarily high growth rates in the majority of other transition countries. Public administration accounted for most new positions in the community services sector, although education roles have steadily declined since 1997. Although compared to other CEE nations, the proportion of employed in that sector is still among the greatest, job destruction in education is also represented by its diminishing fraction of overall employment.(O'Neill, 2021).

In the second half of the 1980s, Slovenia's process of tertiarization picked up steam. In 1980, the services sector accounted for roughly 38% of all employment, producing about 42% of the country's GDP. While these developments less impacted the services sector, industrial output dramatically decreased at the beginning of the 1990s following the recession in the late 1980s (Slovenia was still a part of the former Yugoslavia at the time) (Stare, 2001). Since 1994, the cumulative growth of value added in the services sector has grown more slowly than in the manufacturing sector, but the difference is less dramatic than in Hungary. Around 30% more value was added to the community services sector in 2000 than in the market services sector in 1994. Slovenia experienced the highest growth in the community services industry over that time, regarding value added and employment, among all the countries considered. These changes could be attributed to the construction of a new state, as seen by the nearly one-third increase in employment in public administration.

2000 compared to 1994. The value generated by the tertiary sector climbed from 53% to 59% in 1990 but remained nearly unchanged. The share of total employment increased from 45% in 1993 to 51% in 2000 (World Bank, n.d-b; n.d-d). With jobs increasing by more than 50% since 1994 and value-added up by 20%, real estate, rental, and business services (K) is the market service segment with the most explosive growth. This industry contributed around 12% of the value generated overall and about 5% of employment in 2000. According to data from the balance sheets and profit and loss accounts, the number of businesses in this group expanded by 21% to 8851 between 1995 and 2000. The number of employees climbed by roughly 17% over the same period. The number of enterprises and employees in the real estate sector tripled between 1995 and 2000, and the value contributed per employee was 43% higher than the industry average. Architectural and technical consulting is the most significant activity in terms of value-added and number of employees. However, the data provided shows a gradual drop in businesses and employees. Interestingly, businesses involved in legal, tax, and business consultancy got the worst outcomes. They reported net losses for the entire period 1995 to 2000, with businesses involved in business and management consulting making up the majority of these losses (World Bank, n.d-b; n.d-d).

Contrary to other CEE nations, not only has the share of employment in services increased over the transition period, but so has that in agriculture. Based on data available since 1996 and the NACE categorization, the services sector's proportion of value added increased to 57% in 2000, while employment accounted for 46%. In the tertiary sector overall, employment and value-added were lower in 2000 than in 1996. With a 12% job loss in the community services sector and a slight job rise in market services, employment in the two subsectors changed unevenly (Boersch, 2022.). Only a few subsegments, like real estate and public administration, where employment increased by 22% each, wholesale and retail trade, where jobs increased by 10%, and hotels and restaurants, where employment increased by 2%, are claimed to have seen a significant increase in employment. All other service sectors saw sharp declines: for example, employment in financial intermediation fell by 25%, while transportation and telecommunications dropped by 12%. Jobs in health and social work decreased by 20%, while those in education decreased by 16%, within the community services sector, where employment fell by 12% between 1996 and 2000. The public budget continues to fund these two industries, which are undergoing a process of dramatic reorganization (IEA,2022a).

2.3. GDP Growth by Country

The annual GDP growth in central Europe from 2000 to 2021 could have been more stable. The economy expanded at a yearly rate of between +1% and +4% between 2000 and 2007. The financial crisis significantly impacted the major European economy from 2008 to 2013, with GDP falling by more than 4% in 2009 and then more in 2012. The economy gradually recovered between 2014 and 2019, growing at about 2% yearly. However, because of the COVID-19 outbreak and the subsequent economic repercussions, there was a reduction of around 6% in 2020. The E.U. economy recovered in 2021, and the yearly GDP rose by more than 5%. Between 2000 and 2021, the euro area and Central Europe member states showed a similar trajectory. In the current time frame, the COVID-19 pandemic caused a drop in practically all Member States in 2020, but in 2021, all Member States experienced positive growth. Ireland, Malta, and Croatia had the highest GDP growth rates in 2021, above 10%. Consumption and investment in central Europe follow the same five phases as the GDP, with investment seeing more significant swings. Between 2015 and 2019, investment and consumption increased gradually due to the financial crisis recovery, with yearly growth rates for investment and consumption ranging from 3% to 5%. This pattern altered in 2020, when a fall of 8% and 5%, respectively, was brought on, at least in part, by the COVID-19 pandemic. GDP, investment, and consumption recovered in 2021, increasing by 7% and 4%, respectively. The GDP growth across several central European nations is depicted in the graph below. For the intervals before 2020, when they had a negative growth rate as a result of the COVID-19 pandemic, it can be seen that there have been variances in growth rates throughout the various countries (World Bank, n.d-e).

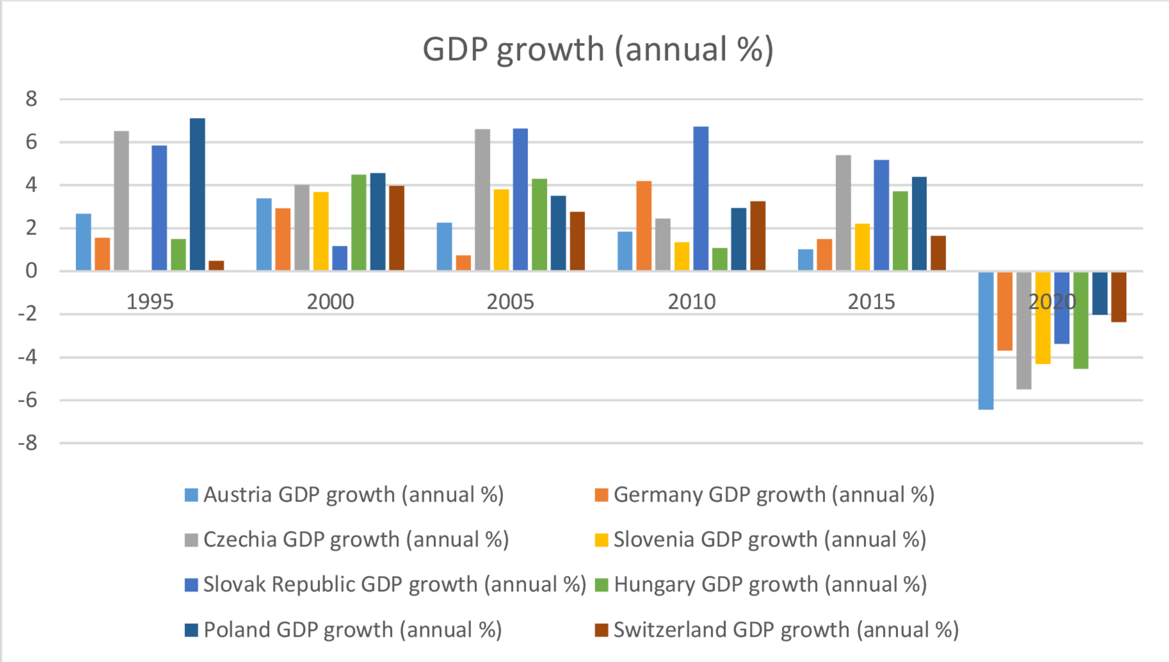

Figure. 2.5. GDP Growth for Central European countries throughout 1995–2020

Source: World Bank, n.d-e.

2.4. Geo-economic analysis of Central Europe

One of the top regions for foreign direct investments is still Central Europe (FDI). It combines a generally open and thriving business environment, low corporate taxes, reasonable labor costs, and developing infrastructure. Also, it offers an educated workforce with a creative attitude (Investment Forum, 2021). Austria, Poland, the Czech Republic, Hungary, Slovakia, Slovenia, and Bulgaria are all central European nations with a shared history and social and cultural traits. One hundred fifty million people live there, with a surface area of more than one million square kilometers. Many opportunities are made possible by the region's advantageous position (World Bank, 2022C).

Poland, the Czech Republic, Hungary, Slovakia, Slovenia, Estonia, Lithuania, and Latvia are eight countries from Central Europe that joined the E.U. in May 2004. Romania and Bulgaria joined the E.U. in 2007, and Croatia joined the E.U. structures in 2013. The new Central European member states comprise about 16% of the population, 9% of the total GDP (measured in purchasing power parity), and 15% of all employment inside the European Union (European Central Bank, 2021). All of the E.U. mentioned above nations are also part of the OECD, which gives businesses peace of mind when deciding on long-term investments. As a result of entering the E.U., these nations have become a customs union, and after joining the Schengen Area, all remaining borders have been eliminated. This enables total freedom of movement for people, goods, capital, and services among the 28 E.U. members (The Visegrád Post, 2018)

The Central European nations' entry into the European Union has allowed them to implement E.U. legislation and obtain the credibility and confidence that swiftly adhering to such regulations may give foreign enterprises and investors. They include a variety of investor safeguards, more straightforward insolvency resolution procedures, and property rights assurances. Being a part of the European Union has increased the countries' ability to flourish and appeal as investment destinations. The increase in prosperity across Central and Eastern Europe since the collapse of communism in 1989 has been genuinely astounding. With growth leaders experiencing a 150% increase in GDP, the per capita amount has increased from less than $2,000 in 1993 to more than $18,000 in 2018. The current burst of GDP growth and increased confidence increase the allure of investing in Central Europe. The strongest economies in Central Europe have had robust and consistent economic growth, with real GDP per capita expanding by more than 800% over the previous 20 years. The GDP, prosperity, and living standards are all significantly rising in Central Europe, with an average annual economic growth rate of 4.5% (Investment Forum, 2021). One of the finest places for foreign direct investments is the Central European region of the E.U. since it has relatively cheap labor costs, a favorable tax environment, access to tax incentives, and since 2013 strong GDP growth trends across most of the economic sectors. It has a high human capital with educated and creative workers across several industries. The availability of economists, engineers, I.T. specialists, and scientists is precious for investment attractiveness. The diversification of the economy is another feature of Central Europe. In Central Europe, several industries are active, including production, the automotive, aerospace, I.T., agricultural, food processing, electrical, and financial sectors (European Central Bank, 2021)

There are several tourist and sporting options in Central Europe. Visitors from all over the world are drawn here by the variety of scenery, natural resources, and the great variety of recreational activities. The decadent cultural richness and history of Central Europe can be used to complement leisure travel choices. The extraordinary rate of the CEE economies' development is driven by the socioeconomic revolution of the region, which began at the turn of the 20th century, and its logical outgrowth in the form of membership in the European Union. The economies of Central and Eastern Europe are steadily catching up to their Western counterparts in terms of productivity, the essential economic determinant. As a share of the German level, labor productivity in CEE increased gradually from 43% in 2000 to 63% in 2017. It indicates that the productivity gap between CEE and Germany has been narrowing by about one percentage point per year on average, indicating a long-term increase in the group of economies under study's overall economic capability (Focus Economics, 2015).

In 2017, the manufacturing, banking, insurance, wholesale, and retail sectors received the majority of FDI. The Visegrad Group countries have had exceptional economic progress. There is essentially no economic growth within the E.A. if the performance capabilities of the V4 nations are not considered—Europe's safest and fastest-growing region in Central Europe. In the V4 nations, the banking industry is autonomous, stable, and offers a business-friendly fiscal environment. The strategic geographic placement of V4 in the center of Europe is one of its key advantages. The market attracts international investment since it serves as a gateway to Central and Southeast Europe. (Central European Bank, 2021; The Visegrád Post, 2018). In V4 nations, a high level of entrepreneurship supports development. It was determined in 2017 using the ratio of SMEs in the non-financial business sector per 1,000 people. The number is the greatest among the EU28 countries in the Czech Republic, much higher than the E.U. average in Slovakia and around the same in Hungary and Poland. The labor force is highly educated, skilled, and reasonably priced, allowing V4 to be integrated into the European production chain as efficiently as possible. 12% of the EU28 population resides in V4 nations. (Central European Bank, 2021)

This collection of nations is diverse. Slovenia's economy expanded significantly, particularly in 2017. Bulgaria boasts the lowest corporate tax rates, a very cheap cost of living, and a strong and reliable defense against foreign economic shocks. Slovenia has a more varied economy and excellent infrastructure, seamlessly integrating into the European industrial system. According to UNCTAD data, the amount of FDI that entered the Baltic nations (Lithuania, Latvia, and Estonia) in 2017 was USD 2,1 billion (at current prices), a 50% increase over the previous year.

Moreover, it was the most significant influx since 2012. The Baltic States received 0.7% of the FDI that entered the EU28 in 2017. In comparison to the years 2013 to 2016, this share grew. The financial crisis of 2009 and its budgetary fallout in the euro area served as the most critical test of how individual economies functioned over the era of global economic growth between 2004 and 2007. Poland passed the test with flying colors, displaying a special ability to withstand any turbulence, including those that just slowed down the rate of world expansion. Only the Polish economy, which grew at 2.8% in the European Union in 2009, continued economic expansion (UNCTAD, n.d.)

Around that time, all other E.U. economies went through a recession, and the biggest ones, including Germany and Italy, lost more than 5% of their real GDP. Poland, which has the region's largest economy among the CEE countries, is a key player. Poland's current standing in the international economic system is the outcome of changes to the Polish economy's structure between 1989 and 2018. We participate in important international organizations, and Polish entities increasingly establish their presence internationally. Regarding the cohesion of the area, Poland's economic performance over the previous few decades has been significant. It has established a favorable climate for the extensive expansion of CEE as an alluring FDI site. Poland accounts for almost 36% of the nominal GDP value of CEE, 31% of CEE exports, and 31% of investments (GFCF). The Polish labor market has 35,8% of the CEE labor force (European Central Bank, 2022).

2.5. Greenhouse gas emissions from different sectors in E.U.

In this section, most of the information and data have been collected by the 2020 report of the European Environment Agency, as it is one of the primary annual data collectors on all sectors of the E.U., in collaboration with the European Topic Centre on Climate Change Mitigation and Energy (ETC/CME) supported by the Joint Research Centre (JRC) and Eurostat. This report is the official inventory submission of the E.U. for the UNFCCC and the Kyoto Protocol, which will be discussed in upcoming sections. The data is collected annually through a unified process which is:

- Member states submit their annual GHG data by January 15th to EEA and the European Commission.
- EEA and its collaborators perform data quality assurance and quality checks, then report back to the member states by February 28th of the same year
- The reviewing body circulates a copy of the draft report generated based on the GHG inventory shared by member states by February 28th for feedback.
- Member States check their national data and the information presented in the EU GHG inventory draft report, respond to specific findings from the initial quality

checks, send updates if necessary and review the E.U. inventory report by March 15th

- The EEA inventory team reviews the comments and feedback from all member states. It prepares the final draft of the GHG inventory report by April 15th to submit to the UNFCCC (the European Environment Agency, 2020).

Therefore, this report is a comprehensive and over-arching document representing all E.U. member states, the United Kingdom and Ireland, who left the E.U. on February 1st, 2020. In this document, the primary GHG trends segregated by the source of emission from 1990 to 2018 have been recorded. In general, there was a decrease in GHG emissions among most sectors between 1990 and 2018, with the "notable exception of transport, including international transport, refrigeration, and air conditioning" (the European Environment Agency, 2020). At the summative level, the most considerable emission reductions were noted for "manufacturing industries and construction, electricity and heat production, iron and steel production (including energy-related emissions), and residential combustion" (the European Environment Agency, 2020). The explanations for these overall reductions are elaborated in upcoming sections on the E.U. initiatives to reduce GHG emissions.

Even though there is progress in the effort to reduce GHG emissions, and there are policies, regulations, and laws put in place to support a cleaner economic production and a greener economy (mainly through biomass utilization as an energy source), numerous sectors still heavily contribute to the surge in emissions as the E.U. transitions into clean energy consumption as the main driver of economic growth and development (the European Environment Agency, 2020). These polluting sectors are mainly road transportation, refrigeration, and air conditioning, with an increase of more than 20 million tonnes of CO_2 equivalent. The road transport sector contributed 172 million tonnes of CO_2 equivalent, around 26% of CO_2 emissions in 2018, while the refrigeration and air conditioning sector contributed 86 million tonnes of CO_2 equivalent (the European Environment Agency, 2020). Public Electricity and Heat production accounted for 27% of CO_2 emissions in 2018, followed by the road transportation sector (26%), manufacturing industries, and construction at 15% of CO_2 emissions 2018 (the European Environment Agency, 2020). Methane, CH_4, emissions accounted for 11% of the total EU GHG emissions and decreased by 38% to 456Mt CO_2 equivalents in 2018, whereby 54% of the produced Methane in 2018 is due to enteric fermentation (36%) and anaerobic waste (18%). Farming accounts for 9% of the Methane produced, Coal Mining and Handling Operations account for 6%, and natural gas for 5% (EEA, 2020). On the other hand, N_2O emissions are responsible for 6% of total EU GHG emissions and decreased by 37% to 252Mt CO_2 equivalents in 2018 (the European Environment Agency, 2020). As noted previously, N_2O emissions arise mainly from the agriculture sector. The two largest key sources responsible for 65% of N_2O emissions in 2018 are agricultural soils' direct N_2O emissions from managed soils (53%) and farming (12%) (the European Environment Agency, 2020).

As for the less prominent GHGs, the 2018 statistics include the gases Hydrofluorocarbons (HFCs), or fluorinated gases, which are responsible for 2.6% of total EU GHG emissions. However, this is the only gas from the GHGs above that has increased beyond their 1990 level by 52% to 111Mt CO_2 equivalents. The leading key source responsible for 78% of HFCs emissions is the sector of refrigeration and air conditioning (the European Environment Agency, 2020). The main reason for this upsurge is the replacement of ozone-depleting substances such as chlorofluorocarbons under the Montreal Protocol, which will be mentioned in the upcoming section with HFCs (mainly in refrigeration, air conditioning, foam production, and aerosol propellants) (the European Environment Agency, 2020).

After exploring the emissions trend by greenhouse gas and the corresponding source per GHG, it is essential to investigate the emission trend by categorizing and prioritizing the sources that contributed the most to the overall GHG emissions in the European Union. In the years 1990 and 2018, the central polluting sector was the energy sector, i.e., combustion and fugitive emissions, representing a total of 78% of overall emissions produced by the E.U., followed by agriculture (10%) and industrial processes (9%) (the European Environment Agency, 2020). It is crucial to examine emission trends through the lens of E.U. member states, and the most polluting E.U. member state is Germany contributed to 858 million tonnes of CO_2 equivalent in 2018; France comes second in line at 445 million tones CO_2 equivalent, the following state, before its leave from the union, is the United Kingdom at 465 million tonnes CO_2 equivalent, fourth in line is Italy at 428 million tonnes CO_2 equivalent, then comes Poland at 413 million tonnes CO_2 equivalent (the European Environment Agency, 2020). These are the biggest polluters, responsible for over 50% of the total GHG emissions of the union in 2018 (the European Environment Agency, 2020).

Germany and the United Kingdom, countries with the highest absolute reductions despite their equally high contributions, achieved total domestic GHG emission reductions of 723 million tonnes CO_2 equivalent compared to 1990 levels, whereby Germany produced 1249 million tonnes CO_2 equivalent and the United Kingdom produced 797 million tonnes

CO_2 equivalent (the European Environment Agency, 2020). These favorable reductions were noted because of the countries' commitment to reducing GHGs as per the international treaties, conventions, and protocols that they have signed and adhered to through policy changes, economic restructuring, transition processes into cleaner, safer, and more environmentally-friendly sources, and the adoption of environmental taxes such as the carbon tax, among other mitigation and reduction measures, all of which will be explored in the upcoming section on the European Union initiatives to reduce greenhouse gases emissions (Moore, 2020; Dinçer, 2022).

2.6. Economic Instruments and Green House Gas Emissions

Environmental regulations are instruments designed to govern the environment environmentally soundly. In addition to all applicable laws, rules, ordinances, codes, licenses, permits, orders, approvals, plans, authorizations, concessions, franchises, and other similar items from all governmental bodies, they are defined as all pertinent judicial, administrative, and regulatory decrees, judgments, and orders relating to the protection of human health or the environment (Barde, 1994). These without exception cover all requirements, including but not restricted to those on reporting, licensing, permitting, investigations, and remediation of emissions, discharges, releases, or threatened releases of hazardous materials, chemical substances, pollutants, contaminants, or dangerous or toxic substances, materials, or wastes whether solid, liquid, or gaseous in nature, into the air, surface water, groundwater, or land. Chemical substances, pollutants, contaminants, hazardous or poisonous materials, or wastes of any kind, whether solid, liquid, or gaseous, as well as any regulations about the protection of flora and fauna, including employees, employers, and the general public, may be covered by them. Theoretically, using economic techniques can assist in improving the efficacy and efficiency of environmental policy (Science Direct, n.d.). Giving polluters more discretion in adhering to a required drop in pollution levels may allow them to achieve a specific degree of environmental protection at a lesser cost or make more environmental improvements without increasing the associated costs. Companies can either pay the tax if marginal abatement costs are high or lower emissions by another unit if doing so would cost less than the emission tax. Because of this, companies with the lowest expenses for pollution abatement cut pollution the most, while those that find it expensive to cut emissions opt to pay the tax (IEEP, 2021). They may drive more rapid innovation in pollution prevention and control techniques because they encourage polluters to find ways to reduce pollution by more than is necessary to comply with current regulatory requirements. Due to the specificity of a tax, polluters must pay for residual emissions in addition to expenses for abatement. Because of this, there is a continuing motivation to reduce costs and emissions associated with pollution in order to avoid paying the tax (von Moltke et al., 2004). Specific financial instruments produce income that can be used in several contexts. More broad policy concerns or the potential for tax reductions determine how environmental tax money and other tax revenue from environmental sources are used. Alternatively, the funds may be put aside for specific purchases, the majority of which would be helpful to the environment. Theoretically, earmarking violates the "Polluter Pays" concept by reducing the net Cost of polluters who benefit from them and could lead to the inefficient use of tax resources. Nevertheless, earmarking may boost the political acceptability of environmental taxes and guarantees by securing a minimum amount of targeted public expenditure on the environment. Furthermore, judicious and controlled subsidy distribution may promote the development of a market-based environmental financing sector (OECD, n.d.).

2.7. Economic Growth in E.U. as a Source of GHG Emissions

With the uncontrollable increase in climate change effects around the globe, mitigation measures have become more appealing (González-Sánchez & Martín-Ortega, 2020). As proven in the sections above of this paper, climate change, most notably inflicted by the increase in GHG emissions, is a consequence of economic growth, represented by energy consumption, since all production and consumption activities within any economy are intrinsically connected to energy consumption (Armeanu et al., 2018). However, energy consumption, the basis of economic growth, has substantially affected global GHG emissions, whereby increases in these emissions were realized across many countries, including the E.U. (Armeanu et al., 2018). Thus, given the detrimental effect of climate change due to the rise in GHGs, economic growth, and globalization, the main drivers of anthropogenic GHG emissions are scenarios that will cause the systemic collapse of the planet's natural resources if not managed (Osadume, 2021; Schnaiberg, 1980).

Under E.U. laws, which were created in support of the international treaties on GHG emissions, all member states are required to report their emissions. Some of these laws and regulations are Regulation (E.U.) No 525/2013, “Mechanism for Monitoring and Reporting GHG," and Decision No 406/2009/E.C., “Effort Sharing” (EEA, 2020). According to the

European Environment Agency (2020), "The EU GHG inventory comprises the direct sum of emissions from the national inventories compiled by the countries making up the EU-27 plus Iceland plus the U.K. Energy data from Eurostat are used for the reference approach for CO_2 emissions from fossil fuels, developed by the Intergovernmental Panel on Climate Change (IPCC)" (EEA, 2020). As a summary of the EU GHG emissions trend, total emissions amounted to 4,234 million tonnes of CO_2 equivalent in 2018, 25.2% less than the 1990 total emission level (EEA, 2020). However, with this decrease in emissions, there was an increase in economic growth represented by an increase in GDP above 60% (EEA, 2020). The relationship between economic growth primarily through energy consumption and its effects on environmental degradation and, indirectly, on greenhouse gas emissions have been extensively analyzed and assessed (Sterpu et al., 2018). According to the European Commission Joint Research Centre (JRC), about 90% of total global CO_2 emissions result from the combustion of fossil fuels, which have been, for the longest time, the primary source of economic development, especially in the industrial sectors across Europe (Jos et al., 2012; Shayanmehr et al., 2020). For this reason, the European Commission (C.E.) aims to reduce the overall production of GHGs and shift their economies into environmentally friendly ones (Sterpu et al., 2018). The targets set by E.U. to progressively reduce greenhouse gas emissions are over ten years; the E.U. aims to reduce GHG emissions by 20% in 2020, compared to its level in the year 1990, and by 40% in 2030, then by 60% in 2040 and by 80% or 90% in 2050, in order to turn the European economy into a "low-carbon energy-efficient one" (Sterpu et al., 2018). However, achieving these ambitious levels is more complicated than achieving the set development goals of the U.N. 2030 SDG agenda because it requires European economics to shift in an accelerated form into renewable energy by 2030 and eliminate internal combustion engines. Essentially, E.U. countries are required to transition into "clean" economic growth (Sterpu et al., 2018).

Many studies have linked the E.U. economic growth in the traditional sense, represented by GDP and energy consumption, to negative environmental impact, represented by the uncontrollable increase in GHG emissions. To this day, many believe that in order for the environment to heal and thrive, economic development should 'suffer'; this belief has been compounded by the COVID-19 pandemic, as has been discussed in the introduction of this paper, where improvements in air quality and overall environmental measures have been noted (Arora et al., 2020), while economies endure losses in revenue due to the measures taken to control the spread of the virus, including lockdown (IMF, 2021b; 2022). However, as seen by the EEA 2020 report, economic growth and GHG emissions do not have to be inversely proportional; in fact, they can both improve with the adoption of new and cleaner sources of energy, and this requires the transformation and shifting of the E.U.

2.8. Barriers that increase GHG emissions

Worldwide, greenhouse gas emissions increased by 53% between 1990 and 2019, with power and heat (31%), agriculture (11%), transportation (15%), forestry (6%), and manufacturing (12%) being the main contributors. 72% of all emissions are caused by generating energy of all kinds. (US EPA, 2015).

Greenhouse gas emissions were studied between 2000 and 2020, and then an outline was presented to predict the emissions globally for the year 2040 (International Energy Agency, 2022a).

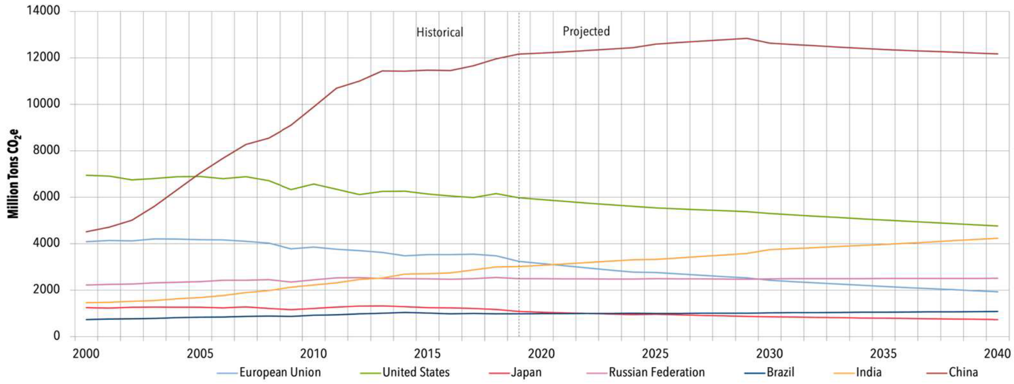

Figure. 2.6. Greenhouse Gas Emissions for Major Economies, throughout 2000–2040
Source: International Energy Agency, 2022a

According to more recent emissions data, a modest decline in the average global emissions in most major economies in 2020, although the trend did not last. According to preliminary data, emissions rose once more in 2021 (International Energy Agency, 2022a).

Discussing Greenhouse gas emissions in the E.U. 1990-2020 by sector will help to define the barriers that increase GHG emissions for each sector. Except for transportation, most sectors in the European Union have seen a decline in greenhouse gas emissions since 1990. Domestic transportation emissions decreased significantly in 2020, to 721 MtCO2e, due to COVID-19-related lockdowns, but they were still seven percent greater than in 1990. While this has happened, emissions from the energy supply have decreased by approximately 50%, reaching a low of 843 MtCO2e. Compared to 1990 levels, the E.U.'s yearly GHG emissions have decreased by about 34% (Statista,n.d.).

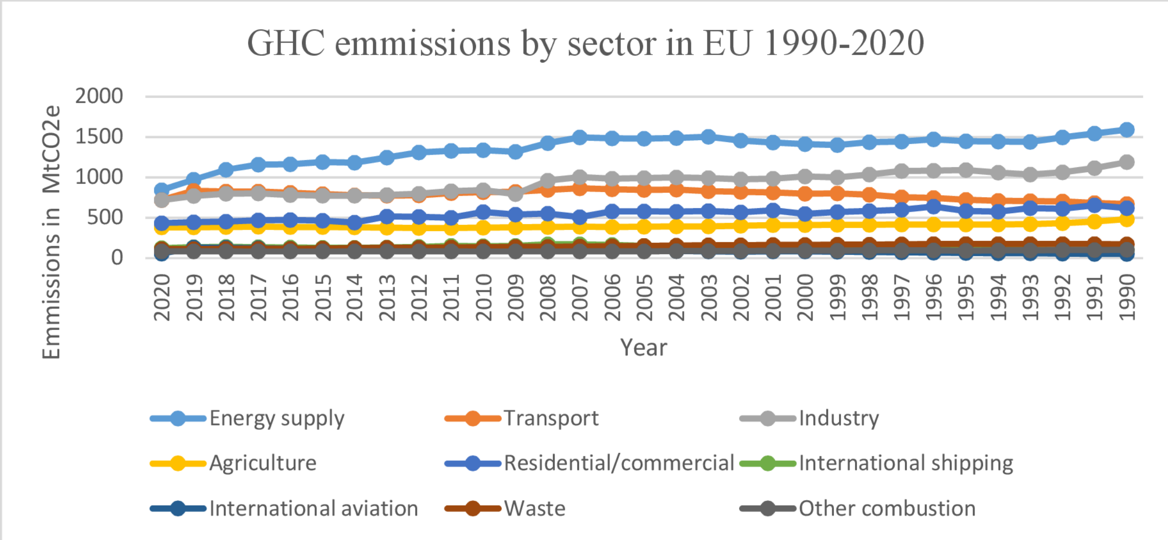

Figure. 2.7. Greenhouse Gas Emissions by sector, throughout 1990–2020 in Europ.

Source: Statista,n.d.

The largest source of greenhouse gas emissions is the energy sector. With a staggering 75.6% (37.6 GtCO2e) global share, energy consumption is the primary source of human-caused greenhouse gas emissions. Transportation, electricity and heating, buildings, manufacturing, construction, fugitive emissions, and other fuel combustion are all included in the energy sector.(Ourworldindata,2023.). The other significant sources of emissions are agriculture, which includes raising livestock and growing crops (5.8 GtCO2e, or 11.6%); industrial processes, which include making chemicals, cement, and other things; waste, which includes landfills and wastewater; and land use, land-use change, and forestry, which includes deforestation (1.6 GtCO2e, or 3.3%). Transportation (8.4 GtCO2e in 2019, or 17% of total emissions), manufacturing and construction (6.3 GtCO2e, or 12.7% of total emissions), and heat and electricity generation account for the majority of emissions within the energy sector (15.8 GtCO2e in 2019, or 31.8% of total greenhouse gas emissions). According to data from as recently as last year, the third quarter of 2022 saw a 2% increase in the E.U. economy's greenhouse gas emissions, reaching 854 million tonnes of CO2-equivalents (CO2-eq). Comparing the third quarter of 2022 to the year before, greenhouse gas emissions rose by 2%. This increase is mainly attributable to the economic recovery that followed the steep decline in activity brought on by the COVID-19 crisis, as evidenced by the growth of the gross domestic product (GDP). In reality, the E.U. economy's greenhouse gas emissions fell by 4% in the third quarter of 2019 compared to the third quarter before the epidemic (from 889 to 854 million tonnes of CO_2-eq) (Statista,n.d.)

Describing the Agriculture Sector Emissions will allow the author to explain the main reason causing that. Both the non-CO_2 emissions produced at the farm gate by crops and livestock operations and the CO_2 emissions brought on by the conversion of natural ecosystems, namely forests and natural peatlands, to agricultural land use are attributed to the agricultural sector. The production of crops and livestock for food contributes to emissions in several ways (Statista,n.d..; Ritchie & Roser, 2020).

- Many agricultural soil management techniques can increase the amount of nitrogen in the soil and cause nitrous oxide emissions (N_2O). The use of synthetic and organic fertilizers, development of nitrogen-fixing crops, drainage of organic soils, and irrigation techniques are specific actions that contribute to N_2O emissions from agricultural lands. Over half of the greenhouse gas emissions from the agriculture industry are attributable to soil management. Methane (CH_4) is produced by livestock, particularly ruminants like cattle, as part of their regular digestive processes. Enteric fermentation is the term for this process, which accounts for more than 25% of the emissions from the agriculture industry.
- The management of livestock waste also influences the emissions of CH_4 and N_2O. The amount of these greenhouse gases produced varies depending on the manure treatment and storage techniques used. Around 12% of the agricultural sector's greenhouse gas emissions are due to manure management.
- Lesser sources of agricultural emissions include burning crop leftovers, which releases N_2O and CH_4 as well as CO_2, liming and urea application, and rice cultivation.

11% of all greenhouse gas emissions in 2020 came from the agricultural economic sector. Since 1990, greenhouse gas emissions from agriculture have risen by 6%. This rise is primarily the result of a 62% increase in the total CH_4 and N_2O emissions from animal manure management systems, which reflects the rise in the usage of liquid emission-intensive systems over this time. Since 1990, emissions from other agricultural sources have mostly been flat or have changed by a negligibly tiny amount (Cycles, 2020).

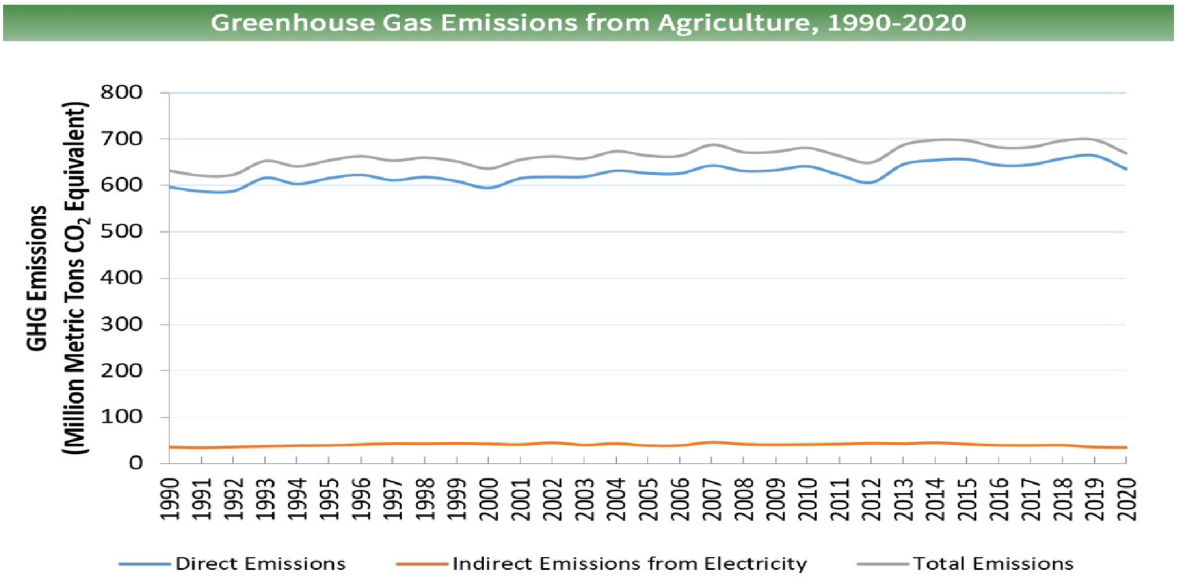

Figure. 2.8. Greenhouse Gas Emissions from Agriculture, throughout 1990–2020 in Europ.

Source: (European environmental agency, 2023)

Based on what was mentioned above, deforestation can be one of the main reasons that impact GHG emissions. Deforestation assumed entirely driven by agriculture, represented nearly three-fourths of these global emissions as agriculture is the most significant driver of deforestation globally. Ravindranath et al. (2013) define deforestation as a long-term or permanent land conversion from forest to non-forest. Deforestation has continuously grown over the years at high rates, especially in the tropical regions of developing countries (Hansen et al., 2013; Vancutsem et al., 2021). It is one of the most significant drivers of greenhouse gas emissions (CO2, NO2, and Methane), biodiversity loss, and constrained ecosystem services (Díaz et al., 2019). Though deforestation is driven by several interconnected processes and factors (Geist & Lambin, 2002), agricultural land use expansion, including cropland, pastures, and tree crops, has been the leading remote cause of tropical deforestation (Busch & Ferretti-Gallon, 2017; De Sy et al., 2012). Deforestation is primarily attributed to rapid emissions turn, influencing the atmospheric condition, consequently leading to global change in the climate.

Several factors and activities such as deforestation, farming, fossil fuel burning, land use change, and mining cause excess CO2 emissions, which in turn lead to a change in the carbon cycle and, consequently, climate change (Reichstein et al., 2013).

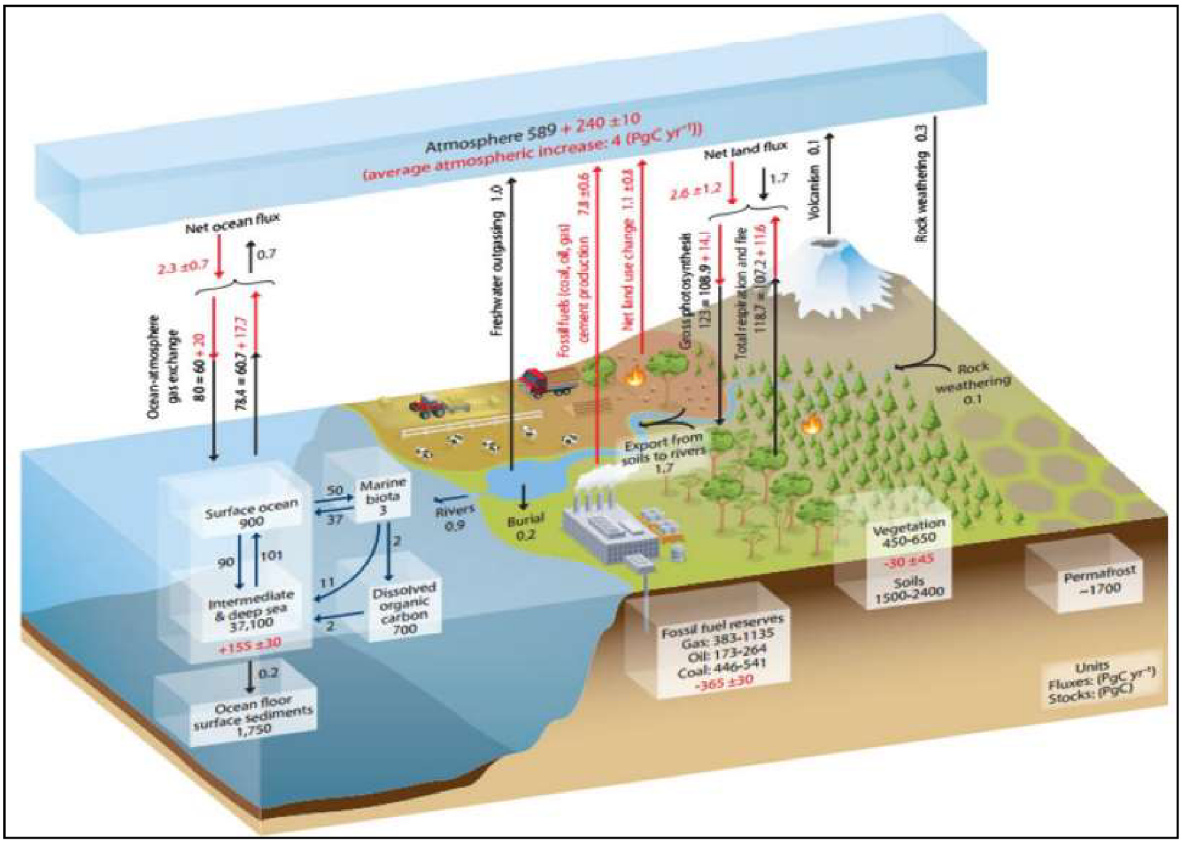

Figure. 2.9. Schematic model of the global carbon cycle between the terrestrial, hydrosphere, biosphere, and atmosphere as illustrated from IPCC AR5.

Source: Reichstein et al., 2013

The Agriculture, Forestry, and Other Land Use sectors contributed to about one-fifth of the global yearly CO2 emissions, which ranks as the top largest CO2 emission source and is a principal contributor to global climate change (Adopted, I. P. C. C, 2014). Globally, several studies have revealed significant relationships between deforestation and CO2 emissions (Crippa et al., 2019; Inyang & Esohe, 2014; Mahmood et al., 2020; Musa, Maijama'a, & Yakubu, 2022), and many models have been employed in determining such relationships (Ahmad et al., 2018; Bano et al., 2018; Ben Jebli et al., 2015; Cai et al., 2018; Isik, Dogru, & Turk, 2018; Kasman & Duman, 2015).

According to US EPA (2015), transportation is the main sector impacting the emissions from the Services side. Transportation was the main source of greenhouse gas emissions in 2020, with roughly 27% of all emissions. The COVID-19 pandemic and related travel restrictions, which reduced travel by 13% between 2019 and 2020, significantly contributed to this drop. GHG emissions from domestic freight transportation fell by 6% over this time, while GHG emissions from passenger transportation fell by 16%. Overall, from 1990 to 2020, there was a rise in transportation emissions, largely as a result of rising travel demand. Between 1990 and 2020, the number of vehicle miles (VMT) driven by light-duty motor vehicles (passenger cars and light-duty trucks) grew by 30% due to several interrelated variables, such as urban sprawl, economic growth, population growth, and times of low fuel prices. Although sales of light-duty trucks surged between 1990 and 2004, the average fuel economy of new cars sold each year decreased. Average new vehicle fuel economy started to rise in 2005, although light-duty VMT growth was largely modest during that time. Since 2005, the fuel economy of new cars has increased on average practically every year, which has slowed the growth of CO2 emissions. In the model year 2020, light-duty trucks make up around 56 % of all new cars (Cycles, 2020).

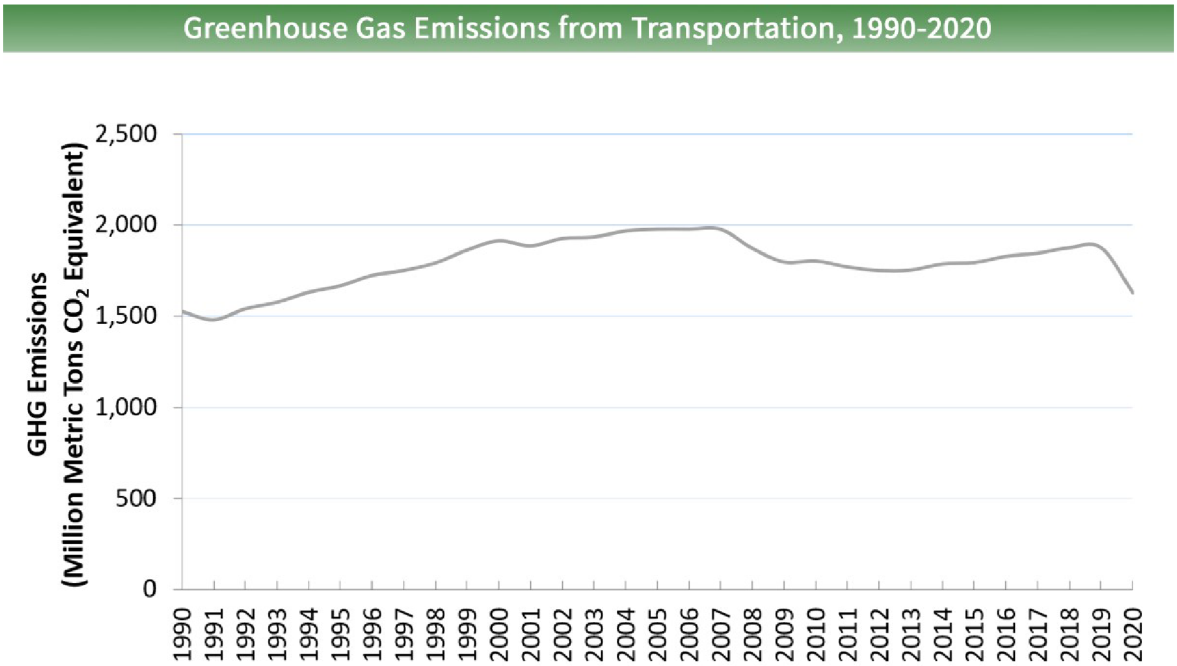

Figure. 2.10.Greenhouse Gas Emissions from Transportation throughout 1990 - 2020

Source: EEA,2021

The movement of people and products by automobiles, trucks, trains, ships, airplanes, and other vehicles is included in the transportation industry. Carbon dioxide (CO2) emissions from the combustion of petroleum-based fuels like gasoline and diesel in internal combustion engines account for the majority of greenhouse gas emissions from transportation. Passenger cars, medium – and heavy-duty trucks, and light-duty trucks, including sport utility vehicles, pickup trucks, and minivans, are the leading producers of transportation-related greenhouse gas emissions. More than half of the emissions from the transportation industry come from these sources. (Statista,n.d) The remaining greenhouse gas emissions from the transportation industry are produced by various forms of transportation, such as railways, pipelines, commercial airplanes, ships, and boats. Methane (CH_4) and nitrous oxide (N_2O) are released relatively tiny quantities during fuel burning. The Transportation industry also accounts for a modest proportion of hydrofluorocarbon (HFC) emissions. Using portable air conditioners and refrigerated transportation contributes to these emissions (Ritchie & Roser, 2020).

After discussing both the agriculture and Services sector and the main barriers for them, the last sector that should be addressed is the industry; according to US EPA (2015), energy is the first cause of emissions, therefore using nonrenewable energy can cause a boost of emissions which will negatively impact the environment.

In 2021, CO_2 emissions from industrial operations and energy combustion increased to their most extraordinary yearly level. According to the IEA's extensive fuel-by-fuel and region-by-region study, which used the most recent official national data and publicly available energy, economic, and weather data, emissions increased by 6% from 2020 to 36.3 gigatonnes (Gt). (IEA, 2021) In 2020, the Covid-19 epidemic significantly impacted energy demand, resulting in a 5.2% decrease in worldwide CO_2 emissions. Since then, however, the world's economy has recovered incredibly quickly thanks to massive fiscal and monetary support as well as a quick, if unequal, roll-out of vaccines. The rebound in energy demand in 2021 was exacerbated by unfavorable weather and the state of the energy market, which increased the amount of coal burned despite the biggest yearly gain in renewable power output. From 2020 levels, emissions climbed by roughly 2.1 Gt. As a result, the year-over-year growth in energy-related CO_2 emissions in absolute terms from 2021 surpasses 2010 for the first time. The 1.9 Gt drop in emissions due to the pandemic that occurred in 2020 was more than reversed by the recovery in emissions in 2021(IEA,2021). The pre-pandemic level of CO_2 emissions in 2019 increased by about 180 megatonnes (Mt) in 2021. In 2021, CO_2 emissions increased by 6%, which was in line with the 5.9% increase in global economic output. Since 2010, when global emissions recovered by 6.1% and economic output climbed by 5.1% as the globe emerged from the Great Financial Crisis, this is the strongest correlation between CO_2 emissions and GDP growth (IEA, 2021).

Electricity and heat production saw the most significant spike in CO_2 emissions by industry in 2021, rising by more than 900 Mt. Since more fossil fuels were used to help satisfy the rising power demand, this was responsible for 46% of the increase in emissions worldwide. Around 14.6 Gt of CO_2 emissions from the sector were produced, a 500 Mt increase over 2019. Almost all of the growth in worldwide emissions from the power and heat sector between 2019 and 2021 was attributed to the People's Republic of China (hereafter referred to as "China"). The decrease in the rest of the globe was insignificant enough to counteract China's growth. Increases in developed and emerging markets and developing economies were the main drivers of the global industrial and building sector's CO2 emissions returning to their levels from 2019. China stood up as an interesting exception, with decreasing industrial coal consumption driving CO2 emissions below their 2019 level for the second year. Transportation was the only industry where worldwide CO2 emissions remained significantly below 2019 levels (IEA, 2021).

The most significant year-over-year increase in worldwide electricity demand in 2021 was the primary cause of the 6.9% increase in CO2 emissions from the electricity and heat sectors. The increase in electricity consumption in 2021 was over 1400 terawatt-hours (TWh), or 5.9%, more significant than the decrease in demand in 2020. Half of the growth in the world's demand for electricity in 2021 was met by coal-fired power plants, with coal's proportion of overall generation rising beyond 36%. Coal-fired power stations' CO2 emissions increased to a record 10.5 Gt, 800 Mt higher than they were in 2020 and more than 200 Mt higher than their previous high in 2018. Global coal use for electricity generation in 2021 would have been much higher if supply shortages and high pricing had not affected China and India at particular times of the year (IEA, 2021). These barriers create the need for sustainable development, which will be described in the next section.

2.9. Environmental Kuznets Curve Research

This curve has been inspired by Simon Kuznets (1955), who explained, with an inverted U-shaped curve, the relationship between income inequality and economic growth (Al-Mulali et al., 2016; Özcan & Ozturk, 2019). Economists Grossman and Krueger (1991) utilized the Kuznets curve to analyze and assess the connection between environmental pollution and economic growth (Al-Mulali et al., 2016; Özcan & Ozturk, 2019). From their analysis, they contended that environmental pollution first worsens alongside the rising per capita income level in the early stages of development, but, in the later stages of the development process, this trend reverses, whereby the environmental pollution level starts decreasing while per capita income level remains on the rise (Al-Mulali et al., 2016; Özcan, and Ozturk, 2019). This is how the standard environmental Kuznets curve (EKC) came into existence.

Advocates of EKC believe that as national economies develop, the pressure they have created while economically progressing on nature grows at first but eventually reaches a turning point, after which further growth diminishes environmental stress (Dietz et al., 2012). This hypothesis implies that EKC is a proposition that explains why economies change over time by creating environmental pressures and why this environmental stress level differs between one country and another (Dietz et al., 2012). Advocates believe this change or turning point will occur when “countries achieve higher income levels at which people demand and afford the more efficient infrastructure and cleaner habitats” (Özcan & Ozturk, 2019; Al-Mulali et al., 2016; Panayotou, 2003). On the other hand, implementation researchers have questioned the curve's validity because of the assumption that it cannot be applied to all countries (Al-Mulali et al., 2016; Özcan & Ozturk, 2019) Their criticism mainly stems from their disbelief in the possibility of the coexistence of environmental enhancement and economic growth (Ozcan, and Ozturk, 2019; Ginevicius et al., 2017). Critics consider combining economic development and environmental improvement an "oxymoron" because natural habitats have been destroyed beyond salvation, mainly due to the upsurge in economic interests (Ginevicius et al., 2017).

When considering economic growth, the three developmental stages of pre-industrial, industrial, and post-industrial phases should be accounted for to understand the economic Kuznets curve from a general theoretical perspective. In the pre-industrial phase, economic growth is the goal to be attained by national economies, thus forsaking environmental preservation in the process; i.e., there is a trade-off between economic growth and environmental quality because slowing economic growth in the interests of protecting the environment because it does not have a priority on the agenda (Özcan, and Ozturk, 2019) This continues up until a certain point when the economy transitions into an industrial economy. The trend reverses in the later stages of industrialization, whereby there is a rising income level, and now people can afford environmental amenities, which results in less pollution (Dietz et al., 2012; Hervieux & Darne, 2013). In the post-industrial phase, economic growth leads to environmental enhancements because of increased demand for environmental quality (Panayotou, 2003).

Synonymous with the development phases, the EKC model has suggested three channels through which economic development impacts the environmental quality, and these channels are scale effects, which indicate that the scale of economic growth is proportional to the growth in environmental contamination and degradation (Stern, 2004a, 2004b). In other terms, we are using more natural resources and exploiting environmental services to expand our production scale 'stemming from trade and investment liberalization,' thus further upsurging the pace of environmental damage (Özcan & Ozturk, 2019). A second channel is the effects composition that performs an inverted U-shaped curve with income level. This is explained by having low-income levels equate to a need to shift the economy towards industrialization, which leads to the environmental quality being traded off. High-income levels due to industrialization equate to diminished environmental pollution because the demand for a high-quality environment is thus mounting (Akbostanci et al., 2009). Finally, the technique effect is correlated with the post-industrial phase, whereby technological advancements due to economic growth lead to a further decline in environmental pollution (Panayotou, 2003).

So far, we have established that the EKC hypothesis describes the relationship between various environmental contaminants and income per capita indicators by examining a quadratic equation between some indicators of environmental degradation and income per capita (Al-Mulali et al., 2016). Despite its popularity, the EKC curve is still debated as non-existent because the inverted-U shape is not consistent across countries, as discovered by researchers who utilized different air, water, soil, and other pollutants to test the EKC hypothesis (Shafik & Bandyopadhyay, 1992; Cole et al., 1997). Also, the EKC curve shape is inconsistent within countries and across country regions, turning the EKC inverted-U shape into a "statistical artifact" (Roberts & Grimes, 1997; Vincent, 1997). Speaking of statistics and equations, the earliest form of EKC equation following the Grossman and Krueger 1991 discovery is the following, based on the Ozcan and Ozturk text:

$$\mathbf{ln(CO_2/P)_{it}} = \propto_i + \gamma_t + \beta_1 \ln(GDP/P)_{it} + \beta_2 \ln(GDP/P)^2{}_{it} + \beta_3 \ln(GDP/P)^3{}_{it} + \varepsilon_{it} \quad \mathbf{(1)}$$

- CO2 is an indicator of environmental pollution
- P is a population
- ln indicates natural logarithms.
- The first two terms on the RHS represent intercept parameters, which vary across countries (or regions), I, and years, t.
- αi implies that the CO2 emissions per capita level may vary across countries at any income level, and the income elasticity is the same for all countries at a given income level.

- ɣt, the time-specific intercept, counts time-varying omitted variables and common stochastic shocks to all countries.

Here the EKC function is the linear, quadratic, and cubic function in the simplest version of the model. Results imply, for an inverted U-shaped curve, $b1 > 0$; $b2 < 0$; and for an N-shaped EKC curve, $b1 > 0$; $b2 < 0$; $b3 > 0$. (Özcan, and Ozturk, 2019).

The determinants of the EKC model vary across research and eras of studies yet remain essential conduits through which the model has received some backlash. When researchers established that the model's curve does not apply within various countries, they considered that income is not the all-catching representative of economic growth. Thus they added different variables to the equation, such as investment shares, trade, civil liberties, political rights, electricity tariffs, and infrastructure (Ozcan & Ozturk, 2019; Stern, 2004a, 2004b; Cole et al., 1997; Richmond, and Kaufmann, 2006). From the perspective of environmental degradation, when using different pollutants to represent pollution, the "turning point" at which an economy shifts from pre-industrialization to industrialization differs. As such, it may take an economy a longer or shorter time to make that shift, which in turn means that it will take a longer or shorter time for the environmental quality of a country to improve and heal (Richmond & Kaufmann, 2006). Another notion worth mentioning is that the EKC model disregards the environmental impact on economic growth, whereby pollution and degradation can negatively affect the productivity of workers and can indirectly affect the economic output (Al-Mulali et al., 2016; Özcan & Ozturk, 2019).

The EKC theory assumes that environmental quality will improve in the post-industrial phase through technological advancement, proper policy implementation, and increased per-capita income; however, it fails to account for two main aspects. One, the environment has a threshold after which improvement or healing cannot be possible or minimal because its resources and services would be extinguished. It takes thousands of years to regenerate, especially considering nonrenewable energy sources such as petroleum, and this is called the ecological threshold. Another aspect is that EKC needed to account for the discrepancies between developed and developing countries. Environmental degradation is faster in developing countries because of the absence of proper measures, infrastructures, and policies stipulating protecting and enhancing the environment. This shows that policymakers should not consider the shape of the curve as a determinant for decision-making but instead focus on installing policies that legislate environmental protection and place market incentives as soon as possible to try and prevent irreversible damage to the developing world's environments (Panayotou, 2003).

2.10. Sustainable Development

The robust economic expansion seen over the past century has been followed by increases in material welfare in every region of the world, driven by technical advancements and global integration. Between 1995 and 2020, the world's economy is expected to increase by 75%, putting more strain on social and environmental resources. The difficulty for governments pursuing sustainable development is figuring out how to balance best the potential and risks of growth and divorce economic expansion from environmental concerns.(Younis, and Chaudhary) It is crucial that nations form powerful coalitions to address issues of shared concern and adapt their institutions and decision-making processes to the ever-increasing globalization, given that many of the most pressing development challenges, such as climate change, are global. The problems they present for the welfare of present and future generations are covered in this chapter, which also provides an overview of some significant economic, environmental, and social developments that are crucial to sustainable development (Younis & Chaudhary, 2017; Raszkowski & Bartniczak, 2019; Sachs et al., 2022; Bochniarz, and Cohen, 2022).

The sustainable development perspective emphasizes the long-term compatibility between development's economic, environmental, and social dimensions while acknowledging potential competition across these areas in the short term. It seeks to link and prioritize aspirations about human welfare. The institutional and technical capability to evaluate the economic, environmental, and social implications of development plans and to design and implement sensible policy responses are essential for achieving the goals of sustainable development (Younis & Chaudhary, 2017; Sachs et al., 2022; Bochniarz, and Cohen, 2022). This chapter examines the ideas of need, capital, and productivity while outlining the essential elements and guiding principles of sustainable development. It also examines how resource substitution, technological advancement, alternative capital valuation, and improved public good provision and price mechanisms contribute to increasing existing assets' productivity. Policymakers may ensure more effective resource use, which results in improved overall welfare and equity both now and in the future, by correcting market signals and providing incentives to change behavior by sustainability (Younis & Chaudhary, 2017; Sachs et al., 2022; Bochniarz, and Cohen, 2022).

It is difficult to quantify things like the potential satisfaction of future demands or the future effects of current activities since the sustainable development agenda is so broad, and these things take time to calculate. The global nature of the primary sustainability concerns makes this issue even more complicated, making monitoring challenging. This discussion is guided by two fundamental queries: What exactly are needs? Furthermore, what is necessary to guarantee that these are met? This chapter looks at different accounting and analytical frameworks used to organize data on sustainable development to describe the role of measurement in addressing these problems. (Sachs et al., 2022).This satisfies the requirement for a comprehensive information set on long-term sustainability challenges in creating and evaluating policy. The initial collection of metrics described here should act as a foundation for creating measurement frameworks that can effectively consider the multifaceted components of sustainable development. (Sachs et al., 2022)

Setting up the proper framework conditions and implementation instruments is necessary for integrating the economic, social, and environmental elements of sustainable development coherently and effectively. This chapter discusses several essential framework requirements and the valuable tools required to implement them in terms focused on policy. It focuses on the main objectives of enhancing the regulatory framework through a more effective, transparent, and efficient regulatory system as well as correcting market and intervention failures by eliminating distortionary subsidies, enacting green tax reforms, and establishing markets for resource management and pollution control (Younis, and Chaudhary, 2017; Sachs et al., 2022). All of these approaches share the requirement to recognize the interconnected yet complementary nature of policy interventions. Other essential components in creating a successful policy framework for sustainable development are broad stakeholder participation and international cooperation. Lastly, only a long-term perspective and a strong, ongoing political will can be used to apply these primary conditions to result in results (Younis & Chaudhary, 2017; Sachs et al., 2022).

How do nations implement environmental and resource use rules that are both cost-effective and consistent? This chapter summarizes many special chapters of the OECD Economic Surveys on promoting environmentally sustainable growth in certain OECD countries. It draws attention to significant themes that run throughout these studies. It covers the use of economic instruments and the necessity of policy coordination, explaining some specific techniques that various nations have implemented to enhance these, such as cost-benefit analysis. The employment of economic tools, such as taxes and tradeable permits, is then examined. Areas where their use could be improved or expanded, along with strategies for removing obstacles to their implementation (Raszkowski & Bartniczak, 2019; Sachs et al., 2022; Bochniarz & Cohen, 2022).

Developing nations, which account for 80% of the global population, will be crucial to guarantee sustainable development in the twenty-first century. Critical challenges like maintaining world peace and political stability and the sustainability of the global commons, including the earth's atmosphere and biological resources, will be significantly impacted by what happens in developing nations. The socioeconomic prospects of OECD countries will also be ever more closely connected to those of developing and transition countries as a result of the expanding economic interdependence of the world. Non-member nations will advance the world economy, eradicate poverty, and maintain stable demographic and environmental balances. Non-member countries must take advantage of the opportunities presented by globalization (such as increased trade and investment links, more efficient resource use, the transfer of capital, and technology) and find sustainable solutions to their problems despite facing issues like rapid population growth, and food security. The creation of solid policy frameworks to support trade and investment and guarantee that these flows benefit society is essential to the development of developing nations. Achieving these goals will require outside help from many nations (Younis & Chaudhary, 2017).

The 21st century will provide challenges for sustainable development due to global climate change. The latest data suggests that global warming caused by humans is already taking place. The natural environment, agricultural practices, human habitation, and health will be impacted, particularly by changes in air temperature, sea levels, and precipitation patterns. Several global, national, and local environmental issues and development challenges, such as biodiversity loss, deforestation, stratospheric ozone depletion, desertification, and freshwater degradation, are interconnected with climate change. Politicians and policymakers face a conundrum because of long time horizons and the uncertainty surrounding potential climate futures (Sachs et al., 2022). Governments are expected to show leadership and take costly action today to benefit the world for future generations (Sachs et al., 2022). Future generations run the risk of bearing a heavy financial burden from inaction, which could also result in a widening of the economic gap between developed and developing nations. Setting goals and creating climate change policies that effectively balance social benefits and costs while considering equitable concerns and practical restrictions is the main difficulty in combating climate change. The poor nations that are most at risk from climate change must receive special consideration due to their weak institutions and severely constrained access to financial resources, technological advancements, and scientific knowledge (Sachs et al., 2022).

2.11. Circular Economy Vs. Linear Economy

The researchers argued about the originator of the circular economy, some of the researchers believe that the Americans, Professor John Lyle and the architect William McDonough, who specialize in sustainable development, were among the first to write about the circular economy (MacArthur, n.d.). Some researchers added economist Walter Stahel as one of the contributors (MacArthur, n.d.). Other researchers believe that the circular economy is inspired by the book Silent Spring published by Rachel Carson in 1962 (Carson, 1962). Others linked "The Limits to Growth," published in 1972, which discussed the possibility of economic growth and population growth with limited resources by computer simulation (Naustdalslid, 2014). All of this was not convincing to the researchers, as they continued their search to reach the first actual formulation of the reformer of the circular economy within the study of "sustainable economic development" by Pearce and Turner (Pearce & Turner, 1994). It highlighted the connections between the economy and the environment. It amended the conventional economic model based on the utilitarian utility cost principle to allow the notion of intergenerational utility (Pearce & Turner, 1994).

The concept of the circular economy is controversial and has been discussed in many research studies to reach a consensus. However, opinions diversified as it was defined as an economic system aimed at sustainability through the selection of sustainable raw materials to change the concept of end-of-life, reuse, and recycling of materials in production processes, distribution, and consumption, which leads to creating environmental quality, economic prosperity, and social fairness in order to benefit both current and future generations is known as sustainable development. This definition was drawn from an analysis of 114 definitions of the circular economy (Kirchherr et al., 2017).

Levels of circularity: It started in the 1970s as the Three R principle which includes (reducing, reusing, recycle) (Wu, 2014). Then it was developed into 6Rs (reuse, recycle, redesign, remanufacture, reduce, recover) (Jawahir et al., 2016) until it reached the comprehensive model of 10Rs developed by Jacqueline Cramer in 2017 (Cramer, 2017).

Cramer defined her model by selecting a word starts with R to describe one of the principles, then she defined these principles as follows (Cramer, 2017):

- Refuse: Avoid using raw materials which are causing environmental risks.
- Reduce: Minimize the utilization of raw materials which potentially cause environmental risks.
- Renew/Redesign: Incorporate circularity into product redesign, which can help in the dematerializing phase.
- Reuse: Instead of keeping using new products, start using second-hand products.
- Repair: Upkeep and fix the products.
- Refurbish: Revive the product.
- Remanufacture: Using second-hand products as raw materials to create new products.
- Repurpose: either multi-function the products or reuse them for a different purpose.
- Recycle: Save the most valuable content streams for later use.
- Recover: Utilize energy recovery to burn waste.

Transition to Circular Economy: Circular economy operates at three different levels. Based on this operation, the move must be made on all three levels (Kirchherr et al.,2018).

1. The micro level is represented by three main pillars: consumers, companies, and products. This level is called niche innovation. This level is based on transformational change and continuous innovation according to different systems (Geels & Schot, 2007). According to the circular economy, by-products from specific companies are discovered and used efficiently, internally through cleaner manufacturing or externally by other industries (Fang et al., 2007).
2. Meso level (eco-industrial parks), The level of environmental industrial complexes is the most popular. It is called the regime term (Smith et al.,2005). Being concerned with environmental industrial complexes, this level depends on the development of the circular economy through the application of the concepts of the industrial environment. Through the establishment of community partnerships with companies aimed at the optimal use of resources and work to provide sustainable energy (Fang et al., 2007).

3. The macro level (city, region, nation, and beyond) is an exogenous environment. This level provides a more extensive structural environment where changes typically occur slowly, it might take decades (Geels & Schot, 2007). As actors cannot immediately affect them, it is seen as an external environment. In contrast to the regime and niche innovations, they are dynamic in that they change relatively slowly (Smith & Voß, 2010). The macro level is based on the development of the circular economy through attention to the industrial structure, and the application of the resource recycling system, with the continuous development of those systems (Fang et al., 2007).

The three levels above are of great importance. For the development of 3 co-industrial parks, governments, companies, and academics seek to develop the industrial system by focusing on the second level (Erkman, 2001). Different countries have sought to implement eco-industrial complexes since the end of the second millennium (Desrochers, 2001). Eco-industrial parks "EIP" have been established since that date, with 16 EIP in operation and 4 in the pre-operational stage. 3 in the planning stage, and 3 in the Attempted stage (Gibbs & Deutz, 2007).

The United States of America and Canada preceded the European Union countries in forming eco-industrial parks, as the number exceeded sixty projects in both countries (Peck, 2002). The national initiative to develop and promote industrial environment applications has increased the primacy of the United States of America in this aspect. U.S. Environmental Protection Agency, in cooperation with the President's Council on Sustainable Development, led that initiative in 1994 (Doyle et al., 1995).

E.U. initiatives for the circular economy: The circular economy is one of the positive trends of the current era. Due to the leadership of the European Commission in accepting and benefiting from every trend that appears publicly and benefits its countries, the European Commission aimed to integrate the environment and climate and the consequent energy policies with industry to create an incubator for sustainable growth. To achieve this, the European Union prepared and applied a plan to benefit from the circular economy in 2015, which the European Commission approved. The Commission has developed an action plan to transform the European Union's economy into a circular economy based on extending the life of products and using recyclable materials, which leads to environmental, economic, and social benefits. According to this plan, the European Union aims to generate approximately three hundred and twenty billion euros by 2025 from the mobility, food, and environment sectors, with 42% of mobility, 36% of food, and 21% of the environment (MacArthur, n.d.).

In continuation of the European Union's efforts to implement the primary goal of transforming the European Union's economies into a circular economy, the European Union is working on the idea of the circular economy. The Member States collectively initiated several policies to primarily promote the circular economy in industry, services, and business. Many studies have studied this aspect and indicated that the implementation of this type takes place at the micro, intermediate, and macro levels. However, studies have shown a gap in understanding and knowledge of the implementation mechanisms of the circular economy in different sectors. Accordingly, the European Union needs to work on developing circular economy policies according to the sector and linking them to appropriate policies that benefit countries, companies, and society (MacArthur, n.d.).

Four hundred fifty-five papers were collected discussing the circular economy during the period 2010 and 2020 in the countries of the Czech Republic, Slovakia, Hungary, Poland, Slovenia, Austria, Germany, Bulgaria, Romania, Croatia, Latvia, Estonia, Lithuania, Malta, Cyprus, Luxembourg, Greece, Spain, Italy, Portugal, Belgium, Netherlands, France, Denmark, Sweden, Finland, United Kingdom, and Ireland. In order to give higher quality results about the application of the circular economy, the studies were filtered and focused on research that discusses the fundamentals closely related to the circular economy, mainly represented by "reducing," "recycling," "recycling," and "resource efficiency ."Filter to 151 searches. The primary objective was to categorize strategies for the circular economy into different sectors (Mhatre et al., 2021). The 151 selected research covered 28 vital sectors represented as follows: education, health, services, agriculture, information, communications, arts, media, finance, accounting, insurance, legal, engineering, commercial and industrial of all kinds, mining, real estate, construction, transportation, storage, scientific research and development, coal, petroleum and various chemical, pharmaceutical and medical products, defense, waste and its treatment, water supply, and treatment, gas and electricity supplies. Dividing the sectors in this way made linking them to the three partial, intermediate, and macro levels easy. Research analysis gives a real and comprehensive opportunity to know the strategies used by the sectors (Mhatre et al., 2021).

With the development of science, the information and communication services sector emerged, which is closely related to other sectors and affects the environment. The transition of companies from traditional data storage to cloud storage enhances efficiency, which helps the environment (Lindström et al., 2018). Quick access to data also gives efficiency at work (Bressanelli et al., 2018). Several European cities have begun to develop the uses of technology in various sectors to facilitate reaching the final goal with the least resources, the most permanent, which helps to manage carbon dioxide emissions (Akande et al., 2019).

Due to the need to work on the three levels to obtain the optimal result, administrations, governments, and local authorities in European countries work in partnership with their societies to network with stakeholders and form community programs to promote a circular economy (Lisjak et al., 2017).

European countries are divided into four categories according to the circular economy's development level. The classification was made by obtaining standard values by considering the effect of seventeen variables from 2010-2016. These values reveal the ranges of the general synthetic measurement and its changes in individual years. Any increase in the upper and lower marginal values reflects an improvement in the European country implementing the circular economy. Luxembourg and the Benelux countries represent the first classification of countries with a high level of circular economy. This classification remained until 2016 when Sweden fell to the second classification. The second ranking in 2010 included Austria, the Czech Republic, Germany, Slovenia, Denmark, Latvia, France, and the United Kingdom. However, with time until 2016, France fell to the third classification, and Lithuania and Poland rose to the second classification, with Sweden joining that classification. The third ranking in 2010 included Spain, Italy, Portugal, Lithuania, Finland, Ireland, Hungary, Poland, Romania, Slovakia, and Croatia. With the descent of France to the third classification, the development of Bulgaria from the fourth to the third level, and the development of Poland and Lithuania to the second level, the third classification became composed of the following countries: Italy, Spain, Portugal, Ireland, Finland, Romania, Hungary, Slovakia, Croatia, Bulgaria, and France. The last level, which represents countries with a tiny implementation of the circular economy, began in 2010 with five countries: Estonia, Bulgaria, Cyprus, Greece, and Malta. With the development of implementation in Bulgaria and its shift to the third level, the other four countries remained in the last level until 2016. (Fura et al., 2020)

Targets of Circular economy: The importance of targets comes from their qualities whereby targets are measurable, accurate, and practical (Lester & Neuhoff, 2009). Achieving them helps achieve high efficiency that drives the circular economy (Akenji et al., 2016).

Ten core targets are closely related to the R Strategies for the Circular economy. The ten targets are categorized into three groups (Morseletto, 2020). The first is under the heading of smarter product use and manufacturing and includes refuse, rethink, and reduce. Where this group is considered the introductory stage that leads to the transition to the circular economy in the pre-production stage, which is the stage that depends on the reuse and dismantling of the product (Despeisse et al., 2017).

The most widely used definition of rethinking is the multifunctional use of products (Potting et al., 2017). The rethinking strategy has three objectives: the first is circular, the second is the constituent elements of the circular economy, and The last is making other circular economy strategies possible (Elia et al., 2017).

From what was mentioned above, the optimal target of the first strategy is to be developed through engineering and design as they facilitate the subsequent circular economy strategies. In practice, it is better to have a large part of the products that can be dismantled and repaired to ensure effective supply chains and higher advantages for new products and services to ensure their compatibility with circular economy strategies (Morseletto, 2020).

After completing the process of rethinking, which enables us to obtain multifunctional products and services. The process of vanishing the product with one function, which enables us to consider it without benefit, is the most appropriate explanation for the Refuse strategy that contributes to making production processes and, thus, the economy circular (Morseletto, 2020).

Due to the different countries and the diversity of lifestyles from one European country to another, each country develops an application mechanism suitable for activities that contribute to transforming the economy into a circular economy, as the disposal of plastic bags is the proposal presented in the research prepared in Poland (Lewandowski, 2016).

Moreover, because the strategies are closely related, reuse and recycling influence and are affected by rejection decisions. When we cannot reuse or recycle, it is better to reject it from the ground up, as in the example of plastic bags. To summarize, it is ideal to use the rejection strategy when the environmental benefit is impossible or when activities/processes are environmentally harmful (Geyer et al., 2016; Haupt et al., 2017).

The third strategy is Reduce, which means fewer natural resources, fewer raw materials, and less energy (Reike et al., 2018). This strategy is implemented through a lightweight design that gives the possibility of eliminating some unnecessary materials or replacing them with better materials while maintaining durability (Akenji et al., 2016). In addition, the anthropogenic carbon resulting from combustion and the nitrogen coming from fertilizers are among the dissipative uses that negatively affect materials and energy and thus affect the economy's productivity. (Moreau et al., 2017).

The second group of strategies is placed within the group of extending the life of products and their parts, which includes five strategies: R3 Reuse, R4 Repair, R5 Refurbish, R6 Remanufacture, and R7 Repurpose (Morseletto, p. 2020). Its main objective is to keep the product as a whole and part of the economic cycle under use with high quality and efficiency for the longest possible period (Guide, 2000).

Working with defective products to repair and maintain them to reach their best use is the ideal definition of repair (Potting et al., 2017). While modernizing an old product, upgrading it, and updating it by lightly replacing certain parts to reach the best possible quality is the best explanation for the concept of refurbishment (Ferguson & Souza, 2010). The next reformer is remanufacturing, in other words, a new life for the product, where parts of the products are reused to obtain a product with the same primary function and high quality (Reike et al., 2018). Repurposing means producing a product with a completely new use of its essential components, and this process is called using the open loop (Willskytt et al., 2016).

It is challenging to define strategies for each of R4, R5, and R6, as the primary goal is to preserve the original product with high quality for as long as possible. However, it is difficult to determine this in advance (Cooper, 2010). In practice, the increase in the replacement of products or their components to obtain remanufacturing and renewal, in addition to the existence of a long-term guarantee, will force companies to produce products with excellent durability and high quality, which contributes to reducing repair and thus contributes to the transition to a circular economy (Wieser, 2016). The costs resulting from repair, refurbishment, and remanufacturing must be considered, as there are cases in which these strategies could be more economically feasible and drain the labor. For several reasons, most notably the lack of replacement parts/parts or the difficulty of disassembling the product to carry out the necessary work (Milios, 2016).

Relocation and resale are the most popular types of reuse. Since reuse is one of the ten strategies to reach a circular economy, it is necessary to differentiate between products according to their quantity. We have products with variable ownership or different users that can maintain ownership (Reike et al., 2018). Reusing and accepting beneficiaries to obtain previously used materials preserves primary resources and reduces continuous production processes, thus saving time, effort, and energy, which reflects positively on the environment (Singh & Ordonez, 2016). In addition, periodic maintenance enhances product sustainability, which contributes to reducing waste (MacArthur, 2013). Parts harvesting refers to recovering certain parts from discarded/unused products to be reused, which also saves us resources (Ferguson & Souza, 2010).

The last two strategies for recovery and recycling fall under a significant goal called the practical application of materials, which is fundamentally related to dealing with solid waste in its organic and inorganic forms in landfills and waste incinerated without heat recovery processes (MacArthur, 2013). The processing processes in these two strategies are costly, but they have the most significant impact on circular policies and the mechanism for reaching a circular economy (Ghisellini et al., 2016).

Recycling refers to processing previously used materials for the possibility of obtaining extracted materials called secondary materials that are used to obtain products of different quality according to need. It is possible to produce materials of higher quality than they were before recycling, the most prominent example of which is the biologically refined extract, and on the contrary, materials of lower quality can be produced, and at other times the recycling process is not possible at all (Worrell & Reuter, 2014).

There are two main classifications of recycling, the first is open-loop recycling and the second is the closed-loop type. Whereas, the partial use of secondary materials in systems to produce other materials expresses open-loop recycling, while the reuse of by-products to obtain the first primary product is closed-loop recycling (WOLF et al, 2010).

To complete the recycling process, there are different factors, most notably the secondary materials that will be obtained and used, how to use these secondary materials and how to use the recycled product, the prices of the recycled product, and the costs of the recycling process, the possible losses that can be obtained through the recycling process (Niero & Olsen, 2016).

Although recycling contributes to a circular economy, this strategy consumes much energy (Turner & Pierce, 1994).

This strategy is the most popular compared to the other eight strategies, as many countries in the developed world adopt this strategy. South Korea, Japan, and China seek to recycle approximately 80 to 95 percent of car products (Wang & Chen, 2013). The European Union adopts a recycling strategy and strives to complete the recycling of 65% of municipal solid waste by 2030 (European Commission, 2015).

Given that achieving good environmental performance is one of the most prominent goals of the circular economy, the combination of reducing waste and obtaining high-quality recycled products, starting the disposal of waste at its sources through direct recycling is an application of anti-recycling goals that contribute to the transition to the economy Ring (Zaman, 2015; Murray et al., 2017).

After the completion of the recycling processes, it is natural that there will remain non-recyclable materials that will be the basis of the recovery process, which will be incinerated. Energy will be recovered after the completion of the incineration process (Potting et al., 2017). Given the European Union's goal of recycling 80 percent of municipal solid waste, it is logical that some solid waste remains unrecyclable. Therefore, although the circular economy seeks zero burning, it will be burned. Achieving zero burning needs to integrate the implementation of the zero-waste strategy that was put forward in the recycling strategy, although it is an ideal strategy that is difficult to be achieved. (Zaman, 2015).

Barriers to the Circular Economy: According to Kirchherr et al. (2018), there are four barriers to the circular economy: cultural barriers, market barriers, regulatory barriers, and technological barriers. About cultural barriers there are two main barriers. The first relates to the culture of the consumer and the company, as whether or not the consumer accepts the products coming from implementing the nine strategies contributes to determining the ease of implementing the circular economy (Mont et al., 2017). The second cultural barrier is mainly related to the company's reluctance to adopt the culture of using the products resulting from the nine strategies (Ranta et al., 2017). With regard to market obstacles, the low prices of virgin materials, which contribute to lower costs of production processes with high investment costs for implementing circular economy strategies, are among the most prominent market obstacles (Kirchherr et al., 2018), and this confirmed by (Mont et al., 2017). They indicated that the high prices of circular materials compared to their linear counterparts increase competition and difficulty transitioning to a circular economy. Therefore, Ranta et al. (2017) stress the need for governmental and societal support to transition to a circular economy. These initiatives require financial support to obtain and reach their economic feasibility. Many regulatory barriers impede the circular economy, most notably the obstacles to the existence of laws and regulations supporting the transition to a circular economy (Rizos et al., 2015).

Furthermore, the lack of global consensus or the difficulty of having a regional consensus for the transition to a circular economy with the limited existence of laws that encourage the purchase of circular products also constitute regulatory obstacles to the transition to a circular economy (Kirchherr et al., 2018). The last type of barrier is the technological barrier, mainly represented by two main constraints. The first is the design of the essential product, which impedes the process of dismantling materials for reuse (Pheifer, 2017). The second is the difficulty of obtaining recycled products of high quality that are satisfactory to users (Kirchherr et al., 2018).

Before answering how to measure, it is essential to explain what to measure by defining the circular economy, mentioning the strategies, and then explaining the measurement type. Potting et al. (2018) formed a pyramid that explains circular economy strategies—divided this pyramid into six sections. The five strategies explain what is called preservation strategies. The pyramid concludes with the sixth strategy, which explains the reference scenario and how to measure it. The first strategy aims mainly to obtain products and services resulting from circular activities by sharing services and products on the one hand and obtaining products and services with multiple functions frequently. The combination of reuse, recovery, recycling, and renewal strategies constitutes the second strategy that seeks to increase the life of products. Moving on to the third strategy, in which we go to the parts of the product that are used again for the same purpose or for different purposes. The fourth strategy explains the use of recycling to keep the materials that make up the products in use condition. After completing the five preservation-related strategies, taking advantage of energy by recovering it is the fifth strategy used in landfill cases. An analogy is necessary to give a final picture of the six circular economy strategies. The sixth strategy depends on placing the linear economy as a reference, measuring it, and comparing it to determine the current situation regarding regression or progress toward a circular economy (Potting et al., 2018).

The study (Moraga et al., 2019) confirmed what was explained in the definitions and strategies of the circular economy above in detail. The circular economy does not operate in a closed system. The same study concluded that three types of measurement are represented by circular economy indicators as follows.

1. Direct circular economy with specific strategies: the adoption of measurement indicators on one or more specific strategies for the circular economy.
2. Direct circular economy without specific strategies: It is the adoption of measurement indicators for many non-predetermined strategies for the circular economy.

3. Indirect Circular Economy: Using additional indicators to help give a broader circular economy assessment. There are many examples of additional indicators, the most prominent of which is the environmental innovation index.

After explaining what measurement is, it is essential to explain how measurement is done. Accordingly, the scope, scale, and types of equations for the circular economy will be explained, which will help answer the question of how to measure. Measurement ranges will be started and explained according to what is called life cycle thinking as well as modeling levels. Life cycle thinking is defined by the possibility of following up the product through the various stages of its cycle from design to production, consumption followed by use, and last of which is disposed to ensure sustainability (De Haes & Van Rooijen, 2005). As a newer approach to analyzing potential impacts, Reike et al., 2017 demonstrate the importance of a systematic resource life cycle.

By defining and clarifying the need for a systematic resource life cycle, it is possible to divide the scopes of measuring the circular economy into three domains. The nucleus is the zero range, which consists of indicators capable of measuring the physical characteristics of technology for each product, service, component, and material away from the life cycle approach of thinking (Graedel et al., 2011).

The following domain considers the life-cycle approach to thinking fully or partially in measuring physical properties (Ardente & Mathieux, 2014).

The final scope includes adding indicators that measure the environmental, economic, and social impacts of technological cycles of services, products, components, and materials in cause-and-effect chain modeling (Huysman et al., 2015).

The implementation measures of the circular economy are closely related to the three levels of the circular economy: the micro level, the meso level (eco-industrial parks), and the macro level. The micro level corresponds to both the service or product and the company. In comparison, the intermediate level corresponds to the various companies' grouping. The macro level corresponds to the region, city, and country (Kirchherr et al., 2017).

After explaining the above, we come to the equation of indicators for evaluating the circular economy. The evaluation of the circular economy is based on methodologies that represent multiple approaches. These methods, of which the Life cycle assessment impact categories are a practical example, link models, indicators, and tools to clarify information that explains circularity (Moraga et al., 2019).

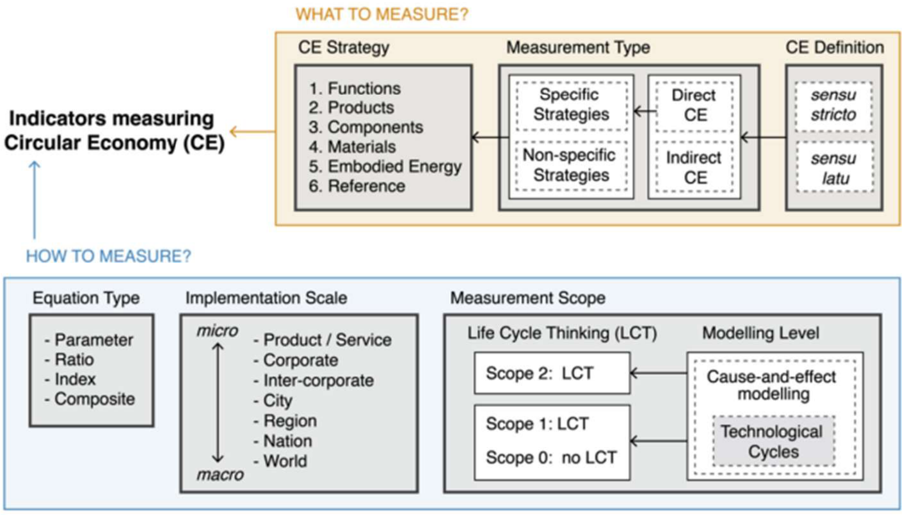

Figure. 2.11. A classification framework for Circular Economy indicators

Source (Moraga et al., 2019).

Linear economy: The concept of the linear economy is the model that global economies followed for long periods, based on a strategy consisting of three stations, the first of which is taking, the second is making, and the third is disposing of. The three stations are translated by extracting raw materials, then by finding products and manufacturing them for consumption. After consumption, it is normal to have leftovers, which are either delivered to landfills or incinerated as a second option (Kaplan, 2016).

The linear economy dated back more than 150 years ago. This economic model is based on two assumptions. The first is the unlimited energy and resources and their ease of availability, and the second is the possibility of renewing those resources. The linear economy is explained by drawing its activities in a line that includes its activities, starting from the extraction of materials to the landfill. The combined process of production and consumption increased with industrial development. As economies continued to manufacture, using the raw materials that are extracted, then completing the manufacturing and consumption process later, until the remnants of the products reached the landfills. Industrial and technological development naturally led to an increase in the demand for products, which increased the economy's productivity. It is the same in increasing product demand due to population growth (Wautelet, 2018).

Linear economy by sector: Linear Economy will be discussed in many sectors; we start with two sectors which are the Waste and Wastewater Management Sectors. As explained in the concept of the linear economy, one of the most critical stages of this model is waste management. Therefore, the linear economy model operates mainly on the traditional waste management system. This system is known as the collection and burning or landfilling of mixed waste with the waste of non-recoverable energy resulting from incineration. Dry and wet waste is complex, requiring unique biological and mechanical treatment plants (Mihai & Minea, 2021). Some countries in Eastern and Central Europe contained landfills, which mainly contributed to the export of human methane (Mihai, 2020), creating environmental risks related to the relationship between air, water, and soil pollution (Mihai & Ichim, 2013).

Eighty percent of global wastewater remains untreated, contributing to the pollution of fresh water and the marine environment (Mihai & Minea, 2021). Some old treatment plants in central and eastern Europe treat urban sewage poorly. In addition, the ineffective networking of sewage systems in villages and small urban areas with the primary sewage system (Strungaru et al., 2019). Not only that, but the treatment plants of industrial facilities also contribute to water pollution (Zaharia, 2017). Turning to the soil as a vital basis and a significant element, poor treatment or the presence of nitrates in the waste pose a real threat to the soil, and the matter extends to threaten groundwater as well, which threatens the environment and public health. Moreover, do not forget that the linear economy does not recover energy, so the environmental threat is accompanied by a waste of energy that could be recovered through the production of biogas (Trombin et al, 2017).

Regarding the agriculture sector, within the linear economy, agriculture still depends on chemical fertilizers and pesticides. In addition, the general form of the linear economy results in waste. By dropping it on the agricultural sector, agricultural waste results naturally from following the mechanisms of the linear economy (Mititelu-Ionuş et al., 2019). Agriculture is one of the sectors that produce organic waste, as its improper disposal through burning in inappropriate places or using it in composting operations leads to environmental risks (Mihai & Ingrao, 2018). Chemical fertilizers are the most widely used in the agricultural sector within the linear economy. Often, these fertilizers are not converted into fertilizer, contributing to nitrate pollution and mainly affecting the environment (Mihai, and Minea, 2021).

Industrial production is another evidence of the antiquity of the linear economy, as since the industrial revolution, industrial production has been considered one of the models representing the linear economy (Torok et al., 2014). Whereas industrial production passes through primary stages in the linear model, the first of which is the extraction of raw materials, so that appropriate treatment is carried out so that the industrial product becomes ready for consumption, and after its consumption, its residues are disposed of (Hartley et al., 2020). By discussing these multiple stages, the basis for obtaining economic growth is raw materials (Zilahy, 2016) as the operations of extracting natural raw materials are witnessing an unprecedented increase, as they increased by three times in 2017 compared to 1970, which poses a threat to the environment (Mulvaney, 2019). Not only that, with the increase in demand, industrial production is increased, and accordingly more natural raw materials are used, and some of these resources are limited and cannot be replaced, so the risks multiply (Csete & Esses, 2022). In addition, this pressure on primary resources, in parallel with the scarcity of some of them, negatively affects the economy due to the high prices due to the lack of supply (Hartley et al., 2020). In the economy, a statistical function was formed that explains production by representing a technological relationship between inputs and outputs. Labor and physical capital represent the inputs, while the quantity resulting from the application of those inputs represents the outputs. This function is called Cobb-Douglas (Cobb, and Douglas, 1928). Csete and Esses (2022) applied the Cobb-Douglas function to investigate the relationship between water use, energy efficiency, and fluid production based on logistics operations. The researchers concluded that the applicable European laws contribute to a negative impact of water use and energy efficiency on production processes.

The linear economy is based on matters that are detrimental to climate policies, namely mining activities and the fossil fuel industry, since the energy in the linear economy is mostly nonrenewable energies, despite the European Union's push for its members to use higher renewable energy (Grecu, et al., 2018; Ţicleanu et al., 2014).

2.12. Renewable Energy Sources

Energy, a crucial component in implementing economic activities and is created, stored, bought, employed in a process, put through a particular process, and recovered, is essential for organizational and economic growth (Almaz, 2021). According to a few characteristics, energy is divided into nonrenewable and renewable energy sources (Azadeh et al., 2008)

Traditional fossil fuels like coal, oil, and gas are nonrenewable energy sources since they will eventually run out. Alternative energy that lessens reliance on fossil fuels can be produced from finite resources, is self-renewable, lessens the environmental consequences of fossil fuels, and improves energy efficiency is known as renewable energy (Fontes et al., 2018).

Solar energy, wind energy, geothermal energy, biomass energy, and hydroelectric energy are some of the renewable energy sources often employed worldwide. These renewable energy sources should be incorporated into and implemented as part of sustainable energy management programs and policies at the national and international levels because they improve the security of energy production, are clean, reduce gas emissions, have economic value, and are environmentally sensitive (Bayraç, 2010).

The utilization of sunlight and heat to generate energy is known as solar energy (Almaz, 2021). It is created when hydrogen gas in the sun's core transforms into helium. It is the most readily available and environmentally friendly energy source since it is renewable, can be converted into heat and power, is inexhaustible when utilized, and is the raw material for fossil and other renewable energy sources (Azadeh et al., 2008).

Solar energy may generate electricity using solar cells, steam, and turbines. Solar energy is employed through concentrated solar energy systems and photovoltaic solar energy systems. Through the use of flat panels, photovoltaic solar energy systems directly capture solar energy and transform it into electrical energy (Mills, 2011).

They are favored systems because they are low-maintenance, silent, free of moving components, do not contribute to air pollution or greenhouse gases, and can be placed in buildings (Kandt & Romero, 2014). The kind, direction, and intensity of the sun's rays affect how well this system performs. As a result, this system performs better when the solar panels get more solar energy. By converting sunlight into heat, concentrated solar energy systems generate energy (Kandt & Romero, 2014).

This system's basis is steam generation by solar water heating. It has three fundamental characteristics, including the ability to concentrate or reflect sunlight, generate electricity using steam, and store the heat energy generated by steam. Unlike the photovoltaic system, this system contains a steam turbine and a heat energy storage tank. As a result, the installation fee is more expensive than a photovoltaic system (Kandt & Romero, 2014)

The energy efficiency is higher, however. Everett (2004) underlined that while solar energy systems have a lifetime comparable to fossil fuel systems, there is no fuel expense associated with solar energy systems. Because solar energy source is limitless, unrenewable, and inexpensive to deploy, it is a preferred renewable energy source. Wind energy is a different type of renewable energy.

The earth's atmosphere and surface heat up to varying degrees and exert pressure due to the sun's rays hitting it at various angles. The pressure and revolution of the earth's axis produce air currents, providing wind energy. A sustainable energy source known as wind energy uses the kinetic energy of the wind first to create mechanical energy, then electrical energy (Almaz, 2021)

Wind energy systems, or wind turbines, convert kinetic energy first into mechanical energy and subsequently into electrical energy. According to their rotating axes, wind energy systems are classified as horizontal or vertical axis systems. According to Bayraç et al. (2018), wind energy provides benefits including cheap cost, reduced greenhouse gas emissions, long-term usage of wind turbines, and low turbine maintenance costs.

They also have several drawbacks, such as expensive installation fees, noise pollution, the necessity for enormous spaces for installation, and varying energy generation according to shifting wind conditions. According to research, wind energy has the highest capacity for utilization of renewable energy worldwide (IEA, 2013). In 2050, it is predicted that wind energy will supply 18% of the world's electrical requirements. One of the renewable energy sources, geothermal energy, is utilized to generate electricity and heat from thermal energy that is gathered at a depth that is accessible and close to the earth's surface (Almaz, 2021)

In some regions of the world, it is acquired directly and indirectly through the digging of wells (Melikoglu, 2017). Direct usage includes getting hot water and heating, whereas indirect use includes using steam power plants to produce electricity. The ability to collect energy consistently, safely, affordably, and cheaply makes it chosen by nations, even though its application area is not as widespread as other renewable energy sources (Canik et al., 2000; Karagöl & Kavaz, 2017).

It offers benefits, including being a domestic resource for the nation in it is located, having a quick installation process, being unaffected by climatic variations, and having minimal installation and maintenance expenses. The limitations of geothermal energy's use area, sound blockage and energy loss, mineral erosion, and environmental degradation are among its drawbacks (Erolu, 2008). Living things and organic waste create biomass energy, which is then transformed into solid, liquid, gaseous, and electrical fuels (Almaz, 2021; Mafakheri & Nasiri, 2014).

Biomass energy may be produced from organic resources such some fast-growing trees and grasses, algae, and agricultural waste (Khan, 2009; Mohtasham, 2015). It has advantages like being the most potent renewable energy source in terms of potential, being storable, being able to be used in conjunction with other energy sources, being clean and harmless, being able to change into other energy sources, and being aware of production techniques (Ladanai & Vinterbäck, 2009).

Poor calorific value, the requirement for water consumption during production, the erosion of soils, low productivity, competition in agricultural regions, high labor and transportation expenses, specific technical issues, and political restrictions are only a few of the drawbacks of biomass energy (Uygur, and Serengil, 2016). According to Bahadori et al. (2013) and Karagöl and Kavaz (2017), hydraulic energy is a renewable energy source that is produced by transforming water energy into electricity.

It is created by converting the kinetic energy produced by the power of the flowing water. Dams and river power plants create hydraulic energy depending on their location. These power plants generate electricity that may either be utilized immediately or stored. Additionally, it is clean, efficient, environmentally friendly, long-lasting, domestic, and requires little upkeep. It is the most popular renewable energy source globally because of its cost advantage (Karagöl & Kavaz, 2017).

When using this energy, nations with arid landscapes and wetlands have an edge. As can be seen, the relevance of renewable energy supports sustainability and lessens environmental harm by expanding the range of resources available to fulfill global energy demands. The usage of renewable energy sources is growing daily and is supported globally, despite our significant dependency on fossil fuels and the fast rate at which they are consumed. Currently, airports employ renewable energy sources and energy-saving practices to fulfill the rising demand for energy while lowering prices, emission rates, and carbon footprint (Baxter et al., 2015; Nam, 2019).

2.13. E.U. initiatives to reduce Greenhouse gas emissions

As represented by the EEA report (2020), the lowered levels of GHG emissions in all E.U. member countries result from collective effort across all sectors within each member state, as dictated by environmental protection policies, treaties, and conventions the E.U. ratified. These global conventions and treaties are compulsory as they translate into country-specific regulations for all economic sectors to achieve the global target of reducing global warming to below 1.5 degrees Celsius. These treaties can be under the auspices of the United Nations or other international bodies, and the treaties are the Paris Agreement, the Kyoto Protocol, European Climate Law, The United Nations Framework Convention on Climate Change, Montreal Protocol, Nairobi Convention, International Tropical Timber Agreement, among other local and international treaties. The most prominent and known treaties will be elaborated on in this section: the Paris Agreement, UNFCCC, the Kyoto Protocol, and the Montreal Protocol (ECOLEX, website).

The Paris Agreement, as already mentioned in the introduction, is an international treaty on climate change, binding 196 countries as of 2016 to reach a global temperature of fewer than 2 degrees Celsius and limit the increase in global temperatures to 1.5 degrees Celsius (UNFCCC, 2022). The Paris Accords stands out from other global conventions not only because it is the landmark in a multilateral climate change process or because it came into existence within the same timeline as the SDGs but also because it realizes the importance of economic and social transformation from the global world, similar to the three pillars that cement the SDGs (UNFCCC, 2022). The timeline of the Paris Agreement requires participating countries to submit their plans by 2020 on how they plan to lower their GHG emissions and what measures they will take to adapt to the inevitable effects of climate change (UNFCCC, 2022). These plans are the "nationally determined contributions" or NDCs. The Paris Agreement Implementation and Compliance Committee (PAICC) is meeting consistently to ensure collective and individual progress toward the 29-articled accords' goals (UNFCCC, 2022). The support achieves collective progress that one participating country gives to another; this includes financial, technical, and capacity-building assistance.

The United Nations Framework Convention on Climate Change (UNFCCC), in which the Paris Agreement enhances the convention's implementation, is an international convention that was created in 1992 with present near-universal membership, notably from the European Union Member States, with the primary goal of preventing anthropogenic interference with the climate system. In this convention, developed countries agreed to support and aid developing countries in climate change activities by providing financial assistance through the system of grants and loans that the convention has set up and is managed by the Global Environment Facility. This convention was the product of the Rio Earth Summit of 1992, along with the U.N. Convention on Biological Diversity and the Convention to Combat Desertification (UNFCCC, n.d.). This U.N. convention and the other two are interconnected in that they work on issues of mutual concern through a joint liaison group. According to ECOLEX, which is a joint program on environmental laws, treaties, and conventions created by U.N. organizations, the main objective of the UNFCCC is "to regulate levels of greenhouse gas concentration in the atmosphere to avoid the occurrence of climate change on a level that would impede sustainable economic development, or compromise initiatives in food production" (ECOLEX, n.d.). This convention is the primary source of global information, data, and research through which parties that ratified it contribute by reporting on GHG emission data, local and regional initiatives undertaken to combat climate change, and also their upcoming strategies for improvement on their current mitigation and adaptation strategies (UNFCCC, n.d.).

The Kyoto Protocol was adopted in 1997 but entered into force in 2005 and has undergone several amendments since then. Through the UNFCCC, the Kyoto Protocol ensures that industrialized countries and transitional economies limit and reduce GHGs. However, it differs from the U.N. convention by binding developed countries and placing a heavier burden on them because the protocol realizes that they are primarily responsible for the current high level of emissions (UNFCCC, n.d.). The protocol follows a principle of the common cause against climate change but different responsibilities based on capabilities (UNFCCC, n.d.). The Kyoto Protocol sets 37 industrialized countries binding emission reduction targets, economies in transition, and the European Union (UNFCCC, n.d.). Even though the UNFCCC produced this protocol, it differs from the convention by its mechanism of application because the protocol requires countries to meet their targets primarily through national measures but also allows a 3-way flexible market mechanism, which are the international emissions trading, clean development mechanism, and joint implementation (Rafferty, 2022a; UNFCCC, n.d.). These mechanisms encourage GHG abatement at a cost-effective beginning, and the overall reduction through these free markets will keep these GHG emissions safe. For example, the clean development mechanism (CDM) encourages developed countries to invest in technologies and infrastructure in developing countries as an opportunity to reduce emissions, whereby the investing country can claim this reduction as credit towards achieving its target under the protocol (Rafferty, 2022a; UNFCCC, n.d.).

On the other hand, emission trading allows countries to buy and sell emission rights, transforming their emissions into a commodity, and this is called the "Carbon Market" (Rafferty, 2022a; UNFCCC, n.d.). However, this protocol did not achieve its goals because the big country emitters, U.S. and China, were not bound by the treaty. The protocol had undergone amendments in both Doha, Qatar, and Durban, South Africa, which produced the Paris Agreement in 2015.

The Montreal Protocol, a 1987 international treaty adopted in Montreal, Canada, aimed to adjust the production and utilization of chemicals that deplete the ozone layer. This treaty came into force after the 1974 scientific discovery and research of chlorofluorocarbons

(CFCs) that produce chlorine and chlorine monoxide in the stratosphere after CFCs decompose due to solar radiation (Rafferty, 2022b). In 1985, 2 years before the protocol, a hole was discovered in the ozone shield over Antarctica. These events empowered UNEP (U.N.'s environment program) to lay the groundwork for the protocol. Additionally, the United States banned CFCs in 1978 due to this discovery. The E.U. and other developed and developing countries worked to phase out the ozone-depleting substances (ODSs) entirely by banning the production and consumption of halons, CFCs, HBFCs, carbon tetrachloride, methyl chloroform, and methyl bromide, which led to their end of use (Rafferty, 2022b). Hydrochlorofluorocarbons (HCFCs) are planned to phase out by 2030. The treaty successfully achieved its set targets because the first signs of ozone layer recovery were discovered in 2018 (Rafferty, 2022b).

It is also crucial to note that country-specific actions, policies, and regulations are put in place that contribute to the countries in the E.U. meeting their treaty-set targets. According to the EEA 2020 report discussed earlier, big E.U. country emitters achieved much lower emissions in 2018 than their 1990 levels (EEA, 2020). A great example would be Germany and the United Kingdom, whereby "they achieved total domestic GHG emission reductions of 723 million tonnes CO2 equivalent compared to 1990, not counting carbon sinks and the use of Kyoto mechanisms” (EEA, 2020). Germany increased its power and heating plant efficiency and then restructured its economy after the reunification, particularly in the iron and steel sector (EEA, 2020). Other measures Germany took included reducing the carbon intensity of fossil fuels by switching from coal to gas, followed by a substantial increase in renewable energy use and waste management measures that reduced the landfilling of organic waste (EEA, 2020). The United Kingdom liberalized the energy markets and, like Germany, switched fuel sources to gas, a much cleaner option for producing electricity, and implemented methane recovery systems at landfill sites (EEA, 2020).

Overall, EU member states resorted to raising their share of renewable energy, especially biomass utilization, driving the use of less carbon-intensive fossil fuels and improvements in energy efficiency and inciting structural changes in the economy (EEA, 2020). Additionally, lower agricultural livestock, lower levels of mining activities, and "lower emissions from managed waste disposal on land and reduced adipic and nitric acid production" instigated reductions in NO2 and CH4 emissions in E.U. (EEA, 2020). These measures the E.U. member states are adopting are required under legislations and regulations they have set to abide by the Kyoto Protocol commitments and other UNFCCC treaties. An example of regulations includes the European Environmental Policy, which functions based on precaution, prevention, and rectifying at-source pollution by installing a "polluters pay" principle (Kurrer, 2021). Additionally, the E.U. has issued multiannual environment action programs (EAPs) as a basic framework for "ensuring well-being for all, while staying within planetary boundaries" and as means for setting forth legislative proposals and goals for the E.U. environment policy (Kurrer, 2021).

The E.U. Commission has defined the "criminal sanctions for environmental offenses" under Directive 2008/99/E.C to ensure environmental law implementation. The environmental offenses that are labeled as criminal pertain to illegal emission or discharge of substances into the air, water, or soil, illegal trade in wildlife, illegal trade in ozone-depleting substances, illegal shipment or dumping of waste, unlawful operation of dangerous activities (including nuclear materials) and the unlawful treatment of waste (Kurrer, 2021).

In addition to the laws, conventions, and country-specific initiatives, the International Energy Agency, comprised mainly of European member states, has launched its own set of initiatives, including the Electric Vehicles Initiative, the Clean Energy Ministerial Hydrogen Initiative, and EU4Energy (IEA, 2022c,d,e). These initiatives foster cooperative energy sector development, support the implementation of sustainable energy policies, introduce the role of hydrogen & fuel cell tech in global clean energy transitions, and accelerate the adoption of electric vehicles (IEA, 2022c,d,e).

2.14. The Role of the European Green Deal to Reduce Carbon Emissions

There has been much study regarding European Green Deal in the literature will be discussed in this chapter. Claeys et al. (2019) classified the agreement into four pillars: industrial policy, transition, sustainable investment, and carbon pricing. Eckert and Kovalevska (2021) also looked at the EGD discourse, a publicly proclaimed official discourse by the European Commission encompassing economics, business, and environmental science. Additionally, it deals with the transition from an unsustainable to a sustainable civilization. Some debates in EGD, however, can be concluded and understood in different ways.

Furthermore, Eckert and Kovalevska (2021) argued that EGD would be used relatively without victimizing anyone. All E.U. nations, states, and inhabitants should assume their financial obligations for the green transition. In the EGD, the circular economy model is also included. Mineral resources, waste management, and raw material recycling are crucial components of the circular economy and the transition to a sustainable society within the context of EGD (Smol et al., 2020). Andreucci and Marvuglia (2021), it is stressed that only green technical and R&D investment may be necessary to reach the United Nations Sustainable Development Goals (SDGs) and the EGD in 10 years, even though they can be accomplished in 30 years. In light of this, it will be simpler for these programs to battle and prepare for climate change. Social and environmental investments have begun with EGD.

The pandemic, however, has specific detrimental effects on the investing process. On the other side, it is said that the importance of environmental issues has been sufficiently acknowledged in the post-pandemic era and that EGD has to be relaunched to accomplish the Paris Agreement's decarbonization objective (Elkerbout et al., 2020; Fetting, 2020). In order to boost the economy and trading system, the E.U. should prioritize transformative technologies like environmentally friendly buildings and low-carbon infrastructure (Eckert & Kovalevska, 2021). Additionally, due to energy and GHG usage, environmental buildings are one of the leading indicators in the EGD (Bonoli et al., 2021). According to Bonoli et al. (2021), life cycle thinking and life cycle assessment are helpful techniques for environmentally friendly construction and waste recycling. The energy transition is a topic of discussion. According to studies, improvements in the energy sector's efficacy significantly influence sustainable development and are crucial for achieving the EGD. As a result, the EU is a leader in sustainable development.

Nevertheless, several E.U. members, like Poland, Bulgaria, Greece, the Czech Republic, Luxembourg, and Lithuania, need to engage in sustainable development as defined by the EGD and Agenda 2030 (Moore, 2020). Other elements include geological conditions and prior energy transition experience, among others. Strong regulations, technological advancements, and societal change are required to achieve the shift to green energy (Hainsch et al., 2022; Tutak et al., 2021). On the other hand, Leonard et al. (2021) noted that the energy transition would have an impact on the economy and trade balance in many regions and that ties between the E.U. and various nations may shift.

To increase economic diversification and trade in green energy, the E.U. should strengthen its ties with countries that export oil and gas, such as Russia, the USA, Algeria, and Saudi Arabia. Additionally, there must be less reliance on China for raw materials, and the possibilities for importing raw materials should be expanded. Global standards may be established for sustainable finance and energy (Hafner & Raimondi, 2020). Climate clubs are also crucial for adjusting the carbon frontier. Global alliances, developing a worldwide E.U. budget, establishing an E.U. Recovery and Resilience Fund, and E.U. policies are additional partner strategies for the E.U. and other nations.

Additionally, among the member nations that include Russia, the energy transition might need to be revised due to competing interests like the cost of energy (Hafner & Raimondi, 2020). Implementing carbon border adjustments is essential for exporting nations to conduct business with the E.U., claims Bektaş (2021). Turkey, for instance, is a significant exporter of iron and steel to the E.U. Energy consumption in Turkey should be taken into consideration for these sectors in order to avoid adverse effects from carbon border adjustment since energy intensities in the iron and steel industry have the most significant influence on GHG emission and low-carbon policies.

Within the framework of the EGD, Simionescu et al. (2020) investigated the impact of RE in final consumption on GDP and the global competitiveness index (GCI). Additionally, RE consumption has a favorable impact on GCI and economic growth. 2020 saw the creation of the European Recovery Fund after the release of the EGD. The energy transition plays one of Just Transition's most significant core functions. Consequently, photovoltaics may significantly facilitate the changeover (Kougias et al., 2021).

According to Wolf et al. (2021), a different study addressed that socioeconomic inequality is necessary to get support for EGD. It is proposed that public investments in EGD should account for about 1.8% of pre-COVID-19 GDP throughout the ensuing decades (Wolf et al., 2021).

As Siddi (2020) said, despite worldwide challenges including climate change denial, economic slowdowns, pandemics, geographic crises, and so on, the European Commission is pursuing climate policies by adhering to the EGD. Policy priorities and the distribution of green funds should be supported to accommodate EGD issues. Additionally, the additional money allocated for the EGD should be added to the existing budget, and transfers of financial and technological resources to the developing world can aid in the fight against climate change.

Additionally, investment should be controlled, and a robust legislative mandate for the E.U. can encourage high-emission nations like the USA, China, and Russia to embrace climate action (Sabato & Fronteddu, 2020). The EGD's climate action plans must be supported for the movement and The Just Transition to succeed (Sabato & Fronteddu, 2020). Additionally, E.U. policy combines higher aspirations for climate action. On the other hand, the E.U. employs the pandemic and its detrimental effects as part of a plan to strengthen climate action (Skjaerseth, 2021). At that time, many policy mechanisms are recommended. For instance, Schoenefeld et al. (2021) suggested a policy monitoring method that was determined to be appropriate for EGD governance through the continual collection and analysis of data to compare with actual results.

Although policies will ensure that the EGD is implemented quickly, Pianta and Lucchese (2020) asserted that the E.U.'s present policies and regulations must be revised to accomplish socio-ecological goals and provide equitable and equitable, and sustainable economic results for countries. The E.U., therefore, requires a wider variety of green industrial policies to achieve effective and equitable outcomes from the EGD in terms of becoming carbon neutral in industry and the economy.

LaBelle et al. (2021) also discussed The Just Transition in the EGS and focused on energy justice, the economy, and jobs for nations that rely heavily on coal, such as Romania. Germany must replace all fossil fuel and nuclear power plants with 100% renewable energy sources in order to achieve net-zero emissions to the EGD, and the German EU Council Presidency should encourage this by negotiating with the member states to include them in the EGD's economic stimulus packages (Hainsch et al., 2022).

2.15. Overview of previous studies

Several empirical studies on the impact of GHGs emissions on economic growth worldwide were conducted. Three different axes will be discussed in previous studies, the first of which is the relationship between greenhouse gas emissions and economic growth in different countries, taking into account the panel data samples. In the second axis, the author discusses the environmental Kuznets curve globally and in Europe. The last axe is the one that discussed economic growth and various greenhouse gas emissions, with many additional variables.

The research assessed the relationship between economic growth, greenhouse gas emissions, and a group of factors given data from 22 European Union countries in 1995-2014. The studied variables are GHG, GDP, Research and experimental development, Energy taxes, and consumption. The examination structure that was used is the fixed effect panel model. Regression coefficients indicating GDP and energy consumption have a positive effect, while research and development taxes and energy taxes have a negative effect. The research additionally introduced that energy consumption and energy taxes, as well as research and development to adjust the direction of EKC in the study sample, can be applied to add to the change of climate change policy. (Lapinskienė, Peleckis, & Slavinskaitė, 2017).

Another review analyzed the relationship between greenhouse gas (GHG) emissions, gross domestic product, inland energy use, and renewable energy consumption for 28 European Union countries from 1990 to 2016. A panel unit root test was performed, followed by panel cointegration. The panel, the Least Square approach, was used. The fixed effect model was then appropriate after running the Hausman test. The panel cointegration method demonstrated that the four macroeconomic indicators had long-run equilibrium relationships. While empirical estimations using panel data techniques, as well as heterogeneous regression for each country in the panel, revealed non-conclusive evidence for the environmental Kuznets curve (EKC) hypothesis, for the models used to estimate the shape of the environmental curve, empirical estimations, using panel data techniques, as well as heterogeneous regression for each country in the panel, revealed non-conclusive evidence for the EKC hypothesis. Furthermore, all models' estimates revealed that an increase in gross energy consumption results in an increase in GHG emissions, but an increase in renewable energy consumption results in a reduction in GHG emissions. (Sterpu et al., 2018).

To continue with the European studies, another study generated a dynamic panel model for the EU27 between 1990 and 2006, which linked GHG emissions to real GDP and aggregate energy consumption. Using a dynamic panel structure, this study first assessed the performance of the vital EU27 countries regarding emissions, growth, and energy. Second, it employed a methodological model, namely the system-GMM approach. The findings showed conditional convergence regarding GHG emissions among the EU27 between 1990 and 2006. These symptoms are persistent when different sub-groups of countries and time periods are investigated. Second, evidence supporting the EKC concept still needs to be discovered. As a result, once the energy and convergence factors were considered, the findings showed no evidence for an inverted-U relationship between emissions and real GDP in Europe. In addition, the study looked into the link between total energy and emissions. This means that a 20% reduction in energy consumption would not be enough to meet the 20% emissions reduction target and that less polluting energy sources would be necessary to meet the target. (Marrero, 2010).

Moreover, by continuing to talk about European studies, but this time focusing on the V4 countries (Czech Republic, Hungary, Poland, and Slovakia), Between 1991 and 2012, a study employed the decoupling method to quantify the link between economic growth and the generation of greenhouse gas emissions. The model defined three sub-categories based on the rate of decoupling elasticity: weak decoupling, strong decoupling, and recessive decoupling. Based on the data, there is currently a strong decoupling, which means that these countries' economies are rising while greenhouse gas emissions are decreasing, which is a positive trend. Emission reductions have been aided by macroeconomic developments as well as governmental actions. (Vavrek & Chovancova, 2016).

Moving to Africa, a study was conducted for 17 Southern and Western African countries using the annual panel data from 2001 to 2012. This study used economic growth as an independent variable, GHG emissions as a dependent variable while (and FDI, natural resources, population growth, financial development, exchange rates, trade openness, infrastructure development, and unemployment) as control variables. The study had two goals. The most important was evaluating greenhouse gas emissions' impact on economic growth. Dynamic GMM pooled OLS and fixed and random effects approaches were used to achieve this goal. According to the empirical element, the influence of financial development on economic growth was positive and significant using the pooled OLS technique. Under the pooled OLS paradigm, the combination of greenhouse gas emissions and financial development has a non-significant positive causal influence on economic growth. Under fixed and random effects, both greenhouse gas emissions and financial development have a non-significant negative impact on economic growth. Nonetheless, both fixed and random effects revealed that the interaction between greenhouse gas emissions and financial development positively impacted economic growth. (Tsaurai, 2018).

In Sub-Saharan Africa, a study was conducted to examine the impact of economic growth on environmental quality, utilizing aggregated panel data from 1970 to 2012. The study discovered a strong relationship between GDP and GHG emissions. The OLS and VAR models were employed as tests. The OLS showed that GDP and CO2 have an N-shape relationship, while NO2 and NH4 have an inverted N-shape. In the long run, economic growth and environmental quality generally show a monotonic diminishing relationship. (Adzawla et all, 2019)

The co-movement and causality relationship between greenhouse gas emissions, energy consumption, and economic growth in 16 Asian countries were investigated in a study conducted in Asia. GHG emissions were used as an independent variable, with energy consumption and GDP as dependent factors, for the study, which spanned from 1990 to

2012. After performing panel unit root tests, panel cointegration approaches were used. The Fully-Modified OLS (FMOLS) technique was then used in conjunction with panel cointegration tests. According to the findings, a bidirectional Granger causality existed between energy consumption, GDP, and greenhouse gas emissions and between GDP, greenhouse gas emissions, and energy consumption. Between greenhouse gas emissions, energy consumption, and economic growth, a non-linear, quadratic link is discovered. (Lu, 2017).

Staying in Asia, a study was conducted in six Gulf countries using annual data from 1996–2017. The study examined the relationship between greenhouse gas (GHG) emissions, energy consumption, and economic growth. This study's empirical findings revealed a bidirectional causal relationship between energy consumption and economic growth, a unidirectional causal relationship between energy consumption and GHG emissions, and a bidirectional causal relationship between economic growth and GHG emissions for the entire region. (Saqib, 2018).

Environmental Kuznets curve (EKC) theory is examined severely by Stern et al. It suggests an inverted U-shape relationship between income per capita and environmental deterioration, with growth eventually reducing the environmental impact of economic activities. (Stern et al.,1996). The theory is based on an economic model in which trade has no impact on environmental degradation and there is no feedback between environmental quality and output potential. Fundamental issues arise in predicting the parameters of an EKC when these assumptions are actually violated. The paper identifies other econometric problems with estimates of the EKC and reviews several empirical studies. The assumption that the distribution of world per capita income is typically the same when the median income is significantly lower than the mean income underlies some of these EKC estimations, which suggest that more development will slow the rate of environmental degradation. We run simulations integrating EKC estimates from the literature with World Bank economic growth forecasts for specific nations, aggregating over countries to derive the global impact. Global SOI emissions are expected to keep rising until 2025, according to the Bank's prediction. Prior to the period's conclusion, the amount of forest loss stabilizes, although tropical deforestation keeps increasing at a steady rate. (Stern et al., 1996).

Halil Altıntaş and Yacouba Kassouri (Altıntaş & Kassouri, 2020) focus on two indicators of environmental degradation, including ecological footprint (EF) and CO2 emissions as target variables to provide new insights into the ongoing discussions of whether the environmental Kuznets Curve (EKC) hypothesis is related to the indicators of environmental pressure used. Estimating a heterogeneous panel model with data on 14 European countries over the period 1990–2014, we provide evidence for the sensitivity of the EKC hypothesis to the type of environmental degradation proxy used. Furthermore, we provide new insights regarding the relevance of EF as an appropriate environmental tool that fits the EKC prediction in contrast to CO2 emissions. Regarding the explanatory variables, the results show that renewable energy is an environmentally friendly source, while fossil fuels contribute to environmental degradation. The inclusion of renewable energy and fossil fuel does not alter the behavior of economic growth in all environmental degradation indicators. The empirical results demonstrate the need to implement environmental management policies that encourage the production/supply of renewable energy and reduce reliance on fossil fuel consumption. This paper is expected to provide policymakers with policy proposals for sustainable environmental and economic development.

Since the pioneering paper by Grossman and Krueger (1991), who initially introduced the Kuznets curve into the research of the relationship between economic development and environmental degradation, researchers have paid greater interest to the economic growth-pollution nexus in energy economic literature. The economic growth-environmental degradation nexus was investigated within the scope of the EKC hypothesis. Selden and Song (1994) used cross-national panel data to examine the inverted- U relationship between pollution (nitrogen oxides and carbon monoxide) and economic development in low, middle, and high-income countries. Employing pooled cross-section, fixed-effects, and random effects estimates, they found that per-capita emissions of all pollutants exhibit inverted-U relationships with per-capita GDP. Azomahou et al. (2006) rejected the EKC hypothesis using kernel regression methods from 1960 to 1966 for a panel of 100 countries. Akbostancı et al. (2009) employed time series cointegration and panel data pooled EGLS methodologies to explore the relationship between three types of pollutants (namely CO2, SO2, and PM10) and per capita income in Turkey over 1968–2003 and 1992–2001. Their empirical results provide evidence against the inverted U-shaped relationship between environmental degradation and income. Markandya et al. (2006) studied the relationship between per capita GDP and SO2 sulfur emissions for 12 Western European countries from 1850 to 2001. The authors revealed the existence of the EKC relationship between SO2 and economic growth. Mazzanti and Zoboli (2009) focused on waste indicators and investigated the relationship between waste and economic growth through the functional form of the Kuznets curve

(WKC). Their results strongly rejected the prediction of the WKC trend between various waste indicators and economic growth between EU countries over the period 1995–2000. Iwata et al. (2010) explored the relationship between France's per capita GDP, trade openness, urbanization, and carbon emissions for the 1960–2013 period. Their results provided evidence supporting the EKC hypothesis. López-Menéndez et al. (2014) employed OLS and panel fixed effect approaches for panel data from 27 EU countries from 1996–2010. According to the empirical findings, only four countries exhibited an inverted U-shaped, while 11 countries followed an increasing pattern; 9 showed a decreasing path and the remaining 3 countries showed a U-shape curve path. In the same vein, Lapinskienė et al. (2014) investigated whether the inverted U-shaped EKC nexus between greenhouse gases and GDP holds true for 29 European countries in the period of 1995–2010. The authors found different patterns in the relationship between greenhouse gases and GDP. This mixed evidence is partly due to several factors including economic factors, environmental policies, and the level of income. Based on panel cointegration and DOLS estimations, Dogan and Seker (2016) showed that the EKC hypothesis was valid for the European Union (Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, the Netherlands, Portugal, Spain, Sweden, and the United Kingdom) between 1980 and 2012. In the same vein, Kasman and Duman (2015) studied the relationship between energy consumption, carbon emissions, economic growth, trade openness, and urbanization for a panel of new EU members (Bulgaria, Croatia, the Czech Republic, Estonia, Hungary, Iceland, Latvia, Lithuania, Macedonia, Malta, Poland, Romania, the Slovak Republic, Slovenia, and Turkey) over the period 1992–2010. Based on panel FMOLS estimation and panel Granger causality tests, they documented the existence of the EKC hypothesis. Can and Gozgor (2017) studied the impact of economic development on carbon emissions in France over the period 1964–2014 and found that the EKC hypothesis is valid in France. In addition, their results highlighted the positive impact of energy consumption on CO2 emissions.

Abid (2017) tested the hypothesis of the EKC with a sample of 58 Middle East and African countries and 41 European Union countries from 1990 to 2011. The author's empirical approach rested on the use of panel GMM. The author found a monotonically increasing relationship between CO2 emissions and GDP in the EU, Middle East, and African regions. Considering a panel of 28 EU countries, Armeanu et al. (2018) investigated the validity of the EKC hypothesis from 1990–2014. Their results showed evidence in favor of the EKC hypothesis in the 28 EU countries. Destek et al. (2018) used a broader measure of environmental degradation to revisit the EKC relationship between environmental degradation in 15 EU countries from 1980 to 2013. Their empirical results indicated that the standard EKC hypothesis is invalid across European countries. Aydin et al. (2019) recently analyzed the EKC hypothesis using the recently advanced panel smooth transition regression (PSTR) model for 26 European countries from 1990–2013. The empirical results differ according to the subcomponents of the ecological used in the study.

The EKC is validated in Acaravci and Ozturk (2010) for 19 European (EU) countries. Subsequently, the EKC is supported by Ben Jebli et al. (2013) for 25 OECD (Organization for Economic Cooperation and Development) countries. While results provided little evidence supporting the existence of the EKC hypothesis for Artic countries (Baek, 2015), Bilgili et al. (2016) confirmed the EKC hypothesis for 17 OECD countries through Fully Modified Ordinary Least Squares (FMOLS) and Dynamic Ordinary Least Squares (DOLS) estimations. Despite not explicitly supporting the EKC hypothesis, Saidi and Hammami (2015) showed that CO2 emissions have a strong negative impact on per capita GDP for 58 countries. Inversely, the EKC hypothesis is rejected by Shafiei and Salim (2014) for 29 OECD countries while using the Stochastic Impacts by Regression on Population, Affluence, and Technology (STIRPAT) model. As in Beşe and Kalayci (2021), who applied ARDL, and Toda-Yamamoto causality tests, the EKC is rejected for Denmark, Spain, and the United Kingdom. Silva et al. (2012) applied Impulse Response Function (IRF) models and showed that income and CO2 emissions variables are overly sensitive to changes in the share of renewable energy sources in the energy mix for Denmark. Despite not confirming the EKC hypothesis, such results underline the persisting linkages among energy, income, and pollution. Overall, previous research demonstrated that extracting renewable fuel from MSW helps to reduce GHG emissions from the waste sector in the EU (Domingos et al., 2017).

Kraft and Kraft (1978) employed Granger causality analysis to examine the causal relationship between economic growth and gross energy consumption for the United States from 1947–1974. They found the conservation hypothesis valid for the United States. Employing a similar approach contrast, Stern (1993) reported evidence in favor of the growth hypothesis in the US from 1947–1990. Erdal, Erdal, and Esengün (2008) employed cointegration and causality techniques to investigate the causal relationship between energy consumption and economic growth from 1970 to 2006 and found that the feedback hypothesis is valid in Turkey. Soytas et al. (2007) studied the effect of energy consumption and economic growth on CO_2 emissions in the United States. Following the Granger causality approach, they showed no causal relationship between energy consumption and economic growth, supporting the neutrality hypothesis. Similar results have been reached by Jalil and Mahmud (2009) in the case of China. Ozturk and Acaravci (2010) examined the causal relationship between economic growth, carbon emissions, energy consumption, and employment ratio in Turkey. They found that neither carbon emissions nor energy consumption caused real GDP per capita, indicating that the neutrality hypothesis is valid in the Turkish case. Saboori and Sulaiman (2013) used the ARDL methodology, Johansen-Juselius maximum likelihood approach, and the Granger causality technique to explore the relationship between environmental degradation, economic growth, and energy consumption in Malaysia. They revealed causality from economic growth to energy consumption, confirming the conservation hypothesis. In recent research, Ozcan and Ozturk (2019) employed a bootstrap panel causality test to examine the renewable energy consumption-economic growth nexus in emerging countries and highlighted that there is no causality between renewable energy consumption and economic growth in nearly all emerging countries except for Poland. Their results provided evidence of the neutrality hypothesis in nearly all emerging economies. Bilgili et al. (2019) employing a continuous wavelet approach through disaggregated data reported that renewable energy positively affects industrial production, supporting the growth hypothesis. The primary consideration that may be extracted from the previous studies is that the literature on energy consumption-economic growth is extensive with different results depending upon the region or period considered and the econometric approach. The second strand of research looked at the energy consumption-economic growth-environmental quality nexus by providing evidence in favor of or against the energy-EKC hypothesis.

(Farzin and Bond, 2006) They have investigated the link between income per capita and environmental quality. Recognizing that the often-cited inverted U-shaped relationship or EKC is not an inevitable result of income growth, a model was developed that specifically accounted for different environmental policy regimes, reflecting the demand for environmental quality as a public good. The political regime was identified as a function of governance and preference variables, with preferences for environmental policy exercised through interactions with the political system. The exercise supports the hypothesis that the qualities of political institutions and several indicators of societal preference interact to create the inverted- U shape, which is frequently cited in the environment-development literature.

Bakirtas et al. (2014) aimed to investigate that problem. In this study, depending on the theory of Environmental Kuznets Curves (EKC), the impact of income on carbon dioxide emission has been measured for 34 OECD and 5 BRICS countries using Dynamic Panel Data Analysis. In this regard, OECD countries are classified by income groups due to the OECD's average per capita income rate to solve the homogeneity problem among OECD countries. On the other hand, the EKC hypothesis analyzed by short and long-run income elasticity will be used to show that a country reduces CO2 emissions with the income increase in this study. According to the findings of the study, 36% of the country sample was coherent with the EKC hypothesis.

Dinda et al. (2000) tested the relationship between suspended particulate matter (spm) and SO2 emissions and per capita income for 33 countries between 1979-1990. They used income and income squared as determinants of environmental quality. In respect of the results, they couldn't find any evidence of EKC.

Dijkgraaf and Vollebergh (2001) researched the inverted U-shaped relationship between CO2 emissions and per capita Gross Domestic Product (GDP) for OECD countries between 1960-1997 using panel data analysis techniques. They also challenge the assumption of country homogeneity and reject the homogeneity hypothesis even for a small country group. According to the findings of this study, eleven of the twenty-four countries confirmed the EKC hypothesis.

Galeotti et al. (2006) also analyzed the relationship between CO2 emission and per capita income, squared, and income cubed using two different CO2 emission data sets for OECD countries and non-OECD countries. They reached an inverted U relationship between per capita income and both CO2 emissions and found a reasonable turning point of per capita income (15.000$ for the first and 20.000$ for the second data set of CO2 emissions) for the OECD panel. However, that relationship has been characterized by an increasing concave for the non-OECD panel.

Narayan and Narayan (2010) tested the short and long-run income elasticity of 43 developing countries to examine the EKC hypothesis. They were propounded as evidence of EKC that if the long-run income elasticity is smaller than the short-run income elasticity, a country has reduced CO2 emissions due to increased income. They also estimated the long-run relationship between per capita CO2 emissions and per capita income with the help of panel cointegration and unit root tests. According to the findings of the study, income elasticity, in the long run, was smaller than in the short run, only in two panels. Even there, it is easy to find a study of EKC in which cross-section and panel data techniques were used. Still, researchers also examined single-country studies in the literature, such as Akbostancı et al. (2009) and Jalil and Mahmud (2009).

(Lapinskienė et al., 2015) Analyses the environmental Kuznets curve relationship between greenhouse gases and chosen indicators of economic development based on the panel data of 20 countries of the EU in the period 2006–2013. Besides the typical variables, such as the share of a particular polluting industry, environmental taxes, energy taxes, and research and development, the dummy variable of the crises and the enterprise's sustainability score were also included in the model. The fixed effect panel model was used as a framework for the analysis. The original contribution of this paper is that the factor referring to the enterprises' sustainability was empirically tested in the expanded model. Higher energy taxes, research and development, and the number of sustainable enterprises decrease the level of greenhouse gases. The size of agriculture, production, and construction has a positive sign, which means that a higher indicator value is associated with a higher level of greenhouse gases. This implies that the analyzed set of factors can be applied to adjust the trend in the region and might be helpful for climate change policy adjustment.

Fosten et al. (2012) considered the emissions of gases concerning the environmental Kuznets curve relationship in the United Kingdom from 1830 to 2003 for the CO2 and the SO2 models. The research showed that long-run results favor the EKC hypothesis, with per capita CO2 and SO2 emissions having an inverted–U relation with real GDP per capita. This suggests that mitigating CO2 or greenhouse gas emissions and SO2 emissions will rely more on legislation than reductions in economic growth. The researchers also used the gas price as the additional variable, partially explaining the results. The authors suggested that the EKC model should be estimated by specifying and incorporating different measures of technological changes.

Esteve and Tamarit (2012) renewed the research for EKC evidence in Spain, using a linear integrated regression model with multiple structural changes. The authors used time-series data on the Spanish economy spanning from 1857 to 2007. They emphasized that the turning point in Spain was dated by 1986 and could be explained by the oil crisis of the 70s, caused by the political instability at the end of the Spanish dictatorship in 1975–1978, and by the shift in the energy mix that took place only at the beginning of the 80s. The coefficient of the relationship estimated between per-capita CO2 and per-capita income (or long-run elasticity) in the presented model showed a tendency to decrease over time. They found that the “income elasticity” coefficient concerning CO2 was smaller than one. This implies that even if the shape of the EKC does not follow an inverted U, it shows a decreasing growth path, pointing to a prospective turning point.

Azam and Khan (2016) performed empirical research based on annual time series data covering 1975–2014. This study verified the EKC hypothesis in the context of Tanzania (a low-income country), Guatemala (a low-middle-income country), China (an upper-middle-income country), and the USA (a high-income country) quantitatively. Energy usage, trade openness, and urbanization growth rates were included in the model as additional factors affecting EKC. The results showed that CO2 emissions positively affect energy consumption and trade openness in all four countries. Hence, the authors concluded that each country should systemize energy consumption and formulate environment-friendly trade policy at the national level to meet future demand and mitigate environmental degradation in order to achieve the ultimate goal of sustainable economic growth and development. In the second group of studies, Tsurumi and Managi (2010) examined the environmental Kuznets curve hypothesis for carbon dioxide, using generalized additive models with a generic flexible, functional form, allowing a potentially non-linear non-monotonic relationship. A sample covered 30 OECD countries for the period 1960–2003. The results imply that economic growth was not sufficient to decrease CO2 emissions. The first group had a negative slope for the high-income levels.

In contrast, the second group had a monotonically increasing trend at all income levels. The third group displayed other trends or had confidence intervals that were too wide to interpret. The results obtained by these authors suggested that more than economic growth is needed to decrease CO2 emissions.

Fujii and Managi (2013) assumed that CO2 emission for an entire country was unclear and did not show individual industrial characteristics or fuel choices. Following the ideas of the economic scale, technology level, and composition effects on the shape of the EKC, the authors chose to estimate the EKC relationship separately, controlling these effects by the type of industry and type of fuel. They hypothesized that the EKC relationship between CO2 and growth would be possible for such industries as the wood, wood products, and the paper, pulp, and printing industries, which do not use fossil fuels as intermediate fuels and whose product value per weight is lower than that of the others.

For other industries, referring, in particular, to steel and metal, which use coal as their primary, intermediate fuel, CO_2 would increase proportionally with the production growth. They considered that industrial structural changes could explain the EKC relationship observed in the previous studies. It was found that overall CO_2 emissions showed the N–shape trend. The EKC hypothesis was supported by the study of the industries producing wood, wood products, paper, and pulp, as well as the printing and construction industries. CO_2 emissions from coal and oil increased with economic growth in upstream industries. Hence, a conclusion was made that three industries were greener than the nine analyzed with respect to CO_2 emissions (Fujii & Managi, 2013).

Kingori (2012) set out to determine the nature of the relationship between environmental degradation and economic growth in Kenya from 1970-2008. The objectives were to determine the impact of economic activities on the environment and to establish whether economic growth is detrimental or beneficial to the environment in Kenya. A structural model was formulated by employing carbon dioxide emissions as the environmental indicator, per capita GDP as a proxy for the scale effect, the share of manufacturing, agricultural, and services sectors as proxies for the composition effect, and polity as a proxy for the technique effect. The ARDL approach to cointegration was adopted to establish the long-run relationship among variables. The findings reveal an inverted N-shaped relationship between economic growth and environmental degradation. The share of agricultural and manufacturing sectors and polity variables are insignificant in the model, implying that changing them does not significantly cause a change in environmental degradation. However, the services sector is a significant contributor to degradation due to the tremendous growth reported in the sector and the high potential for degradation in its sub-sector activities.

Bozkurt and Okumuş (2019) investigate the relationship between per capita CO_2 emissions, per capita energy consumption, per capita real GDP, the squares of per capita real GDP, trade openness, and Kyoto dummies in selected 20 EU countries over the periods from 1991 to 2013 in order to analyze the connection between environmental pollution and Kyoto Protocol using Environmental Kuznets Curve (EKC) framework. According to the EKC hypothesis, there is an inverted-U shape relation between environmental pollution and economic growth. Generally, the relationship between environmental pollution, per capita GDP, and energy consumption has been analyzed for testing the EKC hypothesis. This study uses a dummy variable to analyze the effects of the Kyoto Protocol on environmental degradation in the context of the EKC hypothesis model. The dummy variable indicates the Kyoto Protocol agreement year 2005. The results show a long-run cointegration relationship between CO_2, energy consumption, GDP growth, GDP growth squares, trade openness, and the Kyoto dummy variable. Energy consumption and GDP growth increase the level of CO_2 emissions.

On the contrary, the Kyoto dummy variable decreases CO_2 emissions in EU countries. In addition, the results reveal that the squares of per capita real GDP and trade openness rate are statistically insignificant. As a result of the analysis, the inverted-U shape EKC hypothesis is invalid in these EU countries from 1991 to 2013.

Abdulai and Ramcke (2008) theoretically and empirically explore the interrelations between economic growth, international trade, and environmental degradation. Panel data from developed and developing countries for the period of 1980 to 2003 is used and previous critique, especially on the econometric specification, is embedded. It is not assumed that there is a single link for all countries. Several environmental factors and one sustainability indicator are analyzed for the full sample, regions, and income groups. The results indicate an Environmental Kuznets Curve (EKC) for most pollutants, but with several reservations. None of the various hypotheses that concern the link between trade and environmental degradation can be entirely confirmed. If anything, there is modest support for the Pollution Haven Hypothesis (PHH). In addition, trade liberalization might be beneficial to sustainable development for rich countries, but harmful to poor ones. However, a sustainable development path is particularly important for developing countries, as the poor are most exposed and vulnerable to the health and productivity losses associated with a degraded environment. Given that developing countries usually need more institutional capacities to set up the appropriate environmental policies, developed countries must take the lead in addressing environmental degradation issues and assisting developing countries.

Kułyk and Augustowski (2020) examine the relationship between CO_2 equivalent emissions and agricultural production, considering additional economic and social variables that correct the considered relationship for the six Central and Eastern European countries from 1992 to 2017. The article aimed to confirm or negate the occurrence of the environmental Kuznets curve (EKC) in the countries of Central and Eastern Europe. Countries that experienced a political transformation and were subsequently admitted to the European Union (EU) undergoing a preparatory period were included. The topic is timely as all EU countries are required to monitor their emissions under the EU Climate Monitoring

Mechanism. The discussed problem is significant due to the changes taking place in the standard agricultural policy, the choice of actions to be taken by individual countries in their national policies, and the choice of instruments to support the transformation of agriculture. Agriculture has a tremendous impact on emissions, especially N_2O and CH_4. This paper uses GLS (Generalized least squares) panel regression with random effects considering personal effects for countries. The conducted empirical research confirmed the hypothesis regarding the occurrence of the Kuznets curve in relation to agricultural production. In this situation, it is required to increase the activities of maintaining production growth, with the support of technological changes that significantly increase pro-environmental conditions, because, in the current circumstances, this growth occurs with an increase in CO_2 gas emissions, thus leading to adverse external effects.

Lapinskienė et al. (2014) consider the relationship between greenhouse gas emissions (GHG) as the main variable of climate change and gross domestic product (GDP), using the environmental Kuznets curve (EKC) technique. At early stages of economic growth, EKC indicates the increase of pollution related to the growing use of resources. However, when a certain level of income per capita is reached, the trend reverses. At a higher stage of development, further economic growth leads to the improvement of the environment. According to the researchers, this implies that the environmental impact indicator is an inverted U-shaped function of income per capita. In this paper, the cubic equation is used to empirically check the validity of the EKC relationship for European countries. The analysis is based on the survey of EU-27, Norway, and Switzerland in the period of 1995–2010. The data is taken from the Eurostat database. The findings of the research highlight several areas for further investigation. Firstly, the turning points of EKC in some European countries differ considerably; therefore, analyzing specific influencing factors may be necessary for developing and pursuing an environmental policy. Secondly, the EKC relationship is more stable in developed countries. In contrast, the sharp changes in GDP and other economic factors observed in more volatile countries during the recent financial and economic crisis can provide insight into the factors impacting the shift of the considered EKC.

Şentürk et al. (2020) present an analysis of the relationship between per capita CO_2 emissions as an environmental degradation indicator and per capita gross domestic product (GDP) as an economic growth indicator within the framework of the Environmental Kuznets Curve (EKC). For this purpose, non-linear panel models are estimated for the Annex I countries, non-Annex countries, and whole parties concerning data availability of the United

States Convention on Climate Change (UNFCCC) for 1960–2012. The empirical results of the panel smooth transition models (PSTR) show that environmental deterioration rises in the first phase of growth for all data sets. Afterward, environmental degradation cannot be prevented, but the increase in environmental degradation decreases. The findings of this study give insight into the differential environmental impact of economic growth between developed and developing countries. While the validity of a traditional EKC relation regarding CO2 emissions cannot be affirmed for any group of countries in our sample, empirical results indicate the existence of multiple regimes where economic growth hampers environmental quality. However, its severity decreases at each consecutive regime.

(Sterpu et al., 2018) analyses the relationship between per capita greenhouse gas (GHG) emissions, gross domestic product, gross inland energy consumption, and renewable energy consumption for a panel of 28 countries of the European Union in the period 1990–2016. Two theoretical models, a quadratic and a cubic, are used to estimate the shape of the environmental curve and test the Kuznets hypothesis. The panel cointegration approach proved the existence of long-run equilibrium relations among the four macroeconomic indicators. Empirical estimations, using panel data techniques and heterogeneous regression for each country in the panel, show non-conclusive evidence for the environmental Kuznets curve (EKC) hypothesis. The least-square estimates, with the variables in log per capita form, reveal that the inverted U-shaped EKC hypothesis is verified for the panel and for 17 of the 28 EU countries. Estimates of the cubic model show that the environmental curve has an inverted N-shaped form. These results do not hold when the values are in non-logarithmic form. In addition, the estimations for all models show that an increase in gross energy consumption leads to an increase in GHGs. In contrast, an increase in renewable energy consumption leads to reduced GHG emissions.

Al-Mulali et al. (2015) employed panel data techniques to study the relationship between economic growth, urbanization, trade openness, financial development, renewable energy, and pollution in 23 selected European countries from 1990 to 2013.

Andersson and Nässén (2016) analyze the relationships between materialistic values, environmental concerns, and greenhouse gas (GHG) emissions in a sample of 1004 Swedish residents. The previously established material values scale (MVS) and detailed measurements of the respondents' GHG emissions from travel behavior, residential energy use, diet, and other consumption are employed. The developed structural model reveals a weak but significant association between high MVS scores on the one hand and low environmental concern and high GHG emissions on the other hand. In further analysis, however, the correlation between high MVS scores and high GHG emissions is shown to be traceable to the domain of air travel in the first place, with no correlation found, for example, between MVS scores and size of accommodation and spending on cars, both traditional status commodities. Instead of possessions, the status-oriented materialists in the sample thus appeared to focus more on other aspects of their lifestyle.

Hu et al. (2021) examine the effect of disaggregated energy consumption, technological innovations, and capital on India's economic output and CO2 emissions from 1990–2018. Based on empirical analysis, our long-run elasticities indicate that disaggregated energy consumption and technological innovations positively impact economic growth. In contrast, renewable energy consumption and technological innovations positively impact CO2 emissions. It implies that more energy consumption produces significant CO2 emissions, and using renewable energy consumption and technological innovations (i.e., carbon capture storages) can significantly lower CO2 emissions, indicating that India is moving towards carbon neutrality. The causality analysis further indicates a unidirectional causal relationship between disaggregated energy usage to economic growth and carbon emissions. These empirical findings suggest that the increased consumption of renewable power does not lead to rising carbon emissions, which, in turn, ensures sustainable economic growth.

Wang et al. (2022) aim to explore the decoupling relationship between CO2 emissions and power generation of China's power sector and the driving factors of the decoupling index at the provincial level using the Tapio model and LMDI method. The decoupling analysis shows that Heilongjiang, Beijing, Shanghai, Sichuan, and Yunnan achieved decoupling and most provinces were in expansive coupling states from 2000 to 2019. The number of provinces in the decoupling state during 2011-2015 was twenty-three and more prominent than in 2000-2005, 2006-2010, and 2016-2019. The decomposition analysis indicates that per capita GDP and population size were responsible for inhibiting the decoupling process for most provinces, while thermal power generation efficiency and electricity intensity promoted the decoupling. Specifically, the coal-to-gas of Beijing, the renewable energy utilization of Gansu, and the expansion in nuclear energy of Hainan contributed more to their decoupling. Besides, this paper also explores the regional agglomeration of the decoupling index across provinces based on the global and local Moran's I Index, demonstrating that the spatial autocorrelation was significantly positive from 2016 to 2019.

Ansuategi and Escapa (2002) explore the effect of intergenerational spillovers on the emissions–income relationship. We use a numerically calibrated overlapping generations model of climate–economy interactions. We conclude that: (1) the intertemporal responsibility of the regulatory agency, (2) the institutional capacity to make intergenerational transfers, and (3) the presence of intergenerationally lagged impact of emissions constitute essential determinants of the relationship between economic growth and greenhouse gas emissions.

Yan et al., (2017) follow the energy-environment-economy framework and focus on the decomposition of changes in the energy-related greenhouse gas (GHG) emission in agricultural sectors of the selected European Union (EU) countries. The research relies on country-level data from FAO and Eurostat describing the economic activity, energy use, and GHG emission in the agricultural sectors of the European countries during 1995-2012. The main drivers (carbon factor of energy consumed in agriculture, the energy intensity of agricultural production, and growth in agricultural production) and their impacts on the energy-related GHG emissions in agriculture are analyzed for selected countries. The Generalized Division Index is applied to decompose the changes in energy-related GHG emissions. France, Latvia, and Belgium appeared as the only countries with increased GHG emissions during 1995-2012. In the case of France, energy intensity went up along with an increase in the scale of agricultural production. In Latvia and Belgium, an increase in carbon factor appeared as the primary factor driving an increase in GHG emissions. The appropriate policies need to be employed in these countries seeking to reduce GHG emissions from energy consumption in agriculture. Improvements in energy efficiency are a more feasible means for ensuring further reductions in GHG emissions.

Gavrilyeva et al. (2020) estimate the volume and performance of GHG emissions in critical sectors for 2013–2017 using the IPCC methodology. We discover that GHG emission in the region does not exceed the determined by the Paris Agreement level. Significant territorial differentiation of GHG emission between municipal districts and economic zones of Yakutia caused by climatic and economic factors: energy resources consumption, generating capacities, economic and population location. In contrast with Russia, the environmental Kuznets curve model has not been confirmed for Yakutia. Economic growth has been leading to an increase in emissions; the region is far from reaching the EKC's maximum, although the effect of reducing emissions alongside steadily growing GRP was achieved before 2009.

Kumar et al. (2020) study peatlands and their contribution to global climate change. Classifying peatlands in tropical and subtropical regions can aid in understanding their emission characteristics. The applicability of existing GHG emission factors to land use categories in SEA is discussed. They find that rewetting peatlands can increase CH_4 emissions, and therefore more studies are needed to establish whether peatlands act as a net sink or net sources of GHGs. Few studies have investigated the effectiveness of liming towards reducing peat soil acidity. The review also finds limited data on CO_2 concentrations in drainage and wildfire areas, N_2O fluxes in agriculture areas, and the impact and reduction of CH_4 in tropical peatlands. Addressing these research gaps could support the development of a framework for GHG emission measurements and abatement in tropical peatlands.

Coondoo and Dinda (2002) estimated the causality between per capita CO_2 emission and per capita GDP using a cross-country panel data set including 88 countries from 1960 to 1990. They found a long-run relationship between per capita CO_2 emission and per capita GDP for seven different country groups through unit root and cointegration tests and error correction models based on time series econometric techniques. They also discovered a bi-directional causality between income and CO_2 emissions more or less for all country groups.

Perman and Stern (2003) investigated the EKC hypothesis using a panel data set of SO_2 emissions and GDP for 74 countries for 31 years. In this regard, individual and panel cointegration techniques were used in that study. Considering the results of the study, it was found that many countries have a U-shaped or monotonically increasing relationship between SO_2 emissions and GDP. Regard to the results did not prove the EKC for SO_2 emissions. Martinez-Zarzoso and Bengochea-Morancho (2004) studied the relationship between CO_2 emissions and income per capita for 22 OECD countries from 1975 to 1998. They asserted the homogeneity problem of the countries. The pooled mean group estimator was used in the study to solve the homogeneity problem in the short run. The study findings pointed to an N-shaped relationship for almost all countries.

Hamit-Haggar (2012) performed the study, which analyses the causal relationship between greenhouse gas emissions, energy consumption, and economic growth, to a panel of Canadian industries from 1990–2007. These industries are responsible for about 56% of the total industrial greenhouse gas emitted in 2007 in Canada. The paper is more specifically to determine the nature of the long-run equilibrium and the causal relationship between greenhouse gas emissions, energy consumption, and economic growth by considering the cross-section dependence hypothesis. The results showed strong evidence of a long-run relationship between greenhouse gas emissions and energy consumption. Within industries almost all industries indicate that energy consumption has a statistically significant impact on greenhouse gas emissions. The authors suggested that other factors not included in this model should be considered, such as technology, taxes, trade, etc.

Liao and Cao (2013) examined the historical relationship between economic development and carbon dioxide emission in 132 countries from 1971 to 2009. They included factors such as urbanization, population density, trade, and energy mix in their empirical analysis. While economic development continued to drive up CO2 emission, urbanization, population density, trade, and energy mix would potentially contribute to the reduction of the absolute level of CO2 per capita emission. The authors noted that their results did not support the inverted–U shape concept but described the trend observed in high-income segments as a saturation of trend. As most countries are still below some threshold income per capita level, the economic policy mix, helping to foster green technology development and the additional CO2 emission reduction measures, should be implemented to offset a negative stage of income and CO2 relationship. Otherwise, consistent with a historical trend, poorer countries will still need considerable emission volumes to outweigh their economic backwardness.

Boluk and Mert (2014) utilized panel data fixed effect analysis to examine the relationship between greenhouse gases, energy consumption (fossil energy and renewable energy), and GDP. The paper proposed and estimated a panel model for EU-16 from 1990–2008. Estimated coefficients state that pollution increases with both fossil and renewable energy consumption. Fossil fuel consumption leads to a greater increase in pollution levels than renewable energy consumption. This implies that much more improvement in energy efficiency and a shift in the energy mix towards less polluting energies (renewable energy technologies) could be very important in achieving environmental targets.

Ahmed et al. (2019) investigated the relationship between per capita carbon dioxide emissions and gross domestic product per capita in 63 countries over 51 years from 1960 to 2010. Using a graphical analysis approach, the results of this study showed that the relationship between per capita carbon dioxide emissions and gross domestic product per capita amongst the sample data followed a sigmoid curve indicating that the per capita carbon dioxide emissions of a country increased when its economy transitioned from a labor-intensive technology to a capital-intensive one caused by an increase in the rate of economic growth. The results also showed that the number of relative emissions varied amongst the countries.

Halkos (2012) uses dynamic panel data for 23 OECD and 50 non-OECD countries for the period 1960-1990 in order to estimate the relationship between economic development (in the form of GDP) and environmental pollution (in the form of emissions). Panel data econometric techniques are applied for performing our empirical estimation. The analysis shows significant differences between the most industrialized countries and the rest of the countries considered. This implies that policies to control pollution have to consider the specific economic situation and the structure of the industrial and business sectors in each region. Finally, in terms of policy implications, the study discusses the main abatement options for reduction.

Aboagye et al. (2020) study progresses from previous research to examine the disaggregated impact of economic expansion on the environment. Consequently, the study employs the Autoregressive Distributive Lagged (ARDL) approach to cointegration and annual time series data from 1985 to 2015 from the World Bank database to examine the disaggregated impact of economic expansion on the environment in Ghana. The study finds that the initial stages of agricultural expansion tend to deteriorate the environment, but as agricultural productivity increases beyond a certain point, although the effect of deforestation may still rise, CO2 emission reduces. More so, expansion in industry results in a rise in all three indicators of environmental degradation, both in the short and long run while a harmful effect was found between expansion in service output and CO2 emission at the initial stages of productivity, but not in the long run. The impact of deforestation is harmful to the expansion of service output. The results point to the fact that expansions in agriculture and services will eventually reduce CO2 emissions beyond some productivity threshold.

Lapinskienė et al. (2015) investigate the relationship between economic growth, greenhouse gas emissions, and other factors based on the panel data of 22 countries of the EU in the period 1995–2014. The fixed effect panel model was used as a framework for the analysis. The novel contribution of this paper is that the factors of economic growth, energy consumption, energy taxes, and R&D were tested in one expanded EKC model, including the data of three Baltic States. The regression coefficients referring to GDP, Energy consumption have a positive sign, while R&D and Energy taxes have a negative sign. The empirical analysis combines two steps of evaluation of panel models of different groups of countries. The results imply that the analyzed factors (energy consumption, energy taxes, and R&D) can be applied to adjust the EKC trend in the region and might be helpful for climate change policy adjustment.

Some of the past research works focus on the relationship between disaggregated energy usage, economic growth, and carbon emissions in a single context. For example, Magazzino (2016) argued that energy use is vital for all groups across the globe and helps develop the country. Hajko et al. (2018) report that energy supply and technological development increase economic growth. Paul and Bhattacharya (2004) analyze the causality between India's energy usage and economic development from 1950 to 1996. They apply the Johansen cointegration, Granger causality, and ECM models. Their study found the presence of two-way causation. Koçak and arkgünes¸ (2017) employ traditional production functions to study the relationship between renewable energy usage and economic development. They apply Pedroni panel cointegration and heterogeneous panel causality approaches and find that using renewable resources significantly positively influences economic growth. Their empirical evidence also reports a bidirectional causal relationship between renewable resources and economic growth. Magazzino et al. (2021) studied the relationship between energy consumption and economic growth in Italy covering the period of 1926–2008. Their results indicated that energy consumption positively impacts economic growth, and a bidirectional causality relationship exists between the variables. Menegaki (2011) uses the multivariate panel framework to investigate renewable energy consumption and economic growth for a group of 27 nations and finds the neutrality hypothesis. Ahmad and Du (2017) explore the impacts of energy production and economic growth on CO2 emissions in the case of Iran by employing ARDL, DOLS, and FMOLS methodologies. They affirm the positive link between CO2 emissions and economic development, electricity efficiency, and economic growth. Apergis and Payne (2010a, 2010b) study the correlation between the usage of renewable resources and economic growth for a panel of 13 countries. They use several econometric approaches, such as IPS unit root, Pedroni panel cointegration, FMOLS, and error correction models. Their empirical results show that using renewable power resources positively impacts economic growth. They also find a bidirectional causal relationship between the two factors. Singh et al. (2019) examine how the growth of the economy is affected by the usage of renewable power resources for a group of 20 nations, either developed or developing, spanning 1995–2016. They apply Kao panel cointegration, Pedroni panel cointegration, and FMOLS techniques. They find a positive influence of renewable power resources on the development of these 20 economies. Their study further suggests that, in the case of developed nations, a rise in the usage of renewable power resources helps their economies to grow by 0.7 %. However, for developing nations, the rise in the use of renewable power resources sees a 0.5 % growth in the economy. Therefore, they confirm that the consumption of renewable energy significantly influences the growth of developed nations' economies. Ntanos et al. (2018) investigated the effect of renewable power consumption economic development of 25 European nations. They apply cluster and ARDL approaches. Their empirical results indicate that renewable power usage can positively influence the development of European economies. Magazzino (2018) investigated the relationship between energy consumption and GDP in Italy from 1960–2014. His empirical evidence indicated that energy consumption positively impacted economic growth and reported a unidirectional causality relation from GDP to energy consumption. Apergis and Payne (2014) examine the empirical relationship between renewable power usage and its determinant variables, such as carbon emissions, fossil fuel, and output for a panel of 7 economies from 1980 to 2010. They identify a significant positive effect of renewable power usage on its determinant variables. Their analysis also shows a bidirectional causal correlation that connects the use of renewable resources with its determinant variables. Sebri and Ben-Salha (2014) explore the correlation between trade openness and the other three variables in BRICS economies. They apply multivariate analysis, including ARDL and VECM, and find a bidirectional causal correlation that connects renewable power usage and economic development. Their results further show how renewable power usage can positively influence the development of BRICS economies. Magazzino et al. (2020) examined the impact of nuclear energy consumption on economic growth in Switzerland, spanning 1970–2018. They confirmed that nuclear energy consumption has a positive impact on economic growth. Saidi and Hammami (2015) examine the impact of energy consumption and CO_2 emissions on growth in a panel of 58 countries. They apply the Generalized Method of Moments (GMM) model and find that energy usage can positively affect economic growth.

Maji and Sulaiman (2019) highlight the development of 15 African economies affected by using their renewable power resources by employing the panel unit root tests, Kao and Pedroni, and the DOLS methods. They find that renewable energy reduces economic growth by lowering economic output. They also suggest that renewable energy has no harmful effect on human health. Antonakakis et al. (2017) studied the interrelation among the three variables: energy usage, carbon emissions, and the economic rise for 106 economies, spanning 1971–2011. They apply the impulse response function and panel vector autoregression (PVAR) techniques. Their results find that energy consumption negatively impacts economic growth, and there is bidirectional causality between economic growth and energy consumption. Menyah and Wolde-Rufael (2010) examine the nexus of using renewable resources, carbon emissions, nuclear energy, and economic development for America. They apply various decomposition and Granger causality techniques. Their empirical analysis finds a unidirectional causal link between nuclear power usage and levels of CO2 emissions. Their study, however, could not indicate any connection between the country's economic development and its usage of renewable resources. Magazzino (2017a, 2017b) examined the impact of renewable energy consumption on economic growth in Italy, spanning 1970–2007. The author's findings confirmed that renewable energy consumption reduces economic growth. It implies that renewable energy consumption harms economic growth, and a unidirectional causality runs from renewable energy consumption to economic growth. Mehrara (2007) examines how the power usage of the countries influences the development of the economies of 11 oil-exporting nations. The author employs the LLC, IPS, Pedroni cointegration, and causality models to find a unidirectional correlation between economic development and energy usage. Besides, the paper reports that power consumption conservation has no impact on economic growth. Ang (2008) examines the association between energy usage, pollutant emissions, and output in Malaysia for a long-term period. He uses four types of time series techniques: ADF unit root, Johansen cointegration, causality, and vector error correction.

The paper finds a long- and short-term bidirectional correlation between power usage and the economy. Magazzino (2012) reported that more energy consumption increases economic growth and shows a feedback causality relationship between energy consumption and economic growth from 1883–2009. Marinaș et al. (2018) show how renewable power resources and economic development are interconnected in ten countries from 1990 to 2014. They apply PP and ADF unit-root, ARDL, and VECM techniques and find a bidirectional causal relationship between renewable energy and economic growth. Bello et al. (2018) examine the impact of hydroelectricity on the environment in the case of Malaysia, during 1971–2016, by applying both the ARDL and VECM methods. They observe a significant practical impact of hydroelectricity consumption on environmental degradation. Their analysis shows a unidirectional causality from hydroelectricity consumption to fossil fuel consumption and a bidirectional causality relationship between GDP and all environmental degradation factors (energy consumption). In a study of 14 MENA countries, Omri (2013) analyzes the relationship between power usage, economic growth, and carbon emissions using the generalized method of moments (GMM). The study finds a unidirectional relationship between power consumption to carbon dioxide emitted into the atmosphere. Also, a bidirectional correlation is found between economic development, power usage, and power usage and carbon emissions. Magazzino et al. (2020) reported a unidirectional causality relation from economic growth to energy consumption, spanning 1980–2013. Al-Mulali et al. (2013) analyze renewable resources and their causal connection with the economic conditions of various countries with different income levels by employing Phillips–Perron (PP) unit root and FMOLS techniques. Their results which follow both the growth hypothesis and Neutrality hypothesis, confirm 79 % of bidirectional causality, 19 % of no causality, and 2 % of unidirectional causality.

Four primary considerations can be extracted from the above studies. Firstly, greenhouse gas emissions, economic growth, and the EKC kinds of literature are extensive, with no consistent conclusions. Regarding EKC, some scholars reported an inverted U-shaped relationship between economic growth and environmental degradation, while others provided evidence against it. A similar situation appears for the relationship between GHG emissions and economic growth. Secondly, CO2 emissions are widely used to measure environmental degradation in the extant literature. Thirdly, there need to be more studies considering human ecological footprint as an environmental indicator for estimating the EKC hypothesis. Fourthly, there are limited numbers of studies investigating the impacts of economic growth, renewable energy supply, and fossil fuel consumption on environmental degradation indicators.

.

3. Methodology of the dissertation

3.1. Data

This chapter examines the data and sources employed, as well as the empirical and econometric methods used to achieve the dissertation's goals and apply the dissertation's focus. The data and sources used are covered in the first subsection.

Data from the World Bank's World Development Indicators for the period 1995 to 2018 (24 observations) were analysed annually for the entire focus period (World Bank, n.d-a; n.d-b; n.d-c;n.d-d; n.d;e; Ritchie and Roser, 2020). The variables of interest included real GDP constant of 2015 USD; agricultural, forestry, and fisheries value-added constant of 2015 USD; Industry (including construction), value-added constant of 2015 US$; and Gross fixed capital formation (constant of 2015 US$). The software EVIEWS 10 and XLSTAT software were used to analyse the results. The results and discussions will be presented in the fourth section starting from the descriptive statistics for the variables of interest.

There are different classifications of countries/regions geographically, a per (WoldAtlas, 2021) , 9 countries can be defined as central Europe region. Hereunder is the list of Central European Countries. Liechtenstein was excluded due to the lack of data.

Table 3.1: List of the studied countries

#	Country Name
1	Austria
2	Czech Republic
3	Germany
4	Hungary
5	Poland
6	Slovakia
7	Slovenia
8	Switzerland

Source:(WorldAtlas,2023.)

The study variables consist of four dependent variables (GHGs, CO_2, N_2O, CH_4), one independent variable (GDP), and four control variables (Energy Consumption, Agriculture Value Added, Industry Value Added, Gross Fixed Capital Formation). Table 3.2 below indicates the meaning and definitions of variables used in the econometric analysis of this dissertation.

Table 3.2: Definitions of variables used

Variable	Interpretation and meaning
GHG	Total greenhouse gas emissions, including land-use change and forestry, in tonnes of CO2-equivalents.
CO2	Carbon dioxide (CO2) emissions are based on annual production, measured in tonnes. This is based on territorial emissions, which do not consider emissions from traded goods.
CH4	Total methane emissions in tonnes of carbon dioxide equivalents, including land-use change and forestry.
N2O	Total nitrous oxide emissions, including land-use change and forestry, in tonnes of CO2-equivalents.
GDP	Gross domestic product (GDP) at purchaser's prices is the sum of gross value contributed by all resident producers in the economy, plus any product taxes minus any subsidies not included in the product value. It is estimated without considering the depreciation of manufactured assets or natural resource depletion and degradation. Data is provided in US dollars at constant 2015 prices. Official 2015 exchange rates were used to convert GDP statistics from native currencies to dollars. An alternate conversion factor is employed in a few nations where the official exchange rate

	does not represent the rate effectively applied to foreign exchange transactions.
Agriculture value added	Agriculture, forestry, and fishing (ISIC divisions 01-03) encompass forestry, hunting, fishing, crop cultivation, and livestock rearing. After summing all outputs and deducting intermediate inputs, value added is a sector's net output. It is estimated without considering the depreciation of manufactured assets or natural resource depletion and degradation. The International Standard Industrial Classification (ISIC), edition 4, determines the source of value added. Data is provided in US dollars at constant 2015 prices.
Industry (including construction), value-added	Industry (including construction) corresponds to ISIC divisions 05-43 and includes manufacturing (ISIC divisions 10-33). Mining, manufacturing (sometimes stated as a separate subgroup), building, power, water, and gas are all included. After summing all outputs and deducting intermediate inputs, value added is a sector's net output. It is estimated without considering the depreciation of manufactured assets or natural resource depletion and degradation. The International Standard Industrial Classification (ISIC), edition 4, determines the source of value added. Data is provided in US dollars at constant 2015 prices.
Energy Consumption	The total energy demand of a country is measured by primary energy consumption.

	It includes energy industry consumption, losses during energy transformation (for example, from oil or gas to electricity), energy distribution, and end-user consumption. Energy carriers utilized for non-energy applications are not included.
Gross Fixed Capital Formation	Land improvements (fences, ditches, drains, and so on); plant, machinery, and equipment acquisitions; and the construction of roads, railways, and other structures, such as schools, offices, hospitals, private residential residences, and commercial and industrial buildings are all included in gross fixed capital formation (previously gross domestic fixed investment). Net acquisitions of assets, according to the 2008 SNA, are also considered capital formation. The figures are at constant 2015 prices and are given in US dollars.

Source: World Bank, n.d-a; n.d-b; n.d-c;n.d-d; n.d;e ; Ritchie and Roser, 2020,

3.2. Methodology and Econometric Procedure of Empirical Analysis

The methods used to estimate the models are discussed in this study section. The type of data used in this study is panel data. Panel data, as defined by Arellano and Bond (1991), is the pooling of observations from a cross-section of units of observation through time. As a result, the approaches considered consider the unique characteristics of this data, such as time variation and variance between distinct units observed.

3.2.1. Correlation Analysis

The Pearson correlation coefficient (r) is used to examine the statistical relationship between variables and to provide information on whether the correlation is positive or negative. The Pearson correlation coefficient (r) can be written as:

$$r_{RX,y} = \frac{\sum_{i=1}^{n}(x_i-\bar{x})(y_i-\bar{y})}{\sqrt{\sum_{i=1}^{n}(x_i-\bar{x})^2 \sum_{i=1}^{n}(y_i-\bar{y})^2}} \quad \textbf{(2)}$$

Where; X_i, Y_i (i=1,2,3,....,n) are the time series of the researched variables, and $\bar{X}$ and $\bar{Y}$ are the time series average.

When r is below zero, it implies a negative correlation, and when r is more than zero, it indicates a positive correlation. (Kendall, 1975).

3.2.2. Panel Unit Root Test

The first step to achieving the dissertation objectives is to conduct a Panel unit root test. We have different options which can be conducted, such as Levin-Lin-Chu (Levin et al., 2002), Im-Pesaran-Shin (I'm et al., 2003), Breitung (Breitung, 2001), Harris-Tzavalis (Harris, and Tzavalis, 1999), and Fisher-type (Choi, 2001) tests.

The researcher applies the LLC, and the structure of the LLC analysis may be specified as follows:

$$\Delta y_{it} = py_{it-1} + a_{0i} + a_{1i}t + \mu_{it} \quad , \; i= 1, \ldots N. \quad t=1,\ldots,T \quad \textbf{(3)}$$

The letters Y_i,t represent each variable in our model. The letter ρi denotes the individual fixed effect. The null hypothesis states that $\rho_i = 0$ for all I while the alternative hypothesis states that $\rho_i < 0$ for some I = 1, 2,..., N_1 and I = 0 for I = N_1 + 1,..., N.

(Levin et al., 2002) pointed out that their panel-based unit root tests are better applicable to panels of intermediate size (i.e., 10 < N < 250 and 25 < T < 250). Considering that the study sample is of medium size, and according to what the LLC test provides, it is the most appropriate (Barbieri, 2009).

3.2.3. Panel Cointegration Test

The variables must be evaluated for the presence of a unit root to run a panel cointegration test, which was done in the previous stage. Different cointegration tests, such as Kao and Pedroni, are available (Kao, 1999; Pedroni, 1999, 2004). The presence of a long-run link between variables is checked using cointegration tests. In Pedroni cointegration tests, the null hypothesis is that there is no cointegration. The technique of Pedroni is based on the following model (Pedroni, 1999):

$$y_{it} = a_i + p_i t + \beta_{1i}x_{1i,t} + \beta_{2i}x_{2i,t} \ldots + \beta_{Mi}x_{Mi,t} + £_{i,t} \quad \textbf{(4)}$$

Where $m = 1 \ldots M$ is the number of regressors; ρ_i and α_i are the deterministic components.

3.2.4. Panel VAR

VAR stands for vector autoregression, and all variables are viewed as endogenous and interdependent in VAR models, both dynamically and statically (Ramey & Shapiro, 1998). Both Panel VARs and VAR models have the same structure: all variables are considered endogenous and interdependent. However, the representation is expanded to include a cross-sectional dimension (Canova, and Ciccarelli, 2013)

Panel VAR can be represented as follows:

$$y_{it} = A_{0i}(t) + A_i(l)\, Y_{t-1} + \mu_{it} \qquad i= 1, \ldots. N. \qquad t=1,\ldots,T \qquad \textbf{(5)}$$

Where: y_{It} is a G x 1 vector of random disturbances, whereas G represents the variables.

The results of Panel VAR will include T statistics. It indicates whether there is a significant effect for the independent variables. T statistics value >2 indicates that there is a significant effect. Not only T statistics will be taken into consideration, but also the R-Square coefficient. It indicates the variation in the dependent variable explained by the independent variables. An R-square greater than 0.25 indicates a good model. (Canova, and Ciccarelli, 2013)

3.2.5. Granger Causality

Granger causality states that if X causes Y, then X may be used to predict Y. (Stock & Watson, 2012). The Granger test is written as follows:

$$y_t = a_0 + \sum_{i=1}^{k} a_{1i} y_{t-i} + \sum_{j=k+1}^{d\,max} a_{2j} y_{t-j} + \sum_{i=1}^{k} \sigma_{1i} x_{t-i} + \sum_{j=k+1}^{d\,max} \sigma_{2j} x_{t-j} + v_{1t} \qquad \textbf{(6)}$$

The null hypothesis states that x does not cause y to Granger. X Granger causes Y if the Null Hypothesis is rejected (Granger, 1969).

To implement the equations for this dissertation, we replace Y with GHG, CO2, CH4, and N2O, respectively; then, with each of these Y variables, we use GDP, AVA, IVA, EC, and GFCF, respectively as well.

Where: k represents the determined lag length. d max represents the maximum order of integration which will be identified when testing for a presence of a unit root. AVA is the agriculture value added. IVA stands for Industry value added. EC is the Energy consumption. GFCG is Gross Fixed Capital Formation.

3.2.6. Panel ARDL

ARDL stands for autoregressive distributed lag. Two separate explanatory variables comprise the autoregressive distributed lag model (i.e., variables on the right-hand side of the model). The model includes the lagged values of the dependent variable and the lags of the independent variables (Dougherty, 2016).

One of the key advantages of using an ARDL model is that it allows for the inclusion of complex dynamics while also reducing the problem of multicollinearity (Dougherty, 2016). A dynamic relationship is one in which there is a causal relationship that spans multiple periods (Verbeek, 2017). Alternatively, to put it another way, the model accommodates changes in explanatory variables across time (Rozendal, 2020). This model can also simultaneously estimate long- and short-run relationships (Boutabba, 2014).

ARDL model will be conducted based on the unit root test results. if the studied variables are I(0), I(1) or a combination of I(0), I(1) therefore ARDL can be used (Baek, 2016)

The following is a model representing Panel ARDL:

$$\Delta N2O_{it} = \sigma_0 + \sum_{i=1}^{p} \sigma_{1i} \Delta N2O_{it-1} + \sum_{i=1}^{p} \sigma_{2i} \Delta EC_{it-1} + \sum_{i=1}^{p} \sigma_{3i} \Delta AVA_{it-1} + \sum_{i=1}^{p} \sigma_{4i} \Delta IVA_{it-1} + \sum_{i=1}^{p} \sigma_{5i} \Delta GFCF_{it-1} + \sum_{i=1}^{p} \sigma_{6i} \Delta GDP_{it-1} + \lambda_1 N2O_{it-1} + \lambda_2 EC_{it-1} + \lambda_3 AVA_{it-1} + \lambda_4 IVA_{it-1} + \lambda_5 GFCF_{it-1} + \lambda 6 GDP_{it-1} + E_{it} \quad \textbf{(7)}$$

$$\Delta CH4_{it} = \sigma_0 + \sum_{i=1}^{p} \sigma_{1i} \Delta CH4_{it-1} + \sum_{i=1}^{p} \sigma_{2i} \Delta EC_{it-1} + \sum_{i=1}^{p} \sigma_{3i} \Delta AVA_{it-1} + \sum_{i=1}^{p} \sigma_{4i} \Delta IVA_{it-1} + \sum_{i=1}^{p} \sigma_{5i} \Delta GFCF_{it-1} + \sum_{i=1}^{p} \sigma_{6i} \Delta GDP_{it-1} + \lambda_1 CH4_{it-1} + \lambda_2 EC_{it-1} + \lambda_3 AVA_{it-1} + \lambda_4 IVA_{it-1} + \lambda_5 GFCF_{it-1} + \lambda 6 GDP_{it-1} + E_{it} \quad \textbf{(8)}$$

Δ is the difference operator: p indicates lag length; $\sigma_0$is constant term; σ_{1i} , σ_{2i} , σ_{3i} , σ_{4i}, σ_{5i}, σ_{6i} are error correction dynamics; λ_1, λ_2, λ_3, λ_4, λ_5, λ_6 are long-term coefficients; It is the white noise disturbance term.

3.2.7. **Trend analysis using the Mann-Kendall test:**

Using the Mann-Kendall test, the trend of GHG emissions was examined (Mann, 1945; Kendall, 1975). The test is a non-parametric test with no data distribution assumptions, and it is calculated as follows:

$$S=\sum_{k=1}^{n-1}\sum_{j=k+1}^{n} Sign(X_j - X_k) \quad \textbf{(9)}$$

S indicates Mann-Kendall test statistics.

Annual values for the researched variables in years j and k where j is more significant than k is represented by X_j, X_k

The following is a model representing the studied variables

$$S=\sum_{k=1}^{n-1}\sum_{j=k+1}^{n} Sign(GHG_j - GHG_k) \quad \textbf{(10)}$$

$$S=\sum_{k=1}^{n-1}\sum_{j=k+1}^{n} Sign(CO2_j - CO2_k) \quad \textbf{(11)}$$

$$S=\sum_{k=1}^{n-1}\sum_{j=k+1}^{n} Sign(N2O_j - N2O_k) \quad \textbf{(12)}$$

$$S=\sum_{k=1}^{n-1}\sum_{j=k+1}^{n} Sign(CH4_j - CH4_k) \quad \textbf{(13)}$$

The null hypothesis indicates no trend, while the alternative hypothesis confirms its existence (Mann, 1945; Kendall, 1975).

4. Results and Discussion

The Author has calculated Descriptive statistics (Mean, Standard deviation) for study variables. The Pearson correlation coefficient was computed to measure the association between study variables. Levin, Lin, and Chu's tests were used to check stationarity for study variables. Pedroni test was used for measuring cointegration among independent variables and dependent variables. THE panel VAR model was used to study the relationship between independent and dependent variables (CH4, N2O). THE panel ARDL model was used to study the relationship between independent and dependent variables (GHGs, CO2). The Granger Causality test was used for detecting the causality effect among independent and dependent variables. The econometrics techniques were applied using E-Views 10. Trend Mann-Kendall test is used for checking temporary changes in series using XLSTAT software.

4.1. Data Preparation

In the section, the variables were identified to be used in the model. Variables were given abbreviations such as ENR for energy consumption. Data were collected from 1990 to 2018, but the 1990-1994 data was deleted due to missing data. The period started from 1995 to 2018. There are eight countries in the central European countries (Austria, Czech Republic, Germany, Hungary, Liechtenstein, Poland, Slovakia, Slovenia, and Switzerland). The study variables consist of four dependent variables (GHGs, CO2, N2O, CH4), one independent variable (GDP), and four control variables (Energy Consumption, Agriculture Value Added, Industry Value Added, Gross Fixed Capital Formation).

Table 4.1: Variables Description

Variables	ID
Panel A: Dependent variable	
Greenhouse Gases Emissions	GHGs
CO2 Emissions	CO2
N2O Emissions	N2O
CH4 Emissions	CH4
Panel B: Independent Variables	
Economic Growth	GDP
Panel C: Control Variables	
Energy Consumption	ENR

Agriculture Value Added	AGR
Industry Value Added	IND
Gross Fixed Capital Formation	GFCF

4.2.Descriptive statistics

In this section, the researcher has calculated descriptive statistics (Mean, Standard Deviation, Observations, Minimum, Maximum) for study variables across countries.

Table 4.2: DESCRIPTIVE STATISTICS OF THE STUDY VARIABLES

Variables	Obs	Mean	St.Dev	Min	Max
Panel A: Dependent variable					
GreenHouse Gases Emissions	192	201000000	283000000	7260000	1030000000
CO2 Emissions	192	192000000	271000000	13540462	959000000
N2O Emissions	192	10927292	14317863	770000	64010000
CH4 Emissions	192	21034844	25900079	1920000	112000000
Panel B: Independent Variables					
Economic Growth	192	589000000000	948000000000	26400000000	3560000000000
Panel C: Control Variables					
Energy Consumption	192	846.6107	1186.705	73.629	4091.457
Agriculture Value Added	192	6660000000	6920000000	496000000	28100000000
Industry Value Added	192	159000000000	256000000000	7280000000	990000000000
Gross Fixed Capital Formation	192	201000000	283000000	7260000	1030000000

Source: Author's computations (2022).

As indicated in the table above, in panel A, the mean, standard deviation, minimum, and maximum values of Greenhouse Gases Emissions were 201000000, 283000000, 7260000, 1030000000 respectively. Concerning CO2 emissions, the respective maximum, minimum, mean, and standard deviations were 192000000, 271000000, 13540462, 959000000. With regard to N2O, the values for the same were 10927292, 14317863, 770000, and 64010000 respectively.

The respective mean, standard deviation, minimum, and maximum values for CH4 were 21034844, 25900079, 1920000, 112000000. And finally, in panel B, Economic growth being represented b GDP, had 589000000000, 948000000000, 26400000000, 3560000000000 as values for the mean, standard deviation, minimum, and maximum respectively, while in panel C, energy consumption recorded a mean, standard deviation, minimum and maximum respective values of 846.6107, 1186.705, 73.629, 4091.457 while agriculture value added had 6660000000, 6920000000, 496000000, 28100000000 respectively. The other two variables, industry value added, and Gross fixed capital formation had mean, standard deviation, minimum and maximum values of 159000000000, 256000000000, 7280000000, 990000000000 for industry value added and 201000000, 283000000, 7260000, 1030000000 for Gross fixed capital formation respectively.

4.3.Correlation Analysis

This section used the Pearson Correlation Coefficient to measure the association between independent and dependent variables. Pearson correlation coefficient ranges from -1 to 1. Values with negative signs indicate a negative correlation, while values with positive signs indicate a positive correlation. Values between 0.1 to 0.4 indicate a weak correlation, 0.41-0.7 indicates a moderate correlation, and 0.71-1 indicate a strong correlation. The following table (4.3) shows the correlation analysis for the similar variables

Table 4.3: PEARSON CORRELATION COEFFICATENT

Variables	GHGs	CO2	N2O	CH4
Panel B: Independent Variables				
Economic Growth	0.919**	0.961**	0.841**	0.763**
Panel C: Control Variables				
Energy Consumption	0.991**	0.992**	0.948**	0.899**
Agriculture Value Added	0.967**	0.968**	0.947**	0.910**
Industry Value Added	0.924**	0.965**	0.848**	0.772**
Gross Fixed Capital Formation	0.905**	0.950**	0.825**	0.749**

** significant at level 0.05

Source: Author's computations (2022).

From the above table, it can be seen that there is a strong positive significant high correlation between (Economic Growth, Energy Consumption, Agriculture Value Added, Industry Value Added, Gross Fixed Capital Formation) and GHGs, where all correlation coefficients range from 0.7 to 1. This may entail that there is a strong relationship between the said variables and ma give proof of an existing trend which is completely symmetrical. Similar observations can be made for the other dependent variables, where there is a strong positive significant correlation between (Economic Growth, Energy Consumption, Agriculture Value Added, Industry Value Added, Gross Fixed Capital Formation) and CO_2, N_2O and CH_4 where all correlation coefficients range from 0.7 to 1.

4.4.Stationarity

This section used the Levin, Lin, Chu test to check the stationarity assumption. Series with stationarity at level or first difference leads to using panel ARDL, while with stationarity at first difference only leads to using Panel ARDL or Panel VECM. The Levin, Lin, Chu test has two hypotheses; the null hypothesis is no stationarity, while the alternative hypothesis is "stationarity."

Table 4.4: LEVIN, LIN, CHU TEST FOR STATIONARITY

Variables	At Level	At First Difference
Panel A: Dependent variable		
Greenhouse Gases Emissions	-0.83	-5.33**
CO2 Emissions	-0.7	-2.56**
N2O Emissions	-3.16 **	-
CH4 Emissions	-5.97**	-
Panel B: Independent Variables		
Economic Growth	1.73	-5.79**
Panel C: Control Variables		
Energy Consumption	0.44	-2.38**
Agriculture Value Added	-1.55	-9.46**
Industry Value Added	1.27	-7.48**
Gross Fixed Capital Formation	0.53	-6.7**

** significant at level 0.05

Source: Author’s computations (2022).

The previous table shows a summary of the stationarity test for the variables used in empirical analysis. As noted in table(4.4) above, the stationarity test for N_2O and CH_4 emissions using the Levin, Lin, Chu test for stationarity was integrated of order I(0) and statistically significant at 5% where the p-value <0.05 with statistically significant absolute t-calculated statistic values of -3.16 and -5.97 respectively ,While on the other hand ,Greenhouse Gases Emissions, CO2 Emissions, Economic Growth, Energy Consumption, Agriculture Value Added, Industry Value Added, Gross Fixed Capital Formation were integrated of order I(1)and statistically significant at 5% where the p-value <0.05 with statistically significant absolute t-calculated statistic values of -5.33,-2.56, -5.79, -2.38,-9.46,-7.48 and -6.7 respectively.

4.5. Models

In this section, four models were built to measure the association between independent and dependent variables. A cointegration test as well a panel Var regression were conducted.

4.5.1. GHGs

It should be put on record that based on the results from table (4.4) above for GHGs, the researcher would have normally used Panel VECM because all series are stationary at first difference. However, after doing the cointegration test, Panel Var was used instead because there are no cointegration vectors among independent variables and GHGs as will be seen below.

4.5.1.1.Cointegration Test

In this part, the researcher has used the Pedroni test for cointegration. The test has two hypotheses; the null hypothesis is no cointegration, while the alternative hypothesis is "there is cointegration."

Table 4.5: PEDRONI TEST FOR COINTEGRATION

	Test	Statistic	Prob.
Within-Dimension	Panel PP-Statistic	-0.131	0.4479
	Panel ADF-Statistic	0.88275	0.8113
Between -Dimension	Panel PP-Statistic	-0.3494	0.3634
	Panel ADF-Statistic	0.18523	0.5735

Source: Author’s computations (2022).

Based on the results from table (4.5) above, the variable GHGs seemed to exhibit no presence of a long run relationship (Cointegration) with the independent variables where prob >0.05. So based on this result, we fail to reject the null hypothesis that there is no cointegration, hence the panel VAR will be used instead of Panel VECM because the criteria for panel VECM requires the presence of cointegration between the variable of interest and the independent variable.

4.5.1.2. Panel VAR

Panel VAR was used to measure the effect of independent variables on GHGs. T statistics indicate whether there is a significant effect for the independent variables. T statistics value >2 indicates that there is a significant effect. The r-square coefficient indicates the variation in the dependent variable explained by the independent variables. An R-square greater than 0.25 indicates a good model.

Table 4.6: PANEL VAR FOR GHGS

Variable	Coefficient	Standard Error	t - statistics
GHGS(-1)	0.818349	-0.106790	[7.66284]
GHGS(-2)	-0.176942	-0.100310	[-1.76402]
IND(-1)	0.000067	-0.000180	[0.36113]
IND(-2)	0.000033	-0.000150	[0.22431]
ENG(-1)	-57489.63	-32730.30	[-1.75647]
ENG(-2)	151946.900000	-31796.800000	[4.77868]
AGR(-1)	-0.000887	-0.000720	[-1.23194]
AGR(-2)	0.004035	-0.000750	[5.41297]
GDP(-1)	0.000086	-0.000130	[0.65258]
GDP(-2)	-0.000181	-0.000120	[-1.51814]
GFCF(-1)	-0.000413	-0.000190	[-2.16120]
GFCF(-2)	0.000548	-0.000180	[3.01516]
C	-8350822	-1861807	[-4.48533]
R-squared	0.9989	Log likelihood	-3072.168
Adj. R-squared	0.998819	Akaike AIC	35.05873
Sum sq. resids	15000000000000000	Schwarz SC	35.29291
S.E. equation	9577521	Mean dependent	199000000
F-statistic	12332.12	S.D. dependent	279000000

Source: Author's computations (2022).

Concerning, the effect of the independent variables AGR, ENG and GFCF on GHGs over the short run, a one unit increase in AGR, ENG and GFC increases GHGs by 1.51946,0.004 and 0.0005 respectively with a lag of 2, with the coefficient for these variables having a significant impact on GHGs emissions in central European countries. On the other hand, the results showed that there was no significant effect of IND and GDP on GHGs where the t statistic is less than 2. The model of interest was well-fitted as depicted by a significant F-statistic of 12332.12 and an R-squared greater than 0.25 with a probability value less than 5 percent as desired. The independent variables managed to explain 99% of the variations in GHGs as shown by the R-Squared which was 0.99.

4.5.1.3. Causality Test

In this part, the researcher has conducted the Granger Causality test to check the causality of independent variables for the dependent variable. The test has two hypotheses; the null hypothesis is no causality, while the alternative hypothesis is "there is causality."

Table 4.7: GRANGER CAUSALITY TEST

Null Hypothesis:	F-Statistic	Prob.
GDP does not Granger Cause GHGS	2.23083	0.1106
IND does not Granger Cause GHGS	1.39452	0.2508
ENG does not Granger Cause GHGS	6.62637	0.0001
AGR does not Granger Cause GHGS	6.43426	0.002
GFCF does not Granger Cause GHGS	3.25163	0.0411

Source: Author's computations (2022).

The test for causality in table (4.7) above indicate failure to reject the null hypothesis that GDP and IND do not jointly impact or cause changes in GHGs emissions. This is noted by the corresponding lower F-statistic and other related values, that have a statistically significant probability value of greater than 5 percent(>0.05), which implies that GDP and IND cannot be used to infer causality on GHGs in predicting GHGs emissions, On the other hand, the opposite was true for ENG,AGR,GFCF which was found to cause GHGs where prob <0.05 which indicated the rejection of the null hypothesis that ENG,AGR,GFCF do not jointly impact or cause changes in GHGs emissions in Central European countries.

Today, one of the world's most developed regions in Central Europe. with data demonstrating brisk sectoral economic development across almost all industries. (World Bank, n.d-e). Many studies have found that human-made greenhouse gas (GHG) emissions are primarily to blame for the planet's rise in average temperature during the past 250 years (IPCC,2022). The primary source of artificial GHG emissions is fuel combustion in automobiles, power plants, and residences. Other sources of GHG emissions include agriculture and trash decomposing in landfills (Ansuategi & Escapa, 2002; NRDC,2019; US EPA, 2015). From 2010 to 2014, greenhouse gas emissions in Central Europe decreased gradually. From 2015 to 2017, they slightly increased before falling again in 2018.

Emissions decreased by around 4% in 2019 compared to 2018, the biggest decrease since 2009 (Eurostat, 2023). GHG emissions were over 1 billion tons lower in the same year than in 1990. This translates into a 24% decrease from 1990 levels, exceeding the EU's 2020 reduction goal of 20%. A 55% reduction in GHG emissions from 1990 is the new goal for 2030 (Eurostat, 2023; IPCC, 2022.).The transportation sector, fuel combustion by consumers, and the energy-producing industries all contributed the same amount of greenhouse gas emissions (25.8% each) except for transportation, where the proportion jumped from 14.8% in 1990 to 25.8% in 2019, and agriculture, which saw a little increase from 9.9% to 10.3%, all sectors had their shares decline when compared to 1990 (Eurostat, 2023).

In the EU, enteric fermentation generated 194 Tg CO2 eq. (CH4-100%) of GHG emissions in 2018. Analysis of the proportion of enteric fermentation-related GHG emissions in CE countries in 2018 revealed that over 40% originated in just three nations. The country's size, geography, and policies impact the amount of livestock production, which in turn impacts the GHG emissions from enteric fermentation (Chang et al., 2019). This significantly impacts the percentage of enteric fermentation in all agricultural GHG emissions. In the EU, enteric fermentation-related GHG emissions decreased by 1.75% from 2005 (Mielcarek-Bocheńska and Rzeźnik, 2021). This region's main source of GHG emissions is dairy and beef livestock rearing. By 2030, it has a relatively high potential to reduce GHG emissions. Efficiencies like the feed conversion-to-milk yield ratio, which considerably lowers GHG emissions by 5-15%, are improved by ongoing genetic and breeding efforts.

Moreover, dietary changes that lessen the amount of fiber can reduce emissions by 5–10%.

Moreover, lowering the use of TMR and increasing the proportion of pasture feed in nutrition may lower GHG emissions. The activities above may result in a 10% reduction in GHG emissions. The CE's manure management caused 63 Tg CO2 eq. of greenhouse gas emissions (CH4-65%, N2O-35%) (Eurostat, 2023).

Compared to 2005, manure management-related GHG emissions in central Europe decreased by 7.94% in 2018. As livestock production continues to be intensified, more manure must be managed, which could result in more GHG emissions from the manure management sector. The level of specialization and mechanization of European animal production has also altered, which may decrease emissions (Petersen et al., 2013). Deploying

GHG emission reduction measures on larger farms is challenging but costs less per animal. Improving or altering the housing system is one way to lower GHG emissions. Depending on the animal species, it could lead to a reduction in GHG emissions of up to 30%. Closing the slurry channel and covering manure or storage is another efficient technique that reduces greenhouse gas emissions by 10% (US EPA, 2022). On the other hand, it is relatively inexpensive and may be required by law to cover manure and slurry storage (Bollwahn, 2014).In the same year, agricultural soils in the EU produced 163 Tg CO2 eq. (N2O-100%) of GHG emissions, and in the CE, agricultural soils produced 163 Tg CO2 eq. (N2O-100%) of GHG emissions in 2018. GHG emissions from agricultural soils in the EU increased by 1.36% in 2018 compared to 2005 (Eurostat, 2023). The largest source of GHG emissions in the domain of agricultural soils is fertilization, both natural and manufactured. Optimizing the fertilization process and carefully choosing the fertilizer dose is the most effective strategy to lower these emissions. The method of fertilization has a direct impact on the dose choice. Direct land application of fertilizers is the key strategy for reducing fertilizer dose and GHG emissions. Covering the fertilizers with dirt quickly after they are applied in the field or by applying them directly to the soil helps shorten the time that fertilizers are in contact with the air. It was found that GHG emissions decreased by 20% while using this strategy (Lokupitiya & Paustian, 2006).

Discussion Generally speaking, from 1990 to 2019, the trend of GHG emissions from the agricultural sector in CE countries was downward. Since 2018, the agricultural sector in Europe has yet to be able to lower its emissions. Agriculture is one of Europe's significant sources of greenhouse gas emissions, although it is working on cutting back. Attempts to reduce emissions created by the agricultural, building, and transport sectors, as well as by small and medium-sized enterprises sectors (SMEs), which are not covered by the EU's emissions trading program (ETS) (IAEA, 2016). Together, these industries accounted for almost 55% of all emissions in the EU. The remaining 45% came from the energy, heavy industry, and aviation sectors, whose emissions are covered by the EU ETS. The report's covered sectors must collectively lower their greenhouse gas emissions by 30% by 2030 for Europe to fulfill its emission reduction commitments (EEA, 2022.).The 30% target will significantly help the EU achieve its overall climate goals, which presently call for a 40% reduction in emissions by 2030. Also, the EU is currently working to reinforce its goals due to the new climate law that the European Commission unveiled on March 4, 2020. The updated law commits to raising the percentage from 40% to 50% and 55% (European

Parliament, n.d.). However, the EU agency projects that member states must double their efforts for the bloc's climate objectives to materialize, given that central Europe is halfway toward fulfilling its 2030 targets (La Monaca et al., 2019). As of 2018, the agriculture, construction, and transport industries and SMEs only cut their emissions by 11%. Only approximately a third of what is anticipated of them by 2030 is represented by that. Agriculture could be doing better because its emissions decreased by 1%. Another industry that needs to be managed to pull out all the stops is the transportation sector, which only managed to lower its emissions by 8% (Ritchie & Roser, 2020).

Because climate change is a global issue, only concerted action by many nations, particularly the biggest, can stabilize and lower anthropogenic GHG emissions into the atmosphere, resulting in quantifiable benefits. Determining synergistic impacts will allow one to predict significantly positive policy consequences, which is why various CE countries should coordinate their actions. CE nations' degree of development and economic status determines the proposed strategies and tools to reduce GHG emissions and mitigate climate change. Comparing the years revealed a 2% decline in emissions from the agriculture sector, which is less than the anticipated 10% reduction of GHG emissions in non-ETS sectors. The lofty targets established by the EU for 2030 presumptively reduce non-ETS emissions by 30%. This will necessitate a significant decrease in agricultural GHG emissions. Based on the analysis of the GHG emission structure and the methods for reduction that are currently accessible, it was determined that it should be possible to lower agricultural emissions by around 15% throughout this time (EEA,2023.). Reduced GHG emissions may result from the EU's concentration and intensification of agriculture, which is seen as a threat to the environment. In particular, enteric fermentation, manure management, and agricultural soils account for over 98% of GHG emissions and are areas where emissions may decrease significantly (Smith et al., 2021). Rebuilding existing structures or constructing new ones, purchasing machinery for precisely preparing feed and applying fertilizer, and hiring qualified employees are all linked with reducing emissions from these regions. Applying such strategies results in cheaper investment and operating unit costs for large farms. The use of reduction techniques on smaller farms is just not financially viable. Significant human resources, alterations to legal requirements, expenditures of money, and organizational and technical improvements are needed to reduce GHG emissions. The level of reduction, however, is hard to forecast because it is hard to foresee how the animal population and crop structure will vary over the next ten years, directly affecting GHG emission levels. As said in the opening section of this study, CE countries are the most dedicated to developing renewable energy and lowering their carbon dioxide emissions compared to other regions. According to the President of the ECB, "significant investment is expected to be needed to underpin the energy transformation, with some estimates reaching hundreds of billions of euros per year in the European Union alone ."According to the European Commission, "extra annual expenditure of up to €260 billion is required to achieve the Paris Agreement targets." While most nations are not doing enough to close the "emission gap," businesses and private organizations can reduce emissions at the municipal, city, and regional government levels and help mitigate climate change's effects (Streck et al., 2016).

Also, governments can impose carbon taxes or carbon trading frameworks on significant polluters. Fossil fuel taxes and subsidies for low-emission substitutes are incentives to hasten the switch to carbon-neutral energy sources. A grid's high-level use of solar and wind energy is becoming troublesome for a variety of complicated but now well-established reasons. Demand and supply are not balanced. The intermittent nature of the sun and wind necessitates backup-producing capacity. The system's costs rise over time as its share of variable renewable energy sources rises. To prioritize and subsidize grid systems, policy measures to favor renewable energy sources are typically required; these provisions are present in roughly 50 nations. The usage of solar and wind energy in an autonomous system necessitates the use of an appropriate battery or other forms of storage. The potential for renewable energy sources and the availability of elemental power is increased by the potential for widespread usage of hydrogen as a transportation fuel in the future(Eurostat, 2023.).

The empirical findings by (Ansuategi & Escapa, 2002; Gavrilyeva et al., 2020; Sterpu et al., 2018) imply that institutional elements, defined as laws and policies that direct people's conduct, will offer future direction toward greener production and are equally as crucial to steering economies toward the green economy aim as technological advancement. In other words, the analysis's component for testing hypotheses supported the proposed research hypotheses. The CE nations must concentrate on developing their human capital and luring top talent from around the globe.

Decision 406/2009/ European Commission of the European Parliament and of the Council of April 23, 2009, on the effort of Member States to reduce their greenhouse gas emissions to meet the Community's commitments to reduce greenhouse gas emissions through 2020 states that Member States have set GHG emission limits for 2020 compared to 2005 in non-ETS sectors, including agriculture (Eurostat, 2023). Some of these modifications are to cut emissions. In contrast, others may raise them within the projected limit, depending on the size of the country, the makeup of agriculture, and the changes assumed to occur in this sector. In central Europe, there was a 2% decrease in agricultural GHG emissions between 2005 and 2018 compared to earlier years. This is less than the 10% cap on non-ETS sector investments. All non-ETS sectors, not just agriculture, should be highlighted as subject to the anticipated 2020 GHG emission restrictions. Nevertheless, the GHG reduction target for 2030 is substantially larger and assumes a 30% reduction in the non-ETS sector. In order to meet this aim, a considerable reduction in each non-ETS sector area may be required (Younis & Chaudhary, 2017).

The results disagree with this dissertation's null hypothesis that "economic growth is important and significantly contributes to greenhouse gas emissions in central Europe.". Therefore the alternative hypothesis will be accepted "economic growth is not important and does not significantly contribute to greenhouse gas emissions in central Europe." its conclusions are similar to studies (Gavrilyeva et al., 2020; Kumar et al., 2020; Lapinskienė et al., 2015) and contradictory with (Andersson & Nässén, 2016; Ansuategi & Escapa, 2002).

4.5.2. CO2

Similarly, the same procedures were conducted for CO2 emissions under the same conditions. As the same conclusion was reached as that of GHGs hence the same model adoption criteria applied here.

4.5.2.1. Cointegration Test

Table 4.8: PEDRONI TEST FOR COINTEGRATION

	Test	Statistic	Prob.
Within-Dimension	Panel PP-Statistic	0.04751	0.5189
	Panel ADF-Statistic	-1.5822	0.0568
Between -Dimension	Panel PP-Statistic	0.24754	0.5978
	Panel ADF-Statistic	0.46032	0.6774

Source: Author’s computations (2022).

Based on the results from table (4.8) above, just like GHGs, the variable CO2 seemed to exhibit no presence of a long run relationship (Cointegration) with the independent variables where prob >0.05. So based on this result, we fail to reject the null hypothesis that there is no cointegration, hence the panel VAR will be used instead of Panel VECM because the criteria for panel VECM requires the presence of cointegration between the variable of interest and the independent variable.

4.5.2.2.Panel VAR

Table 4.9: PANEL VAR FOR CO2

Variable	Coefficient	Standard Error	t - statistics
CO2(-1)	1.18359600	-0.15981000	[7.40646]
CO2(-2)	-0.16655700	-0.15913000	[-1.04664]
GDP(-1)	-0.00009040	-0.00010000	[-0.86775]
GDP(-2)	0.00006840	-0.00009400	[0.73185]
IND(-1)	0.00022900	-0.00014000	[1.57744]
IND(-2)	-0.00017900	-0.00012000	[-1.55343]
AGR(-1)	-0.00229200	-0.00057000	[-4.02623]
AGR(-2)	0.00261400	-0.00056000	[4.63037]
ENG(-1)	-162205.7	-37526.0	[-4.32249]
ENG(-2)	152330.90000000	-36795.60000000	[4.13992]
GFCF(-1)	-0.00028000	-0.00015000	[-1.89844]
GFCF(-2)	0.00034200	-0.00014000	[2.44293]
C	-166058.70000000	- 1410053.00000000	[-0.11777]
R-squared	0.999284	Log likelihood	-3027.45
Adj. R-squared	0.999231	Akaike AIC	34.55
Sum sq. resids	9000000000000000.00	Schwarz SC	34.78
S.E. equation	7428734.00	Mean dependent	190000000
F-statistic	18946.60	S.D. dependent	268000000

Source: Author's computations (2022).

Similarly for CO2, the table (4.9) above showed the effect of the independent variables AGR,ENG and GFCF on CO2 over the short run, a one unit increase in AGR,ENG and GFC increases CO2 emissions by 0.004 ,151946 and 0.0005 respectively with a lag of 2, with the coefficient for these variables having a significant impact on CO2 emissions in central European countries. On the other hand, the results showed that there was no significant effect of IND and GDP on CO2 where the t statistics is less than 2. The model of interest was well-fitted as depicted by a significant F-statistic of 18946.6 and an R-squared greater than 0.25 with a probability value less than 5 percent as desired. The independent variables managed to explain 99% of the variations in CO2 as shown by the R-Squared which was 0.99.

4.5.2.3.Causality test

Table 4.10: GRANGER CAUSALITY TEST

Null Hypothesis:	F-Statistic	Prob.
GDP does not Granger Cause CO2	3.16331	0.0448
IND does not Granger Cause CO2	0.88902	0.4129
ENG does not Granger Cause CO2	6.8701	0.0013
AGR does not Granger Cause CO2	9.72462	0.0001
GFCF does not Granger Cause CO2	4.41249	0.0135

Source: Author's computations (2022).

The test for causality in Table (4.10) above indicates the failure to reject the null hypothesis that IND does not impact or cause changes in CO2 emissions. This is noted by the corresponding lower F-statistic and other related values, that have a statistically significant probability value of greater than 5 percent(>0.05), which implies that IND cannot be used to infer causality on CO2 in predicting CO2 emissions, On the other hand, the opposite was true for GDP, ENG, AGR, GFCF which was found to cause CO2 where prob <0.05 which indicated the rejection of the null hypothesis that GDP, ENG, AGR, GFCF do not jointly impact or cause changes in CO2 emissions in Central European countries and can therefore be used to infer causality on CO2 in predicting the levels of CO2 emissions.

Carbon dioxide (CO2) emissions were the main focus of scientific studies in the past that dealt with climate policy. However, they are just one-way human activity affects the global climate. Carbon dioxide (CO2) emissions from the combustion of fossil fuels (mainly oil and oil products, natural gas, coal, and peat) increased by 6.3% in 2021 compared to the previous year when the majority of the COVID-19 containment measures were withdrawn (Eurostat, 2022). Around 75% of the emissions of greenhouse gases caused by human activity in Central Europe come from CO2 emissions from energy usage, which were a significant factor in the development of global warming (IEA,2021.; Hu et al., 2021). A few elements that affect emissions are weather conditions (such as a cold/long winter or a hot summer), economic growth, population size, transportation, and industrial activities (Streck et al., 2016). Fossil fuel combustion results in CO2 emissions, produced in the nation where the fuel is used to produce electricity, heat transportation, make steel, etc. Imports and exports of energy products are subsequently impacted. For instance, importing coal to produce electricity causes the importing nation's emissions to rise.

In contrast, since emissions are reported in the nation where the electricity was produced, imported electricity has no impact on the emissions of the importing nation (IEA,2021). Emissions from the farm gate and emissions from land usage both climbed during the 2000s, and then, as seen in tables 2.9,2.11, and 4.14, trends in these two components started to diverge. From 2000–2018, emissions from agricultural and animal activities increased and were 14% higher in 2018 than in 2000, as per World Bank and European Bank data, as seen in Table 2.8. On the other hand, emissions from land use and land use change declined across the study period, in line with trends in the amount of deforestation that were seen.

In light of this, the results see Table 4.9 for the EKC theory show evidence of an inverted U-shaped relationship between CO2 emissions and economic growth (GDP), as the coefficient associated with the linear term GDP is cheerful, and that associated with the nonlinear term (GDP) is negative. This finding validates the EKC Hypothesis (Stern, 2018), which holds that CO2 emissions rise during the early stages of economic expansion and fall after crossing a specific threshold for the eight Central European countries across the study period. Consequently, a long-term rise of 1% in GDP will result in an initial increase of 6.0% in CO2 emissions, followed by a decline of 9.04% ceteris paribus.

The results disagree with this dissertation's null hypothesis that " economic growth is important and significantly contributes to greenhouse gas emissions in central Europe.", therefore the alternative hypothesis will be accepted "economic growth is not important and does not significantly contribute to Carbon dioxide emissions in central Europe." and its conclusions are similar to studies (Ahmed et al., 2019; Hu et al., 2021), and contradictory with (Bozkurt & Okumuş, 2019; Halkos, 2012; Kułyk & Augustowski, 2020; Şentürk et al., 2020; Stern et al., 1996).

4.5.3. N2O

Unlike GHGs and CO2 which were having the same level of difference, this section acknowledge that the tests for variables' stationarity, with variables being a mixture of I(0) and I(1) orders of integration, hence panel ARDL was the appropriate next step as suggested by the previous sections, where AIC criterion established the optimal lags of 2 for the variables N2O and CH4.

Table 4.11: PANEL ARDL MODEL FOR N2O

Variable	Coefficient	Std. Error	t-Statistic	Prob.*
Long Run Equation				
GDP	-0.000034	0.000011	-3.011075	0.003100
AGR	-0.000536	0.000161	-3.337807	0.001100
IND	0.000123	0.000032	3.834920	0.000200
GFCF	-0.000103	0.000036	-2.879369	0.004600
Short Run Equation				
COINTEQ01	-0.26840	0.07223	-3.71611	0.00030
D(GDP)	0.00003	0.00001	2.56504	0.01140
D(AGR)	0.00015	0.00008	1.72111	0.08740
D(IND)	-0.00002	0.00002	-1.41350	0.15970
D(GFCF)	0.00001	0.00001	0.99361	0.32210
C	9750960	6364446	1.53210	0.12780
Mean dependent var	-198097.8	S.D. dependent var		1276413
S.E. of regression	992106.3	Akaike info criterion		26.5648
Sum squared resid	147000000000000.0	Schwarz criterion		27.2943
Log likelihood	-2507.2	Hannan-Quinn criter.		26.8603

Source: Author's computations (2022).

According to the previous table, it is notable that, the effect of the independent variables AGR, ENG and GFCF on N2O over both the short run and long run, a one unit increase in GDP, AGR and GFC reduces N2O, by -0.000034, -0.000536 and -0.000103. respectively with the coefficient for these variables having an adverse significant impact on N2O emissions in central European countries. On the other hand, the results showed that there was a positive significant effect of IND on N2O emissions by 0.000123. Additionally, COINTEQ01 significantly affects N2O where prob = 0.0003 is less than 0.05 and the coefficient is -0.268401, which indicates the model is a good fit

N2O, also known as nitrous oxide, is a significant greenhouse gas. Agricultural practices and soil microbiological activity are their main atmospheric release pathways. Reactive nitrogen is subjected to conversion processes, especially nitrification (creation of nitrate from ammonia) and denitrification when it is typically supplied to soils to promote agricultural development (fertilization) (reduction of nitrate into molecular nitrogen). Both procedures produce N2O as a byproduct (Leip et al., 2011) .N2O release rates vary significantly throughout time and space. The highest N2O emissions are seen for these two main processes at intermediate aeration, even though these two processes are based on microbial activities that require different chemical regimes, i.e., nitrification occurs under aerobic conditions.

In contrast, denitrification requires anaerobic conditions (Firestone et al., 1979; Granli & Bockman, 1995; Garrido, 2002). Soil characteristics, including carbon content (soil organic carbon, or SOC), and water accessibility are crucial. The outcomes of the available field measurements demonstrate the enormous variety. There have been attempts to identify driving parameters based on such measurement compilations, but the claimed uncertainties are still substantial (Stehfest & Bouwman, 2006).

The parties to the United Nations Framework Convention on Climate Change (UNFCCC) must report the amount of N2O emissions from each source sector. Although models and (clustered) measurement data are available, the results are considered so unreliable that practically all countries use the most straightforward method recommended by the IPCC national emission inventory guidelines (IPCC, 2006). This approach scales emissions according to a single emission factor indiscriminately to all potential sources of nitrogen input to soils based on the plot measurements previously indicated. Notwithstanding the approach's drawbacks, the uncertainty related to these emissions often exceeds the uncertainty of national GHG inventories as a whole (Leip et al., 2011; Winiwarter & Muik, 2010)

The Common Agricultural Policy (CAP) provides the framework of legislation for EU agriculture. Direct payments to farmers under Pillar 1 of the CAP include greening initiatives and payments unrelated to what farmers produce crop diversification, permanent grassland protection, and ecological focus areas (EU's Common Agricultural Policy, 2023).

Agriculture is a sector that has wide-ranging effects on things like food security, trade, the environment, chemicals, waste, and natural resources. Depending on the international trade policy in place, agreements between the EU and other nations or regional trading blocs may impact the rates at which products are exported from or imported into central Europe. (International Trade Administration, 2018; Bongardt and Torres, 2018).For instance, the c- and quota-free access to the EU market. Extended supply chains and the emissions they contain may have an effect on global warming. The Renewable Energy Directive (2009/28/EC) also requires the use of renewable energy in the transportation industry, which encourages the growth of biofuel crops in a bid to cut back on the usage and emissions of fossil fuels (European Commission, n.d.a). However, the energy and water required for growing the crop and processing it make biofuels contentious because they may not significantly reduce overall emissions and may hurt food inventories, which may lead to an increase in food imports. The production of chemical fertilizers for agricultural use generates emissions and a specific quantity of trash that must be disposed of following the Waste Framework Directive (European Commission, n.d.a). It is essential to remember that the examined period includes the 2008–2014 global economic slump, which would have impacted the observed declining trends in N2O concentrations over the analyzed period. The results agree with this dissertation's null hypothesis that "economic growth is important and significantly contributes to Nitrous oxide emissions in central Europe".

4.5.4. CH4

like N2O which was having a mixture of I(0) and I(1) orders of integration for variables' stationarity, hence panel ARDL was the appropriate next step as suggested by the previous sections.

Table 4.12: PANEL ARDL MODEL FOR CH4

Variable	Coefficient	Std. Error	t-Statistic	Prob.*
Long Run Equation				
GDP	-0.00006	0.00013	-0.44441	0.65740
IND	-0.00002	0.00053	-0.03209	0.97440
AGR	0.00862	0.01155	0.74675	0.45650
GFCF	0.00086	0.00114	0.75484	0.45160
Short Run Equation				
COINTEQ01	-0.00699	0.00530	-1.31997	0.18900
D(GDP)	0.00001	0.00001	0.81933	0.41400
D(IND)	0.00000	0.00002	0.24701	0.80530
D(AGR)	-0.00003	0.00002	-1.67076	0.09700
D(GFCF)	-0.00001	0.00001	-0.51860	0.60490
C	-2278549	1853599	-1.22926	0.22100
Mean dependent var	-446467.40	S.D. dependent var		1095321
S.E. of regression	610949.40	Akaike info criterion		26.17798

Sum squared resid	55600000000000	Schwarz criterion	26.90752
Log likelihood	-2470.09	Hannan-Quinn criter.	26.47345

Source: Author's computations (2022).

The panel ARDL results for CH4 on table (4.12) above shows that there was no significant effect of all the independent variables, namely GDP, IND, AGRI,GFCF on CH4 prob 0.657 was greater than 0.05.This entails that in central European countries, the said variables have no impact on CH4 whatsoever. Variable (ENG) was deleted automatically due to a Non-Singular Matrix Error.

According to some estimates, wetlands and other biogenic (natural) sources account for around 40% of all methane emissions, whereas the remaining 60% are anthropogenic (manufactured) sources (Hettiarachchi, 2011). Agriculture is the primary source of anthropogenic methane emissions. Methane emissions have decreased overall by 37% since 1990, and they now account for 11% of all GHG emissions in the EU, according to the EEA greenhouse gas inventory for CE, published in 2017 (EEA, 2021.; Lokupitiya & Paustian, 2006). Anaerobic waste and enteric fermentation are the two leading causes. In 2015, they contributed 53% of all (CH4) emissions in the EU (EEA, 2023). Comparatively speaking, methane emissions from the gas sector are low. According to the European Environment Agency (EEA, 2023.), gas activities contributed 5% of all methane emissions in 2015 or 0.6% of all greenhouse gas emissions in the EU. Following carbon dioxide, methane is the second most significant greenhouse gas contributing to climate change. Methane has a potential for global warming that is 28 times bigger over a 100-year period than carbon dioxide and 84 times greater over a 20-year period. Hence, methane emissions are essential to 2050 climate goals (Active Sustainability,2023.).In addition, methane contributes to the development of ozone, which in and of itself poses a significant health risk. The energy industry accounts for around one-third of all anthropogenic methane emissions worldwide. Since that methane may be sold as natural gas, the International Energy Agency estimates that 45% of those emissions can be reduced without incurring net costs. By 2050, a reduction in world temperature of 0.2°C due to human activity might be achieved, making a substantial contribution to keeping the rise in global temperature below two °C (IEA,2021.).One of the top priorities in the European Green Deal and the EU's methane strategy, released in October 2020, is reducing methane emissions (Olczak & Piebalgs, 2019). This initiative has the potential to significantly increase the EU's efforts toward important climate goals, such as a higher ambition for greenhouse gas reduction. The policy aims to lower projected temperature rises through 2050, enhance air quality, and strengthen the EU's position as a leader in the global fight against climate change. Because these industries produce almost all of the anthropogenic methane emissions, they will concentrate on reducing methane emissions in the energy, agricultural, and waste sectors. Using cross-sector synergies, such as the generation of biomethane, this cross-sectoral approach will take specific action in each area (European Commission,n.d.b)

Companies in the oil and gas industry would need to regularly inspect their equipment to find leaks, repair them quickly, typically within five to fifteen working days and check that the repairs were successful. The proposal also prohibits routine flaring and venting, allowing venting only under extraordinary or unavoidable conditions for safety concerns. Flaring is permitted only when re-injection, on-site use, or transporting the methane to a market is technically impractical. Lastly, complete combustion must be present for flaring to occur. In order to ensure that safety concerns in coal mines are taken into consideration, the proposal for coal calls for a phase-out of methane venting and flaring (Zhongming, 2018).

Additionally, the proposal requires EU nations to create mitigation plans for dormant oil and gas wells and abandoned coal mines. Several technologies are available. You have biogas created from agricultural manure, for instance, or landfill gas recovery from waste. They can be converted into biomethane to generate heat and electricity directly. Biogas has a significant potential to cut methane emissions from the agricultural sector.

Moreover, recovered methane can be used to create hydrogen. Nevertheless, since green hydrogen is created using renewable energy sources like solar and wind power, it is preferable because it produces no emissions. Due to the synergies in reducing greenhouse gases and air pollutants, reducing methane emissions enhances climate change mitigation and better air quality (Office of ENERGY EFFICIENCY & RENEWABLE ENERGY, n.d.).

Methane accounted for 12% of all greenhouse gas emissions in CE in 2020, with the agricultural sector producing half of these emissions. Methane emissions have significantly decreased in the energy supply, waste management, and, until recently, agriculture over the past 30 years since 1990. Decreased emissions result from fewer farmed animals, less coal being mined, improved oil and gas pipeline networks, less trash being dumped on the ground, and more garbage being recycled, composted, recovered landfill gas, and burned for heat and electricity. (RMI, 2023). Although earlier results have been encouraging, future methane emission reductions in agriculture are becoming more challenging but still attainable. The food choices made by customers can help reduce methane emissions and develop and apply methane-reducing strategies and technologies (WRI,2023). Natural gas primarily consists of methane (CH_4). It is a short-lived greenhouse gas (GHG) that significantly impacts climate change and global warming. In addition to being a potent GHG, CH_4 is also a precursor to ozone, which has effects on air quality, human health, and vegetation degradation like crop and forest loss. Hence, lowering CH_4 emissions helps to improve ecosystem services, air quality, and climate change mitigation. (Zhongming, 2018) The results disagree with this dissertation's null hypothesis: "economic growth is important and significantly contributes to Methane emissions in central Europe.“ It accepts the alternative hypothesis: economic growth is unimportant and does not significantly contribute to Methane emissions in central Europe. The postulated hypothesis and the findings of this dissertation indicate some form of consensus with most studies (Chang et al., 2019; Smith et al., 2021).

After conducting all the above analysis, it is very important to go in deep for each country, discuss the details, compare and provide best recommendations.

Austria is one of the most prominent countries seeking to reach carbon neutrality by 2040, preceded by many countries. Under European Union legislation to share efforts, it was agreed with Austria to reduce emissions by sixteen percent by the end of 2020 and to continue reducing emissions to reach thirty-six percent by the end of 2030 (Federal Ministry for sustainability and tourism, 2019; Federal Ministry for sustainability and tourism and Federal Ministry for transport, 2018; IEA, 2020).

Austria has suffered slightly from a decline in terrestrial carbon sequestration due to the loss of agricultural land as a result of dense urban sprawl. Austria loses approximately thirteen hectares of soil every day, which has affected agricultural sector emissions, which increased by two percent during the first two decades of this century, which is consistent with the results of the current study. Austria has approved a national plan to support this sector through several measures, most notably providing more sustainable reserves of wood for use as materials or in energy generation, ensuring forest growth using high-performance tree species, reducing the use of mineral fertilizers and increasing bioenergy (Federal Ministry for sustainability and tourism, 2019; Federal Ministry for sustainability and tourism and Federal Ministry for transport, 2018; IEA, 2020).

Regarding the services sector, the most prominent cause of emissions is transportation. The transportation sector represents the largest share, thirty percent, of total emissions in Austria, which has achieved a decrease over the last two decades by one percent of greenhouse gas emissions, which is consistent with the results of the study. However, with the expected increase in the tourism and services sector that Austria is working on, emissions are expected to increase due to the significant increase in distances traveled and refueling in transit traffic in Austria, which makes it necessary to work on them (Federal Ministry for sustainability and tourism, 2019; Federal Ministry for sustainability and tourism and Federal Ministry for transport, 2018; IEA, 2020).

The sectors of industries that include energy as a basis have achieved a significant reduction in emissions by thirty-six percent over the last two decades, bringing their total participation in overall net emissions to thirteen percent. The conversion of approximately thirty-four percent of Austria's energy needs to renewable energy contributed to this decline. This decrease is considered an achievement of the state's goal for the year 2020, with an increase of more than 9.2 percent compared to the base year. The manufacturing and construction industries followed the same path, declining by twenty-six percent for the same years in question, which fully agreed with the results of the study. To reach Austria's goals for the years 2030 and 2040, the government will focus on energy efficiency in the heating sectors in buildings and transformation in the transportation and electricity sectors (Federal Ministry for sustainability and tourism, 2019; Federal Ministry for sustainability and tourism and Federal Ministry for transport, 2018; IEA, 2020).

To achieve this, Austria seeks to obtain half of its energy from alternative energy sources by the year 2030. This fundamental transformation will help Austria to completely transfer electricity generation to obtain green electricity by the year 2030, and this is what was officially approved by the Austrian Parliament in 2021, obligating the government to obtain green electricity. By reaching that date.

Austria has divided its work into stages to reach climate neutrality, as it will work to reduce emissions by thirty-six percent in the current third decade compared to the base year of 2005. Austria has a national energy and climate plan. Despite this, it is clear that implementing the plan will enable Austria to reach an emissions rate nine percent lower than the target. The plan aims to completely switch to green electricity and phase out the use of fossil fuels to heat new buildings. Banning natural gas heating for new buildings from 2025 and phasing out oil or coal-fired heating systems. For all buildings by 2035. That is why Austria has approved several projects such as hydrogen, biomethane, photovoltaics, and biomass projects. The photovoltaic cell project is distinctive, as the government seeks to raise the target for rooftop photovoltaic installations from one hundred thousand to one million by 2030(Federal Ministry for sustainability and tourism, 2019; Federal Ministry for sustainability and tourism and Federal Ministry for transport, 2018; IEA, 2020).

The Czech Republic produces three and a half percent of the European Union's total greenhouse gas emissions. Industry has an important role in the Czech economy, as the levels of energy-intensive industry in the economy have increased, and therefore this naturally affects the proportion of emissions that come from the Czechs’ heavy reliance on coal in various areas of the economy. In accordance with the effort-sharing legislation, the European Union allowed emissions to continue to increase until 2020, stipulating that they be reduced by fourteen percent by 2030 compared to the base year for that legislation. Total Czech emissions have now decreased by approximately thirteen percent compared to 2005. The Czech Republic, in cooperation with the European Union, will seek to reduce emissions by an additional twenty percent, without taking into account the impact of land use developments, land use change and forestry (Ministry of Industry and Trade, 2014; 2019; Rečka, Máca, & Ščasný, 2023).

The percentage of emissions for the industrial sector (industries whose basis is energy, manufacturing, and industrial processes) decreased by eight percent, reaching sixty percent of the total emissions in the Czech Republic during the last two decades. This decline is attributed to the decline of some heavy industries after the fall of communism. The high percentage of emissions is due to the Czechs' heavy reliance on coal in various areas of the economy. Energy industries represent the largest portion of greenhouse gas emissions for the industrial sector in the Czech Republic, as they reached forty-two percent of total emissions by the year 2005 and continued to decline over time until they reached twenty-two percent in 2019. The Czech Republic has advanced environmentally in manufacturing and construction industries, reducing its share of total emissions by forty-five percent compared to the base year during the last two decades. The production of iron, steel, chemicals, mineral extraction and coal are important industries in the Czech economy with energy-intensive consumption. If the use of coal is moved away according to what is planned, the energy industry’s emissions will decrease further due to the entry of both coal and lignite into the production of electricity and heating by fifty and sixty percent, respectively. The Czech Republic has a coal committee that has recommended the complete elimination of coal by 2038 (Ministry of Industry and Trade, 2014; 2019).

Within the services sector, the transportation and waste sectors suffered increases in emissions. But heating buildings is an important cause of emissions. Because it is of great importance, working on it brings the Czech Republic closer to its environmental goals, so building renovation has been included in the national energy and climate plan. The support program for the renovation of private homes is scheduled to continue. Moreover, the plan aims to take action on replacing coal boilers. It is accompanied by community awareness campaigns. With regard to transportation, the Czech Republic seeks to reach fourteen percent of renewable energy sources used in transportation by the year 2030, an increase of approximately six percent compared to the year 2020. To achieve this, the Czech Republic will seek to find and use biofuels that are not currently available. According to the National Energy and Climate Plan, it is possible that battery-powered electric cars and accompanying charging points will increase. The weak point in this is the lack of financial incentives to move to electric cars in the Czech Republic (Ministry of Industry and Trade, 2014; 2019; McKinsey Company, 2020; Rečka, Máca, & Ščasný, 2023).

In accordance with the results of the study, the agricultural sector has been affected during the last two decades and contributed to emissions, due to the outbreak of the bark beetle, which led to unprecedented deforestation. Salvage logging increased from fifteen and a half million cubic meters to more than thirty-two million cubic meters between 2014 and 2019. The Czech land use and agricultural sector is expected to continue to be a source of emissions over the next decade. Since land use measures, forestry, afforestation, and organic agriculture are not a high priority (Ministry of Industry and Trade, 2014; 2019; McKinsey Company, 2020; Rečka, Máca, & Ščasný, 2023).

The Czech Republic doubled its share of renewable electricity during the ten years extending between 2009 and 2019, which contributed greatly to making the Czech environmental reality acceptable in the period extending until 2020. However, the future of the Czech Republic until 2030 in electricity transformation does not meet the ambition due to their desire to increase this share by three to three. Only tenths of a percentage (Ministry of Industry and Trade, 2014; 2019; McKinsey Company, 2020; Rečka, Máca, & Ščasný, 2023).

The package of measures will focus on doubling its solar capacity and tripling its wind power. In addition to producing biomethane from organic waste and building geothermal energy by 2030. However, with these measures, the Czech Republic will reach twenty-two percent of renewable energy in the energy mix, which disappoints the European Union. As mentioned, the Czech Republic is seeking to support the transportation and heating sector through the use of biofuels, which has increased the concerns of the European Union and the

European Commission regarding the risks of land use pressures, in addition to the Czechs moving away from the idea of electrification of transportation (Ministry of Industry and Trade, 2014; 2019; McKinsey Company, 2020; Rečka, Máca, & Ščasný, 2023).

Overall, during the last two decades, the Czech Republic has been able to reduce the intensity of its emissions as a percentage of GDP by approximately fifty-seven percent, which justifies the results of the study in general (Ministry of Industry and Trade, 2014; 2019; McKinsey Company, 2020; Rečka, Máca, & Ščasný, 2023).

Germany is one of the industrialized countries that has a significant proportion of greenhouse gas emissions in Europe. It contributed approximately twenty-two percent. During the past two decades, greenhouse gas emissions have decreased to less than eighteen percent of total European Union emissions (German Federal Government, 2019a; 2019b; 2020).

With regard to the industrial sector, energy industries contributed twenty-nine percent of the industry's total emissions by the end of the second decade, which decreased by thirty-five percent by the end of the second decade compared to what it was before 2005. In contrast to the first section of industries, emissions resulting from manufacturing and construction industries increased during the last twenty years by 8.7%, and from this, the total emissions issued by the industrial sector decreased during the time period studied, which is consistent with the results of our practical study (German Federal Government, 2019a; 2019b; 2020).

Waste management was distinguished by its low emissions, as emissions fell to less than one percent by the end of the second decade, a decrease of fifty-six percent compared to the base year. Germany does not plan to consume energy in the waste management sector as it has other priorities. Emissions in the transportation sector rose by one and a half percent during the same period. Germany aims to reach a reduction in transport emissions of just over twenty-three percent by 2030 compared to emissions in 2019. The government will support the purchase of zero and low emission vehicles, increase the use of public transport, support active mobility and invest in the railway network. In addition to raising the share of renewable energy in transportation to twenty-seven percent by 2030. To replace heating with green solutions, Germany will provide financial aid to stimulate the use of renewable energy in this sector to reach an emissions rate equal to twenty-seven percent by 2030. It is possible to price carbon dioxide. Carbon for the transport and heating sectors. Regarding agriculture, the government will work to develop organic agriculture and enhance natural carbon sinks.

And creating certified organic matter in the soil (German Federal Government, 2019a; 2019b; 2020).

One of the most prominent reasons for reducing emissions is what Germany has done by increasing the use of renewable energy, solar, wind and biomass. In addition to the transition from coal to gas. It achieved an achievement by closing the last three nuclear power plants in 2023. Germany plans to phase out coal-fired plants by 2038. To compensate for this energy, it will work to develop energy production from onshore and offshore wind farms, and enhance photovoltaic and bioenergy capacity. By the end of the second decade, Germany achieved the 2020 target of reaching a renewable energy share of eighteen percent of total final energy consumption. Germany has set a target for 2030 to reach thirty percent (German Federal Government, 2019a; 2019b; 2020).

Germany is distinguished by the desire of its various segments to move to a green economy, and one of the evidence for this is that the German Federal Constitutional Court recognized that the country's climate law is not consistent with basic rights and demanded that standards be increased and the reduction target for 2030 be raised from fifty-five percent to sixty-five percent and the achievement of net zero emissions by The year 2045. Not only that, they did not make the goal of closing coal-fired power plants in 2038 theoretical, but rather attached it to a law that was approved in 2020 to prevent the establishment of new plants that use coal starting in August of the same year if they had not obtained their operating licenses in advance. In 2021, the German government approved a new law for the transportation and heat generation sectors to trade fuel emissions (German Federal Government, 2019a; 2019b; 2020).

Hungary has achieved a thirty-five percent reduction in carbon intensity over the past two decades, consistent with the results of the study. In general, Hungary has achieved a reduction in emissions by more than sixteen percent over the past two decades compared to the approved base year. Hungary is similar to the Czech Republic in that the European Union agreed to increase emissions until 2020 exceptionally under the decision to share efforts in specific sectors. Hungary achieved a transition of twelve and six tenths percent to renewable energy sources by 2019. In agreement with the European Union, Hungary seeks to reduce its emissions by seven percent compared to the base year of 2005 by 2030. Therefore, Hungary must take many measures to achieve this. Hungary seeks to convert approximately twenty-one percent of its energy into renewable energy (Bart, Csernus & Sáfián, 2018; Vadovics, 2019; Hungary Ministry of Innovation and Technology, 2019).

The industrial sector as a whole achieved an overall reduction in emissions from the sector, but emissions varied between sub-sectors of the industry. The energy industries sector was distinguished as it achieved a reduction in emissions of thirty-seven and a half percent by the year 2019, as the total emissions issued by this sector reached nineteen and six tenths percent. Emissions associated with manufacturing and construction industries increased by nineteen percent (Bart, Csernus & Sáfián, 2018; Vadovics, 2019; Hungary Ministry of Innovation and Technology, 2019).

Consistent with the results of our study, emissions in the agricultural sector increased by sixteen percent. This increase is due to the increased use of fertilizers, the increasing number of cows, in addition to the increased milk production per cow. In the services sector, transportation is a major cause of emissions, rising from three percent to twenty-two percent by 2020 (Bart, Csernus & Sáfián, 2018; Vadovics, 2019; Hungary Ministry of Innovation and Technology, 2019).

Hungary will focus on specific sectors to reduce emissions, as electricity and industry can contribute to reducing emissions by eight percent and seventeen percent by the years 2030 and 2040, respectively. It is clear that the agricultural sector is not among the priorities for support, so it is expected that emissions will continue to increase by an additional ten percent by 2030. Hungary's vision and what it is currently doing are not consistent with the requirements of the European Commission regarding the energy goals for the year 2030, as the Commission believes that these plans do not meet the ambition (Bart, Csernus & Sáfián, 2018; Vadovics, 2019; Hungary Ministry of Innovation and Technology, 2019).

One tenth of emissions in the European Union come from Poland. Total gas emissions over the past two decades have decreased by ten percent, which agrees with the overall results of the study (Poland Ministry of Climate and Environment, 2021)

Poland, similar to the Visegrad Group countries, obtained an exception to increase emissions until 2020 by fourteen percent, on the condition that it reduces seven percent by 2030. It has converted and used twelve and two-tenths of a percent of the energy as renewable energy and is working to achieve approximately twenty-three percent in total by 2030. Poland did not achieve its desired goal of reaching fifteen percent of renewable energy by 2020. Poland relies essentially on coal as a primary source of energy, as by the end of the second decade, coal represented forty-one percent of its energy components, in addition to sixty-nine percent of electricity coming from coal. Although coal is believed to be an essential component currently, it has declined over the last two decades, being replaced by natural gas, oil, and biofuels (Kiuila, 2018; Poland MINISTRY OF NATIONAL ASSETS, 2019; Polish Economic Institute, 2020, Poland Ministry of Climate and Environment, 2021; Centre for Climate and Energy Analyses, 2021)

The industrial sector, especially the energy-dependent sector, constitutes the largest contributor to emissions, at a rate of thirty-eight percent. This sector has declined by seventeen percent over the last two decades. While the manufacturing and construction industries contributed to reducing emissions by approximately nine percent. As for the services sector, like most countries in the region, the transportation sector increased its emissions from nine to seventeen percent, while waste management achieved a decrease of fourteen percent. Similar to the study results, emissions from agriculture increased by eight percent during the same time period (Poland MINISTRY OF NATIONAL ASSETS, 2019; Polish Economic Institute, 2020, Poland Ministry of Climate and Environment, 2021; Centre for Climate and Energy Analyses, 2021)

According to the discussion, transport received a primary focus from Poland in its 2030 plan. Poland is working to switch to non-existent and low-emission public transportation to achieve its goal of reducing transport emissions from new vehicles by fifteen percent in 2025, doubling that for small trucks, with the desire to reach a reduction of thirty-seven and a half percent for cars during the year 2030. In addition, Poland plans to invest in creating liquefied natural gas infrastructure (Poland MINISTRY OF NATIONAL ASSETS, 2019; Polish Economic Institute, 2020, Poland Ministry of Climate and Environment, 2021; Centre for Climate and Energy Analyses, 2021)

Poland issued its energy policy as a roadmap to reach its sustainable development goals until 2040. Poland seeks to reach a total of renewable energy of approximately twenty-three percent in 2030. Not only that, Poland is seeking to set an additional target for electricity, which aims to make the contribution of coal not exceed fifty-six percent, in addition to that renewable energy contribute thirty-two percent of the electricity generation. It is hoped that the heating sector will have a share of renewable energy at a rate exceeding Sunday quarters. The European Commission still believes that Poland is not fully on track in terms of planning (Kiuila, 2018; Poland MINISTRY OF NATIONAL ASSETS, 2019; Polish Economic Institute, 2020, Poland Ministry of Climate and Environment, 2021; Centre for Climate and Energy Analyses, 2021).

Slovakia contributes one and one tenths of percent to greenhouse gas emissions in the European Union as a whole, despite achieving rapid growth in the last twenty years of more than sixty percent. The decrease in emissions over the last two decades confirms the findings of our study. Like all Visegrad Group countries, the European Union agreed to allow Slovakia to increase emissions by thirteen percent in 2020 on the condition that they reduce them by approximately twelve percent in 2030. Slovakia plans to exceed this, achieving a twenty percent reduction in emissions (SLOVAK MINISTRY OF ECONOMY, 2019; Horváth, & Szemesová, 2023).

Slovakia has outdone itself and exceeded the 2020 goal of switching to renewable energy by more than three percent, reaching the threshold of 17 percent of its energy sources as renewable energy, and is approaching the 2030 goal of nineteen and two percent (SLOVAK MINISTRY OF ECONOMY, 2019; World Bank, 2019; OECD, 2021).

Unlike the other countries we discussed above, the agricultural sector did not witness an increase in gas emissions, as they remained stable. This is considered a natural result of Slovakia's efforts, as the state has a special sector policy concerned with land use, forestry, and environmentally friendly agricultural practices, in addition to government support to enhance investment in farms. Forty-one percent of Slovak territory is covered by forests, which makes these projects extremely important. Slovakia has approved an environmental strategy called “Green Slovakia,” which aims to achieve a circular economy and work to protect natural resources and invest them properly, which contributes to reducing emissions (SLOVAK MINISTRY OF ECONOMY, 2019; World Bank, 2019; OECD, 2021; Horváth, & Szemesová, 2023).

Like most countries, industry has a pivotal role in shaping emissions, as it contributes a rate equivalent to thirty-seven percent of total emissions, despite achieving a significant decline during the last two decades, in accordance with the results of the study. The services sector is similar to its counterparts in other countries with an increase in emissions, with the percentage divided between manufacturing and construction industries by sixteen percent, and the uses of products and multiple industrial processes by twenty-one percent (SLOVAK MINISTRY OF ECONOMY, 2019; World Bank, 2019; OECD, 2021; Horváth, & Szemesová, 2023).

The above positive results for Slovakia are also due to its use of approximately fifty-six percent of nuclear energy to generate electricity, twenty-three percent of which is due to multiple renewable energy sources, while the remaining form only fossil fuels by 2020. In addition, Slovakia is currently closing the operations of producing electricity from coal and coal mining, in addition to closing the Novaki station previously used to generate electricity from lignite. Slovakia is also working to close the Vojanj hard coal power plant in 2025. Like other surrounding countries, Slovakia will rely on replacing fossil fuels with nuclear energy by building two additional reactors at the Mošovce plant. Slovakia issued a renewable energy law and reformed it to suit the goals, and it entered into force in 2019. The goal of the amendment was to enhance electricity production, taking advantage of renewable energy, taking into account costs and effectiveness. Slovakia will invest in the heating and transportation sectors by working to reach nineteen percent of bioenergy in the heating sector and utilizing biofuels at an average of fourteen percent by the year 2030 (SLOVAK MINISTRY OF ECONOMY, 2019; World Bank, 2019; OECD, 2021; Horváth, & Szemesová, 2023).

Slovenia's emissions are considered small compared to Central European countries, as they represent only half a percent of the total greenhouse gas emissions in the European Union. Slovenia has achieved a reduction in emissions since the beginning of this century, consistent with the results of our study. Slovenia joins the countries that the European Commission allowed to increase emissions in certain sectors until 2020 by four percent, on the condition of achieving a reduction in emissions by 2030 by fifteen percent (Government of the Republic of Slovenia, 2020).

Energy is a contributor to industrial and economic processes as a whole, and the decrease in energy emissions has contributed to the overall decrease in emissions. Slovenia seeks to reach a twenty-seven percent share of renewable energy, based mainly on hydro and solar energy. This share is considered achievable because Slovenia reached twenty-two percent in 2020. Coal is considered one of the energy sources in Slovenia, and to achieve lower emissions, the Slovenian government expanded its decision to reduce coal consumption by thirty percent until the year 2030, to completely eliminate it by 2033. Slovenia will replace this energy in a similar way to neighboring countries through nuclear energy as a first option, by operating a joint high-quality reactor with Croatia, in addition to evaluating the construction of a new unit to increase energy. By 2030, Slovenia plans to distribute renewable energy, represented by biomass, solar energy, and hydroelectric energy, to various sectors, the first of which is the electricity sector, the second is heating, and the third is transportation (Pušnik, M., & Sučić, 2014; Government of the Republic of Slovenia, 2020).

The agricultural sector is divided into two main time periods. The first was from the beginning of the current century until 2013, when the economic sector was in good condition in terms of emissions. The second stage is not good, given that Slovenia is facing several events that affected the agricultural sector, most notably an outbreak of bark beetles similar to the case in the Czech Republic, in addition to ice storms. The government seeks to undertake early recovery operations directly through forest protection and nurturing projects in exchange for incentives and the provision of appropriate forest technology. In conjunction with these measures and to achieve the goal of reducing emissions from agriculture by one percent by 2030, Slovenia will support the shift of production from animal feed to human nutrition, and encourage shorter food supply chains (Pušnik, M., & Sučić, 2014; Government of the Republic of Slovenia, 2020).

The proportion of emissions from transport has increased as the most important component of the service sector in Slovenia. The percentage of emissions increased until 2019 by more than twenty-five percent in the share of total emissions, and this is mainly due to the people's shift to using private cars in a large way compared to public transportation. The mix of energy, industry and waste management had a similar situation with lower emissions from all of them (Pušnik, M., & Sučić, 2014; Government of the Republic of Slovenia, 2020).

The Swiss economy is generally considered distinguished, as the country's nominal per capita GDP is higher than the OECD average. The Swiss economy is diversified to include the services sector by approximately seventy percent, industry by twenty-five percent, and others. As is known, Switzerland does not belong to the European Union, but it is a key partner in both the European Free Trade Association and the Schengen Agreement. Looking at emissions between 1990 and 2020, it is clear that Switzerland has done a good job of reducing those emissions by eighteen percent, which is consistent with the results of our study. One of the most prominent reasons is due to the Carbon Dioxide Law, which obligated the state to work to reduce these emissions by twenty percent in 2020. Although Switzerland achieved its goal for the year 2020, sectors varied in reducing emissions. Emissions from the transportation and construction sectors were higher than expected, but reducing emissions beyond the target in the rest of the sectors overshadowed that. Switzerland seeks to reduce greenhouse gas emissions by fifty percent by 2030 (Swiss Federal Office of Energy 2019; 2020; 2021)

The transportation sector leads the other energy-using sectors in terms of greenhouse gas emissions with a rate of approximately forty-two percent, followed by buildings with a rate of thirty-four percent, and industry and electricity with a rate of sixteen and less than eight percent, respectively. This is due to the faster number of vehicles in Switzerland compared to public transportation. The government plans to move to electric mobility and popularize the idea of car sharing as measures to contribute to reducing emissions (Eidgenössische Energieforschung Kommission CORE, 2020; 2021; 2022; 2023; Swiss Federal Office of Energy 2019; 2020; 2021)

By the end of the second decade, oil was the main energy producer at a rate of approximately sixty-six percent, natural gas played a role at a rate of twenty-one percent, followed by waste at a rate of twelve percent, and the smallest was coal at a rate of approximately one percent. In the last two decades as a whole, Switzerland has sought to partially replace oil with natural gas as an energy source. Switzerland has provided an additional advantage for small and medium-sized energy-intensive companies to participate in the energy efficiency target agreement. This agreement grants the benefit of recovering additional fees and entitles companies to participate in energy saving projects. Residential buildings contribute to emissions because their heating comes from fossil fuels at a rate of approximately sixty percent, and electricity does not exceed eight percent (Kannan & Turton, 2016; SFOE, 2018; Balthasar, 2022; Eidgenössische Energieforschung Kommission CORE, 2020; 2021; 2022; 2023; Swiss Federal Office of Energy 2019; 2020; 2021).

4.6.Trend Analysis.

In this section, the researcher has used the Mann-Kendall test to detect any temporary changes in GHGs, CO2, N2O, and CH4 emissions. This is done so as to assess whether a set of data values is increasing or decreasing over time and whether this trend is significant in either direction the null hypothesis is that there is no trend, while the alternative hypothesis is that there is a trend.

4.6.1. GHGs

Table 4.13: Mann-Kendall for Trend Test for GHGs

Kendall's tau	-0.459
S	-8416.000
Var(S)	792520.667
p-value (Two-tailed)	< 0.0001
Alpha	0.05

Source: Author’s computations (2022).

According to the previous table, there is a notable trend in GHGs where the p-value <0.05.

4.6.2. CO_2

Table 4.14: Mann-Kendall for Trend Test for CO_2

Kendall's tau	-0.507
S	-9304.000
Var(S)	792522.667
p-value (Two-tailed)	< 0.0001
Alpha	0.05

Source: Author's computations (2022).

According to the previous table, there is a notable trend in CO_2 where the p-value <0.05.

4.6.3. N_2O

Table 4.15: Mann-Kendall for Trend Test for N_2O

Kendall's tau	-0.439
S	-8037.000
Var(S)	792473.667
p-value (Two-tailed)	< 0.0001
Alpha	0.05

Source: Author's computations (2022).

According to the previous table, there is a notable trend in N_2O where the p-value <0.05.

4.6.4. CH_4

Table 4.16: Mann-Kendall for Trend Test for CH_4

Kendall's tau	-0.533
S	-9762.000
Var(S)	792508.000
p-value (Two-tailed)	< 0.0001
Alpha	0.05

Source: Author's computations (2022).

According to the previous table, there is a notable trend in CH_4 where the p-value <0.05.

4.7.Recommendations

- Austria:

- Given the lack of completion of a law or legislation for the deployment of renewable energy similar to the Electricity Law, consider improving the economic conditions under which the establishment of existing and new hydroelectric power plants is permitted.
- Explaining the twelve key projects within the Austria 2030 plan to the Austrian people Awareness campaigns and early and targeted engagement with local communities to promote public acceptance and fundamental behavior change regarding transport and home heating.
- Creating price incentive systems that contribute to reducing fossil fuel consumption for both transportation and heating, and linking this to promoting renewable energy.
- One of the ideas of the current government in Austria is to undertake social and environmental tax reform, and therefore it is important to consider supporting the transportation sector by increasing support for zero-emission cars, increasing the progressive carbon dioxide consumption tax on inefficient vehicles, and evaluating the increase in the gasoline and diesel tax.
- Supporting the agricultural sector by focusing on supporting the future forestry program, which will contribute to more sustainable wood reserves in addition to increasing carbon sequestration on forest floors.

- Czech

- Work on the acceleration of the replacement of coal as an energy source than previously planned. Energy can be generated through the production of renewable and nuclear electricity.
- Develop a plan to train coal miners and workers in related companies benefiting from the European Union's Just Transition Fund for other jobs.
- Creating incentive mechanisms that help stimulate new investments in heat and power generation as an alternative to coal.
- Switch to more efficient heating systems by replacing coal boilers with renewable technologies. Benefiting from public support to renovate public buildings for energy-efficient renovation, including schools, hospitals, and others.

- Studying new legislation to promote the creation and support of renewable fuels that are not covered by Law 165/2012 to contribute to achieving effective emissions reductions.
- Support the dissemination of the use of electric vehicles, and implement the measures specified in the National Mobility Electrification Action Plan.
- Using natural gas as a primary alternative to coal, taking into account replacing natural gas with other renewable energy sources. In addition to enhancing natural gas security in the medium and long term for the Czech Republic by expanding Moravia's capabilities to enhance local transportation capacity.
- Ensuring the construction of new, third-generation nuclear projects, benefiting from experiences in OECD countries.
- Provide ČEZ with the supports and follow up the new construction project of the Dukovany II unit with strict standards to ensure the fundamental interests of the Czech Republic.
- It is necessary to continuously update the radioactive waste management and spent fuel management policy to ensure the maximum safe benefit from nuclear energy.

    ➢ Germany

- Motivating citizens to move to electric vehicles while enhancing public and multi-modal transportation options, ensuring a decrease in energy demand in transportation. Given the expectation that transportation will increase in the future, it is necessary to build new transportation lines to meet the needs.
- Re-evaluating the tax structure for traditional fuels in the transportation and heating sectors and working to change taxes and enhance incentives to facilitate the use of alternative fuels. Likewise, reviewing electricity taxes and fees so that they do not become an obstacle to the transition to renewable energy sources.
- Work on repairing existing buildings to achieve greater energy efficiency in existing buildings.
- As Germany continues to use natural gas, it supports the construction of liquefied natural gas terminals and facilitates connectivity to the natural gas supply chain. With an assessment of the transition to biogas/biomethane for supply to the heating and transportation sectors.

- Due to the closure of nuclear power reactors in Germany, it is necessary to work to safely end the remaining nuclear activities, which include dismantling and decommissioning, waste management, nuclear technology, research and development.

➢ Hungary:

- Accelerating the implementation of the renewable energy aid program, which aims to build new electricity generation units on the one hand, and implementing the PAX II project to increase nuclear energy by building two new units with a total installed capacity of 2,400 megawatts. Bringing the total number of units to six, which are supposed to cover a large portion of the electricity need until 2037.
- Expanding the "Green Bus" project launched in 2020, "which aims to replace half of public buses in Hungary with low-emission and zero-emission vehicles with a budget of 100 million euros," to include all public buses, thus contributing to reducing emissions in the largest emitter in the service sector.
- Starting to implement the plans that were previously taken regarding developing the infrastructure for alternative fuels. In addition to encouraging the local use and production of biofuels.

➢ Poland

- Activating the agreement between the miners' unions and the Polish government aimed at closing the last coal mine in 2049, in accordance with the "fair regional transition plan" issued by the Lodz region to end coal mining and close the Bełchatów coal-fired power plant.
- Investing in LNG and electricity infrastructure and switching to public and low-emission transport
- Construction of the six nuclear power plants scheduled by the Polish government in a manner consistent with the second version of nuclear power plants, which will contribute to providing a total of 1.6 gigawatts maximum by 2033 to be invested in electricity.
- Monitoring the implementation of the four standard reactors that KHGM seeks to implement with a capacity of seventy-seven megawatts to operate its operations as the second largest consumer of electricity in the country.

- Making amendments to the renewable energy goals for the year 2030 to add a greater contribution to solar photovoltaic energy to accelerate reaching the European Union goals.
    - Slovakia
- Evaluation of the waste prevention program that began in 2019 and is scheduled to end in 2025 to verify that the amount of mixed municipal waste has been reduced by half compared to the base year of 2016. Making the necessary repairs to the project and extending it.
- Support the purchase of environmentally friendly low-emission vehicles and create appropriate infrastructure for the development of electric mobility. In addition to encouraging biofuels in land transportation and implementing the government plan to provide a ten percent share of renewable energy sources for transportation.
- Financing and implementing a decarbonization proposal from the Steel Košice steel factory to replace coal-fired furnaces with electric furnaces, which reduces emissions by eighty percent for the largest steel factory in Central Europe.
    - Slovenia
- Approval of the implementation of the planned solar power station development project with Dravske elektrarne Maribor with a capacity of 30 MW.
- Accelerating the implementation of the Prapritno solar power station project, which will contribute 3 megawatts scheduled with the state holding company Slovenski Electrán.
- Monitor and evaluate the implementation of the 2021 ban on the use of fuel oil in new buildings; Stop selling and installing new fuel oil boilers in 2023.
- Imposing fees on vehicles entering cities, as well as creating financial incentives for the production of advanced biofuels.
    - Switzerland
- Evaluating the topics covered by the Carbon Dioxide Law and making appropriate amendments to address a broader period after 2030.
- Working to provide a law to support transportation by providing the environment and infrastructure for electric mobility on the one hand, and

amending fees for using the transportation network as a short and medium-term solution to motivate individuals to use it.

- Evaluating the distribution of renewable energy resources across sectors, for example shifting the use of biomass to vital industries that require relatively high temperatures instead of providing it for heating buildings, and finding a more durable solution for buildings.
- Given that natural gas is the first alternative to abandoning the use of fossil oil, medium and long-term planning is required to provide gas infrastructure and secure it according to energy horizons.

5. Conclusion

The whole world, most of which participated in the Paris Agreement, aims to reduce the global temperature rise to 1.5 degrees Celsius. clean and affordable energy" and "climate action", which together will ensure access to economic growth in the right way. The European Union countries were not satisfied with that agreement alone and the series of agreements and protocols that preceded it, but they crystallized all agreements to obtain the European Green Deal. The European Green Deal has a primary goal, which is by the year 2050 to bring the European Union to be the first climate-neutral bloc in the world (La Monaca, et al, 2019) In order to reach this long-term goal, these countries seek to reduce greenhouse gas emissions by 55%, which European countries consider a medium-term goal by 2030 (Wolf et.al, 2021).

The dissertation aims to investigate the impact of greenhouse gas emissions on economic growth in Central Europe. The dissertation was not satisfied with that, as it studied carbon dioxide, methane, and nitrous oxide emissions separately. To find out the contribution of greenhouse gas emissions and their main components "carbon dioxide, methane and nitrous oxide" to the economic growth of Central Europe. The results do not agree with the null hypothesis of this dissertation that "economic growth is significant and contributes significantly to emissions of greenhouse gases, carbon dioxide, and methane in Central Europe." The alternative hypothesis is accepted: economic growth is not significant and does not contribute significantly to GHG, CO2 and CH4 emissions in Central Europe. The postulated hypothesis and the results of this dissertation indicate a kind of agreement with (Gavrilyeva et al., 2020; Kumar et al., 2020; Lapinskienė et al., 2015).

Except for N2O, the overall output was positive throughout the study period. However, in order to have a complete picture that will aid in understanding where Central European countries stand and what they must do for their future, we must present the projections and plans of each nation separately, as well as how they are each contributing to the achievement of the Paris Agreement's and the European Green Deal's ultimate objectives.

All countries in the study seek to reach climate neutrality, but they differ in the maximum time required to achieve this, as Austria seeks to be the first to arrive in the year 2040, followed by countries one after another.

By taking countries individually for comparison and achieving the desired benefit from the research, during the study period, the agricultural sector in Austria contributed to an increase in emissions, mainly due to urban sprawl, which caused the country to lose large areas of soil. Emissions from the transport and industrial sectors have decreased, although emissions from transport are expected to increase due to the significant increase in distances travelled and refuelling in transit traffic, while Austria will convert half of its energy to renewable energy and all of its electricity to green electricity by 2030. In line with the case of Austria, the Czech Republic has reduced Its emissions in the service and industrial sectors increased in agriculture due to the outbreak of the bark beetle, which led to unprecedented deforestation. One of the most prominent reasons for the decline in emissions from industry is due to the decline of some heavy industries after the fall of communism. However, the Czech Republic still relies excessively on the use of fossil coal in its industries, and to achieve a green economy, the Czech Republic will seek to completely eliminate coal by 2038. Heating buildings also has a role in emissions, and the Czech Republic will work to take measures to replace coal boilers with sustainable environmental options, while working to Providing biofuels for transportation and increasing battery-powered electric vehicles and their accompanying charging points. Germany is the most prominent country in terms of the proportion of emissions in Europe. Emissions resulting from manufacturing and construction industries rose with the decline of all other forms of industry, which made emissions resulting from industry decrease. Similarly, transportation caused a slight increase in emissions, but the rest of the components of the service sector reduced their emissions, which led to a decrease in emissions from the total service sector. This was achieved due to the increased use of renewable energy, the shift from coal to gas. The last three nuclear power plants were closed. The government will work to develop organic agriculture, and work in more than one direction to close coal-fired power plants and provide better alternatives. The industrial sector in Hungary is similar to Germany in terms of emissions. Emissions from manufacturing and construction industries rose while all other forms of industry declined, making emissions from industry decrease. Emissions from the agricultural sector have increased due to the increased use of fertilizers, in addition to the mechanisms used to increase milk production for the increasing number of cows. In the services sector, transportation is a major cause of emissions. Hungary decided to focus on specific sectors to reduce emissions: electricity and industry. Poland's reality is consistent with the aforementioned countries, as it achieved a reduction in emissions from the industrial and service sectors in general. Going into details, as in the case of the Czech Republic and partly Germany, Poland relies mainly on coal as a primary source of energy, which gave the main cause of emissions, and transportation was the sub-sector of services that must be developed environmentally. Emissions from agriculture increased during the study period. Poland's priorities will be reducing coal's contribution to energy, creating liquefied natural gas infrastructure, and switching to non-existent, low-emission public transport. Slovakia is a major contributor to environmental agreements to reduce greenhouse gas emissions in Europe, as it works on various sectors to reduce greenhouse gas emissions. It launched an environmental strategy called "Green Slovakia" and provided government support to enhance investment in farms. It is based on nuclear energy and multiple renewable energy sources, and has taken distinctive measures to get rid of coal and lignite, which has contributed to reducing emissions in the industrial and service sectors. Slovenia, in addition to the Visegrad Group countries, has been conditionally allowed to increase emissions until 2020 in some sectors. Despite this, it has achieved an overall reduction in emissions over time. To obtain better results, Slovenia is working to replace its main source of energy, which is coal. By eliminating it completely by 2033. And replacing it in a similar way to neighboring countries through nuclear energy as the first option and distributing renewable energy, represented by biomass, solar energy, and hydroelectric energy, to various sectors, the first of which is the electricity sector, the second is heating, and the third is transportation. Regarding the agricultural sector, Slovenia suffered from the same environmental disaster as the Czech Republic, namely bark beetles, in addition to snow storms, which increased emissions resulting from the agricultural sector. The government seeks to carry out early recovery operations directly through forest protection and care projects in exchange for incentives and the provision of appropriate forest technology. Switzerland is distinguished by its carbon dioxide law, which obligates the state to work to reduce these emissions, which the state achieves, with variation in some sectors in reducing emissions. Emissions from the transport and construction sectors were higher than expected, which is the focus of Switzerland. With regard to energy, oil is the main energy product, natural gas is waste, the smallest of which is coal at a rate of approximately one percent. Switzerland has worked hard to partially replace oil with natural gas as an energy source through the targeted energy efficiency agreement (Federal Ministry for sustainability and tourism, 2019; Federal Ministry for sustainability and tourism and Federal Ministry for transport, 2018; IEA, 2020; Ministry of Industry and Trade, 2014; 2019; McKinsey Company, 2020; Rečka, Máca, & Ščasný, 2023; German Federal Government, 2019a; 2019b; 2020; Bart, Csernus & Sáfián, 2018; Vadovics, 2019; Hungary Ministry of Innovation and Technology, 2019;

Poland MINISTRY OF NATIONAL ASSETS, 2019; Polish Economic Institute, 2020, Poland Ministry of Climate and Environment, 2021; Centre for Climate and Energy Analyses, 2021; SLOVAK MINISTRY OF ECONOMY, 2019; Horváth, & Szemesová, 2023; Pušnik, M., & Sučić, 2014; Government of the Republic of Slovenia, 2020; Kannan & Turton, 2016; SFOE, 2018; Balthasar, 2022; Eidgenössische Energieforschung Kommission CORE, 2020; 2021; 2022; 2023; Swiss Federal Office of Energy 2019; 2020; 2021).

Czechia and Poland, two countries in central Europe, show that the electricity industry will only make modest improvement over the next ten years, which will have an effect on all the other economic sectors (Moore. 2020). Germany's 2030 transfer strategy has made slow progress. Coal is still anticipated to play a significant part in Germany's electricity mix in 2030, which contains relatively high proportions of fossil fuels (Moore. 2020; Date, et. al. 2019). By 2030, over 59% of all emissions from energy generation in the EU will originate in Germany, Poland, and the Czech Republic (Moore, 2020).

New wind and solar installations have begun in Poland and Czechia. Czechia will use renewable energy less aggressively over the next ten years. Along with the modest progress toward renewable and clean energy in the aforementioned nations, Poland and Germany will continue to burn coal after 2030 (Date, et. al. 2019). In addition to Czechia, Poland and Germany anticipate keeping 90% of the remaining coal-based electricity generation compared with the whole EU that will be used in both industry and agriculture sectors (Moore, 2020).

When burned, fossil fuels have an effect on the environment by producing carbon dioxide, and their extraction and transportation also contribute to the production of methane. Therefore, limiting its use will be the second priority after eliminating coal, although Germany will continue to utilize it at a second-place level between 2025 and 2030 (Moore, 2020).

Therefore, accelerating that deployment of wind and solar for Czechia, as well as phasing-out of nuclear energy, and replacing both nuclear and fossil fuels with a better energy in Germany will be a good solution to keep the economy growing with decreasing the emissions. Besides, a decrease of coal-based electricity generation is required before 2030 in Czechia, Poland, and Germany to reach the mid-term goal of European green deal. As an alternative plan, Germany Czechia, Austria, Slovakia, and Hungary needs to work more to have electricity generation from bioenergy mainly for Germany Czechia as they are not growing well with solar and wind energy (Moore, 2020).

Based on the overall results as well as where each country stands in the 2050 plan, clean energy, circular economy and Farm to Fork are the strategies required to be implemented & accelerated to reach the climate-neutral bloc (Kiselakova, et al. 2020).

comprehensive approach of 10Rs is fully describing what circular economy and how to can be implemented. A circular economy is described by the European Parliament as "a model of production and consumption that entails a process starts of sharing, reusing, until it reaches recycling existing materials and products which will extend the life cycle of items (European Parliament, 2015). Batteries, building and construction, ICT, plastics, and textiles are the five key pillars that the European Parliament's Circular Economic Action Plan (CEAP) was created to address. The complete consideration of these issues, in addition to putting the 10Rs into practice, will be a solution to further the circular economy transition. These topics include packaging, food, and water (World Business Council

for Sustainable Development, 2020).

The need to follow up on the findings of the technical committee of the International Organization for Standardization TC 323, which is concerned with developing the various fields of the circular economy and the laws and tools for developing methods of implementing and measuring the activities of all those concerned with the transition to the circular economy (ISO, n.d).

The “farm to fork” strategy is not only a strategy related to the sustainability of food, but also the way to obtain it in an environmentally friendly way. Rather, it extends to more than that to include the selection of appropriate agricultural materials, production methods, agricultural methods used, and the transportation process (Purnhagen et al., 2021 ;Wesseler, 2022). Based on the results of our analysis, the economies of Central European countries are affected by gas emissions, mainly nitrous oxide, which comes directly from the agricultural process and what is going on around it. Accordingly, it is necessary to adhere to the rapid and accurate implementation of the agreement, which is an important and vital part of the European Green Agreement by 2030, by converting a quarter of agriculture in the European Union in general, and mainly including Central European countries, into organic agriculture. It is accompanied by the elimination of fifty percent of the use of agricultural pesticides that are not environmentally friendly. In addition, reducing food waste by half, applying the recycling strategy, and using recycled products resulting from the actual application of the circular economy. Last but not least, the gradual disposal of 20 percent of non-environmentally friendly fertilizers, on top of which fertilizers that contain ammonia in their composition, has begun due to the huge energy required to produce this type of fertilizer. The continuation of research and development within this field is one of the most important recommendations in this sector for each country separately, as the European Union has allocated a budget of 10 billion euros for research operations related to this strategy (Food and Agriculture Organization, 2020; Moschitz, et al. 2021). In addition to this recommendation, it is necessary to study the cases of Germany, Poland and the Czech Republic separately, for the need to know the exact situation of those three countries with regard to their progress in implementing the European Green Agreement, which helps to provide recommendations to decision makers to know which sector to focus on.

6. References

Abdulai, A., & Ramcke, L. (2008, July). New Empirical Evidence for the Impact of Trade and Economic Growth on the Environment. In *DEGIT Conference Papers* (No. c013_022). DEGIT, Dynamics, Economic Growth, and International Trade.

Abid, M. (2017). Does economic, financial and institutional developments matter for environmental quality? A comparative analysis of EU and MEA countries. *Journal of environmental management*, *188*, 183-194.

Aboagye, S., Appiah-Konadu, P., & Acheampong, V. (2020). Economic expansion and environmental degradation in Ghana: a sector decomposition analysis. *African Journal of Economic Review*, *8*(1), 106-124.

ABSL. (2023). *Innovation in Poland's modern business services sector is on the rise*. https://absl.pl/en/news/p/innovation-polands-modern-business-services-sector-rise.

Acaravci, A., & Ozturk, I. (2010). On the relationship between energy consumption, CO2 emissions and economic growth in Europe. *Energy*, *35*(12), 5412-5420.

Active Sustainability. (2023). *METHANE IS THE SECOND MOST DANGEROUS GREENHOUSE GAS*. https://www.activesustainability.com/climate-change/methane-greenhouse-gas/?_adin=12033057740

Adopted, I. P. C. C. (2014). Climate change 2014 synthesis report. *IPCC: Geneva, Szwitzerland*.

Adzawla, W., Sawaneh, M., & Yusuf, A. M. (2019). Greenhouse gasses emission and economic growth nexus of sub-Saharan Africa. *Scientific African*, *3*, e00065.

Ahmad, A., Liu, Q. J., Nizami, S. M., Mannan, A., & Saeed, S. (2018). Carbon emission from deforestation, forest degradation and wood harvest in the temperate region of Hindukush Himalaya, Pakistan between 1994 and 2016. *Land use policy*, *78*, 781-790.

Ahmad, N., & Du, L. (2017). Effects of energy production and CO2 emissions on economic growth in Iran: ARDL approach. *Energy*, *123*, 521-537.

Ahmed, R., Sabau, G., & Haghiri, M. (2010). The long run relationship between economic growth and environmental quality. *Carbon*, *4*(5), 6.

Akande, A., Cabral, P., & Casteleyn, S. (2019). Assessing the gap between technology and the environmental sustainability of European cities. *Information systems frontiers*, *21*, 581-604.

Akbostancı, E., Türüt-Aşık, S., & Tunç, G. İ. (2009). The relationship between income and environment in Turkey: is there an environmental Kuznets curve?. *Energy policy*, *37*(3), 861-867.

Akenji, L., Bengtsson, M., Bleischwitz, R., Tukker, A., & Schandl, H. (2016). Ossified materialism: introduction to the special volume on absolute reductions in materials throughput and emissions. *Journal of Cleaner Production*, *132*, 1-12.

Almaz, F. (2021). Energy oriented management approach as a market activity tool in achieving competitive advantage. In *Strategic Approaches to Energy Management: Current Trends in Energy Economics and Green Investment* (pp. 231-241). Cham: Springer International Publishing.

Al-Mulali, U., Solarin, S. A., & Ozturk, I. (2016). Investigating the presence of the environmental Kuznets curve (EKC) hypothesis in Kenya: an autoregressive distributed lag (ARDL) approach. *Natural Hazards*, *80*, 1729-1747.

Altıntaş, H., & Kassouri, Y. (2020). Is the environmental Kuznets Curve in Europe related to the per-capita ecological footprint or CO2 emissions?. *Ecological indicators*, *113*, 106187.

And https://unctadstat.unctad.org/wds/TableViewer/tableView.aspx?ReportId=101

Andersson, D., & Nässén, J. (2016). Should environmentalists be concerned about materialism? An analysis of attitudes, behaviours and greenhouse gas emissions. *Journal of Environmental Psychology*, *48*, 1-11.

Andreucci, M. B., & Marvuglia, A. (2021). Investigating, implementing and funding regenerative urban design in a post-COVID-19 pandemic built environment: A reading through selected UN Sustainable Development Goals and the European Green Deal. In *Rethinking sustainability towards a regenerative economy* (pp. 395-413). Cham: Springer International Publishing.

Ang, J. B. (2008). Economic development, pollutant emissions and energy consumption in Malaysia. *Journal of Policy Modeling*, *30*(2), 271-278.

Ansuategi, A., & Escapa, M. (2002). Economic growth and greenhouse gas emissions. *Ecological Economics*, *40*(1), 23-37.

Antonakakis, N., Chatziantoniou, I., & Filis, G. (2017). Energy consumption, CO2 emissions, and economic growth: An ethical dilemma. *Renewable and Sustainable Energy Reviews*, *68*, 808-824.

Apergis, N., & Payne, J. E. (2010a). Renewable energy consumption and growth in Eurasia. *Energy economics*, *32*(6), 1392-1397.

Apergis, N., & Payne, J. E. (2010b). Renewable energy consumption and economic growth: evidence from a panel of OECD countries. *Energy policy*, *38*(1), 656-660.

Apergis, N., & Payne, J. E. (2014). The causal dynamics between renewable energy, real GDP, emissions and oil prices: evidence from OECD countries. *Applied Economics*, *46*(36), 4519-4525.

Ardente, F., & Mathieux, F. (2014). Identification and assessment of product's measures to improve resource efficiency: the case-study of an Energy using Product. *Journal of cleaner production*, *83*, 126-141.

Arellano, M., & Bond, S. (1991). Some tests of specification for panel data: Monte Carlo evidence and an application to employment equations. *The review of economic studies*, *58*(2), 277-297.

Armeanu, D., Vintilă, G., Andrei, J. V., Gherghina, Ş. C., Drăgoi, M. C., & Teodor, C. (2018). Exploring the link between environmental pollution and economic growth in EU-28 countries: Is there an environmental Kuznets curve?. *PloS one*, *13*(5), e0195708. https://doi.org/10.1371/journal.pone.0195708

Armeanu, D., Vintilă, G., Andrei, J. V., Gherghina, Ş. C., Drăgoi, M. C., & Teodor, C. (2018). Exploring the link between environmental pollution and economic growth in EU-28 countries: Is there an environmental Kuznets curve?. *PloS one*, *13*(5), e0195708.

Arora, S., Bhaukhandi, K. D., & Mishra, P. K. (2020). Coronavirus lockdown helped the environment to bounce back. *Science of the Total Environment*, *742*, 140573.

Aydin, C., Esen, Ö., & Aydin, R. (2019). Is the ecological footprint related to the Kuznets curve a real process or rationalizing the ecological consequences of the affluence? Evidence from PSTR approach. *Ecological indicators*, *98*, 543-555.

Azadeh, A. G. H. A. D. E. R. I., Ghaderi, S. F., & Sohrabkhani, S. (2008). Annual electricity consumption forecasting by neural network in high energy consuming industrial sectors. *Energy Conversion and management*, *49*(8), 2272-2278.

Azam, M., & Khan, A. Q. (2016). Testing the Environmental Kuznets Curve hypothesis: A comparative empirical study for low, lower middle, upper middle and high income countries. *Renewable and Sustainable Energy Reviews*, *63*, 556-567.

Azomahou, T., Laisney, F., & Van, P. N. (2006). Economic development and CO2 emissions: A nonparametric panel approach. *Journal of Public Economics*, *90*(6-7), 1347-1363.

Baek, J. (2015). Environmental Kuznets curve for CO2 emissions: the case of Arctic countries. *Energy Economics*, *50*, 13-17.

Bahadori, A., Zahedi, G., & Zendehboudi, S. (2013). An overview of Australia's hydropower energy: Status and future prospects. *Renewable and sustainable energy reviews*, *20*, 565-569.

Bakirtas, I., Bayrak, S., & Cetin, A. (2014). Economic growth and carbon emission: A dynamic panel data analysis. *European Journal of Sustainable Development*, *3*(4), 91-91.

Balthasar, A. (2022). Energy Governance in Switzerland. In *Handbook of Energy Governance in Europe* (pp. 1187-1215). Cham: Springer International Publishing.

Bano, S., Zhao, Y., Ahmad, A., Wang, S., & Liu, Y. (2018). Identifying the impacts of human capital on carbon emissions in Pakistan. *Journal of Cleaner Production*, *183*, 1082-1092.

Banski, J. (2008). Agriculture of Central Europe in the period of economic transformation. *Contemporary changes of agriculture in East-Central Europe*, 7.

Barbieri, L. (2009). Panel unit root tests under cross-sectional dependence: An overview. *Journal of Statistics: Advances in Theory and Applications*, *1*(2), 117-158.

Barde, J. P. (1994). Economic instruments in environmental policy: Lessons from the OECD experience and their relevance to developing economies.

Bart, I., Csernus, D., & Sáfián, F. (2018). Analysis of climate-energy policies & implementation in Hungary. *National Society of Conservationists—Friends of the Earth Hungary: Budapest, Hungary*.

Baxter, G., Sabatini, R., & Wild, G. (2015, May). Sustainable airport energy management: A case study of Copenhagen Airport. In *Proceedings of the International Symposium on Sustainable Aviation, Istanbul, Turkey* (Vol. 31).

Bayraç, H. N. (2010). KÜRESEL ENERJİ POLİTİKALARI VE TÜRKİYE: PETROL VE DOĞAL GAZ KAYNAKLARI AÇISINDAN BİR KARŞILAŞTIRMA. *Eskişehir Osmangazi Üniversitesi Sosyal Bilimler Dergisi*, *10*(1), 115-142.

Bayraç, H. N. (2018). Uluslararası doğalgaz piyasasının ekonomik yapısı ve uygulanan politikalar. *Eskişehir Osmangazi Üniversitesi İktisadi ve İdari Bilimler Dergisi*, *13*(3), 13-36.

Bektaş, A. (2021). The Impact of European Green Deal on Turkey's Iron and Steel Industry: Decomposition Analysis of Energy-Related Sectoral Emissions. *Celal Bayar University Journal of Science*, *17*(1), 17-29.

Bello, M. O., Solarin, S. A., & Yen, Y. Y. (2018). The impact of electricity consumption on CO2 emission, carbon footprint, water footprint and ecological footprint: the role of hydropower in an emerging economy. *Journal of environmental management*, *219*, 218-230.

Ben Jebli, M., Ben Youssef, S., & Ozturk, I. (2013). The environmental Kuznets curve: the role of renewable and non-Renewable energy consumption and trade openness.

Ben Jebli, M., Ben Youssef, S., & Ozturk, I. (2015). The role of renewable energy consumption and trade: Environmental kuznets curve analysis for sub-saharan Africa countries. *African Development Review*, *27*(3), 288-300.

BERD. (n.d.). *The EBRD in Poland: Overview*. https://www.ebrd.com/where-we-are/poland/overview.html.

Beşe, E., & Kalayci, S. (2021). Environmental Kuznets curve (EKC): empirical relationship between economic growth, energy consumption, and CO2 emissions: evidence from 3 developed countries. *Panoeconomicus*, *68*(4), 483-506.

Bilgili, F., Koçak, E., & Bulut, Ü. (2016). The dynamic impact of renewable energy consumption on CO2 emissions: a revisited Environmental Kuznets Curve approach. *Renewable and Sustainable Energy Reviews*, *54*, 838-845.

Boersch. (2022). *Eurozone economic outlook, December 2022*. Deloitte. https://www2.deloitte.com/us/en/insights/economy/emea/eurozone-economic-outlook.html

Bochniarz, Z., & Cohen, G. B. (Eds.). (2022). *The environment and sustainable development in the new Central Europe*. Berghahn Books.

Bollwahn, S. (2014). Storing manure on small farms–deciding on a storage option. In *Michigan State Univ*.

Bölük, G., & Mert, M. (2014). Fossil & renewable energy consumption, GHGs (greenhouse gases) and economic growth: Evidence from a panel of EU (European Union) countries. *Energy*, *74*, 439-446.

Bongardt, A., & Torres, F. (2018). Trade agreements and regional integration: the European Union after Brexit. In *Handbook of International Trade Agreements* (pp. 296-306). Routledge.

Bonoli, A., Zanni, S., & Serrano-Bernardo, F. (2021). Sustainability in building and construction within the framework of circular cities and european new green deal. The contribution of concrete recycling. *Sustainability*, *13*(4), 2139.

Bozkurt, C., & Okumuş, İ. (2019). Environmental Kuznets curve hypothesis in selected EU countries: Kyoto effect. *Balkans Journal of Emerging Trends in Social Sciences*, *2*(2), 134-139.

Bressanelli, G., Adrodegari, F., Perona, M., & Saccani, N. (2018). Exploring how usage-focused business models enable circular economy through digital technologies. *Sustainability*, *10*(3), 639.

Browne, G. (2021) Wildfires in Lebanon punish an already battered population. *The National News*. https://www.thenationalnews.com/mena/jordan/2021/11/15/wildfires-in-lebanon-punish-an-already-battered-population/

Busch, J., & Ferretti-Gallon, K. (2017). What drives deforestation and what stops it? A meta-analysis. *Review of Environmental Economics and Policy*.

Cai, Y., Sam, C. Y., & Chang, T. (2018). Nexus between clean energy consumption, economic growth and CO2 emissions. *Journal of cleaner production*, *182*, 1001-1011.

Canik, B., Çelik, M., & Arıgün, Z. (2000). Jeotermal enerji. *Ankara: AÜ FF Yayınları*.

Canova, F., & Ciccarelli, M. (2013). Panel Vector Autoregressive Models: A Survey☆ The views expressed in this article are those of the authors and do not necessarily reflect those of the ECB or the Eurosystem. In *VAR models in macroeconomics–new developments and applications: Essays in honor of Christopher A. Sims* (Vol. 32, pp. 205-246). Emerald Group Publishing Limited.

Carson, R. (1962). Silent spring (Greenwich) Fawcett publications.

Cederborg, J., & Snöbohm, S. (2016). Is there a relationship between economic growth and carbon dioxide emissions?. http://www.diva-portal.org/smash/get/diva2:1076315/FULLTEXT01.pdf

Centre for Climate and Energy Analyses. (2021). Poland net-zero 2050: the roadmap toward achievement of the EU climate policy goals in Poland by 2050.

Claeys, G., Tagliapietra, S., & Zachmann, G. (2019). *How to make the European Green Deal work* (Vol. 5). Brussels, Belgium: Bruegel.

Cobb, C. W., & Douglas, P. H. (1928). A theory of production.

Cole, M. A., Rayner, A. J., & Bates, J. M. (1997). The environmental Kuznets curve: an empirical analysis. *Environment and development economics*, *2*(4), 401-416.

Coondoo, D., & Dinda, S. (2002). Causality between income and emission: a country group-specific econometric analysis. *Ecological Economics*, *40*(3), 351-367.

Cooper, T. (Ed.). (2010). *Longer lasting products: Alternatives to the throwaway society*. Gower Publishing, Ltd..

Cramer, J. (2017). The raw materials transition in the Amsterdam metropolitan area: Added value for the Economy, Well-Being, and the Environment. *Environment: Science and Policy for Sustainable Development*, *59*(3), 14-21.

Crippa, M., Solazzo, E., Guizzardi, D., Monforti-Ferrario, F., Tubiello, F. N., & Leip, A. J. N. F. (2021). Food systems are responsible for a third of global anthropogenic GHG emissions. *Nature Food*, *2*(3), 198-209.

Cycles, T. (2020). Text Provides General Information S Assumes No Liability for the Information Given Being Complete or Correct D to Varying Update, Text SCDM Up-to-DDTR in the. Topic: Pharmaceuticals in India. Statista. *Topic: Essential Oils [Internet]. Statista*.

Date, R. P., Asia, N. O., & East, M. (2019). Global and Regional Coal Phase out Requirements of the Paris Agreement: Insights from the IPCC Special Report on 1.5 C. *Climate Analytics: Berlin, Germany*.

De Haes, H. U., & Van Rooijen, M. (2005). Life Cycle Approaches–The road from analysis to practice. *UNEP/SETAC Life Cycle Initiative*, *67*.

De Sy, V., Herold, M., Achard, F., Asner, G. P., Held, A., Kellndorfer, J., & Verbesselt, J. (2012). Synergies of multiple remote sensing data sources for REDD+ monitoring. *Current Opinion in Environmental Sustainability*, *4*(6), 696-706.

Despeisse, M., Baumers, M., Brown, P., Charnley, F., Ford, S. J., Garmulewicz, A., ... & Rowley, J. (2017). Unlocking value for a circular economy through 3D printing: A research agenda. *Technological Forecasting and Social Change*, *115*, 75-84.

Desrochers, P. (2001). Eco-industrial parks: the case for private planning. *The Independent Review*, *5*(3), 345-370.

Destek, M. A., Ulucak, R., & Dogan, E. (2018). Analyzing the environmental Kuznets curve for the EU countries: the role of ecological footprint. *Environmental Science and Pollution Research*, *25*, 29387-29396.

Díaz, S. M., Settele, J., Brondízio, E., Ngo, H., Guèze, M., Agard, J., ... & Zayas, C. (2019). The global assessment report on biodiversity and ecosystem services: Summary for policy makers.

Dietz, T., Rosa, E. A., & York, R. (2012). Environmentally efficient well-being: Is there a Kuznets curve?. *Applied Geography*, *32*(1), 21-28.

Dinçer, H. (2022). *Clean Energy Investments for Zero Emission Projects: An Analysis on How to Reduce the Carbon Footprint*. Springer Nature.

Dinda, S., Coondoo, D., & Pal, M. (2000). Air quality and economic growth: an empirical study. *Ecological Economics*, *34*(3), 409-423.

Dogan, E., & Seker, F. (2016). The influence of real output, renewable and non-renewable energy, trade and financial development on carbon emissions in the top renewable energy countries. *Renewable and Sustainable Energy Reviews*, *60*, 1074-1085.

Domingos, H. A., De Melo Faria, A. M., Fuinhas, J. A., & Marques, A. C. (2017). Renewable energy and greenhouse gas emissions from the waste sectors of European Union member states: a panel data analysis. *Environmental Science and Pollution Research*, *24*, 18770-18781.

Dougherty, C. (2016). Introduction to Econometrics, femte upplagan.

Doyle, B., Lowe, E. A., Moran, S. R., & Holmes, D. B. (1996). Fieldbook for the development of eco-Industrial parks'. *Indigo Development*.

Eckert, E., & Kovalevska, O. (2021). Sustainability in the European Union: Analyzing the discourse of the European green deal. *Journal of Risk and Financial Management*, *14*(2), 80.

ECOLEX (n.d.). *International Treaties, Environmental Laws and Conventions.* https://www.ecolex.org/result/?q=&type=treaty&xkeywords=climate+change&xdate_min=&xdate_max=

Eden, S. H., & Jin, J. C. (1992). Cointegration tests of energy consumption, income, and employment. *Resources and energy*, *14*(3), 259-266.

Eidgenössische Energieforschung Kommission CORE. (2020). *Jahresbericht 2019 Eidgenössische Energieforschung Kommission*

Eidgenössische Energieforschung Kommission CORE. (2021). *Jahresbericht 2020 Eidgenössische Energieforschung Kommission*

Eidgenössische Energieforschung *Kommission CORE*. (2022). *Jahresbericht 2021 Eidgenössische Energieforschung Kommission*

Eidgenössische Energieforschung Kommission CORE. (2023). *Jahresbericht 2022 Eidgenössische Energieforschung Kommission*

Elia, V., Gnoni, M. G., & Tornese, F. (2017). Measuring circular economy strategies through index methods: A critical analysis. *Journal of cleaner production*, *142*, 2741-2751.

Elkerbout, M., Egenhofer, C., Núñez Ferrer, J., Catuti, M., Kustova, I., & Rizos, V. (2020). The european green deal after corona: implications for eu climate policy. *CEPS Policy Insights*, *6*, 1-12.

Emissions, R. N. O., Farms, M. M. H., Ranch, F. M. M., Farms, N. R. D. J., Vineyard, P. R., Farming, S. P., ... & Ranch, J. T. L. W. Nitrous Oxide Emissions.

Erkman, S. (2001). Industrial ecology: A new perspective on the future of the industrial system. *Swiss medical weekly*, *131*(37-38), 531-538.

Esteve, V., & Tamarit, C. (2012). Threshold cointegration and nonlinear adjustment between CO2 and income: the environmental Kuznets curve in Spain, 1857–2007. *Energy economics*, *34*(6), 2148-2156.

EUROPEA. (2019). *Agriculture in the Czech Republic*. https://europea.org/agriculture-in-the-czech-republic/ .

European Central Bank. (2019). *Developments in the services sector and its relationship with manufacturing*.. https://www.ecb.europa.eu/pub/economic-bulletin/focus/2019/html/ecb.ebbox201907_02~860ce32c39.en.html

European Central Bank. (2022). *Structure of the euro area economy*. https://www.ecb.europa.eu/mopo/eaec/html/index.en.html.

European Commission. (2015). Closing the Loop – an EU Action Plan for the Circular Economy. http://eur-lex.europa.eu/resource.html?uri=cellar:8a8ef5e8-99a0-11e5- b3b7-01aa75ed71a1.0012.02/DOC_1&format=PDF.

European commission. (2020). *From Farm to Fork*. https://ec.europa.eu/commission/presscorner/detail/en/fs_19_6727 .

European Commission. (2023). *Switzerland– Energy policy review*.

European Commission. (n.d.a). Agriculture by country https://agriculture.ec.europa.eu/cap-my-country/performance-agricultural-policy/agriculture-country_en

European commission. (n.d.b). *COMMUNICATION FROM THE COMMISSION TO THE EUROPEAN PARLIAMENT, THE EUROPEAN COUNCIL, THE COUNCIL, THE EUROPEAN ECONOMIC AND SOCIAL COMMITTEE AND THE COMMITTEE OF THE REGIONS The European Green Deal.* https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52021DC0550

European Environment Agency. (2020). *Annual European Union greenhouse gas inventory 1990–2018 and inventory report 2020 – Submitted to the UNFCCC.* https://www.eea.europa.eu//publications/european-union-greenhouse-gas-inventory-2020

European Environment Agency. (2021) *Annual European Union greenhouse gas inventory 1990–2020 and inventory report 2021 Submission to the UNFCCC Secretariat.* Annual European Union greenhouse gas inventory 1990–2019 and inventory report 2021 — European Environment Agency (europa.eu)

European Environment Agency. (2022) *Annual European Union greenhouse gas inventory 1990–2020 and inventory report 2022 Submission to the UNFCCC Secretariat.* Annual European Union greenhouse gas inventory 1990-2020 and inventory report 2022 — European Environment Agency (europa.eu)

European Environment Agency. (2023) *Greenhouse gases viewer.* https://www.eea.europa.eu/data-and-maps/data/data-viewers/greenhouse-gases-viewer

European Parliament. (2015). *Circular economy: definition, importance and benefits.* https://www.europarl.europa.eu/news/en/headlines/economy/20151201STO05603/circular-economy-definition-importance-and-benefits.

European Parliament. (n.d.). European Climate Law enshrining the 2050 climate neutrality objective | Legislative Train Schedule L https://www.europarl.europa.eu/legislative-train/theme-environment-public-health-and-food-safety-envi/file-european-climate-law

European Union. (n.d.) *Facts and figures, EU economy | European Union.* https://european-union.europa.eu/principles-countries-history/key-facts-and-figures/economy_en

European Union's Common Agricultural Policy. (2023). *EU's CAP is central to the EU Green Deal & its F2F and Biodiversity strategies.* https://eu-cap-network.ec.europa.eu/common-agricultural-policy-overview_en.

Eurostat. (2022). *CO2 emissions from energy use up by more than 6% in 2021.* CO2 emissions from energy use up by more than 6% in 2021 - Products Eurostat News - Eurostat (europa.eu)

Eurostat. (2023). *Greenhouse gas emission statistics - emission inventories.* Greenhouse gas emission statistics - emission inventories - Statistics Explained (europa.eu).

Everett, R. (2004). Solar thermal energy.

Fang, Y., Côté, R. P., & Qin, R. (2007). Industrial sustainability in China: Practice and prospects for eco-industrial development. *Journal of environmental management*, *83*(3), 315-328.

Farzin, Y. H., & Bond, C. A. (2006). Democracy and environmental quality. *Journal of Development Economics*, *81*(1), 213-235.

Federal Ministry for sustainability and tourism and Federal Ministry for transport. (2018). *innovation and technology, #mission2030 – Austrian climate and energy strategy*.

Federal Ministry for sustainability and tourism. (2019) *Integrated National Energy and Climate Plan for*

Ferguson, M. E., & Souza, G. C. (2010). Commentary on closed-loop supply chains. *Closed loop supply chains: new developments to improve the sustainability of business practices. Taylor and Francis/CRC Press, Boca Raton*, 1-6.

Fetting, C. (2020). The European Green Deal. *ESDN Report, December*.

Firestone, M. K., & Tiedje, J. M. (1979). Temporal change in nitrous oxide and dinitrogen from denitrification following onset of anaerobiosis. *Applied and Environmental Microbiology*, *38*(4), 673-679.

Focus Economics. (2015). *Central & Eastern Europe Economic Outlook.* https://www.focus-economics.com/regions/central-and-eastern-europe.

Fontes, C. H. D. O., & Freires, F. G. M. (2018). Sustainable and renewable energy supply chain: A system dynamics overview. *Renewable and Sustainable Energy Reviews*, *82*, 247-259.

Food and Agriculture Organization. (2020). *Farm to Fork strategy.*https://www.fao.org/family-farming/detail/en/c/1402354/ or Wayback Machine (archive.org) .

Food and Agriculture Organization. (n.d.). *FAO and EU Partnership.* http://www.fao.org/europeanunion/en

Fosten, J., Morley, B., & Taylor, T. (2012). Dynamic misspecification in the environmental Kuznets curve: evidence from CO2 and SO2 emissions in the United Kingdom. *Ecological Economics*, *76*, 25-33.

Frumkin, H. (Ed.). (2016). *Environmental health: from global to local*. John Wiley & Sons. https://www.odi.org/sites/odi.org.uk/files/odi-assets/publications-opinion-files/9938.pdf

Fujii, H., & Managi, S. (2013). Which industry is greener? An empirical study of nine industries in OECD countries. *Energy Policy*, *57*, 381-388.

Fura, B., Stec, M., & Miś, T. (2020). Statistical evaluation of the level of development of circular economy in European Union member countries. *Energies*, *13*(23), 6401.

Galeotti, M., Lanza, A., & Pauli, F. (2006). Reassessing the environmental Kuznets curve for CO2 emissions: A robustness exercise. *Ecological economics*, *57*(1), 152-163.

Garrido, F., Hénault, C., Gaillard, H., Perez, S., & Germon, J. C. (2002). N2O and NO emissions by agricultural soils with low hydraulic potentials. *Soil Biology and Biochemistry*, *34*(5), 559-575.

Gavrilyeva, T., Sugimoto, A., Bochkarev, N., Stepanova, N., Nogovitcyn, A., & Semenova, L. (2020). Economy-related green-house gases emissions and validation of the environmental Kuznets curve for Sakha Republic (Yakutia). *Polar Science*, *23*, 100507.

Geels, F. W., & Schot, J. (2007). Typology of sociotechnical transition pathways. *Research policy*, *36*(3), 399-417.

Geist, H. J., & Lambin, E. F. (2002). Proximate Causes and Underlying Driving Forces of Tropical DeforestationTropical forests are disappearing as the result of many pressures, both local and regional, acting in various combinations in different geographical locations. *BioScience*, *52*(2), 143-150.

German *Federal Government, Federal. (2019b). Climate Change Act.*

German *Federal Government. (2019a) Climate action programme 2030.*

German Federal Government. (2020). *Integrated national energy and climate plan.*

Geyer, R., Kuczenski, B., Zink, T., & Henderson, A. (2016). Common misconceptions about recycling. *Journal of Industrial Ecology*, *20*(5), 1010-1017.

Ghisellini, P., Cialani, C., & Ulgiati, S. (2016). A review on circular economy: the expected transition to a balanced interplay of environmental and economic systems. *Journal of Cleaner production*, *114*, 11-32.

Gibbs, D., & Deutz, P. (2007). Reflections on implementing industrial ecology through eco-industrial park development. *Journal of Cleaner Production*, *15*(17), 1683-1695.

Ginevičius, R., Lapinskienė, G., & Peleckis, K. (2017). The evolution of the environmental Kuznets curve concept: The review of the research. *Panoeconomicus*, *64*(1), 93-112.

Government of the Republic of Slovenia. (2020). *Integrated national energy and climate plan of the Republic of Slovenia.*

Gozgor, G. (2017). Does trade matter for carbon emissions in OECD countries? Evidence from a new trade openness measure. *Environmental Science and Pollution Research*, *24*(36), 27813-27821.

Graedel, T. E., Allwood, J., Birat, J. P., Buchert, M., Hagelüken, C., Reck, B. K., ... & Sonnemann, G. (2011). What do we know about metal recycling rates?. *Journal of Industrial Ecology*, *15*(3), 355-366.

Granger, C. W. (1969). Investigating causal relations by econometric models and cross-spectral methods. *Econometrica: journal of the Econometric Society*, 424-438.

Granli, T., & Bøckman, O. C. (1995). Nitrous oxide (N 2 O) emissions from soils in warm climates. *Fertilizer research*, *42*, 159-163.

Grecu, E., Aceleanu, M. I., & Albulescu, C. T. (2018). The economic, social and environmental impact of shale gas exploitation in Romania: a cost-benefit analysis. *Renewable and Sustainable Energy Reviews*, *93*, 691-700.

Green, M. (2018, November 30). *The global goals we've made progress on and the ones we haven't*. TEDx [Video]. YouTube. https://www.youtube.com/watch?v=N3SQlrmV1cE

Grossman, G. M., & Krueger, A. B. (1991). Environmental impacts of a North American free trade agreement.

Guide Jr, V. D. R. (2000). Production planning and control for remanufacturing: industry practice and research needs. *Journal of operations Management*, *18*(4), 467-483.

Hafner, M., & Raimondi, P. P. (2020). Priorities and challenges of the EU energy transition: From the European Green Package to the new Green Deal. *Russian Journal of Economics*, *6*(4), 374-389.

Hainsch, K., Löffler, K., Burandt, T., Auer, H., del Granado, P. C., Pisciella, P., & Zwickl-Bernhard, S. (2022). Energy transition scenarios: What policies, societal attitudes, and technology developments will realize the EU Green Deal?. *Energy*, *239*, 122067.

Hainsch, K., Löffler, K., Burandt, T., Auer, H., del Granado, P. C., Pisciella, P., & Zwickl-Bernhard, S. (2022). Energy transition scenarios: What policies, societal attitudes, and technology developments will realize the EU Green Deal?. *Energy*, *239*, 122067.

Hajko, V., Sebri, M., Al-Saidi, M., & Balsalobre-Lorente, D. (2018). The energy-growth nexus: history, development, and new challenges. In *The economics and econometrics of the energy-growth nexus* (pp. 1-46). Academic Press.

Halkos, G. E. (2011). Environmental pollution and economic development: explaining the existence of an environmental Kuznets curve. *Journal of Applied Economic Sciences (JAES)*, *6*(16), 148-159.

Hamit-Haggar, M. (2012). Greenhouse gas emissions, energy consumption and economic growth: A panel cointegration analysis from Canadian industrial sector perspective. *Energy Economics*, *34*(1), 358-364.

Hansen, M. C., Potapov, P. V., Moore, R., Hancher, M., Turubanova, S. A., Tyukavina, A., ... & Townshend, J. (2013). High-resolution global maps of 21st-century forest cover change. *science*, *342*(6160), 850-853.

Harris, R. D., & Tzavalis, E. (1999). Inference for unit roots in dynamic panels where the time dimension is fixed. *Journal of econometrics*, *91*(2), 201-226.

Hartley, K., van Santen, R., & Kirchherr, J. (2020). Policies for transitioning towards a circular economy: Expectations from the European Union (EU). *Resources, Conservation and Recycling*, *155*, 104634.

Haupt, M., & Zschokke, M. (2017). How can LCA support the circular economy?—63rd discussion forum on life cycle assessment, Zurich, Switzerland, November 30, 2016. *The International Journal of Life Cycle Assessment*, *22*, 832-837.

Herrera, V. (2019). Reconciling global aspirations and local realities: Challenges facing the Sustainable Development Goals for water and sanitation. *World Development*, *118*, 106-117.

Herrera, V. (2019). Reconciling global aspirations and local realities: Challenges facing the Sustainable Development Goals for water and sanitation. *World Development*, *118*, 106-117.

Hervieux, M. S., & Darné, O. (2013). Environmental Kuznets curve and ecological footprint: a time series analysis.

Hettiarachchi, V. C., Hettiaratchi, P. J., Mehrotra, A. K., & Kumar, S. (2011). Field-scale operation of methane biofiltration systems to mitigate point source methane emissions. *Environmental pollution*, *159*(6), 1715-1720.

Horváth, J., & Szemesová, J. (2023). Is a Carbon-Neutral Pathway in Road Transport Possible? A Case Study from Slovakia. *Sustainability*, *15*(16), 12246.

Hu, K., Raghutla, C., Chittedi, K. R., Zhang, R., & Koondhar, M. A. (2021). The effect of energy resources on economic growth and carbon emissions: A way forward to carbon neutrality in an emerging economy. *Journal of Environmental Management*, *298*, 113448.

Hungary Ministry of Innovation and Technology. (2019). *National energy and climate plan.*

Huysman, S., De Schaepmeester, J., Ragaert, K., Dewulf, J., & De Meester, S. (2017). Performance indicators for a circular economy: A case study on post-industrial plastic waste. *Resources, conservation and recycling*, *120*, 46-54.

Chang, J., Peng, S., Ciais, P., Saunois, M., Dangal, S. R., Herrero, M., ... & Bousquet, P. (2019). Revisiting enteric methane emissions from domestic ruminants and their δ13CCH4 source signature. *Nature Communications*, *10*(1), 3420.

Choi, I. (2001). Unit root tests for panel data. *Journal of international money and Finance*, *20*(2), 249-272.

IEEP. (2021). How can taxes and other economic instruments help to make polluters pay? https://ieep.eu/publications/how-can-taxes-and-other-economic-instruments-help-to-make-polluters-pay/.

International Energy Agency. (2013). *Technology Roadmap - Wind Energy 2013.* https://www.iea.org/reports/technology-roadmap-wind-energy-2013

International Energy Agency. (2020). *Assessment of the final national energy and climate plan of Austria, SWD(2020) 919 final.*

International Energy Agency. (2021). *CO2 Emissions in 2021 – Analysis.* https://www.iea.org/reports/global-energy-review-co2-emissions-in-2021-2

International Energy Agency. (2021). *Global Energy Review 2021.* https://www.iea.org/reports/global-energy-review-2021

International Energy Agency. (2022a) *Global Energy Review: CO2 Emissions in 2021*. https://www.iea.org/reports/global-energy-review-co2-emissions-in-2021-2

International Energy Agency. (2022b). *Methane emissions from the energy sector are 70% higher than official figures.* https://www.iea.org/reports/global-methane-tracker-2022

International Energy Agency. (2022c). Electric Vehicles Initiative – Programme. https://www.iea.org/programmes/electric-vehicles-initiative

International Energy Agency. (2022d). The Clean Energy Ministerial Hydrogen Initiative. https://www.iea.org/programmes/cem-hydrogen-initiative

International *Energy Agency. (2022e). EU4Energy – Programme.* https://www.iea.org/programmes/eu4energy

International Monetary Fund. (2019). *2019 annual report.* https://www.imf.org/external/pubs/ft/ar/2019/eng/

International Monetary Fund. (2020). *2020 annual report.* https://www.imf.org/external/pubs/ft/ar/2020/eng/

International Monetary Fund. (2021a). *2021 annual report.* https://www.imf.org/external/pubs/ft/ar/2021/eng/

International Monetary Fund. (2021b). World economic outlook October 2021. https://www.imf.org/en/Publications/WEO/Issues/2021/10/12/world-economic-outlook-october-2021.

International Monetary Fund. (2022). *World economic outlook January 2022*. https://www.imf.org/en/Publications/WEO/Issues/2022/01/25/world-economic-outlook-update-january-2022#Overview

International Organization for Standardization. (n.d.). *ISO/TC 323 - Circular economy*. https://www.iso.org/committee/7203984.html

International Trade Administration. (2018). *EU - Country Commercial Guide - Trade Agreements.* EU - Trade Agreements

Investment Forum. (2021). *Central Europe overview*. Central Europe Overview | Investment Forum (investincentraleurope.com).

Inyang, M. P., & Esohe, K. P. (2014). Deforestations, environmental sustainability and health implications in Nigeria: A review. *International Journal of Science, Environment and Technology*, *3*(2), 502-517.

IPCC. (2006). *Guidelines for National Greenhouse Gas Inventories.* https://www.ipcc.ch/report/2006-ipcc-guidelines-for-national-greenhouse-gas-inventories/

IPPC. (2022). The Evidence is Clear: The Time for Action is Now. We Can Halve Emissions by 2030.

Isik, C., Dogru, T., & Turk, E. S. (2018). A nexus of linear and non-linear relationships between tourism demand, renewable energy consumption, and economic growth: Theory and evidence. *International Journal of Tourism Research*, *20*(1), 38-49.

Iwata, H., Okada, K., & Samreth, S. (2010). Empirical study on the environmental Kuznets curve for CO2 in France: the role of nuclear energy. *Energy policy*, *38*(8), 4057-4063.

Jalil, A., & Mahmud, S. F. (2009). Environment Kuznets curve for CO2 emissions: a cointegration analysis for China. *Energy policy*, *37*(12), 5167-5172.

Jawahir, I. S., & Bradley, R. (2016). Technological elements of circular economy and the principles of 6R-based closed-loop material flow in sustainable manufacturing. *Procedia Cirp*, *40*, 103-108.

JJL. (2020). *Business services sector in Poland 2020.* https://www.jll.pl/en/trends-and-insights/research/business-services-sector-in-poland.

Kandt, A., & Romero, R. (2014). *Implementing Solar Technologies at Airports* (No. NREL/TP-7A40-62349). National Renewable Energy Lab.(NREL), Golden, CO (United States).

Kannan, N., & Vakeesan, D. (2016). Solar energy for future world:-A review. *Renewable and sustainable energy reviews*, *62*, 1092-1105.

Kannan, R., & Turton, H. (2016). Long term climate change mitigation goals under the nuclear phase out policy: The Swiss energy system transition. *Energy Economics*, *55*, 211-222.

Kao, C. (1999). Spurious regression and residual-based tests for cointegration in panel data. *Journal of econometrics*, *90*(1), 1-44.

Kaplan, S. (2016). By 2050, there will be more plastic than fish in the world's oceans, study says. *The Washington Post*, *20*.

Karagöl, E. T., & Kavaz, İ. (2017, October). Kaya gazı devrimi: küresel enerji piyasalarındaki yansımaları ve Türkiye'deki geleceği. In *ICPESS (International Congress on Politic, Economic and Social Studies)* (No. 3).

Karagöl, E. T., & Kavaz, İ. (2017, October). Kaya gazı devrimi: küresel enerji piyasalarındaki yansımaları ve Türkiye'deki geleceği. In *ICPESS (International Congress on Politic, Economic and Social Studies)* (No. 3).

Kasman, A., & Duman, Y. S. (2015). CO2 emissions, economic growth, energy consumption, trade and urbanization in new EU member and candidate countries: a panel data analysis. *Economic modelling*, *44*, 97-103.

Kasman, A., & Duman, Y. S. (2015). CO2 emissions, economic growth, energy consumption, trade and urbanization in new EU member and candidate countries: a panel data analysis. *Economic modelling*, *44*, 97-103.

Kendall, M. G. (1975). Rank correlation methods, London: Charles Griffin & Co.

Kingori, S. W. (2012). Environmental degradation and economic growth in Kenya: an ARDL *bounds testing approach* (Doctoral dissertation, University of Nairobi, Kenya).

Kirchherr, J., Piscicelli, L., Bour, R., Kostense-Smit, E., Muller, J., Huibrechtse-Truijens, A., & Hekkert, M. (2018). Barriers to the circular economy: Evidence from the European Union (EU). *Ecological economics*, *150*, 264-272.

Kirchherr, J., Reike, D., & Hekkert, M. (2017). Conceptualizing the circular economy: An analysis of 114 definitions. *Resources, conservation and recycling*, *127*, 221-232.

Kiselakova, D., Stec, M., Grzebyk, M., & Sofrankova, B. (2020). A Multidimensional Evaluation of the Sustainable Development of European Union Countries—An Empirical Study. *Journal of Competitiveness*, *12*(4), 56-73.

Kiuila, O. (2018). Decarbonisation perspectives for the Polish economy. *Energy Policy*, *118*, 69-76.

Kougias, I., Taylor, N., Kakoulaki, G., & Jäger-Waldau, A. (2021). The role of photovoltaics for the European Green Deal and the recovery plan. *Renewable and Sustainable Energy Reviews*, *144*, 111017.

Kraft, J., & Kraft, A. (1978). On the relationship between energy and GNP. *The Journal of Energy and Development*, 401-403.

Kułyk, P., & Augustowski, Ł. (2020). Conditions of the occurrence of the environmental Kuznets curve in agricultural production of Central and Eastern European countries. *Energies*, *13*(20), 5478.

Kumar, P., Adelodun, A. A., Khan, M. F., Krisnawati, H., & Garcia-Menendez, F. (2020). Towards an improved understanding of greenhouse gas emissions and fluxes in tropical peatlands of Southeast Asia. *Sustainable Cities and Society*, *53*, 101881.

Kurrer, C. (2021) Environment policy: general principles and basic framework. European Parliament.: https://www.europarl.europa.eu/factsheets/en/sheet/71/environment-policy-general-principles-and-basic-framework#:~:text=European%20environment%20policy%20rests%20on,all%20areas%20of%20environment%20policy.

La Monaca, S., Spector, K., & Kobus, J. (2019). Financing the green transition. *Journal of International Affairs*, *73*(1), 17-32.

LaBelle, M. C., Bucată, R., & Stojilovska, A. (2021). Radical energy justice: a Green Deal for Romanian coal miners?. *Journal of Environmental Policy & Planning*, 1-13.

Ladanai, S., & Vinterbäck, J. (2009). Global potential of sustainable biomass for energy.

Lapinskienė, G., Peleckis, K., & Radavičius, M. (2015). Economic development and greenhouse gas emissions in the European Union countries. *Journal of Business Economics and Management*, *16*(6), 1109-1123.

Lapinskienė, G., Peleckis, K., & Slavinskaitė, N. (2017). Energy consumption, economic growth and greenhouse gas emissions in the European Union countries. *Journal of Business Economics and Management*, *18*(6), 1082-1097.

Lapinskienė, G., Peleckis, K., & Slavinskaitė, N. (2017). Energy consumption, economic growth and greenhouse gas emissions in the European Union countries. *Journal of Business Economics and Management*, *18*(6), 1082-1097.

Lapinskienė, G., Tvaronavičienė, M., & Vaitkus, P. (2014). Greenhouse gases emissions and economic growth–evidence substantiating the presence of environmental Kuznets curve in the EU. *Technological and economic development of economy*, *20*(1), 65-78.

Lee, B. X., Kjaerulf, F., Turner, S., Cohen, L., Donnelly, P. D., Muggah, R., ... & Gilligan, J. (2016). Transforming our world: implementing the 2030 agenda through sustainable development goal indicators. *Journal of public health policy*, *37*, 13-31.

Leip, A., Achermann, B., Billen, G., Bleeker, A., Bouwman, A., de Vries, W., ... & Winiwarter, W. (2011). Integrating nitrogen fluxes at the European scale.

Leip, A., Britz, W., Weiss, F., & de Vries, W. (2011). Farm, land, and soil nitrogen budgets for agriculture in Europe calculated with CAPRI. *Environmental pollution*, *159*(11), 3243-3253.

Leonard, M., Pisani-Ferry, J., Shapiro, J., Tagliapietra, S., & Wolff, G. B. (2021). *The geopolitics of the European green deal* (No. 04/2021). Bruegel Policy Contribution.

Levin, A., Lin, C. F., & Chu, C. S. J. (2002). Unit root tests in panel data: asymptotic and finite-sample properties. *Journal of econometrics*, *108*(1), 1-24.

Lewandowski, M. (2016). Designing the business models for circular economy—Towards the conceptual framework. *Sustainability*, *8*(1), 43.

Liao, H., & Cao, H. S. (2013). How does carbon dioxide emission change with the economic development? Statistical experiences from 132 countries. *Global Environmental Change*, *23*(5), 1073-1082.

Lindström, J., Hermanson, A., Blomstedt, F., & Kyösti, P. (2018). A multi-usable cloud service platform: A case study on improved development pace and efficiency. *Applied Sciences*, *8*(2), 316.

Lisjak, J., Schade, S., & Kotsev, A. (2017). Closing data gaps with citizen science? Findings from the Danube region. *ISPRS International Journal of Geo-Information*, *6*(9), 277.

Lokupitiya, E., & Paustian, K. (2006). Agricultural soil greenhouse gas emissions: a review of national inventory methods. *Journal of Environmental Quality*, *35*(4), 1413-1427.
Lokupitiya, E., & Paustian, K. (2006). Agricultural soil greenhouse gas emissions: a review of national inventory methods. *Journal of Environmental Quality*, *35*(4), 1413-1427.
Lu, W. C. (2017). Greenhouse gas emissions, energy consumption and economic growth: A panel cointegration analysis for 16 Asian countries. *International journal of environmental research and public health*, *14*(11), 1436.

MacArthur, E. (2013). Towards the circular economy. *Journal of Industrial Ecology*, *2*(1), 23-44.

MacArthur, E. (n.d.). *What is a circular economy*?. What is a circular economy? | Ellen MacArthur Foundation

Mafakheri, F., & Nasiri, F. (2014). Modeling of biomass-to-energy supply chain operations: Applications, challenges and research directions. *Energy policy*, *67*, 116-126.

Magazzino, C. (2012). Wagner versus Keynes: Public spending and national income in Italy. *Journal of Policy Modeling*, *34*(6), 890-905.

Magazzino, C. (2016). The relationship between CO2 emissions, energy consumption and economic growth in Italy. *International Journal of Sustainable Energy*, *35*(9), 844-857.

Magazzino, C. (2017a). Renewable energy consumption-economic growth nexus in Italy. *International Journal of Energy Economics and Policy*, *7*(6), 119-127.

Magazzino, C. (2017b). The relationship among economic growth, CO2 emissions, and energy use in the APEC countries: a panel VAR approach. *Environment Systems and Decisions*, *37*(3), 353-366.

Magazzino, C. (2018). GDP, energy consumption and financial development in Italy. *International Journal of Energy Sector Management*, *12*(1), 28-43.

Magazzino, C., Mele, M., & Schneider, N. (2020). The relationship between municipal solid waste and greenhouse gas emissions: Evidence from Switzerland. *Waste Management*, *113*, 508-520.

Magazzino, C., Mele, M., Schneider, N., & Sarkodie, S. A. (2021). Waste generation, wealth and GHG emissions from the waste sector: Is Denmark on the path towards circular economy?. *Science of the Total Environment*, *755*, 142510.

Mahmood, H., Alkhateeb, T. T. Y., & Furqan, M. (2020). Industrialization, urbanization and CO2 emissions in Saudi Arabia: Asymmetry analysis. *Energy Reports*, *6*, 1553-1560.

Maji, I. K., Sulaiman, C., & Abdul-Rahim, A. S. (2019). Renewable energy consumption and economic growth nexus: A fresh evidence from West Africa. *Energy Reports*, *5*, 384-392.

Managing Methane in the Waste Sector. https://rmi.org/our-work/climate-intelligence/managing-methane-in-the-waste-sector/

Mann, H. B. (1945). Nonparametric tests against trend. *Econometrica: Journal of the econometric society*, 245-259.

Marinaş, M. C., Dinu, M., Socol, A. G., & Socol, C. (2018). Renewable energy consumption and economic growth. Causality relationship in Central and Eastern European countries. *PloS one*, *13*(10), e0202951.

Markandya, A., Pedroso-Galinato, S., & Streimikiene, D. (2006). Energy intensity in transition economies: is there convergence towards the EU average?. *Energy Economics*, *28*(1), 121-145.

Marrero, G. A. (2010). Greenhouse gases emissions, growth and the energy mix in Europe. *Energy economics*, *32*(6), 1356-1363.

Mazzanti, M., & Zoboli, R. (2009). Municipal waste Kuznets curves: evidence on socio-economic drivers and policy effectiveness from the EU. *Environmental and Resource Economics*, *44*, 203-230.

Mbah, R. E., & Wasum, D. F. (2022). Russian-Ukraine 2022 War: A review of the economic impact of Russian-Ukraine crisis on the USA, UK, Canada, and Europe. *Advances in Social Sciences Research Journal*, *9*(3), 144-153. https://doi.org/10.14738/assrj.93.12005

McKinsey & Company. (2020). *Pathways to decarbonize the Czech Republic - Carbon-neutral Czech Republic 2050.*

McMichael, A. J., Woodruff, R. E., & Hales, S. (2006). Climate change and human health: present and future risks. *The Lancet*, *367*(9513), 859-869.

Mehrara, M. (2007). Energy consumption and economic growth: the case of oil exporting countries. *Energy policy*, *35*(5), 2939-2945.

Melikoglu, M. (2017). Geothermal energy in Turkey and around the World: A review of the literature and an analysis based on Turkey's Vision 2023 energy targets. *Renewable and Sustainable Energy Reviews*, *76*, 485-492.

Menegaki, A. N. (2011). Growth and renewable energy in Europe: A random effect model with evidence for neutrality hypothesis. *Energy economics*, *33*(2), 257-263.

Menyah, K., & Wolde-Rufael, Y. (2010). CO2 emissions, nuclear energy, renewable energy and economic growth in the US. *Energy policy*, *38*(6), 2911-2915.

Merriam-Webster. (n.d.). *Agriculture Definition & Meaning*. https://www.merriam-webster.com/dictionary/agriculture

Mhatre, P., Panchal, R., Singh, A., & Bibyan, S. (2021). A systematic literature review on the circular economy initiatives in the European Union. *Sustainable Production and Consumption*, *26*, 187-202.

Mielcarek-Bocheńska, P., & Rzeźnik, W. (2021). Greenhouse gas emissions from agriculture in EU countries—state and perspectives. *Atmosphere*, *12*(11), 1396.

Mihai, F. C. (2020). Assessment of COVID-19 waste flows during the emergency state in Romania and related public health and environmental concerns. *International Journal of Environmental Research and Public Health*, *17*(15), 5439.

Mihai, F. C., & Minea, I. (2021). Sustainable Alternative Routes versus Linear Economy and Resources Degradation in Eastern Romania. *Sustainability*, *13*(19), 10574.

Mihai, F., & Ichim, P. (2013). Landfills–territorial issues of cities from North-East Region, Romania. *Romania*.

Michigan State University. (2023). *Slovakia: Economy.* https://globaledge.msu.edu/countries/slovakia/economy/.

Milios, L. (2016). Policies for Resource Efficient and Effective Solutions: A review of concepts, current policy landscape and future policy considerations for the transition to a Circular Economy.

Mills, R. (2011). Airport solar and geothermal power.

Ministry of Industry and Trade. (2019). National Energy and Climate Plan of the Czech Republic.

Ministry of Industry and Trade. (2014). *State Energy Policy of the Czech Republic*.

Mititelu-Ionuş, O., Simulescu, D., & Popescu, S. M. (2019). Environmental assessment of agricultural activities and groundwater nitrate pollution susceptibility: a regional case study (Southwestern Romania). *Environmental monitoring and assessment*, *191*, 1-15.

Mont, O., Plepys, A., Whalen, K., & Nußholz, J. L. (2017). Business model innovation for a Circular Economy: Drivers and barriers for the Swedish industry–the voice of REES companies.

Moore, C., Tunbridge, P., Kasprzak, M., & Graham, E. (2020). Vision or division? What do National Energy and Climate Plans tell us about the EU power sector in

2030. *Ember: https://ember-climate. org/wp-content/uploads/2020/10/Vision-or-Division-Ember-analysis-of-NECPs. pdf.*

Moraga, G., Huysveld, S., Mathieux, F., Blengini, G. A., Alaerts, L., Van Acker, K., ... & Dewulf, J. (2019). Circular economy indicators: What do they measure?. *Resources, Conservation and Recycling*, *146*, 452-461.

Moreau, V., Sahakian, M., Van Griethuysen, P., & Vuille, F. (2017). Coming full circle: why social and institutional dimensions matter for the circular economy. *Journal of Industrial Ecology*, *21*(3), 497-506.

Morseletto, P. (2020). Targets for a circular economy. *Resources, Conservation and Recycling*, *153*, 104553.

Moschitz, H., Muller, A., Kretzschmar, U., Haller, L., de Porras, M., Pfeifer, C., ... & Stolz, H. (2021). How can the EU Farm to Fork strategy deliver on its organic promises? Some critical reflections. *EuroChoices*, *20*(1), 30-36.

Mulvaney, D. (2019). *Solar power: Innovation, sustainability, and environmental justice*. University of California Press.

Murray, A., Skene, K., & Haynes, K. (2017). The circular economy: an interdisciplinary exploration of the concept and application in a global context. *Journal of business ethics*, *140*, 369-380.

Musa, K. S., Maijama'a, R., & Yakubu, M. (2022). Deforestation, Sectoral Co2 Emissions and Environmental Pollution Nexus: Evidence from Nigeria. *Asian Research Journal of Current Science*, 161-181.

Nam, V. H. (2019). Green Sustainable Airports: The Deployment of Renewable Energy at Vietnam Airports. Is that Feasible?. *Journal of Mechanical Engineering Research and Developments*, *42*, 61-65.

Narayan, P. K., & Narayan, S. (2010). Carbon dioxide emissions and economic growth: Panel data evidence from developing countries. *Energy policy*, *38*(1), 661-666.

Naustdalslid, J. (2014). Circular economy in China–the environmental dimension of the harmonious society. *International Journal of Sustainable Development & World Ecology*, *21*(4), 303-313.

Nicolai, S., Hoy, C., Berliner, T., & Aedy, T. (2015). Projecting progress: Reaching the SDGs by 2030. *London: Overseas Development Institute*. Retrieved on March 30, 2021 from: https://www.odi.org/sites/odi.org.uk/files/odi-assets/publications-opinion-files/9938.pdf

Niero, M., & Olsen, S. I. (2016). Circular economy: To be or not to be in a closed product loop? A Life Cycle Assessment of aluminium cans with inclusion of alloying elements. *Resources, Conservation and Recycling*, *114*, 18-31.

NRDC. (2019). *Greenhouse Effect 101.* https://www.nrdc.org/stories/greenhouse-effect-101

Ntanos, S., Skordoulis, M., Kyriakopoulos, G., Arabatzis, G., Chalikias, M., Galatsidas, S., ... & Katsarou, A. (2018). Renewable energy and economic growth: Evidence from European countries. *Sustainability*, *10*(8), 2626.

O'Neill, A. (2021). *Slovakia - Statistics & Facts*. Statista. Slovakia - Statistics & Facts | Statista.

O'Neill, A. (2022). Global inflation rate from 2016 to 2026. Statista. https://www.statista.com/statistics/256598/global-inflation-rate-compared-to-previous-year/

O'Neill, A. (2023). *Poland: Distribution of gross domestic product (GDP) across economic sectors from 2011 to 2021.* Statista. Poland - GDP distribution across economic sectors 2021 | Statista.

OECD. (2021). *Regional Outlook 2021: Slovak Republic – Progress in the net zero transition.*

OECD. (n.d.) *Sustainable Development: Critical Issues - free overview of the report.* https://www.oecd.org/greengrowth/sustainabledevelopmentcriticalissues-freeoverviewofthereport.htm.

Office of ENERGY EFFICIENCY & RENEWABLE ENERGY. (n.d.). *hydrogen-production*. https://www.energy.gov/eere/fuelcells/hydrogen-production

Olczak, M., & Piebalgs, A. (2019). *How far should the new EU Methane Strategy go?*. European University Institute.

Omri, A. (2013). CO2 emissions, energy consumption and economic growth nexus in MENA countries: Evidence from simultaneous equations models. *Energy economics*, *40*, 657-664.

Osadume, R., & University, E. O. (2021). Impact of economic growth on carbon emissions in selected West African countries, 1980–2019. *Journal of Money and Business*, *1*(1), 8-23.

Özcan, B., & Ozturk, I. (Eds.). (2019). *Environmental Kuznets curve (EKC): a manual*. Academic Press.

Ozturk, I., & Acaravci, A. (2010). CO2 emissions, energy consumption and economic growth in Turkey. *Renewable and Sustainable Energy Reviews*, *14*(9), 3220-3225.

Panayotou, T. (2003). Economics growth and the environmental. *Harvard University and Cyprus International Institute of Management*. https://www.unece.org/fileadmin/DAM/ead/sem/sem2003/papers/panayotou.pdf

Paul, S., & Bhattacharya, R. N. (2004). CO2 emission from energy use in India: a decomposition analysis. *Energy Policy*, *32*(5), 585-593.

Peck, S. (2001). When Is an Eco-Industrial Park Not an Eco-Industrial Park?. Journal of *Industrial Ecology*, *5*(3), 3-5.

Pedroni, P. (1999). Critical values for cointegration tests in heterogeneous panels with multiple regressors. *Oxford Bulletin of Economics and statistics*, *61*(S1), 653-670.

Pedroni, P. (2004). Panel cointegration: asymptotic and finite sample properties of pooled time series tests with an application to the PPP hypothesis. *Econometric theory*, *20*(3), 597-625.

Perman, R., & Stern, D. I. (2003). Evidence from panel unit root and cointegration tests that the environmental Kuznets curve does not exist. *Australian Journal of Agricultural and Resource Economics*, *47*(3), 325-347.

Petersen, S. O., Blanchard, M., Chadwick, D., Del Prado, A., Edouard, N., Mosquera, J., & Sommer, S. G. (2013). Manure management for greenhouse gas mitigation. *Animal*, *7*(s2), 266-282.

Pheifer, A. G. (2017). Barriers and enablers to circular business models. *White Paper. Brielle*.

Pianta, M., & Lucchese, M. (2020). Rethinking the European Green Deal: An industrial policy for a just transition in Europe. *Review of Radical Political Economics*, *52*(4), 633-641.

Poland Ministry of Climate and Environment. (2021). *Energy Policy of Poland until 2040.*

Poland MINISTRY OF NATIONAL ASSETS. (2019). *National energy and climate plan for 2021-2030 – Objectives and targets, and policies and measures.*

Polish Economic Institute. (2020). *Time for decarbonization.*

Potting, J., Hekkert, M. P., Worrell, E., & Hanemaaijer, A. (2017). Circular economy: measuring innovation in the product chain. *Planbureau voor de Leefomgeving*, (2544).

Purnhagen, K. P., Clemens, S., Eriksson, D., Fresco, L. O., Tosun, J., Qaim, M., ... & Zilberman, D. (2021). Europe's farm to fork strategy and its commitment to biotechnology and organic farming: conflicting or complementary goals?. *Trends in plant science*, *26*(6), 600-606.

Pušnik, M., & Sučić, B. (2014). Integrated and realistic approach to energy planning–a case study of Slovenia. *Management of Environmental Quality: An International Journal*, *25*(1), 30-51.

Rafferty, J (2022b) Montreal Protocol – International Treaty. *Encyclopedia Britannica.* https://www.britannica.com/event/Montreal-Protocol

Rafferty, J. (2022a). Kyoto Protocol – International Treaty, 1997. *Encyclopedia Britannica.* https://www.britannica.com/event/Kyoto-Protocol

Ranta, V., Aarikka-Stenroos, L., Ritala, P., & Mäkinen, S. J. (2018). Exploring institutional drivers and barriers of the circular economy: A cross-regional comparison of China, the US, and Europe. *Resources, Conservation and Recycling*, *135*, 70-82.

Ravindranath, N. H., Srivastava, N., Murthy, I. K., Malaviya, S., Munsi, M., & Sharma, N. (2012). Deforestation and forest degradation in India–implications for REDD+. *Current Science*, 1117-1125.

Rečka, L., Máca, V., & Ščasný, M. (2023). Green Deal and Carbon Neutrality Assessment of Czechia. *Energies*, *16*(5), 2152.

Reichstein, M., Bahn, M., Ciais, P., Frank, D., Mahecha, M. D., Seneviratne, S. I., ... & Wattenbach, M. (2013). Climate extremes and the carbon cycle. *Nature*, *500*(7462), 287-295.

Reike, D., Vermeulen, W. J., & Witjes, S. (2018). The circular economy: new or refurbished as CE 3.0?—exploring controversies in the conceptualization of the circular economy through a focus on history and resource value retention options. *Resources, conservation and recycling*, *135*, 246-264.

Richmond, A. K., & Kaufmann, R. K. (2006). Is there a turning point in the relationship between income and energy use and/or carbon emissions?. *Ecological economics*, *56*(2), 176-189.

Ritchie, H., & Roser, M.,. (2020). *CO_2 and Greenhouse Gas Emissions.* Our World in Data. Greenhouse gas emissions - Our World in Data

Rizos, V., Behrens, A., Kafyeke, T., Hirschnitz-Garbers, M., & Ioannou, A. (2015). The circular economy: Barriers and opportunities for SMEs. *CEPS Working Documents*.

RMI. (n.d.). *Managing Methane in the Waste Sector.* https://rmi.org/our-work/climate-intelligence/managing-methane-in-the-waste-sector/

Roberts, J. T., & Grimes, P. E. (1997). Carbon intensity and economic development 1962–1991: A brief exploration of the environmental Kuznets curve. *World development*, *25*(2), 191-198.

Sabato, S., & Fronteddu, B. (2020). A socially just transition through the European Green Deal?. *ETUI Research Paper-Working Paper*.

Saboori, B., & Sulaiman, J. (2013). CO2 emissions, energy consumption and economic growth in Association of Southeast Asian Nations (ASEAN) countries: A cointegration approach. *Energy*, *55*, 813-822.

Sachs, J., Kroll, C., Lafortune, G., Fuller, G., & Woelm, F. (2022). *Sustainable development report 2022*. Cambridge University Press.

Saidi, K., & Hammami, S. (2015). The impact of CO2 emissions and economic growth on energy consumption in 58 countries. *Energy Reports*, *1*, 62-70.

Saqib, N. (2018). Greenhouse gas emissions, energy consumption and economic growth: Empirical evidence from gulf cooperation council countries. *International Journal of Energy Economics and Policy*, *8*(6), 392-400.

Sariatli, F. (2017). Linear economy versus circular economy: a comparative and analyzer study for optimization of economy for sustainability. *Visegrad Journal on Bioeconomy and Sustainable Development*, *6*(1), 31-34.

Science direct. (n.d.) *Economic Instrument—An overview | ScienceDirect Topics*. (n.d.). https://www.sciencedirect.com/topics/social-sciences/economic-instrument

Sebri, M., & Ben-Salha, O. (2014). On the causal dynamics between economic growth, renewable energy consumption, CO2 emissions and trade openness: Fresh evidence from BRICS countries. *Renewable and Sustainable Energy Reviews*, *39*, 14-23.

Selden, T. M., & Song, D. (1994). Environmental quality and development: is there a Kuznets curve for air pollution emissions?. *Journal of Environmental Economics and management*, *27*(2), 147-162.

Şentürk, H., Omay, T., Yildirim, J., & Köse, N. (2020). Environmental Kuznets curve: non-linear panel regression analysis. *Environmental Modeling & Assessment*, *25*, 633-651.

SFOE. (2018). Energy strategy 2050 once the new energy act is in force.

Shafiei, S., & Salim, R. A. (2014). Non-renewable and renewable energy consumption and CO2 emissions in OECD countries: a comparative analysis. *Energy policy*, *66*, 547-556.

Shafik, N., & Bandyopadhyay, S. (1992). *Economic growth and environmental quality: time-series and cross-country evidence* (Vol. 904). World Bank Publications.

Schnaiberg, A. (1980). The environment: From surplus to scarcity.

Schoenefeld, J. J., Schulze, K., Hildén, M., & Jordan, A. J. (2021). The challenging paths to net-zero emissions: insights from the monitoring of national policy mixes. *The International Spectator*, *56*(3), 24-40.

Siddi, M. (2020). The European Green Deal: Asseasing its current state and future implementation. *UPI REPORT*, *114*.

Silva, S., Soares, I., & Pinho, C. (2012). The impact of renewable energy sources on economic growth and CO2 emissions: a SVAR approach.

Simionescu, M., Strielkowski, W., & Tvaronavičienė, M. (2020). Renewable energy in final energy consumption and income in the EU-28 countries. *Energies*, *13*(9), 2280.

Singh, J., & Ordoñez, I. (2016). Resource recovery from post-consumer waste: important lessons for the upcoming circular economy. *Journal of Cleaner Production*, *134*, 342-353.

Singh, N., Nyuur, R., & Richmond, B. (2019). Renewable energy development as a driver of economic growth: Evidence from multivariate panel data analysis. *Sustainability*, *11*(8), 2418.

Skjærseth, J. B. (2021). Towards a European Green Deal: The evolution of EU climate and energy policy mixes. *International Environmental Agreements: Politics, Law and Economics*, *21*(1), 25-41.

SLOVAK MINISTRY OF ECONOMY. (2019). *Integrated national energy and climate plan for 2021 to 2030.*

Smith, A., Stirling, A., & Berkhout, F. (2005). The governance of sustainable socio-technical transitions. *Research policy*, *34*(10), 1491-1510.

Smith, A., Voß, J. P., & Grin, J. (2010). Innovation studies and sustainability transitions: The allure of the multi-level perspective and its challenges. *Research policy*, *39*(4), 435-448.

Smith, P., Reay, D., & Smith, J. (2021). Agricultural methane emissions and the potential formitigation. *Philosophical Transactions of the Royal Society A*, *379*(2210), 20200451.

Smol, M., Adam, C., & Preisner, M. (2020). Circular economy model framework in the European water and wastewater sector. *Journal of Material Cycles and Waste Management*, *22*, 682-697.

Soytas, U., Sari, R., & Ewing, B. T. (2007). Energy consumption, income, and carbon emissions in the United States. *Ecological Economics*, *62*(3-4), 482-489.

Stare, M. (2001). Advancing the development of producer services in Slovenia with foreign direct investment. *Service Industries Journal*, *21*(1), 19-34.

Statista. (n.d.) *EU-27: GHG emissions by sector 1990-2020 | Statista*. https://www.statista.com/statistics/1171183/ghg-emissions-sector-european-union-eu/

Stehfest, E., & Bouwman, L. (2006). N 2 O and NO emission from agricultural fields and soils under natural vegetation: summarizing available measurement data and modeling of global annual emissions. *Nutrient cycling in agroecosystems*, *74*, 207-228.

Stern, D. I. (1993). Energy and economic growth in the USA: a multivariate approach. *Energy economics*, *15*(2), 137-150.

Stern, D. I. (2004a). The rise and fall of the environmental Kuznets curve. World *development*, *32*(8), 1419-1439.

Stern, D. I. (2004b). The environmental Kuznets curve. In *Modelling in Ecological Economics* (pp. 173-202). Edward Elgar Publishing.

Stern, D. I., Common, M. S., & Barbier, E. B. (1996). Economic growth and environmental degradation: the environmental Kuznets curve and sustainable development. *World development*, *24*(7), 1151-1160.

Sterpu, M., Soava, G., & Mehedintu, A. (2018). Impact of economic growth and energy consumption on greenhouse gas emissions: Testing environmental curves hypotheses on EU countries. *Sustainability*, *10*(9), 3327.

Strungaru, S. A., Nicoara, M., Jitar, O., Moglan, I., & Plavan, G. (2019). An overview on the development and progress of water supply and wastewater treatment in Romania. *Environmental Engineering & Management Journal (EEMJ)*, *18*(2).

Swiss Federal Office of Energy. (2018). *ENERGY STRATEGY 2050 MONITORING-REPORT 2021 ABRIDGED VERSION.*

Swiss Federal Office of Energy. (2019*). ENERGY STRATEGY 2050 MONITORING-REPORT 2021 ABRIDGED VERSION.*

Swiss Federal Office of Energy. (2020). *ENERGY STRATEGY 2050 MONITORING-REPORT 2021 ABRIDGED VERSION.*

Swiss Federal Office of Energy. (2021). *ENERGY STRATEGY 2050 MONITORING-REPORT 2021 ABRIDGED VERSION.*

Szalmáné Csete, M., & Esses, D. (2022). Usage of Production Function in Linear Economy. *Periodica Polytechnica Transportation Engineering*, *50*(2), 223-226.

The International Atomic Energy Agency. (2016). *Greenhouse gas reduction.* https://www.iaea.org/topics/greenhouse-gas-reduction

The Visegrád Post. (2018). *Central Europe and the European economy.* *https://visegradpost.com/en/2018/03/13/central-europe-and-the-european-economy/*

Tian, H., Xu, R., Canadell, J. G., Thompson, R. L., Winiwarter, W., Suntharalingam, P., ... & Yao, Y. (2020). A comprehensive quantification of global nitrous oxide sources and sinks. *Nature*, *586*(7828), 248-256. https://doi.org/10.1038/s41586-020-2780-0

Ţicleanu, M., Nicolescu, R., & Ion, A. (2014). Exploitation of shale gas by hydraulic fracturing-a method with possible middle and long term catastrophic consequenses. In *14th INTERNATIONAL MULTIDISCIPLINARY SCIENTIFIC GEOCONFERENCE SGEM 2014* (pp. 299-306).

Torok, A., Torok, A., & Heinitz, F. (2014). Usage of production functions in the comparative analysis of transport related fuel consumption. *Transport and Telecommunication Journal*, *15*(4), 292-298.

Trombin, G., Ragazzi, M., Isarie, C., Ciudin, R., & Torretta, V. (2017). Environmental assessment of the Sibiu County, Romania: Proposal for sewage sludge and OFMSW management. In *MATEC Web of Conferences* (Vol. 121, p. 10006). EDP Sciences.

Tsaurai, K. (2018). Greenhouse gas emissions and economic growth in Africa: does financial development play any moderating role?. *International Journal of Energy Economics and Policy*, *8*(6), 267.

Tsurumi, T., & Managi, S. (2010). Decomposition of the environmental Kuznets curve: scale, technique, and composition effects. *Environmental Economics and Policy Studies*, *11*(1-4), 19.

Turner, R. K., & Pearce, D. (1994). The role of economic instruments in solid waste management policy. *Economic incentives and environmental policies: principles and practice*, 251-273.

Tutak, M., Brodny, J., & Bindzár, P. (2021). Assessing the Level of Energy and Climate Sustainability in the European Union Countries in the Context of the European Green Deal Strategy and Agenda 2030. *Energies*, *14*(6), 1767.

UNCTAD. (n.d.), *Beyond 20/20 WDS - Table view—Merchandise: Total trade and share, annual*. https://unctadstat.unctad.org/wds/ReportFolders/reportFolders.aspx?sCS_ChosenLang=en

United Nations (2012) *United Nations Conference on Sustainable Development, Rio+20*. https://sustainabledevelopment.un.org/rio20

United Nations Framework Convention on Climate Change (2021) *COP26 Sees Significant Progress on Issues Related to Agriculture*. https://unfccc.int/news/cop26-sees-significant-progress-on-issues-related-to-agriculture

United Nations Framework Convention on Climate Change (2022) *Paris Agreement Implementation and Compliance Committee Meets to Assess Challenges*. https://unfccc.int/news/paris-agreement-implementation-and-compliance-committee-meets-to-assess-challenges

United Nations Framework Convention on Climate Change (n.d.) *The Paris Agreement*. https://unfccc.int/process-and-meetings/the-paris-agreement/the-paris-agreement

US EPA. (2015). *Sources of Greenhouse Gas Emissions*. https://www.epa.gov/ghgemissions/sources-greenhouse-gas-emissions.

US EPA. (2022). *Practices to Reduce Methane Emissions from Livestock Manure Management*. https://www.epa.gov/agstar/practices-reduce-methane-emissions-livestock-manure-management

Uygur, B., & Serengil, Y. (2016). Carbon Sequestration Potential of Forest Biomass in Turkey. In B. B. Uzun, E. Apaydın Varol, J. Liu, & V. J. Bruckman (Eds.), *Biochar: A Regional Supply Chain Approach in View of Climate Change Mitigation* (pp. 184–196). Cambridge University Press; Cambridge Core. https://doi.org/10.1017/9781316337974.010

Vadovics, E. (2019). The energy challenge in Hungary: A need for more complex approaches. *Energy demand challenges in Europe*, 83.

Vancutsem, C., Achard, F., Pekel, J. F., Vieilledent, G., Carboni, S., Simonetti, D., ... & Nasi, R. (2021). Long-term (1990–2019) monitoring of forest cover changes in the humid tropics. *Science Advances*, *7*(10), eabe1603.

Vásáry, V. (2005). THE ROLE OF AGRICULTURE IN CENTRAL AND EASTERN EUROPEAN RURAL DEVELOPMENT: ENGINE OR SOCIAL BUFFER? IAMO Forum, 2004. *Acta Oeconomica*, *55*(3), 341-346.

Vavrek, R., & Chovancova, J. (2016). Decoupling of greenhouse gas emissions from economic growth in V4 countries. *Procedia Economics and Finance*, *39*, 526-533.

Vincent, J. R. (1997). Testing for environmental Kuznets curves within a developing country. *Environment and development economics*, *2*(4), 417-431.

Viszt, E., & Borsi, B. (2001). Structural Changes in the Hungarian Economy and Foreign Trade in 1993–1998. *Acta Oeconomica*, *51*(3), 385-414.

Vollebergh, H. R., & Dijkgraaf, E. (2001). A note on testing for environmental Kuznets curves with panel data. *Available at SSRN 286692*.

von Moltke, A., McKee, C., & Morgan, T. (2004). Energy Subsidies: Lessons Learned in Assessing their Impact and Designing Policy Reforms. *Management of Environmental Quality: An International Journal*, *15*(4), 459–460

Wahl, D. C. (2017). Making the Sustainable Development Goals work for local communities everywhere. *Noteworthy. Accessed January*, *3*, 2019. https://blog.usejournal.com/making-the-sustainable-development-goals-work-for-local-communities-everywhere-3f00bd5db31

Wang, J., Li, Z., Wu, T., Wu, S., & Yin, T. (2022). The decoupling analysis of CO2 emissions from power generation in Chinese provincial power sector. *Energy*, *255*, 124488.

Wang, L., & Chen, M. (2013). Policies and perspective on end-of-life vehicles in China. *Journal of cleaner production*, *44*, 168-176.

Wautelet, T. (2018). Exploring the role of independent retailers in the circular economy: a case study approach. *Eur. Univ. Econ. Manag*, *10*, 177.

Wesseler, J. (2022). The EU's farm-to-fork strategy: An assessment from the perspective of agricultural economics. Applied Economic Perspectives and Policy, 44(4), 1826-1843.

Wieser, H. (2016). Beyond planned obsolescence: Product lifespans and the challenges to a circular economy. *GAIA-Ecological Perspectives for Science and Society*, *25*(3), 156-160.

Willskytt, S., Böckin, D., André, H., Ljunggren Söderman, M., & Tillman, A. M. (2016). Framework for analysing resource-efficient solutions. In *EcoBalance Conference 2016*.

Winiwarter, W., & Muik, B. (2010). Statistical dependence in input data of national greenhouse gas inventories: effects on the overall inventory uncertainty. *Climatic Change*, *103*(1-2), 19-36.

WoldAtlas. (2021). *Central European Countries* https://www.worldatlas.com/articles/which-countries-make-up-central-europe.html

WOLF, M. A., CHOMKHAMSRI, K., BRANDAO, M., PANT, R., ARDENTE, F., PENNINGTON, D., ... & GORALCZYK, M. (2010). International Reference Life Cycle Data System (ILCD) Handbook-general guide for life cycle assessment-detailed guidance.

Wolf, S., Teitge, J., Mielke, J., Schütze, F., & Jaeger, C. (2021). The European Green Deal—more than climate neutrality. *Intereconomics*, *56*, 99-107.

World Bank (2018). *Total greenhouse gas emissions (kt of CO2 equivalent.* https://data.worldbank.org/indicator/EN.ATM.GHGT.KT.CE?end=2018&start=1970&view=chart

World Bank. (2019). *A low-carbon growth study for Slovakia: implementing the EU 2030 climate and energy policy framework.*

World Bank. (2022-a). *Global Growth to Slow through 2023, Adding to Risk of 'Hard Landing' in Developing Economies.* https://www.worldbank.org/en/news/press-release/2022/01/11/global-recovery-economics-debt-commodity-inequality/

World Bank. (2022-b*) Global Economic Prospects, January 2022*. Washington, DC: World Bank. DOI: 10.1596/978-1-4648-1758-8. https://elibrary.worldbank.org/doi/abs/10.1596/978-1-4648-1758-8

World Bank. (2022-c). *Population, total - Central Europe and the Baltics*. Population, total - Central Europe and the Baltics | Data (worldbank.org)

World Bank. (n.d-a). *Agriculture, forestry, and fishing, value added (annual % growth)—Austria, Germany, Poland, Slovenia, Slovak Republic, Czechia, Switzerland | Data*. https://data.worldbank.org/indicator/NV.AGR.TOTL.KD.ZG?locations=AT-DE-PL-SI-SK-CZ-CH

World Bank. (n.d-b).*Industry (including construction), value added (% of GDP)—Austria, Germany, Poland, Slovenia, Slovak Republic, Czechia, Switzerland | Data*. https://data.worldbank.org/indicator/NV.IND.TOTL.ZS?locations=AT-DE-PL-SI-SK-CZ-CH

World Bank. (n.d-c). *Manufacturing, value added (annual % growth)—Austria, Germany, Poland, Slovenia, Slovak Republic, Czechia, Switzerland | Data* https://data.worldbank.org/indicator/NV.IND.MANF.KD.ZG?locations=AT-DE-PL-SI-SK-CZ-CH

World Bank. (n.d-d). *Services, value added (% of GDP)—Austria, Germany, Poland, Slovenia, Slovak Republic, Czechia, Switzerland | Data*.

https://data.worldbank.org/indicator/NV.SRV.TOTL.ZS?locations=AT-DE-PL-SI-SK-CZ-CH

World Bank. (n.d-e). *GDP (current US$) - Central Europe and the Baltics*. GDP (current US$) - Central Europe and the Baltics | Data (worldbank.org).

World Business Council for Sustainable Development. (2020). *Circular Economy Action Plan (CEAP) 2020 summary for business*. WBCSD_Circular_Economy_Action_Plan_2020–Summary_for_business.pdf

World Resources Institute. (n.d.). *5 Mitigation Strategies to Reduce Global Methane Emissions* https://www.wri.org/insights/methane-gas-emissions-climate-change.

WorldAtlas. (n.d) *What Are The Biggest Industries In Slovakia?* https://www.worldatlas.com/articles/what-are-the-biggest-industries-in-slovakia.html

Worrell, E., & Reuter, M. A. (2014). Recycling in Context Handbook of Recycling.

Wu, H. Q., Shi, Y., Xia, Q., & Zhu, W. D. (2014). Effectiveness of the policy of circular economy in China: A DEA-based analysis for the period of 11th five-year-plan. *Resources, conservation and recycling*, *83*, 163-175.

Yan, Q., Yin, J., Baležentis, T., Makutėnienė, D., & Štreimikienė, D. (2017). Energy-related GHG emission in agriculture of the European countries: An application of the Generalized Divisia Index. *Journal of Cleaner Production*, *164*, 686-694.

Younis, F., & Chaudhary, M. A. (2017). Sustainable development: Economic, social, and environmental sustainability in Asian economies.

Zaharia, C. (2017, August). Comparative overview of primary sedimentation-based mechanical stage in some Romanian wastewater treatment systems. In *IOP Conference Series: Materials Science and Engineering* (Vol. 227, No. 1, p. 012138). IOP Publishing.

Zaman, A. U. (2015). A comprehensive review of the development of zero waste management: lessons learned and guidelines. *Journal of Cleaner Production*, *91*, 12-25.

Zhongming, Z., Linong, L., Xiaona, Y., Wangqiang, Z., & Wei, L. (2018). Reducing methane emissions can play a key role in reducing ozone worldwide.

Zilahy, G. (2016). Sustainable business models–what do management theories say?. *Vezetéstudomány-Budapest Management Review*, *47*(10), 62-72.

Zoghi, M., Ehsani, A. H., Sadat, M., javad Amiri, M., & Karimi, S. (2017). Optimization solar site selection by fuzzy logic model and weighted linear combination method in arid and semi-arid region: A case study Isfahan-IRAN. *Renewable and Sustainable Energy Reviews*, *68*, 986-996.