GREENHOUSE GAS EMISSIONS AND GUIDELINES FOR CHANGES IN ENVIRONMENTAL GOVERNANCE OF EUROPEAN UNION COMPANIES

Turjak, Sofija

Josip Juraj Strossmayer University of Osijek
Faculty of Economics in Osijek
Inter-university Interdisciplinary Doctoral Program Entrepreneurship and Innovativeness

Sofija Turjak

GREENHOUSE GAS EMISSIONS AND GUIDELINES FOR CHANGES IN ENVIRONMENTAL GOVERNANCE OF EUROPEAN UNION COMPANIES

DOCTORAL THESIS

Osijek, 2023

Josip Juraj Strossmayer University of Osijek
Faculty of Economics in Osijek
Inter-university Interdisciplinary Doctoral Program Entrepreneurship and Innovativeness

Sofija Turjak

GREENHOUSE GAS EMISSIONS AND GUIDELINES FOR CHANGES IN ENVIRONMENTAL GOVERNANCE OF EUROPEAN UNION COMPANIES

DOCTORAL THESIS

Mentor: Ivan Kristek, PhD, associate professor

Osijek, 2023

Sveučilište Josipa Jurja Strossmayera u Osijeku
Ekonomski fakultet u Osijeku
Međusveučilišni interdisciplinarni doktorski studij Poduzetništvo i inovativnost

Sofija Turjak

STAKLENIČKI PLINOVI I SMJERNICE ZA PROMJENAMA U UPRAVLJANJU OKOLIŠEM PODUZEĆA EUROPSKE UNIJE

DOKTORSKI RAD

Mentor: izv. prof. dr. sc. Ivan Kristek

Osijek, 2023

IZJAVA

O AKADEMSKOJ ČESTITOSTI, PRAVU PRIJENOSA INTELEKTUALNOG VLASNIŠTVA, SUGLASNOSTI ZA OBJAVU U INSTITUCIJSKIM REPOZITORIJIMA I ISTOVJETNOSTI DIGITALNE I TISKANE VERZIJE RADA

1. Kojom izjavljujem i svojim potpisom potvrđujem da je doktorski (navesti vrstu rada: završni / diplomski / specijalistički / doktorski) rad isključivo rezultat osobnoga rada koji se temelji na mojim istraživanjima i oslanja se na objavljenu literaturu. Potvrđujem poštivanje nepovredivosti autorstva te točno citiranje radova drugih autora i referiranje na njih.
2. Kojom izjavljujem da je Ekonomski fakultet u Osijeku, bez naknade u vremenski i teritorijalno neograničenom opsegu, nositelj svih prava intelektualnoga vlasništva u odnosu na navedeni rad pod licencom *Creative Commons Imenovanje – Nekomercijalno – Dijeli pod istim uvjetima 3.0 Hrvatska*.
3. Kojom izjavljujem da sam suglasan/suglasna da se trajno pohrani i objavi moj rad u institucijskom digitalnom repozitoriju Ekonomskoga fakulteta u Osijeku, repozitoriju Sveučilišta Josipa Jurja Strossmayera u Osijeku te javno dostupnom repozitoriju Nacionalne i sveučilišne knjižnice u Zagrebu (u skladu s odredbama Zakona o znanstvenoj djelatnosti i visokom obrazovanju, NN br. 123/03, 198/03, 105/04, 174/04, 02/07, 46/07, 45/09, 63/11, 94/13, 139/13, 101/14, 60/15).
4. Izjavljujem da sam autorica predanog rada i da je sadržaj predane elektroničke datoteke u potpunosti istovjetan s dovršenom tiskanom verzijom rada predanom u svrhu obrane istog.

Ime i prezime studentice: Sofija Turjak

JMBAG: 358

OIB: 55132976645

e-mail za kontakt: sofija.turjak@efos.hr

Naziv studija: Međusveučilišni interdisciplinarni doktorski studij Poduzetništvo i inovativnost

Naslov rada: Staklenički plinovi i smjernice za promjenama u upravljanju okolišem poduzeća Europske unije

Mentor rada: izv. prof. dr. sc. Ivan Kristek

U Osijeku, 12. lipnja 2023. godine

Potpis Sofija Turjak

TEMELJNA DOKUMENTACIJSKA KARTICA

Sveučilište Josipa Jurja Strossmayera u Osijeku **Doktorska disertacija**
Ekonomski fakultet u Osijeku

Znanstveno područje: Društvene znanosti
Znanstveno polje: Ekonomija

STAKLENIČKI PLINOVI I SMJERNICE ZA PROMJENAMA U UPRAVLJANJU OKOLIŠEM PODUZEĆA EUROPSKE UNIJE

Sofija Turjak

Disertacija je izrađena u: Osijeku
Mentor: izv. Prof. dr. sc. Ivan Kristek

Kratki sažetak doktorske disertacije:
Europska unija ubrzano razvija zakone i politike u borbi protiv klimatskih promjena. Stoga su analiza Sustava trgovanja emisijama Europske unije (EU ETS), analiza emisija stakleničkih plinova, analiza ciljeva održivog razvoja i analiza ekološke ocjene u središtu ove disertacije. EU ETS je analiziran tijekom 13 godina (2008.-2020.), ekološke ocjene tijekom 5 godina (2016.-2020.) i emisije stakleničkih plinova država članica tijekom 7 godina (2013.-2019.). Rezultati studije pokazali su da je EU ETS tržišno djelomično učinkovit, da se države članice ne razlikuju po emisijama stakleničkih plinova i da ekološke inovacije i korištenje resursa imaju pozitivan utjecaj na ocjene okoliša. Autorica naglašava što bi tvrtke trebale promijeniti u svom upravljanju okolišem kako bi poboljšale svoju tranziciju prema niskougljičnoj ekonomiji.

Broj stranica: 236
Broj slika: 20
Broj tablica: 21
Broj literaturnih navoda: 400
Jezik izvornika: engleski
Ključne riječi: klimatske promjene, tržišna učinkovitost, ESG ocjene, UN ciljevi održivog razvoja, upravljanje okolišem

Datum obrane: 12. lipnja 2023. godine

Stručno povjerenstvo za obranu:
1. prof. dr. sc. Sanja Pfeifer, predsjednica
2. prof. dr. sc. Nataša Šarlija, član
3. prof. dr. sc. Željko Tomšić, član
4. izv. prof. dr. sc. Marina Stanić, zamjena

Disertacija je pohranjena u: Nacionalnoj i sveučilišnoj knjižnici Zagreb, Ul. Hrvatske bratske zajednice 4, Zagreb; Gradskoj i sveučilišnoj knjižnici Osijek, Europska avenija 24, Osijek; Sveučilištu Josipa Jurja Strossmayera u Osijeku, Trg sv. Trojstva 3, Osijek; Ekonomskom fakultetu u Osijeku, Trg Lj. Gaja 7, Osijek

BASIC DOCUMENTATION CARD

Josip Juraj Strossmayer University of Osijek **PhD thesis**
Faculty of Economics in Osijek

Scientific Area: Social sciences
Scientific Field: Economics

GREENHOUSE GAS EMISSIONS AND GUIDELINES FOR CHANGES IN ENVIRONMENTAL GOVERNANCE OF EUROPEAN UNION COMPANIES
Sofija Turjak

Thesis Written in: Osijek
Supervisor: Ivan Kristek, PhD, associate professor

Short Abstract:
The European Union is rapidly developing laws and policies in the fight against climate change. Therefore, this dissertation aims to analyse the European Union Emissions Trading System (EU ETS), greenhouse gas emissions, sustainable development goals and environmental ratings. The EU ETS has been analysed for 13 years (2008-2020), environmental ratings for 5 years (2016-2020) and the Member States GHG emissions for 7 years (2013-2019). The study results showed that EU ETS is partially market efficient, that Member States do not differ on their GHG emissions, and that environmental innovation and resource use positively affect environmental ratings. The author emphasises what companies should change in environmental governance to improve their transition toward a low-carbon economy.

Number of Pages: 236
Number of Figures: 20
Number of Tables: 21
Number of Rreferences: 400
Original in: English
Keywords: climate change, market efficiency, ESG ratings, UN SDGs, environmental governance

Date of the Thesis Defense: 12th June, 2023

Reviewers:
1. Sanja Pfeifer, PhD, Full Professor, Chairperson
2. Nataša Šarlija, PhD, Full Professor, Member
3. Željko Tomšić, PhD, Full Professor, Member
4. Marina Stanić, Associate Professor, Substitute

Thesis deposited in: National and University Library in Zagreb, Ul. Hrvatske bratske zajednice 4, Zagreb; City and University Library of Osijek, Europska avenija 24, Osijek; Josip Juraj Strossmayer University of Osijek, Trg sv. Trojstva 3, Osijek; Faculty of Economics in Osijek, Trg Lj. Gaja 7, Osijek

Greenhouse gas emissions and guidelines for changes in environmental governance of European Union Companies

ABSTRACT

Climate change has been widely discussed, mainly due to its harmful effects on nature, life quality and business decisions. The European Commission unveiled The Green Deal in 2019; it represents a package of policy initiatives that aim to help Europe toward a green transition, eventually reaching the goal of climate neutrality by 2050.

The shift to a low-carbon economy is both an excellent business opportunity and a substantial challenge. Commercialising low-carbon solutions, such as clean energy technologies, is seen as a chance to further accelerate a significantly rising market and aid in the change of the global energy system. However, this change presents a substantial challenge due to the high cost of economies dependent on a fossil fuel energy infrastructure transitioning toward a low-carbon economy. The relationship between public and private sectors, and the potential for businesses to work internationally, are key to a successful transformation, which demands close coordination between policy, technology, and finance. The task, from a financial perspective, is to evaluate the ever-changing market efficiency of the European Union Emission Trading System (EU ETS) and the environmental, social, and corporate governance (ESG) of enterprises in the European Union. To that end, carbon markets have been rapidly evolving and attracting significant attention from politicians and investors. The United Nations (UN) has also acknowledged climate change as an issue, including greenhouse gas emission reductions in its Agenda for Sustainable Development, which is built on 17 Sustainable Development Goals (SDGs). As a result, a growing number of businesses are instituting policies for environmentally responsible growth and releasing annual ESG reports.

The author analysed the EU ETS market efficiency, the UN SDGs indicators that measure GHG emissions among countries, and the businesses' ESG reports. The data analyses consist of methods for market efficiency, the Kruskal-Wallis test and fixed effects panel regression. The results showed that EU ETS has been partially market efficient in Phase III compared to Phase II, which was market inefficient. Moreover, there are no differences between the Member States and their GHG emissions. The environmental innovation and resource use showed a positive effect on the environmental ratings of EU companies.

Based on the conducted results, the author emphasises that companies should change their environmental governance to improve their transition toward a low-carbon economy. In addition, the author proposes recommendations for further research at three levels for businesses, policymakers and agencies that provide ESG data.

Keywords: climate change, market efficiency, ESG ratings, UN SDGs, environmental governance

Staklenički plinovi i smjernice za promjenama u upravljanju okolišem poduzeća Europske unije

SAŽETAK

O klimatskim promjenama naširoko se raspravlja, uglavnom zbog štetnih učinaka koje imaju na prirodu, kvalitetu života i poslovne odluke. Europska komisija predstavila je Europski zeleni plan 2019. godine koji predstavlja paket političkih inicijativa koje imaju za cilj pomoći Europi prema zelenoj tranziciji, konačnom postizanju cilja klimatske neutralnosti do 2050. Prijelaz na niskougljičnu ekonomiju izvrsna je prilika i značajan izazov. Komercijalizacija rješenja s niskim udjelom ugljika, kao što su tehnologije čiste energije, smatra se šansom za daljnje ubrzanje značajno rastućeg tržišta i pomoć u promjeni globalnog energetskog sustava. Međutim, ova promjena predstavlja znatan izazov zbog visokih troškova gospodarstava ovisnih o energetskoj infrastrukturi fosilnih goriva koja prelaze na niskougljičnu ekonomiju. Odnos između javnog i privatnog sektora i potencijal za poslovanje poduzeća na međunarodnoj razini ključni su za uspješnu transformaciju, koja zahtijeva blisku koordinaciju između politike, tehnologije i financija. Zadatak je, iz financijske perspektive, procijeniti stalno promjenjivu tržišnu učinkovitost Europskog sustava za trgovanje Sustava Europske unije za trgovanje emisijama (EU ETS) i ekološko, društveno i korporativno upravljanje (ESG) poduzeća u Europskoj uniji. U tu svrhu, tržišta ugljika brzo se razvijaju i privlače značajnu pozornost političara i investitora. UN je također priznao klimatske promjene kao problem, uključujući smanjenje emisije stakleničkih plinova u svojoj Agendi za održivi razvoj, koja se temelji na 17 ciljeva održivog razvoja (SDG). Kao rezultat toga, sve veći broj poduzeća uvodi politike za ekološki odgovoran rast i objavljuje godišnja ESG izvješća.

Autorica je analizirala tržišnu učinkovitost EU ETS-a , pokazatelje UN-ovih ciljeva održivog razvoja koji mjere emisije stakleničkih plinova među državama te ESG izvješća poduzeća. Analiza podataka sastoji se od metoda procjene tržišne učinkovitosti, Kruskal-Wallisovog testa te panel regresijske analize s fiksnim efektima. Rezultati su pokazali kako je EU ETS djelomično tržišno učinkovit tijekom trećeg razdoblja u donosu na drugo razdoblje u kojem je bio tržišno neučinkovit. Također, rezultat si pokazali kako ne postoje razlike između država članica EU i njihovih emisija stakleničkih plinova. Ekološke inovacije i korištenje resursa pozitivno utječu na ekološku ocjenu poduzeća.

Autorica je dala preporuke za daljnja istraživanja na tri razine za tvrtke, kreatore politika i agencije koje prikupljaju ESG podatke. Također, na temelju provedenih rezultata autorica naglašava što bi tvrtke trebale promijeniti u svom upravljanju okolišem kako bi poboljšale tranziciju prema niskougljičnoj ekonomiji.

Ključne riječi: klimatske promjene, tržišna učinkovitost, ESG ocjene, UN ciljevi održivog razvoja, upravljanje okolišem

To my parents

Your unconditional love and support helped me achieve everything.

To Filip, Dragana, Tena, Josip, Diana, Matej, Maja and Lobel

Having you by my side means the world to me.

TABLE OF CONTENTS

List of Abbreviations

AAU – assigned amount unit

ADB - Asian Development Bank

BE – bioeconomy

BES - biodiversity and ecosystem services

CDM – Clean Development Mechanism

CE – circular economy

CER – certified emission reduction

CFC – chlorofluorocarbon

COMESA - Common Markets for Eastern and Southern Africa

CSP – corporate social performance

CSR – corporate social responsibility

CWS - Corporate Water Stewardship

EAP - Environmental Action Programme

EBRD - European Bank for Reconstruction and Development

ECOSOC - Economic and Social Council

EEA – European Economic Area

EGD – European Green Deal

EGDIP - European Green Deal Investment Plan

EHM – Efficient Market Hypothesis

EITE - energy-intensive trade-exposed

ERU – emission reduction unit

ESG – Environmental, social and governance

ETF – enhanced transparency framework

EU – European Union

EU ETS – European Union Emission Trading System

EU-KP – European Union Kimberly Process

EUA – European Union Allowance

GCF - Green Climate Fund

GDP – gross domestic product

GDPR - General Data Protection Regulation

GE – green economy

GHG – greenhouse gas emission

GIF - Global Indicator Framework

HEI - Higher Education Institution

HLPF - High-Level Political Forum

IAEG-SDG - Inter-Agency and Expert Group on Sustainable Development Goals Indicators

ICAP - International Carbon Action Partnership

IPC - International Paralympic Committee

IPCC - Intergovernmental Panel on Climate Change

IUCN - International Union for Conservation of Nature and Natural Resources

JI – Joint implementation

JISC – Joint Implementation Supervisory Committee's

LT-LEDS – long-term low greenhouse gas emission development strategies

LULUCF – land use, land-use change, and forestry

MDG - Millennium Development Goals

MSR – Market Stability Reserve

NASA - National Aeronautics and Space Administration

NDC – nationally determined contribution

NDRC – National Development and Reform Commission

NECP – The national energy and climate plan

NGO - non-governmental organisation

NRDC – Natural Resources Defense Council

NZ ETS – New Zealand Emissions Trading Scheme

OECD - Organisation for Economic Co-operation and Development

OLADE - Latin American Energy Organization

OPEC - Organization of Petroleum Exporting Countries

RGGI – Regional Greenhouse Gas Initiative

RMU – removal unit

SDG – Sustainable development goal

UK – United Kingdom

UK ETS – United Kingdom Emissions Trading Scheme

UN – United Nations

UNEP - UN Environment Programme

UNFCCC – United Nations Framework Convention on Climate Change

UNGA - General Assembly of the United Nations

UNICEF – United Nations Children's Fund

WCED - World Commission on Environment and Development

WCS – World Conservation Strategy

WHO - World Health Organization

WMO - World Meteorological Organization

WTCC - World Travel and Tourism Council

WWF - Worldwide Fund for Nature

1. Introduction

The world is getting rapidly warmer, and many scientists believe that it is being caused mainly by carbon dioxide and other greenhouse gases (GHG) emitted by human activities (Wuebbles and Jain, 2001; Forster et al., 2007; Meehl et al., 2007; Matthews and Caldeira, 2008; Plattner et al., 2008; Solomon et al., 2009; Solomon et al., 2010). Human activities that influence GHG emissions involve personal and work-related activities. Scientists and researchers have attempted to draw attention to the deterioration of the foundation of human civilisation, resulting from unsustainable behaviour. They have extensively documented the adverse effects of this behaviour (Steffen et al., 2006; Stern, 2007; Intergovernmental Panel on Climate Change, 2007; Millennium Ecosystem Assessment, 2008; Rockström et al., 2009; Steffen et al., 2011; Carson, 2015; Meadows et al., 2015). According to Wackernagel et al. (2021), humanity consumed 73% more resources than the earth can offer in 2019. By 2030, two planets will not be able to support current human consumption rates (World Wildlife Fund et al., 2012).

So far, many scientists (Dietz et al., 2009; Nejat et al., 2015; Dubois et al., 2019) have researched personal activities and their GHG emissions and concluded that different energy and climate policies could decrease GHG emissions, but these policies are not mandatory. On the other hand, numerous scientists (Schleich and Betz, 2004; Engels et al., 2008; Engels, 2009; Abrell et al., 2011; Rodriguez Lopez et al., 2017; Schleich et al. 2020.) researched human activities in their work-related activities. More than 11000 companies in Europe are obligated to participate in the EU ETS under different criteria listed in Annex I of Directive 2003/87/EC (European Commission, 2003).

In 1997 the Kyoto Protocol was adopted by the United Nations Framework Convention on Climate Change (UNFCCC). The Kyoto Protocol is based on the principle of common but differentiated responsibilities: it acknowledges that individual countries have different capabilities in combating climate change, owing to economic development, and therefore puts the obligation to reduce current emissions on developed countries on the basis that they are historically responsible for the current levels of greenhouse gases in the atmosphere. In 2005 the first GHG trading scheme in the world was established, known as the European Union Emissions Trading System (EU ETS).

The EU ETS operates in all European Union countries, including Iceland, Liechtenstein, and Norway. It limits GHG emissions from more than 11000 heavy energy-using installations as well as airlines operating between these countries. The EU ETS works on the “cap and trade” principle; a cap is set on the total amount of greenhouse gases that all participating installations can emit. Within the cap, companies receive or buy emission allowances, which they can trade with one another as needed. They can also buy limited amounts of international credits from emission-saving projects around the world. The limit on the total number of allowances available, ensures that they have a value. The EU ETS has four phases (Phase I: 2005-2007; Phase II: 2008-2012; Phase III: 2013-2020; Phase IV: 2021-2030), of which Phase III will be the focus of this dissertation.

As Engels (2009) defines, since January 2005, the EU ETS has become mandatory for all member countries of the EU, including the accession countries, from the moment they acquire membership status. It is the largest mandatory scheme in the world and is seen by many as the prototype of a future global carbon trading scheme. Emissions trading requires companies operating under the new system to develop new knowledge and competencies within the organisation. Companies need to establish organisational routines to deal with emission allowances and represent new “objects” in the company’s accounting system (MacKenzie, 2007).

In 2015, the Paris Agreement was adopted by 196 parties at the 21st Conference of the Parties of the UNFCCC. The Paris Agreement is a legally binding international treaty on climate change. It has more rigorous aims than the Kyoto Protocol; its main goal is to limit global warming to well below 2, preferably to 1.5 degrees Celsius, compared to pre-industrial levels.

To fight against poverty and other deprivations, the UN developed 17 Sustainable Development Goals (SDGs) in 2015, out of which two are related to climate change and are the focus of this dissertation. Each of the 17 SDGs has a few sub-goals, and their performance is measured by different indicators that the UN determines. Goal 9 (Build resilient infrastructure, promote inclusive and sustainable industrialisation and foster innovation) and Goal 13 (Take urgent action to combat climate change and its impacts) consist of different indicators that measure GHG emissions reduction. Goal 9 consists of five sub-goals, and sub-goal 9.4 aims to upgrade infrastructure and retrofit industries to make them sustainable, with increased resource-use efficiency and greater adoption of clean and environmentally sound technologies and industrial processes, with all countries acting in accordance with their respective capabilities, by 2030. The sub-goal 9.4 is measured by indicator 9.4.1. CO_2 emissions per unit of value added. Goal 13 consists of three sub-goals, and sub-goal 13.2 aims to integrate climate change measures into national policies, strategies, and planning. The sub-goal 13.2 is measured by indicator 13.2.2. total GHG emissions per year. The author will use these indicators in the dissertation to determine the differences between European Union Member States and their development in the battle against climate change. A greater reduction in the country's GHG emissions leads to a better position toward a low-carbon economy.

In addition, the author will analyse companies in the European Union and their environmental, social and governance (ESG) ratings provided by Refinitiv, with a focus on environmental ratings, to determine the effect of indicators. In addition, the author will propose changes in the environmental governance of companies in the European Union.

1.1. Research Aims and Research Gaps

The EU ETS is the most crucial carbon market in the world; it is artificial and dependent on environmental policy and regulation; therefore, it is exposed to greater levels of uncertainty than is the case for most "natural" commodities (Ibikunle et al., 2016). As the EU ETS is the first carbon market in the world, it is essential to estimate its market efficiency. Daskalakis and Markellos (2008) examined the efficiency of the European carbon market during Phase I of its operation (2005–2007), "*in other words, do emission allowance prices reflect all available information to the extent that no investor can systematically gain excess returns?* (Daskalakis and Markellos; 2008:105)." The authors provided evidence that the EU ETS was far from efficient, a finding they attributed to its short history. In addition, Montagnoli and de Vries (2010) came to a similar conclusion; their analysis indicated that following a period of inefficiency (Phase I), the EU ETS shows the first signs of restoring market efficiency. As Sattarhoff and Gronwald (2018) conclude, the public expectation is that this market's degree of efficiency generally increases over time as the market develops from a new to a more mature state.

The Carbon Majors Database is a study published in 2017 by Griffin. The study points out that 100 fossil fuel producers are responsible for 71% of global GHG emissions. Griffin (2017:5) showed that over half (52%) of global industrial GHG, since the dawn of the industrial revolution, was produced from direct operational and product-related carbon dioxide and methane emissions (1854-2015). As Griffin stated (2017:7), *"…The fossil fuel industry and its products accounted for 91% … If the trend in fossil fuel extraction continues over the next 28 years as it has over the previous 28, then global average temperatures would be on course to* *rise around 4°C above preindustrial levels by the end of the century."* If the temperature rises around 4°C, it would have devastating consequences for future life on Earth, such as significant species extinction, food scarcity, climate changes and even more severe consequences. Since the fossil fuel industry has a significant negative effect on climate change, it also has an opportunity to transform its business and prevent further climate change. The transformation of fossil fuel companies would be radical, but it could have an enormous effect on the fight against climate change. There are different carbon-offset options, such as reducing operational emissions, shifting to lighter fossil fuels, using renewables instead of fossil fuels and more. At the same time, it can represent an opportunity as well as a challenge for fossil fuel companies.

The UN created 17 SDGs to help the world in the fight against climate change. In 2015, 193 Member States of the United Nations adopted the 2030 Agenda for Sustainable Development.[1] The SDGs are set high, but they are achievable among developed and developing countries (United Nations Development Group, 2017). The main goal of UN SDGs is to accomplish a sustainable future for all generations by 2030. The measuring tool is the SDG Tracker, which "*presents data across all available indicators using official statistics from the UN and other international organisations*" (SDG Tracker, n.d.). The SDG Tracker only shows data about the progress achieved by each country toward SDGs, but there is no institution that will give a warning to a country if it is now efficient in implementing SDGs. Scientists (Desai and Sidhu, 2015; Novitz and Pieraccini, 2020) question monitoring the development in achieving UN SDGs through the High-Level Political Forum on Sustainable Development (HLPF) since the HLPF meets only annually as a part of the UN Economic and Social Council (ECOSOC), and for two days every four years as Heads of State and Government under the General Assembly of the UN (UNGA). Also, new challenges arise since the SDGs are set high, and the timeframe for achieving them is 15 years. Negative shocks that influenced global economy, such as the Covid-19 pandemic, occurred in the last few years. These situations changed economies around the world, impacting supply chains, production, the energy sector and much more. Covid-19 pandemic showed that limiting transportation and production less GHG emission have been emitted, but it was mostly recognised as a negative shock due to different constraints that impacted labour market, food market etc.

[1]Transforming Our World: The 2030 Agenda for Sustainable Development (UN General Assembly resolution 70/1, 25 September 2015) or in short, The 2030 Agenda

Scientists (Forster et al., 2007; Meehl et al., 2007; Kennedy et al., 2009; Mohajan, 2011; Nejat et al. 2015; Dubois et al., 2019) state that global warming is continually increasing with anthropogenic releases of GHG contributing toward global climate change. Different organisations such as the Intergovernmental Panel on Climate Change (IPCC), the UN Environment Programme (UNEP), World Meteorological Organization (WMO), the Green Climate Fund (GCF), the Organisation for Economic Co-operation and Development (OECD) Secretariat, the Common Markets for Eastern and Southern Africa (COMESA) Secretariat, the Pacific Community, Local Governments for Sustainability, the International Paralympic Committee (IPC), the Latin American Energy Organization (OLADE), the World Travel and Tourism Council (WTTC), the European Bank for Reconstruction and Development (EBRD), the Asian Development Bank (ADB) and others put an emphasis on climate change and made advances towards climate neutrality. For the companies and countries around the world that are emitting GHG, the fight against climate change presents a challenge. On the one hand, they need to find a way to reduce their GHG emissions efficiently, and on the other hand, they need to change their policies and governance to reduce and, in the end, stop pollution.

According to Abhayawansa and Tyagi (2021), several scientific and media articles highlight how ESG ratings from various agencies exhibit substantial variation (Chatterji et al., 2016; Corporate Governance Watch, 2018). According to Allen (2018), in terms of ESG performance among global automotive businesses in September 2018, FTSE ranked Tesla lowest, MSCI ranked it first, and Sustainalytics ranked it somewhere in the middle. Scientists Semenova and Hassel (2015) explored the convergence validity of environmental ratings provided by three agencies (Thomson Reuters, Global Engagement Services and MSCI). They found that ratings do not generally converge, despite having certain shared dimensions. In addition, Doefleinter et al. (2015) compared individual ESG and economic scores as well as the aggregate ESG scores of three rating products: Thomson Reuters, MSCI ratings and the ESG data set of Bloomberg. They came to the conclusion that the correlation between Thomson Reuters and Bloomberg aggregate score was as high as 0.62 for individual dimension; in comparison to the other two ratings, the MSCI ratings did not share many similarities. According to the abovementioned studies, the problem of different methodological approaches regarding ESG ratings is substantial. A unified measurement methodology should help companies track their progress and compare their progress with competitors.

Despite the fact that there are numerous studies dealing with EU ETS market efficiency, GHG emissions of countries as well as companies, and environmental ratings of companies, there are research gaps that will be filled with this doctoral dissertation. These gaps include:

1. most studies are limited to EU ETS market efficiency during Phase I and Phase II without testing the efficiency during Phase III;
2. GHG emissions have been a main cause of climate change, but studies do not test the differences in GHG emissions between countries nor between companies according to industry or company size;
3. ESG ratings have been studied a lot in recent years. Still, most studies focus on differences between ESG ratings from different databases instead of testing the determinants of ESG ratings and their impact on ratings. This dissertation focuses on environmental ratings and their determinants.

The main aim of this dissertation is to fill these gaps and explore how the EU is transitioning toward a low-carbon economy. There are three levels that the author will analyse and make a conclusion on. First is the macro level that focuses on the EU ETS market efficiency. Second is the mezzo level with differences between the EU Member States and their GHG emissions. And the third is the micro level that analyses EU companies and their environmental ratings. In addition, developing guidelines for effective environmental governance among companies will help companies in transition toward a low-carbon economy.

Four additional aims will support the main aim of the dissertation listed as follows:

1. estimating the market efficiency of the EU ETS during Phase III;
2. testing UN SDGs to find differences between European countries and their progress toward GHG emissions reduction;
3. testing the relationship of company size and industry to GHG emissions between EU Member States and companies;
4. finding the differences between companies in the EU and their environmental ratings, as well as testing the relationship of determinants of environmental ratings.

1.2. Research Questions

The author addresses the main research question: How is the EU transitioning toward a low-carbon economy? To answer the main research question, the author will analyse three levels; the macro level (the EU ETS market efficiency); the mezzo level (the EU Member States and their GHG emissions); and the micro level (companies and their environmental ratings). The following research questions will help the author analyse all three levels in-depth and recommend further actions and research.

In addition, the author addresses the first additional question: Is the EU ETS market efficient in Phase III? Many authors (Daskalakis and Markellos, 2008; Montagnoli and de Vries, 2010; Ibikunle et al., 2016) researched the first two phases of the EU ETS and concluded that EU ETS is not market efficient and that it would improve in the next phase. Therefore, it is essential to analyse the Phase III of the EU ETS and conclude if the market is efficient or if it could improve more.

Also, the author addresses the second additional question: Do EU Member States differ by GHG emissions measured by the UN SDG indicators? Certain EU Member States are making better progress than others in achieving the UN's Sustainable Development Goals. According to Ricciolini et al. (2022), there are problems from the standpoint of social sustainability, with large inequities persisting for economic and environmental sustainability and stagnant sufficiency levels. Nordic nations generally score better, with Sweden first, followed by Denmark and Finland; France and Austria can also be regarded as good. In contrast, the eastern European states, notably Romania, Bulgaria, and Greece, score the lowest results due to their inadequate values. In addition, Hametner and Kostetckaia (2020) state that when looking at each country's progress toward the 17 SDGs, Germany seems to be the most consistent in the short term, with low to medium progress toward almost all goals. Other countries, like Croatia, Malta, Luxembourg, and Lithuania, on the other hand, are changing in quite different ways, with substantial progress in some areas and a decline in others. Vavrik (2021) indicates that greater alignment of EU policy with UN SDGs is possible.

Furthermore, the author addresses the third additional question: Do company size and industry positively influence the GHG emissions of the companies? In the EU ETS, companies surpassing certain limits are regulated. For example, the EU ETS covers installations with more than 20 MW of thermal-rated input in sectors that use a lot of energy. Even though the EU ETS regulates different companies with different installations in the same sectors, most studies on EU ETS only look at coverage scope to tell which sectors are targeted and which are not (European Commission, 2016). For example, Bohringer et al. (2009), Allan et al. (2014), and Bohringer et al. (2014) all used multi-sector computable general equilibrium models to look at EU ETS sectors without taking the unique characteristics of the companies into account. According to Koo, Lee and Kim (2019), if only large companies are required to implement mitigation plans, GHG emissions will be decreased to a lesser extent and utility will fall more. This indicates that firm size has a greater impact on GHG emissions than industry. They showed that, in some industry sectors, small and medium-sized enterprises would experience more negative consequences than large businesses under an ETS, even if the mitigation burden is exclusively borne by large businesses. Different studies (Prado-Lorenzo et al., 2009; Wahyuningrum, Djajadikerta and Suprapti, 2019) showed that disclosing companies' GHG emissions may differ between the size of companies. The size of the company and its amount of GHG emissions were not the focus of these studies. The author can assume that most of the researchers were not interested in differences between company size and its GHG emissions, but in other characteristics of the companies that influence GHG emissions. These studies (Berry and Rondinelli, 1998; Sharma and Vredenburg, 1998) indicate that businesses may learn from one another and apply environmental governance proactively by adopting proactive environmental management practices. In addition, Heuer (2012) discovered that ecosystem management is essential for connecting businesses, organisational areas, and worldwide sustainability initiatives. Companies that wish to learn from one another and apply environmental governance proactively should prioritise ecosystem management. Jin, Wang, and Wheeler (2010) studied the impact of environmental performance rating and disclosure. The results showed that businesses with higher ratings perceive favourable implications on market competitiveness, total market value, and connections with various stakeholders, whereas firms with lower rating experience a decline. Therefore, companies with lower environmental ratings can learn a lot from companies with higher environmental ratings.

Also, the author addresses the fourth additional question: How do companies in the EU differentiate by environmental ratings? Auer (2017) studied the change in environmental ratings of the companies over time. Environmental ratings have become very important for corporate leaders since they regard them as a main tool for communicating their environmental performance and incentives (Brockett and Rezaee, 2012). In addition, Auer (2017) concluded that environmental ratings influence consumers, employees, activists and socially responsible investments. Correspondingly, Sáez-Martínez et al. (2016) studied SMEs and their compliance with environmental legislation. Their results showed that despite the fact that practically all SMEs in Europe comply with environmental regulations, half of them do not wish to go beyond the legislative standards.

The author will use a few methodological approaches to answer all the research questions since the analysis is based on secondary data from different sources and cannot be analysed by the same model.

1.3. Research Hypotheses

As previously discussed, different scientists and researchers pointed out that EU ETS was not market efficient during the first two phases of development. Even though the third phase has finished, market efficiency should be tested. Based on previous research, some signs indicate that the EU ETS will become more efficient. The third phase consists of challenges that did not occur in the first two phases since it was confronted with negative shocks such as the Covid-19 pandemic. During the second phase, EU ETS was confronted with the global financial crisis, but since the market was developing, it was not characterised as a big problem. As scientists suggested, the third phase was supposed to be more efficient; therefore, this dissertation will show if the market could efficiently tackle challenges such as Covid-19 pandemic. Formally, the author proposes the following hypothesis (H1):

H1: The EU ETS is market efficient during Phase III.

As the UN SDGs became more important, countries put more effort into implementing them and reporting their progress. There are a lot of challenges when it comes to reporting and making them achievable, but in recent years their role has been comprehended as very important. Countries, like companies, differ from each other, but their role is significant. Cooperation between countries in order to achieve the UN SDGs enables better results to be achieved. Although studies have shown that achieving the UN SDGs by 2030 is very uncertain, using common resources and financial forces will help achieve better results. Reporting on the realised results brings the possibility of comparison between countries and their progress to accomplish a common goal - to achieve the UN SDGs. The differences between countries and their progress will help show how to approach the struggle against all challenges in achieving the UN SDGs, and the use of best practices will show how to realise the stated goals. The dissertation will determine the differences between the countries. Formally, the author proposes the following hypothesis (H2):

H2: There are statistically significant differences in distribution of percentage change of GHG emissions of the European Union Member States.

Based on previous research, companies included in EU ETS were the ones that emitted a lot of GHG. Moreover, the type of industry was also one of the criteria that obligated companies in the EU to participate in the trading process. In addition, as the size of a company is one of the main characteristics that differentiate one company from another, the dissertation will show how company size influences GHG emissions and how industry type influences GHG emissions. The dissertation will test the GHG emissions of the company according to the size of the company and the industry. Formally, the author proposes the following hypotheses (H3, H4, H5):

H3: According to industry, there are statistically significant differences in distribution of GHG emissions of the European Union companies.

H4: According to company size, there are statistically significant differences in distribution of GHG emissions of the European Union companies.

H5: Industry and company influence the GHG emissions of the European Union companies.

Companies can profit from implementing environmental governance. It can help them fight against GHG emissions, maintain sustainability, and influence future decisions. Environmental governance has not been required by law, but it would help companies to make better decisions and to facilitate their progress toward sustainability. Environmental ratings consist of numerous variables that will be analysed. Therefore, the author will analyse the differences between EU companies and their environmental ratings. Moreover, the author will test environmental innovation and resource use and their effect on environmental ratings, as well as GHG emissions and their effect on environmental ratings. Formally, the author proposes the following hypotheses (H6, H7, H8):

H6: There are statistically significant differences in the distribution of environmental ratings between European Union companies according to their size.

H7: Resource use and environmental innovation have a positive effect on the environmental ratings of European Union companies.

H8: GHG emissions have a greater effect on the environmental ratings of European Union companies than resource use and environmental innovation.

As a result of the conducted analysis, the author discusses how environmental innovation and resource use help achieve better environmental ratings. Moreover, the author proposes guidelines for changes in environmental policies to achieve common goals in the fight against climate change. Based on the number of reported variables of each company, the author proposes what variables should be omitted from future reporting of environmental ratings. As the companies are not obligated to report their ESG ratings, they choose individually what information to report, and therefore it makes it more difficult to compare companies and their progress toward a low-carbon economy.

Based on the results, a decision will be made on whether the hypotheses are confirmed. From the results, the author will write future recommendations for companies and institutions dealing with the issues of this dissertation.

1.4. Scientific Contribution

This doctoral thesis aims to fill the above-mentioned research gaps. To fill the research gaps, the author decided to test three levels of the EU (market, countries, and companies). As far as the author is aware, no studies studied all three levels together. Therefore, this doctoral thesis would also be valuable for policymakers, institutions, entrepreneurs, and the scientific community. The author derives applicative and scientific contributions based on the research of the dissertation.

The applicative contributions can be recognised by entrepreneurs because of the importance of environmental ratings in the fight against climate change. Understanding the environmental ratings help entrepreneurs change their businesses and help achieve lower GHG emissions. Based on the environmental ratings, interested stakeholders can evaluate companies' development toward sustainability. The ability to re-design environmental governance allows each company to act responsibly and propose new innovative strategies to reduce GHG emissions. Likewise, measuring environmental ratings would help companies determine their weaknesses and opportunities for further growth and improve their market positions.

Moreover, the analysis of the content of environmental ratings can help competent authorities create policies and implement the standardisation of companies' sustainability reports. Standardisation is important due to the creation of prerequisites for establishing uniform reporting that will increase the quality of reports and their improvement. In addition, companies that are obligated to participate in the EU ETS would get a better understanding of the market since it is still developing and did not reach its full market efficiency. The EU ETS is partially market efficient, meaning the market participants should trade cautiously to anticipate negative and positive shocks. The differences between countries can help policymakers at a country level as well as at an EU level to propose improved guidelines for further GHG emissions reductions to achieve a low-carbon economy. Furthermore, the results of the dissertation can be useful to the authorities and regulators for monitoring the sustainable operations of countries and companies.

The scientific contribution results from the systematisation of knowledge through detailed study and synthesis of scientific literature. A comprehensive review and analysis of related research and their methods and results in EU ETS market efficiency, GHG emissions, and ESG ratings contributed to the development of scientific knowledge. Moreover, previous research provided evidence that EU ETS was not market efficient in the first two phases. This dissertation provided evidence that it is partially market efficient in the third phase, especially when confronted with negative shock. In addition, the author determined that EU Member States do not differ in GHG emissions measured by UN SDG indicators. This finding is important in establishing that EU Member States are making similar progress toward a low-carbon economy. The author used panel regression to determine differences between companies and their environmental ratings. The panel regression provided enough information to determine effect size of determinants and to discuss environmental innovation and resource use. The environmental innovation and resource use are important determinants of environmental ratings and studying them helps companies change their environmental governance.

1.5. Research Outline

This doctoral dissertation consists of six chapters. It begins by introducing the reader to GHG emissions, EU ETS, the UN SDGs, and environmental ratings. In this chapter, the studies of market efficiency, implementation of the UN SDGs and differences in environmental ratings are highlighted as research gaps, and research hypotheses are set. The aims of the research are also defined, as well as the research questions. In addition, the practical and scientific contributions are described. The summary of all subsequent chapters may be found at the conclusion of the first chapter.

The dissertation's second chapter gives an overview of previous and recent research on climate change, international agreements, UN SDGs, GHG emissions in EU Member States and EU environmental governance. First, the main terms used in the dissertation are defined. Then, a historical overview of climate change and the development of research on climate change has been described. The author describes international agreements on climate change (the Kyoto Protocol and the Paris Agreement). Furthermore, the UN SDGs have been analysed as business opportunities for companies. Moreover, GHG emissions in the EU Member States have been described. In the last sub-chapter, the author describes the development of EU environmental governance, emphasising EU climate policy, EU ETS and the EU Green Deal.

The third chapter of the dissertation focuses on the methodology. It describes the research design used to conduct all the analysis. In addition, it explains all the datasets used to test the hypotheses, as well as methods. There are three different datasets since the dissertation studies three levels of the EU. The author gives a systematic overview of each dataset used to test all the hypotheses. The estimation of market efficiency, panel data modelling methods, and the Kruskal-Wallis test are explained. The author uses different methods since the analysed data represents different entities (countries and companies).

The fourth chapter of the dissertation describes the empirical analysis. Based on the complexity of their analyses and the statistical research techniques used to analyse the data, the chapter is divided into five parts. The first four sub-chapters present the conducted analysis, the obtained results, and the decisions on whether or not the hypotheses have been confirmed. In addition, a summary of the conducted empirical analysis has been presented in the last sub-chapter.

After testing the hypotheses, the fifth chapter of the dissertation systematically discusses the research analysis and obtained results in detail. The discussion is divided into two sub-chapters where the first sub-chapter discusses results from the conducted analysis, while the second sub-chapter represents the author's proposal of guidelines for changes in the environmental governance of EU companies.

In the sixth chapter, a conclusion on the mentioned topic is given. Moreover, the advantages and limitations of the conducted research, as well as recommendations resulting from the conducted research, are explained. In addition, the author gives recommendations for further research. The references and lists of all the tables, figures, abbreviations and appendices are presented at the end of the doctoral dissertation. The author's bibliography concludes the doctoral dissertation.

2. Theoretical Background and Literature Review

Between 2030 and 2060, GHG emissions are projected to exceed double their pre-industrial levels (Stern, 2007). This will result in a 2°C to 5°C increase in the global average temperature by the end of the twenty-first century. Greenland and Antarctic ice will drastically melt, causing sea levels to rise and disrupting the circulation of global ocean currents. There will likely be more droughts and floods, and more land will be threatened by desertification, all of which will have huge negative economic and social effects for humanity. In 1997, in response to these global environmental concerns, the United Nations initiated the Kyoto Protocol, which aims to reduce greenhouse gas emissions through international cooperation. Under the context of the Kyoto Protocol, the worldwide GHG emission trading markets, also known as the carbon emission markets, were established to increase efficacy and minimize the costs of emissions abatement. In 2015, the Paris Agreement was signed, and more stringent rules than what was contained in the Kyoto Protocol were defined among all the parties. Each country that signed the Paris Agreement is responsible for determining, planning, and frequently reporting on its contribution to combating global warming. No mechanism compels a country to adopt a specific emissions target by a certain date, but each successive target should exceed the preceding one.

Within this chapter, the author will explain the main terms, the development of global and European climate policy, the development of the EU ETS, and EU environmental governance. In addition, a broader analysis of UN SDGs will be explained, as well as the most important agreements, which aim to help decrease GHG emissions and achieve a sustainable future.

2.1. Overview of Main Terms

When discussing a sustainable future, terms such as climate change, GHG emissions, sustainability, green economy, circular economy, and bioeconomy need to be defined. The definition of these terms helps us to understand the concepts and processes involved in the fight against climate change, that influence life nowadays and that determine life in future.

Climate change is *"a long-term shift in temperatures and weather patterns"* (United Nations, n.d.). In addition, the UN explains that those shifts can be natural due to variations in the solar cycle. Still, since the 1800s, human activities have been the main driver of climate change because the world has become more industrialized. Humans started using fossil fuels like coal, oil and gas, which generate greenhouse gas emissions. NASA's (n.d.) definition is broader than the UN's definition and states that *"climate change is a long-term change in the average weather patterns that have come to define Earth's local, regional, and global climates"*. NASA includes the term "local, regional, and global climates" because of those long-term changes in weather patterns. The Australian Academy of Science (n.d.) follows the UN's definition. It defines that *"climate change is a change in the pattern of weather, and related changes in oceans, land surfaces and the ice sheets, occurring over time scales of decades or longer"*. When one is trying to understand what climate change means, the simplest explanation is the following: a long-term change in temperatures and weather patterns caused by natural and human activities, which influences the climate changes around the world.

As the UN mentions that human activities influence human impact on climate change by emitting greenhouse gas and causing the greenhouse gas effect, it is necessary to understand what the greenhouse gas effect is. As the Natural Resources Defense Council (NRDC) states, the greenhouse gas effect is *"identified by scientists as far back as 1896; it is the natural warming of the earth that results when gases in the atmosphere trap heat from the sun that would otherwise escape into space"* (Natural Resources Defense Council, n.d.). On the one hand, the greenhouse effect is a bad thing because it is warming the Earth. On the other hand, it is a good thing because, without greenhouse gases that make the greenhouse effect, the Earth's temperature would be too low for living, and life would not exist as people know it (British Geological Survey, n.d.).

The leading gases that cause the greenhouse gas effect are carbon dioxide, methane, nitrous oxide, water vapour, and fluorinated gases (NRDC, n.d.). Even though four out of five gases occur naturally, only fluorinated gases are synthetic, and their usage should be strictly monitored. A carbon footprint that leaves those gases can be defined as *"the quantity of GHGs expressed in terms of CO_2-e, emitted into the atmosphere by an individual, organisation, process, product or event from within a specified boundary"* (Pandey, et al., 2011:138).

There are different ways to fight against the greenhouse gas effect, and one is the transition towards a low-carbon economy. A low-carbon economy refers to the *"green ecological economy based on low energy consumption and pollution"* (Chen and Wang, 2017:252). While the greenhouse effect has been known since the 19th century, the term low-carbon economy was first presented in public in 2003 in a white paper published by Department for Trade and Industry (2003) of the United Kingdom.

As humankind faces climate change, new challenges arise. The EU's long-term goal is to reduce GHG emissions significantly by 2050. Still, at the same time, the world population will grow and reliance on current technology would entail higher use of energy as well as natural resources that make it impossible to reduce GHG emissions. New opportunities can develop new ways to produce food for the growing population, making environmental innovation a core business objective in order to meet the 2050 goal and help the world become a better place to live for future generations.

Determination toward sustainable development has been essentially rooted (Smith et al. 2018) in documents such as Transforming our world: the 2030 Agenda for Sustainable Development (short Agenda 2030) and the Sustainable Development Goals, adopted by the UN in 2015. In addition, D'Amato et al. (2017) explains three main sustainability concepts: the circular economy (CE), the green economy (GE), and the bioeconomy (BE). These three concepts inform international and national policies around the world and recommend different explanations to meet economic, environmental, and social goals. D'Amato et al. (2017) mentions that studying these three concepts is determined by their purpose of adapting to or transforming the current economy towards a more sustainable one.

To ensure sustainability over time, it is necessary to maintain a dynamic equilibrium between a growing human population and its demands, the changing capacity of the physical environment to absorb the waste of human activity, and the changing opportunities opened up by new knowledge and technological advances, and the values, aspirations, and institutions that shape human behaviour (Anand, 2016). Therefore, to safeguard this dynamic balance, the concepts of sustainability must naturally change in order to adapt to future challenges.

Many scientists and practitioners (Ollikainen, 2014; Loiseau et al., 2016; Hagemann et al., 2016; Székács, 2017; D'Amato et al., 2017) have identified CE, GE, and BE as fundamental and interconnected concepts in sustainability research and suggested a relationship among them. Figure 1 shows how these three concepts interact and what occurs when they do, according to D'Amato and Korhonen (2021).

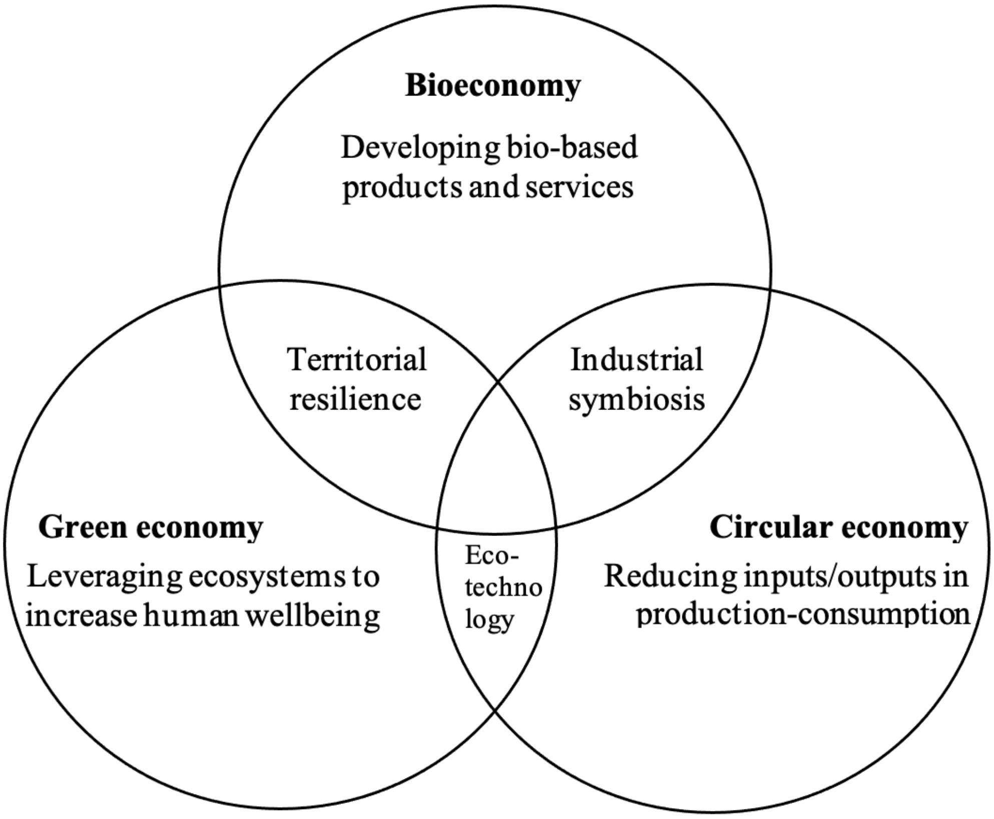

Figure 1 The interface between three sustainability macro-concepts

Source: author according to D'Amato and Korhonen (2021)

These three concepts offer different pathways for sustainability transformations based on economic, social, and ecological goals. They have the same goal, to achieve a sustainable future, but they use different methods and techniques in achieving it. More details about these concepts, as well as sustainability, will be discussed in the following text.

2.1.1. Sustainability and Sustainable Development

Usually, when climate change is discussed as a cause of global warming, sustainability and sustainable development are mentioned as a solution. According to Van Zon and Kuipers (2002, as cited in du Pisani, 2006), the terms "sustainability" and "sustainable" appeared for the first time in the Oxford English Dictionary during the second half of the 20th century. The term "sustainability" was first mentioned by Hans Carl von Carlowitz in his book *Sylvicultura Oeconomica*. The manuscript was finished in 1712, and the book was first published in 1713 (Bendix, 2014). It was referred to as the "sustainable use" of forest resources in forestry circles, which required keeping a balance between cutting down old trees and making sure there were enough new trees to replace them. Since forestry is a component of the environment, sustainability is based on forestry, and the two are intertwined. In the beginning, sustainability was connected only to the environment, and to overcome that shortcoming, in the 1980s, the concept was expanded, and other dimensions were included.

The International Union for Conservation of Nature and Natural Resources (IUCN) published the World Conservation Strategy (WCS) in 1980. In the strategy, three main objectives of living resource conservation were described: *"(1) to maintain essential ecological processes and life support systems, (2) to preserve genetic diversity, (3) to ensure the sustainable utilization of species and ecosystems"* (IUCN, 1980:VI). This approach represented a significant effort to unite environmental and development challenges under the general term "conservation".

An important political turning point for the idea of sustainable development was marked by the publication of the UN-sponsored World Commission on Environment and Development (WCED), *Our Common Future*, in 1987 (Mebratu, 1998). The WCED, also known as the Brundtland Commission, defined sustainable development as *"development that meets the needs of the present without compromising the ability of future generations to meet their own needs"* (WCED, 1987:15). This definition of sustainable development was adopted as the universal definition at the Earth Summit in Rio de Janeiro, in 1992.

Environmental concerns are important, according to the description above. Still, the focus is on the intergenerational function that the environment should play in the context of protecting resources for future generations. Based on the WCED definition of sustainable development, there is long-term and short-term sustainability. Short-term sustainability is accomplished by providing for the requirements of the present generation, while long-term sustainability is achieved by providing for the needs of the future generation. The term sustainability is defined as a way of life that considers society and the environment, while the term development is defined as ensuring that everyone's needs are met. The definition also emphasizes the two fundamental ideas of needs and limitations. Limitations can be seen as elements that may pose a danger to the fulfilment of the requirements of both the present and future generations. Needs are the necessities of all people, with a focus on helping the poor.

Harris (2003) questions three elements of sustainable development due to its multidimensionality. If, for example, a goal is to help the poor and sustainable development recommends using non-polluting energy sources that are more expensive than polluting ones, this has a reverse effect of increasing poverty because the poor are more dependent on polluting energy sources. What if, for instance, ensuring sufficient food and water supplies call for changes to land use that would reduce biodiversity? In addition, Norgaard (1994:20) explains that only one objective at a time can be achieved and says, *"it is impossible to define sustainable development in an operational manner in detail and with the level of control presumed in the logic of modernity"*.

There has been much criticism of the WCED definition, mainly in relation to the vagueness of what sustainability and sustainable development means (Jacobs, 1999; Paehlke, 2001; McKenzie, 2004; Adams, 2005). Paehlke (2001) argues that the meaning of sustainable development is ambiguous and might imply anything. The sustainability field is confusing due to the variety of definitions, terms, approaches, methods, and tools, many of which are designed for particular fields only (Huesemann 2001, Robèrt et al. 2002). As a result, there is an increasing need to understand how these concepts relate to sustainability and to one another.

Purvis et al. (2019) conducted a thorough study of the three pillars of sustainability, and they found that the number of publications on "sustainability" has increased dramatically over the past 20 years, to the point that "sustainability science" is frequently regarded as a separate subject (Kates et al., 2001; Komiyama and Takeuchi, 2006; Schoolman et al., 2012; Kajikawa et al., 2014). Nevertheless, "sustainability" continues to be a vague term with many possible meanings and contexts. There are different names for the three dimensions of sustainability such as pillars (Viederman, 1994; Stigson, 1998; Basiago, 1999; Pope et al., 2004; Gibson, 2006; Van Cauwenbergh et al., 2007; Waas et al., 2011; Hansmann et al., 2012; Osti, 2012; Moldan et al., 2012; Schoolman et al., 2012; Boyer et al., 2016, Rodríguez-Serrano et al., 2017; Asche et al., 2018; Purvis et al. 2019;); dimensions (Stirling 1999; Bryden and Shucksmith, 2000; Lehtonen 2004; Krajnc and Glavič, 2005; Moir and Carter, 2012; Mori and Christodoulou, 2012; Kristensen and Mosgaard, 2020), components (Du Pisani 2006; Rosen, 2012; Zijp et al., 2015), stool legs (Dawe and Ryan, 2003; Vos, 2007), aspects (Goodland, 1996; Sikdar, 2003; Lozano, 2008; Erol et al., 2009; Tanguay et al. 2010), perspectives (Brown et al. 1987; Arushanyan et al. 2017), etc., including "goals" or economic, social, and environmental (or ecological) aspects.

It may be challenging to put realistic public and private acts into practice due to the variety of ideas, viewpoints, and interests in sustainable development. Different ideas, strategies, and tools may seem to be at odds with one another when used as tools, but ultimately, taking action needs at least some level of agreement among the decision-makers based on evidence. In order to achieve the shared aim of global net sustainability, existing knowledge should be implemented in a strategic and complementary way, taking various ideas, methodologies, techniques, and instruments into consideration. D'Amato and Korhonen (2021:2) defined global net sustainability as *"if an individual sustainability approach, concept, tool or instrument is applied in a certain project in a certain time and in a certain place, and sustainability gains are achieved, this does not result through complex systems feedback mechanisms into a situation that, somewhere else in the focus system 'society within biosphere' now or in future, negative sustainability impacts increase as a result".* Strong sustainability (Daly, 1996; Ott, 2003; Korhonen, 2006; Dietz and Neumayer, 2007; Rockstrom et al., 2009; Roome, 2011; Folke et al., 2016) acknowledges that the economy and society always operate as components of the biosphere. On the other hand, weak sustainability permits absolute increases in social and environmental costs if the relative cost per unit of economic production lowers.

Combining the bioeconomy, the circular economy, and the green economy helps tackle the universal problem of achieving economic, social, and ecological objectives all at once using various methods. As such, they may be seen as "additions" that support sustainable development rather than replacing it.

2.1.2. Circular Economy

The concept of circular economy has been broadly researched among scholars and practitioners (Kirchherr et al., 2017, Korhonen et al. 2018.). As Santeramo (2022) mentioned, the idea of a circular economy first surfaced in 1966 when Boulding suggested structuring the economy as a circular system to promote sustainable growth. The concept was founded a few decades later, in 1989, by Pearce and Turner. According to Pearce and Turner (1989), in their book *Economics of Natural Resources and the Environment*, the authors lay out the various ideas that make up the field of economics of natural resources, as well as how they interact and have an impact on the idea of how economies function. The writers go into detail about how the environment receives waste as well as contributes to it. Since this is a linear or open-ended system without an integrated system for recycling, they provide an example of how disregarding the environment also means ignoring the economy.

As the concept is known worldwide, it does not have a unique definition (Yuan et al., 2006; Lieder and Rashid, 2016; Kirchherr et al., 2017; Murray et al., 2017). Kirchherr et al. (2017:229) analysed 114 definitions of the CE and defined the CE as *"an economic system that replaces the 'end-of-life' concept with reducing, alternatively reusing, recycling, and recovering materials in production/distribution and consumption processes. It operates at the micro-level (products, companies, consumers), meso-level (eco-industrial parks) and macro-level (city, region, nation and beyond), with the aim to accomplish sustainable development, thus simultaneously creating environmental quality, economic prosperity, and social equity, to the benefit of current and future generations. It is enabled by novel business models and responsible consumers"*. This CE definition considers what Frosch and Gallopoulos (1989) said, to achieve the correct balance between narrowly defined economic gains and environmental demands, a comprehensive approach will be necessary.

Traditional manufacturing techniques are intended to maximize the immediate advantages to the producer and customer of specific items rather than to the economy as a whole. The CE can be seen as a new business model (Haezendonck and Van den Berghe; 2020). It represents a new view of the production process; since the production process was previously linear – inputs were made into outputs during the production and waste was made. The CE means a circular production because it uses inputs that become outputs during the production process, while surplus materials are used for further processes. Therefore, CE is a business model that helps prevent future environmental deterioration and preserves scarce resources.

The first purpose of the CE is to facilitate more intelligent product use and production. Reusing, rethinking, and cutting back are the three methods that are employed to accomplish this purpose. The concept of reuse can be stated as rendering a product unnecessary by removing its function entirely or supplanting it with the functionality of a different (digital) good or service (Küfeoğlu, 2021). One way to think of rethink, is as boosting the product's level of utilization intensity (e.g. sharing product). In addition, reducing can mean lowering the amount of resources and materials used while simultaneously raising the level of product efficiency. The second thing that the CE is good for is making sure that a product and all of its components have a longer lifespan. There are five different approaches that can be taken to fulfill the role. These include reuse, repair, refurbishment, remanufacturing, and repurposing (Küfeoğlu, 2021). The reuse technique involves reprocessing an abandoned product that is still in usable condition and has been used by another client to successfully complete its primary purpose. The strategy of repair can be defined as the process of inspecting and maintaining a damaged product in order to lengthen the amount of time that the product can continue to perform its original purpose. In addition, the process of refurbishing includes restoring and modernizing an older product in order to make it competitive again. Remanufacturing is the process of using decommissioned or obsolete products in the production of new products that serve the same function. Repurposing is repurposing the abandoned product's elements in a novel product with different aims. The application of materials in productive ways is the final step in the CE's process. Both recycling and recovering are methods that are utilized in order to accomplish this function. Recovering waste materials for the purpose of reprocessing into new products, materials, or substances is the objective of the recycling process. The incineration of waste materials for the purpose of achieving energy recovery is the last part of the recovery process (Iordachi 2020; Khaw-ngern et al., 2021).

According to the definition proposed by Kirchherr et al. (2017) redesigning the life cycle of the product that produces as little production waste as possible involves multiple actions at different organizational levels. Environmental pollution might be decreased by reaching net reductions at the organizational supply chain and industrial levels (MacArthur, 2013; Murry et al., 2015). There is a big focus on inter-sectoral dynamics and cooperation since the fundamental notion is to turn a certain industry's waste materials into a resource for another industry (D'Amato et al., 2017).

2.1.3. Green Economy

Pearce and Turner (1989) proved that the economy and the environment are not distinct but rather interrelated concepts and proposed the notion of GE for the first time. The phrase "green economy" has been used in a study "Blueprint for a Green Economy", conducted by Pearce and Turner. The purpose of the study was to advise the UK government on whether the phrase "sustainable development" had a common meaning and what impact it may have on how projects and policies are evaluated and how economic growth is measured. The authors followed up on the original study with *Blueprint 2: Greening the World Economy* and *Blueprint 3: Measuring Sustainable Development*, which were published in 1991 and 1994, respectively. The first Blueprint report's main message was that economics can and should support environmental policy, but the subsequent reports expanded this message to include issues with the global economy, such as climate change, ozone depletion, tropical deforestation, and resource depletion in developing nations. Each paper drew on decades' worth of environmental economics experience and research.

The GE is one that *"improves human well-being and social equity, while significantly reducing environmental risks and ecological scarcities",* according to the UNEP (2011a:1). It aims to put into practice economic models that may generate profit without harming the environment, taking into account eco-innovation, better resource and waste management, the recycling of raw materials, and the shift towards sustainable consumption and production.

The GE refers to a *"fundamental change in the economy as a whole, in all its sectors, and to an identification of the basic features of green growth and its sources. It contains two key principles: an efficient price for carbon and decoupling of growth from the use of energy, material, and emissions"* (Ollikainen 2014:361 as cited in UNEP 2011b).

In addition, GE aims to put into practice economic models that may make money without harming the environment, taking into account eco-innovation, better resource and waste management, the recycling of raw materials, and the shift towards sustainable consumption and production (Ferreira Gregorio et al., 2018). GE uses green innovation in all human activities to reduce the number of harmful events to the environment and enable a sustainable life for future generations. It is challenging to achieve green innovation since it requires investing a lot of capital, but the result would benefit all stakeholders that are directly and indirectly involved in green innovation. Furthermore, environmental deterioration is becoming a serious danger to human life. Many groups and communities have turned to green innovation as a means of achieving environmental conservation and economic development. In addition to being very important, economic profitability and environmental sustainability are also very important (Takalo et al., 2021). Green innovation can guide firms toward achieving sustainable competitive advantages (Hur et al., 2013). Besides, green innovation is becoming a crucial instrument that companies may use to grow their market share, improve their market position, and sustain themselves over time.

2.1.4. Bioeconomy

The bioeconomy (BE), also known as "bio-based economy" or "knowledge-based bio-economy", is described by McCormick and Kautto (2013) as an economy in which the fundamental constituents of materials, chemicals, and energy are obtained from biological resources that are renewable, like sources of plants and animals. The main drivers of this process are biotechnology and knowledge-based innovations (D'Amato and Korhonen, 2021). It is challenging to use technology to turn biomass into a variety of goods, including bioenergy and fuels, paper and commodities, textiles, chemicals, and pharmaceuticals. Thus, bioeconomy products span from low-value, biomass-demanding products like biofuels to high-value, biomass-required products like bio-based chemicals or compounds (D'Amato and Korhonen, 2021). Even though it is policy-driven, BE is widely regarded at the industrial level as a catalyst for development, particularly in the forest and agricultural industries (McCormick and Kautto, 2013). Given its interdisciplinary nature, the BE presents a singular chance to holistically solve societal issues like food security, resource scarcity, reliance on fossil fuels, and climate change while attaining sustainable economic growth.

According to the European Commission (2012), the development of BE in Europe has enormous potential since it has the ability to sustain and expand economic activity and employment in rural, coastal, and industrial areas, lessen reliance on fossil fuels, and enhance the sustainability of primary production and processing sectors from an economic and environmental standpoint.

The BE can be seen as an opportunity to decrease the disparity between less developed and developed countries. Less developed countries are rich in biomass potential, and they could take part in global value creation. The BE can build partnerships between less developed and developed countries through their cooperation. Less developed countries could provide their biomass to developed countries that have enough technology to process that biomass and increase value creation (von Braun, 2014). Through cooperation between less developed and developed countries, public and private sectors would benefit, and it would improve their relationship.

A crucial category for influencing specialization and regional growth is the BE. Specific areas of smart specialization were defined and chosen by the regions under the direction of the European Union authorities (Adamowicz, 2017). The BE might serve a crucial integration purpose for several economic sectors. The advancement of bioeconomy research and support for its practical development may play a significant role in improving the international competitiveness of all countries implementing it.

2.2. History of Climate Change

Climate change has been an emerging problem in the world in the 21st century. Historically, many scientists have pointed out the climate problem since the end of the 18th century. John Leslie, a Scottish scientist, travelled to the Swiss Alps in 1796 in search of proof for his idea that the Earth is gradually warming due to the build-up of solar energy that has been absorbed (Hoffman, 2019). Leslie predicted for four decades the finding of a previous Ice Age by geologists, and while his theory of climate change was flawed due to his ignorance of the Earth's outgoing non-luminous (infrared) radiation, his conclusion regarding glacier retreat was sound (Hoffman, 2019). In the absence of an unexplained change in radiative forcing, it was unexplainable according to the climatic science of the nineteenth century if it was not due to the topographic lowering of the Alps.

French scientist Jean Baptiste Fourier is credited with developing the Fourier series. He demonstrated how infinite mathematical series, now known by his name, the Fourier series, may be used to analyse the transfer of heat in solid substances (Struik, 2022). His work inspired research in mathematical physics, which has since been frequently associated with the solution of boundary-value problems, embracing numerous natural occurrences like sunspots, tides, and the weather. His work also went far beyond the topic of heat conduction. Fourier was the first one that present the concept of the "greenhouse effect", in 1824, by comparing it to a "glass bowl" that transmits sunlight but traps infrared radiation emitted from the ground (Climate Policy Watcher, 2022).

Svante Arrhenius was a Swedish scientist who won the Nobel Prize in 1903 for his work in chemistry. According to Rodhe et al. (1997), Arrhenius' work on the "greenhouse effect" was initially motivated by a desire to explain the temperature variations during the quaternary glaciation cycles; he soon applied his findings to the issue of potential future climate change resulting from industrial CO_2 emissions. His first estimate of an anthropogenic change in world temperature was published in a Swedish magazine in 1896. (Rodhe et al., 1997).

According to Britannica (n.d.), beginning with the emergence of oil resources in Texas and the Persian Gulf, the period from 1920 to 1925 is characterized by massive petroleum development. The United States controlled the oil industry during the nineteenth century (Sampson 1975; Yergin 1991). During this time, the US dominated the global oil markets. In the 1860s, the US exported more than half of its kerosene production, and by the 1880s, oil products were the fourth-largest US export (Penrose, 1968). On the other side of the world, the Persian government granted William D'Arcy an oil concession in 1901 (Stevens, 2013). The second oil discovery at Masjid-i-Sulaiman in 1908 effectively marked the beginning of a new age characterized by the availability of inexpensive oil outside of the United States, much of it from the Middle East (Stocking, 1971). Development of the oil and petroleum industry started to have an impact on the environment since many fields needed to be deforested to be available for oil extraction. Moreover, burning gas meant more GHG emissions emitted in the air and polluting the air.

Serbian scientist Milutin Milankovitch published "Mathematical Climatology and the Astronomical Theory of Climatic Changes" in 1920. His work represents comprehensive mathematical foundations of climate change research. The long-term, cumulative effects of changes in Earth's position in relation to the Sun, according to Milankovitch, are thought to be a significant driver of Earth's long-term climate and are responsible for the beginning and conclusion of glaciation eras (Global Climate Change, 2020). This paper provided the first comprehensive mathematical analysis of how minor variations in the rotation and trajectories of planets around the Sun affect insolation and the quantity of solar energy that planets receive. It so laid the groundwork for comprehending Earth's climate history as well as the reasons behind its major ice ages (Cvijanovic et al., 2020).

In 1957, Roger Revelle and H. E. Seuss wrote that *"human beings are now carrying out a large-scale geophysical experiment of a kind that could not have happened in the past nor be reproduced in the future. Within a few centuries, we are returning to the atmosphere and oceans the concentrated organic carbon stored in sedimentary rocks over hundreds of millions of years"* (Keller, 1999:366). Scientists have to overcome a long-standing counterargument before they would take greenhouse effect warming seriously (Weart, 2003). It appeared certain that any excess carbon dioxide that could result from human activity would be promptly absorbed by the enormous quantity of the oceans. The unusual chemistry of saltwater, Revelle discovered, precludes that from happening. His study with Suess is now largely considered the catalyst for the discussions surrounding global warming.

Charles Keeling was inspired to conduct measurements of atmospheric carbon dioxide by Revelle and Seuss. The following "Keeling curve" vividly shows how much CO_2 has increased from preindustrial times (Keller, 1999). In addition, the Keeling Curve is a graph depicting the concentration of CO_2 in Earth's atmosphere since 1958. More than anything else, these findings of the increase in the atmospheric concentration of a potent GHG have increased the likelihood that humans are warming the planet.

The 1973-1974 first oil shock was an economically and politically significant event that sparked controversies in the years that followed. The oil price quadrupling between 1973 and 1974 was the most notable event of the closing decades of the 20th century (Baumeister and Kilian, 2016). As the oil market tightened, the Arab world began to use oil as a tool to achieve its economic and political objectives. This was accomplished mostly through the oil embargo imposed in October 1973 during the war between Egypt and Israel (Hamilton, 2013). Saudi Arabia refused to raise output to prevent a price decline unless the United States supported the Arab cause. Arab oil ministries opted to impose an embargo to achieve their political objectives. Monthly production was to be lowered by 5% until the West surrendered (Illie, 2006). Those nations who took a “friendly” stance towards Arab governments would not be affected. Organization of Petroleum Exporting Countries (OPEC) members established the official oil price at $11.65/barrel. From $3/barrel to $11.65/barrel, the price increase was unprecedented in oil’s history (Lenczowski, 1975). The embargo precipitated a severe global economic crisis. The Arab embargo was imposed at a time when American oil output was declining, and imports and demand were rising. The combination of a decline in OPEC output and a lack of global overcapacity caused an oil shortage and, subsequently, an increase in price. In 1974, after the embargo was imposed, the price of oil quadrupled (Britannica, 2020). After the embargo, significant efforts were made to save energy and transition from oil to alternative energy sources.

Molina and Rowland (1974) published a paper *Stratospheric sink for chlorofluoromethanes: chlorine atom-catalysed destruction of ozone*, that studies the destruction of ozone. The paper is the first proof of chlorine chemicals being involved in ozone depletion. Chlorine has a big impact on ozone because one chlorine atom can destroy more than one hundred thousand ozone molecules before it is eliminated from the stratosphere (US EPA, 2021). Ozone can be destroyed faster than it is formed naturally.

Similar to its predecessor in 1973–1974, the second oil shock of the 1970s was triggered by events in the Middle East, as well as robust worldwide oil demand. The Iranian Revolution began in early 1978 and ended a year later (Graefe, 2013). By January 1979, Iranian oil production had decreased by 7% of the world’s production at the time (Hamilton, 2013). However, this disruption in oil supplies may not have been the most significant reason driving up oil prices. Rather, the Iranian disruption may have triggered widespread speculative hoarding out of fear of future disruptions. Slowing economic activity in industrial nations and investments in new energy production and energy conservation technologies eventually helped to saturate the market with oil, bringing an end to the oil crisis. Midway through the 1980s, real oil prices began to decrease, initiating a secular decline that would endure for the majority of the next two decades.

In 1990 the first report from the Intergovernmental Panel on Climate Change (IPCC) report described the trend of the previous warming and indicated that future warming is probable. The natural greenhouse effect already causes the Earth to be warmer than it would be otherwise. Human activities are significantly increasing the concentrations of the greenhouse gases carbon dioxide, methane, chlorofluorocarbons (CFCs), and nitrous oxide in the atmosphere (IPCC, 1990). These increases will strengthen the greenhouse effect, resulting in an average increase in the Earth's surface temperature. The principal greenhouse gas, water vapour, will grow in response to global warming and contribute to its acceleration.

Global warming and climate change became more discussed topics at the United Nations conference in 1992 in Rio de Janeiro, the UN Framework Convention on Climate Change (UNFCCC) was established. The UNFCCC represents international collaboration to combat climate change by limiting average global temperature increases and the associated climate change and preparing for repercussions that were by then unavoidable (UNFCCC, n.d.a). Even though climate change and global warming have been in the spotlight of different studies and research, at the global level, the first international cooperation was established at the end of the 20th century.

The first international protocol was signed in 1997 in Kyoto, and it is known as the "Kyoto Protocol". The main aim of "The Kyoto Protocol" was to make UNFCCC operative by obligating industrialized nations and economies in transition to limit and reduce GHG emissions in accordance with agreed individual targets (UNFCCC, 1997). At that time, GHG emissions from human activities were recognized as the main driver of global warming.

In 2001, the third IPCC report noted that warming due to GHG emissions had become increasingly probable. In addition, the following findings were included:

- since the pre-industrial era, human activities have boosted atmospheric quantities of greenhouse gases and aerosols,

- according to the instrumental record (1861-2000), 1998 was the warmest year, and the 1990s was the warmest decade
- snow cover and ice extent have decreased (IPCC, 2001).

The Kyoto Protocol was adopted in 1997, but it entered into force in 2005. According to the United Nations Treaty Collection (n.d. a), 192 Parties have signed The Kyoto Protocol, among which Afghanistan signed it in 2013 and Australia in 2007. The US has never signed the Kyoto Protocol. In addition, Canada decided to withdraw from the Kyoto Protocol in 2011.

In 2007, the fourth IPCC report noted that the effects of global warming are occurring. In addition, the following findings were included:

- observations of increases in global average air and ocean temperatures, widespread melting of snow and ice, and rising global average sea levels indicate unequivocally that the climate system is warming
- the majority of the global average warming over the past 50 years is "extremely likely" (based on expert opinion) to have been caused by human activity
- due to the increased frequency and intensity of some extreme weather events, the impacts of climate change will most likely rise
- due to the timescales of climate processes and feedback, anthropogenic warming and sea level rise would continue for centuries even if GHG emissions were to be decreased sufficiently to stabilize GHG concentrations
- many repercussions [of climate change] can be mitigated, deferred, or avoided (IPCC, 2007a).

In 2015, a new protocol was issued by UNFCCC, known as "The Paris Agreement". It was supposed to replace the Kyoto Protocol and give stronger guidelines to all the Parties. The biggest improvement was that even the US signed it (United Nations Treaty Collection, n.d.), which indicates important progress toward mitigating climate change.

The sixth IPCC report, published in 2021, emphasizes categorically that human activity has caused rapid and extensive changes to the atmosphere, hydrosphere, and biosphere. It is only conceivable to avoid a warming of 1.5°C or 2°C if GHG emissions are immediately and drastically reduced and to strengthen international cooperation to ensure enough support in climate action. In addition, the following findings were included:

- climate mitigation is positively and quantifiably affected by international cooperation - it provides vital assistance for numerous mitigating initiatives
- carbon dioxide removal is required to achieve a net-zero reduction
- the potential for cities to reduce greenhouse gas emissions is substantial, for example urban trees, lakes, and other blue and green infrastructure can, directly and indirectly, cut GHG emissions
- in 2019, buildings accounted for 21% of worldwide GHG emissions, where eighty to ninety percent of their emissions can be reduced while contributing to other Sustainable Development Goals
- the report proposes a new strategy for lowering greenhouse gas emissions from buildings: SER equals Sufficient, Effective, and Renewable
- the report acknowledges certain climate action improvements; for instance, in Europe, Asia, and North America, the rate of deforestation reduced after 2010 and the total forest cover increased in recent years due to replanting (IPCC, 2022).

The history of climate change is complex, but it describes the most important events that occurred from the 18th century until nowadays. Research about climate change was conducted even before the 18th century, but the author has only explained the events that have contributed to emphasising the problem as well as ways of dealing with climate change and global warming.

2.3. International Agreements on Climate Change

Over the past several decades, countries have vowed to reduce global warming. Despite greater diplomacy, the world may soon be faced with the catastrophic repercussions of climate change. The majority of environmental issues are transboundary and frequently global in scope, necessitating international cooperation for their effective resolution.

The Montreal Protocol of 1987 was a landmark environmental agreement that served as a template for future diplomacy on the subject. Universal acceptance forced countries to cease producing ozone-depleting compounds, such as chlorofluorocarbons (CFCs). Nearly 99% of these ozone-depleting chemicals have been eliminated thanks to the protocol (Nelson, 2017). The determination of countries to reduce harmful compounds in the atmosphere showed that the result of the protocol could be achieved if all countries act together, even though it takes time. The Montreal Protocol is frequently regarded as a prime example of multilateralism at its most productive.

2.3.1. The Kyoto Protocol

The Kyoto Protocol was established in 1997 due to a complicated ratification process, it went into effect in 2005. The Kyoto Protocol makes the UNFCCC operative by obligating industrialized nations and economies in transition to limit and reduce GHG emissions in accordance with agreed individual targets. The UNFCCC itself only requires these nations to implement mitigation policies and actions and to submit periodic reports. The Kyoto Protocol is founded on the ideas and provisions of the UNFCCC, and its structure is based on its annexes. It exclusively binds industrialized countries and lays a higher burden on them in accordance with the notion of "*common but differentiated responsibility and distinct capabilities*", recognizing that they are primarily responsible for the current high levels of GHG emissions in the atmosphere (UNFCCC, n.d. b).

The introduction of flexible market mechanisms based on the trading of emission permits was an important aspect of the Kyoto Protocol. According to the Protocol, countries must primarily accomplish their targets through national methods. However, the Protocol also provides them with three market-based instruments to achieve their objectives:

- International Emissions Trading
- Clean Development Mechanism (CDM)
- Joint implementation (JI) (UNFCCC, n.d. b).

These strategies should stimulate the beginning of GHG abatement where it is most cost-effective, such as in developing countries. It is irrelevant where emissions are lowered so long as they are eliminated from the atmosphere. This encourages green investment in developing nations and engages the private sector in efforts to reduce and maintain a safe level of GHG emissions. It also allows the potential of bypassing older, dirtier technology in favour of newer, cleaner infrastructure and systems, with evident long-term benefits and more cost-effectiveness.

2.3.1.1. International Emissions Trading

Market-based instruments are rules that encourage conduct via market signals as opposed to explicit mandates concerning pollution control levels or methods (Stavins, 2003). Global trading systems in emission trading have been emerging due to the Kyoto Protocol. Parties with obligations under the Kyoto Protocol have accepted emission reduction or limitation goals in GHG emissions. During the 2008-2012 commitment period, these objectives are expressed as emission levels or allotted amounts. The permitted emissions are divided into quantity units (AAUs). As outlined in Article 17 of the Kyoto Protocol, countries with excess emission units (emissions allowed but not "used") may sell them to countries that have exceeded their emission reduction goals. Thus, a new commodity in the form of emission reductions or removals was produced. Since carbon dioxide is the primary greenhouse gas, people simply refer to carbon trading. Carbon is currently monitored and traded like a commodity. The term for this is "carbon market" (UNFCCC, n.d. c).

Under the Kyoto Protocols' emissions trading scheme, more than actual emission units can be bought and sold. Other transferable units under the scheme, each equal to one tonne of CO_2, may take the following forms:

- removal unit (RMU) based on land use, land-use change, and forestry (LULUCF) activities such as reforestation
- emission reduction unit (ERU) produced by a joint implementation project
- certified emission reduction (CER) produced by a clean development mechanism project (UNFCCC, n.d. c).

Transfers and acquisitions of these units are monitored and recorded by the Kyoto Protocol registry systems. A global transaction log safeguards the international transfer of emission reduction units.

Each Party is required to maintain a reserve of ERUs, CERs, assigned amount units (AAUs), and/or RMUs in its national registry in order to address the possibility that Parties could "oversell" units, leaving them unable to meet their own emissions targets (UNFCCC, 2009). This reserve referred to as the "commitment period reserve" (CPR) should not fall below 90% of the Party's assigned amount or 100% of five times its most recently reviewed inventory, whichever is lower (UNFCCC, n.d. c).

At the national and regional levels, emissions trading schemes can be implemented as climate policy instruments. Under such programs, governments establish emission targets for participating entities. The emissions trading scheme of the European Union is the first and largest in operation. The following Table 1 shows global carbon markets and their comparison.

Table 1 Market design comparison of key national/regional emission trading system

Country/ region	European Union	New Zealand	The United States[2]	California and Quebec	South Korea	China	United Kingdom
Name	EU ETS	NZ ETS	RGGI	WCI	K ETS	China ETS	UK ETS
Start date	2005	2008	2009	2013	2015	2021	2021
Size of cap	The Union-wide cap for 2021 from stationary installations is fixed at 1,571 Mt. The annual reduction corresponding to the linear reduction factor is 43 Mt.	Expected to be close to 160 Mt over 2021-2025.	2021 adjusted cap is 75.15 million short tons (68.2 million metric tCO_2), declining at a rate of 2.275% annually through 2030.	California: 334.2 $MtCO_2e$ in 2020. Over 2021-2030, the cap declines by an amount 4% per year to reach 200.5 $MtCO_2e$ in 2030. Quebec: 54.7 $MtCO_2e$ in 2020. The cap will be reduced annually by about 2.2% to reach 44.14 $MtCO_2e$ in 2030.	For phase 3 (2021-2025): 3.08 billion tonnes, composed of 2.9 billion tonnes of allocated allowances in 176 million tonnes of reserves.	4,590 Mt for 2020.	The cap is set at 156 Mt in 2021 and estimated to be 118 Mt in 2030.
% economy-wide emissions covered by ETS	~40%	~50%	~10%	California: ~75% Quebec: ~78%	~70%	~40% at the beginning (power sector only), gradually expanding to the 75% during 2021-2025 (all eight sectors)	~30%

[2] The Regional Greenhouse Gas Initiative is voluntary and following states have joined Connecticut, Delaware, Maine, Maryland, Massachusetts, New Hampshire, New Jersey, New York, Rhode Island, and Vermont, Virginia

Name	EU ETS	NZ ETS	RGGI	WCI	K ETS	China ETS	UK ETS
2030 reduction target	At least 55% below 1990 GHG levels by 2030 proposed (European Green Deal), to be set in Climate Law	30% reduction from 2005 GHG levels	30% reduction below the 2020 cap	California: 40% reduction from 1990 Quebec: 37.5% reduction from 1990	24.4% compared to 2017GHG levels	Peak CO_2 emission before 2030 (as announced by President in September 2020); lowering CO_2 emissions per unit of GDP by about 65% from 2005 levels (updated NDC)	68% reduction from 1990 GHG levels (Updated NDC)
Market value	€201 billion (2020)	€516 million (2020)	€1.7 billion (2020)	€24 billion (2020)	€870 million (2020)	€257 million (eight regional pilot ETS in 2020)	n/a
Offset provisions	Not allowed from 2021.	As of June 2015, international units are not eligible under the NZ ETS.	Use of offsets is limited to 3.3% of a covered entity's compliance obligation for each control period.	California: the share of offsets used for compliance will decrease to 4% per year for 2021-2025 emissions and will increase to 6% starting with 2026 emissions. Quebec: up to 8% of each entity compliance obligation.	Offset usage has been reduced from 10% to 5% from 2021, meaning a company can submit maximum of 5% of international offsets or 5% domestic, or a mix of the two.	China Certified Emissions Reduction (CCER) can be used to cover up to 5% of entity's verified emissions for compliance in the national ETS.	The use of offsets for compliance is not permitted as of now, but government has indicated it is open to review this at later stage.

Source: Author based on International Carbon Action Partnership (ICAP, n.d.)

As a means of placing a price on GHG emissions, nations and regions throughout the world are creating emissions trading schemes. Such programs are currently in effect in Europe, North America, and portions of Asia; their implementation in South America and other regions are being discussed. Given the difficulty of securing agreement on climate change mitigation measures through multilateral climate discussions, momentum appears to have shifted from the world to the national and regional levels (Tuerk et al., 2013). In the fast-rising economies of Brazil, China, India, and South Korea, new trading systems are being discussed or have already been developed, revealing a particularly robust dynamic. According to International Carbon Action Partnership (ICAP), there are 49 ETS around the world. They are divided into three categories: under development (10 ETS), under consideration (14 ETS) and in action (25 ETS) (ICAP, n.d.).

National emission trading programs have been discussed in the United States and Canada, but they have not yet received the required political support. Instead, North American carbon trading systems have arisen at the regional level: nine U.S. states have joined forces in a cooperative trading system known as the Regional Greenhouse Gas Initiative (RGGI), and in January 2014, the Canadian province of Quebec joined California's emissions trading program (Tuerk and Zelljadt, 2016). The RGGI is a carbon market among northeastern and mid-Atlantic states that became operational on January 1, 2009. It only addresses CO_2 emissions from energy production. The Western Climate Endeavor (WCI) is an initiative of US states and Canadian provinces to establish climate change policy in collaboration. Only California and Quebec have adopted pollution trading systems as of January 1, 2013 (Tuerk and Zelljadt, 2016).

Five Chinese cities and two provinces have launched experimental carbon markets, accounting for almost one-fourth of China's gross domestic product and CO_2 emissions, respectively (ICAP, n.d.). In 2011, the National Development and Reform Commission (NDRC) announced its intention to establish seven official ETS trial programs in Beijing, Shanghai, Tianjin, Chongqing, and Shenzhen, as well as two provinces (Guangdong and Hubei) plus one ETS program in Fujian since 2016 (Tuerk and Zelljadt, 2016). The Chinese government implemented a national emissions pricing plan in 2021 and China's national ETS, the world's largest in terms of emissions covered, went into effect in 2021(ICAP, n.d.). It is based on the successful implementation of pilot carbon markets in eight locations. The ETS aims to contribute to the effective control and progressive reduction of carbon emissions and, as confirmed as part of the 1+N policy framework in October 2021, will be a key policy instrument to accomplish China's goals to reach peak emissions by 2030 and carbon neutrality by 2060.

The ETS regulates more than 2,000 power sector firms (including combined heat and power and captive power plants in other industries) that emit more than 26,000 tCO_2 annually (ICAP, n.d.). The Chinese national ETS is anticipated to cover more than 4 billion metric tons of carbon dioxide or more than 40% of the country's carbon emissions. It is an intensity-based approach with post-hoc modifications to the cap based on actual amounts of production. Currently, compliance requirements are limited and vary by kind of power generation. Over time, the system will be expanded to other industries, and its policy design and implementation will be refined.

In January 2015, South Korea's pollution trading program went into effect. Other sections of the Asia-Pacific region present a mixed picture. Since 2010, the Tokyo Metropolitan Government has operated a trading system for indirect CO_2 emissions (Tuerk and Zelljadt, 2016). However, Japan has no plans to develop a nationwide trading mechanism for emissions. While New Zealand's modest ETS has been in operation since 2008, Australia's long-planned national ETS was abandoned after a government change in 2013. The New Zealand Emissions Trading Scheme (NZ ETS) went into effect in 2008 and is the only emissions trading scheme to encompass the forestry sector. The Korean ETS went into effect in January 2015 and covered over 60% of the nation's emissions (Tuerk and Zelljadt, 2016). Over 500 organizations (thousands of individual sites) in the energy and industry sectors, as well as waste management and domestic aviation, are covered. The Kazakhstan Emissions Trading Scheme's pilot phase for CO_2 emissions began in 2013. Included are the energy, mining and metals, chemicals, cement, and electricity sectors (Tuerk and Zelljadt, 2016).

The EU ETS, which has been operational since 2005, has encountered a number of obstacles as a result of the formation of the largest market for an environmental commodity in human history (ICAP, n.d.). Currently, the EU ETS includes CO_2 emissions from emitters in the power sector, combustion plants, oil refineries, and iron and steel works, as well as facilities producing cement, glass, lime, bricks, ceramics, and pulp and paper. More than 11,000 covered companies are responsible for approximately 2 gigatons, or 40%, of the EU's total greenhouse gas emissions (ICAP, n.d.). The United Kingdom Emissions Trading Scheme (UK ETS) began in January 2021. Numerous aspects of the new system's architecture resemble those of phase 4 of the EU ETS, in which the United Kingdom has participated since 2005. The UK ETS encompasses energy-intensive industries, the power industry, and aviation inside the UK and European Economic Area (EEA), which account for approximately one-third of the UK's GHG emissions.

Existing and emerging trading schemes differ greatly in terms of design characteristics such as scope and allocation technique. While the EU-ETS focuses on industry and large energy producers and ETS schemes in the United States and Canada have similar coverages (with the exception of the linked California/Quebec program, which also includes transport emissions), some of the emerging schemes in Asia include smaller facilities, buildings, and indirect energy consumption emissions (ICAP, n.d.). While schemes in the United States and Europe employ absolute caps, the Chinese pilot ETS primarily employs an intensity index for necessary reductions. Only a handful of ETS around the world utilizes auctioning from the start. Similar to the EU-ETS, where grandfathering (a technique of allocating permits to emitters based on their historical emissions) was initially utilized, the Chinese ETS pilots distribute the majority of allowances for free.

Although neither the United States nor Canada have national emission pricing schemes, regional carbon markets exist in both countries. Various ETS are simultaneously evolving at the regional and national levels in Asia. Some of these differ from “conventional” schemes in industrialized nations (such as RGGI and the EU ETS), which focus primarily on emissions from heavy industries and the power sector. In contrast, some of the more recent plans use smaller facilities or buildings and indirect energy usage emissions. Given the current state of affairs in Asia, the future of global emissions trading will be contingent on developments in Asia and, to a lesser extent, other developing regions. If this trend continues, emerging economies could eventually surpass the European Union and other members of Organization for Economic and Co-operation development (OECD) as centres for emissions trading, which would radically alter the style, character, and challenges of a future international carbon market (Tuerk and Zelljadt, 2016).

2.3.1.2. Clean Development Mechanism

Article 12 of the Protocol defines the Clean Development Mechanism (CDM), which permits a nation with an emission-reduction or emission-limitation commitment under the Kyoto Protocol (Annex B Party) to implement an emission-reduction project in developing countries. These projects can generate tradable certified emission reduction (CER) credits, each of which is equivalent to one tonne of CO_2 and can be counted against Kyoto targets. The mechanism is regarded by many as an innovator. It is the first worldwide environmental investment and credit system of its sort, offering CERs as a standard tool for offsetting emissions (UNFCCC, n.d. c).

An example of a CDM project activity might be rural electrification utilizing solar panels or the construction of more energy-efficient boilers. The mechanism encourages sustainable development and carbon reductions while providing industrialized nations with considerable flexibility in meeting their emission reduction or limitation goals.

The CDM was presented so late in the drafting of the Kyoto Protocol that it has been dubbed the "Kyoto surprise" (Werksman, 1998). In June 1997, barely six months prior to the Kyoto discussions, the Brazilian delegation suggested the establishment of a Green Development Fund (GDF) that would be sponsored by countries not in compliance with their obligations and would fund mitigation programs in developing nations. Although supported by the G77 and China, this idea failed to gain traction since developed nations opposed penalties for disobedience. On the other hand, poor countries were adamantly opposed to any structure that would repeat the logic of the Activities Implemented Jointly (AIJ) of the UNFCCC (Lecocq and Ambrosi, 2007).

CDM projects would generate additional credits in countries without commitments, which would then be transferred to countries with obligations, so increasing the overall number of carbon credits in circulation (Lecocq and Ambrosi, 2007). The hazards associated with such "money creation" were not missed by the negotiators. In spite of these fundamental obstacles and the turbulence of international climate negotiations in the years following the adoption of the Kyoto Protocol, the CDM has become a thriving market in less than a decade. In 2005 alone, over 180 transactions were documented that sent $2.5 billion in carbon money to developing nations, which is equivalent to 2.5% of total net Official Development Assistance (ODA) (Capoor and Ambrosi, 2006).

In 2008, the average price of a CER credit from the CDM peaked at €16.8 (Kossoy and Ambrosi, 2010). However, in 2014, the average price of a CER fell to €0.17. (Kossoy, 2015). Since then, there has been no meaningful price rebound. In effect, the market has collapsed due to the precipitous decrease in the product's exchange value (Watt, 2018).

Organizations governed by the ETS have utilized a substantial quantity of carbon offsets for compliance purposes, hence increasing the overall supply of carbon credits. Approximately 1,600 million CERs can be used to deliver the needed emission reductions under the ETS from 2008 to 2020. (Alberola et al. 2015: 10). As the excess of emissions permits in the ETS is over 2,100 million carbon units, it is apparent that the introduction of carbon market offsets has significantly exacerbated the oversupply (Carbon Market Watch, 2014). Thus, the EU's flagship climate program has been undermined by the recession, alternative carbon reduction plans, insufficient targets, and offsetting provisions.

By 2020, the CDM plan, which centred on the cancellation system, was nearly liquidated. The main reason contributing to the liquidation was the fact that many investment firms reluctantly accepted the loss-reducing cancellation of certified emission reduction credits at the conclusion of the project's duration. However, the CDM plan was revived due to unexpected backing from the United States and developing nations (Kainou, 2022).

The quantity of cancelled certified emission reductions via the voluntary cancellation procedure amounted to 77 million tonnes of CO_2, which was greater than anticipated (Kainou, 2022). Surprisingly, the majority of users were American businesses and individuals. In terms of purchase volume, companies qualifying for the emission credit trading systems of California and 13 East Coast states accounted for the majority of the total, although U.S. citizens represented the largest user group in terms of the number of purchases (Kainou, 2022). Citizens were eager to purchase verified emission reductions at their own discretion, notwithstanding the government's refusal to sign either the Kyoto Protocol or the Paris Agreement.

Numerous developing nations, including China, Mexico, and South Africa, have agreed to permit the use of certified emission reduction credits inside their domestic environmental tax systems and emission credit trading systems (Kainou, 2022). The 2019 implementation of South Africa's carbon tax system is a prime example. Under this system, major carbon emitters, such as electric power and mining companies, are taxed based on their emission volume at a nominal tax rate of approximately $8/tonne of CO_2 but are exempt from paying taxes on the portion of their emissions covered by voluntarily cancelled certified emission reductions (Kainou, 2022).

As a result, the CDM program has been on the path to revival in recent years. Since 2013, 1200 new projects have been registered, and 2 billion tonnes of CO_2 certified emission reduction credits have been issued (Kainou, 2022). The majority of these new projects and freshly awarded credits are the results of investments by corporations in China, Mexico, and South Africa seeking to stockpile verified carbon reductions for future use (Kainou, 2022). A financially distressed South African electric power utility is accumulating certified emission reduction certificates as intangible assets for emergencies such as harsh weather disasters and sudden tax increases.

However, it would be erroneous to believe that the CDM scheme's future is good. The current favourable outcomes of the CDM program are purely coincidental. Given that the price of certified emission reduction credits has maintained between €1 and €2 per tonne of CO_2, the current scenario should be viewed as temporary. Fundamentally, the world of carbon financing, including the CDM scheme, is inherently susceptible to panic due to the possibility of a far bigger supply than demand. Moreover, since the world is full of investment firms that were forced to absorb enormous losses and financial institutions that had a terrifying experience with carbon finance, it would be overly optimistic to assume that the situation has improved since the Paris Agreement replaced the Kyoto Protocol (Kainou, 2022).

2.3.1.3. Joint Implementation

The mechanism known as "joint implementation" (JI) as defined in Article 6 of the Kyoto Protocol, enables a country with an emission reduction or limitation commitment under the Kyoto Protocol (Annex B Party) to earn emission reduction units (ERUs) from an emission-reduction or emission removal project in another Annex B Party, each equivalent to one tonne of CO_2, which can be counted towards meeting its Kyoto goal. JI allows Parties to achieve a portion of their Kyoto commitments in a flexible and cost-effective manner while the host Party benefits from foreign investment and knowledge transfer (UNFCCC, n.d. b).

A JI project must offer a decrease in emissions by sources or an increase in removals by sinks that would not have occurred otherwise. Projects must be approved by the host Party, and participants must be permitted by a Party participating in the project. Projects beginning as early as the year 2000 may qualify as JI projects provided they match the necessary criteria, although ERUs may only be given for crediting periods beginning after the start of 2008.

If a host Party satisfies all eligibility conditions to transfer and/or acquire ERUs, it may verify emission reductions or improvements of removals from a JI project as extra to those that would have otherwise occurred. Upon such verification, the host Party is permitted to issue the correct number of ERUs. This treatment is generally known as the Track 1 procedure (UNFCCC, n.d. b). If a host Party does not achieve all eligibility standards, but only a subset, verification of emission reductions or upgrades of removals as being additional must be conducted through the Joint Implementation Supervisory Committee's verification mechanism (JISC). Before the host Party can issue and transfer ERUs under this so-called Track 2 procedure, an independent institution recognized by the JISC must determine whether the applicable standards have been met. A host Party that satisfies all qualifying requirements may at any time elect to use the JISC verification procedure (Track 2 procedure) (UNFCCC, n.d. b).

2.3.2. Paris Agreement

The Paris Agreement is a legally enforceable international climate change accord. It was adopted by 196 Parties at the 21st Conference of the Parties in Paris on December 12, 2015, and entered into force on November 4, 2016. It aims to restrict global warming to far below 2 degrees Celsius, preferably 1.5 degrees Celsius, relative to pre-industrial levels (UNFCCC, 2015). To attain this long-term temperature ambition, nations want to reach the global peak of GHG emissions as quickly as feasible in order to achieve climate neutrality by mid-century.

The Paris Agreement is a watershed moment in the multilateral climate change process because, for the first time, a legally binding agreement unites all nations in a joint effort to battle climate change and adapt to its consequences. Utilizing the latest current science, implementation of the Paris Agreement necessitates economic and social reform. The Paris Agreement, according to UNFCCC (2015), operates on a five-year cycle of increasingly ambitious climate action by participating nations. Countries submit their climate action plans, known as nationally determined contributions (NDCs), by 2020. In their NDCs, nations outline the steps they will take to cut their GHG emissions in order to meet the Paris Agreement’s objectives. In their NDCs, countries also describe the steps they will take to enhance resilience and adapt to the effects of rising temperatures.

To further frame efforts towards the long-term objective, the Paris Agreement urged countries to design and submit by 2020 long-term low greenhouse gas emission development strategies (LT-LEDS). LT-LEDs offer the NDCs with a long-term perspective (UNFCCC, 2015). In contrast to NDCs, they are not required. In spite of this, they situate the NDCs within the context of countries’ long-term planning and development aspirations, so offering a vision and direction for future growth.

The Paris Agreement provides a framework for countries in need of financial, technical, and capacity-building assistance. It maintains that rich countries should take the lead in providing financial help to less endowed and more vulnerable countries, while also for the first time encouraging voluntary contributions from other Parties. Large-scale expenditures are required to considerably cut emissions, which necessitates climate finance for mitigation. Climate finance is similarly vital for adaptation, as substantial financial resources are required to adapt to and mitigate the negative effects of climate change.

The Paris Agreement outlines the objective of fully implementing technological development and transfer for enhancing climate change resilience and decreasing greenhouse gas emissions. It establishes a technology framework to provide the Technology Mechanism with overarching direction. Through its policy and implementation arms, the mechanism expedites the development and transfer of technology.

Many of the issues brought about by climate change are insurmountable for a portion of emerging nations. As a result, the Paris Agreement places a significant emphasis on developing countries' climate-related capacity-building and demands that all wealthier nations increase their support for such initiatives.

With the Paris Agreement, nations established an enhanced transparency framework (ETF). Starting in 2024, under the ETF, governments will report openly on their activities and progress in climate change mitigation, adaptation, and support supplied or received. It also stipulates worldwide protocols for evaluating submitted reports. The information obtained by the ETF will be incorporated into the Global Stocktake, which will assess the collective progress toward long-term climate objectives. This will result in recommendations for countries to establish more ambitious goals in the subsequent phase (Elliot and Chin, 2021).

Achieving the goals of the Paris Agreement requires a major increase in climate change action, but in the years since it's coming into force, low-carbon solutions and new markets have emerged. Increasing numbers of nations, regions, cities and businesses are creating carbon neutrality goals. Carbon-free solutions are becoming increasingly competitive across economic sectors that account for 25% of emissions. This trend is especially evident in the energy and transportation industries, where it has opened numerous new business opportunities for early adopters. By 2030, zero-carbon solutions might be competitive in sectors that account for more than 70% of global emissions.

2.4. The UN SDGs

The Sustainable Development Goals (SDGs) or Global Goals are a set of 17 interconnected global goals intended to serve as a *"common blueprint for peace and prosperity for people and the planet, now and in the future"* (UN Office for Sustainable Development, n.d.). The

Sustainable Development Goals (SDGs) were established in 2015 by the United Nations General Assembly (UNGA) and are meant to be attained by 2030 (UN DESA, 2015). They are included in a United Nations General Assembly resolution titled the 2030 Agenda. The SDGs were established in the Post-2015 Development Agenda as the successor to the Millennium Development Goals, which expired in 2015. Two years later, on 6 July 2017, a resolution voted by the General Assembly of the United Nations made the SDGs more "actionable", notwithstanding its breadth and interdependence. The resolution defines detailed objectives for each objective, as well as the metrics used to monitor progress toward each objective (UN, 2017). Typically, the year by which the objective is to be attained falls between 2020 and 2030 (UNSD, n.d.). For several of the objectives, no completion date is specified. All 17 UN SDGs are presented in Figure 2.

Figure 2 UN SDGs

Source: author according to UN DESA (n. d.)

The 17 goals consist of 169 targets that should be achieved. Targets are monitored by 232 distinctive indicators (SDG Tracker, n.d.). The objectives are wide and interrelated. The key to achieving the SDGs is to make data on the 17 objectives generally available and understandable, as well as to mobilize relevant stakeholders at all levels.

Despite their good intentions, two critical details were ignored when the SDGs were agreed upon. The first point to mention is that the focus on the delivery was sure to change. For instance, developed countries are less likely to prioritize SDG 1 (fighting poverty) and SDG 2 (eliminating hunger), while these two SDGs are going to be more prioritized in developing countries. As Leal Filho (2020) states, there is also a need to dispel the commonly held belief that the SDGs are solely for poor countries and those wealthier ones should not participate in some of them. In addition, the implementation of specific goals must be based on a rigorous structure that incorporates planning, budgeting, delivering activities, and monitoring and evaluation. All countries involved in SDGs do not have equal possibilities to participate in all SDGs because they are less likely to have enough knowledge or finance to achieve certain goal.

Finally, despite much discussion, interactions between Higher Education Institutions (HEIs) and the community have not yet been completely incorporated into the design or implementation of most sustainability projects. This is still a gray region in which action is required. As a result, there is a genuine risk that the SDGs may not be met by 2030 (Leal Filho, 2020). The academic community, which was not sufficiently involved in the talks that led to the SDGs, can and has made a significant contribution to the goals' implementation. Aside from informing millions of students at HEIs about the SDGs. The transformative potential of research can substantially aid in creating a deeper knowledge of the SDGs' numerous socioeconomic and environmental dimensions, and hence promote their implementation. The SDGs are thought to have the potential to revitalize the sustainable development research agenda (Leal Filho et al., 2018).

While it is unknown whether the SDGs will be fully realised by 2030, it is apparent that efforts must be taken to accomplish as many of the SDGs as possible by that time. It is critical to the food security, health, and well-being of billions of people worldwide.

2.4.1. Development of the UN SDGs

From a historical standpoint, negotiations regarding developing the SDGs began in June 2012 (UN, 2012) at the United Nations Conference on Sustainable Development in Rio de Janeiro, Brazil (often known as Rio 20+). The purpose of the SDGs initiative was to create a set of global goals that address the world's critical environmental, political, and economic concerns, which affect both developed and developing countries. The SDGs were supposed to succeed the Millennium Development Goals (MDGs), which launched a global effort in 2000. The

MDGs established at the time widely agreed-upon goals for combating extreme poverty and hunger, preventing lethal diseases, and expanding primary education to all children, among other development priorities (UNDP, 2016).

Unfortunately, the MDGs did not fully achieve the goals they set within the time frame allotted (2000-2015). Leal Filho (2020) points out three major factors why MDGs were unsuccessful:

- Even though they were endorsed by 189 UN members, the financial resources required to support their implementation were not completely made available.
- No effective procedures for measuring and rewarding progress were in place.
- While the MDGs were significant, they were not as visible or as present in international discussions and debates as they should have been.

However, the MDGs did drive success in a few critical areas such as moderately reducing poverty levels in some countries, giving much-needed access to water and sanitation, lowering child mortality, and increasing maternal health, among many others (Leal Filho, 2020). They also inspired governments to invest in their future generations by launching a global campaign for free elementary education.

The legacy and accomplishments of the MDGs gave useful lessons and experiences for the start of work on the new goals, the SDGs. The UN General Assembly approved the Secretary General's Synthesis Report on December 5, 2014, stating that the agenda for the post-2015 SDG process would be based on the Open Working Group ideas (UN Office for Sustainable Development, n.d.).

2.4.2. Measuring the SDGs Indicators

The UN Statistical Commission (2017) adopted the Global Indicator Framework (GIF) in March 2017. The framework consists of 232 statistical indicators meant to measure the 17 objectives and 169 targets of the 2030 Agenda. The objective of the GIF is to give high-quality, verifiable proof of the 2030 Agenda's progress. However, filling these indicators and supplying this evidence presents significant obstacles (MacFeely, 2020). In addition, Table 2 shows the difference between UN SDGs and MDGs. The main difference is not only in the number of goals, targets and indicators but in the possibility of successfully monitoring the progress toward achieving all of them. As Leal Filho (2020) stated, MDGs failed to achieve the aims it set within the time span provided.

Table 2 UN SDGs and MDGs comparison

UN SDGs	MDGs
17 goals 169 targets 232 indicators	8 goals 21 targets 60 indicators

Source: author's own interpretation

From a statistical standpoint, the 2030 Agenda and the associated GIF have huge ramifications. Not only has the number of goals and targets increased significantly compared to the MDGs but so has the complexity of these targets. The scope of the 2030 Agenda is likewise far broader than its predecessor, seeking to encompass the entire range of development concerns, encompassing not just areas of society, economics, and the environment but also institutional coordination (MacFeely, 2020).

The first problem statisticians faced was determining precisely what was to be measured. The main problem is the lack of precise definitions and unequal use of terminology in The Agenda 2030, which forced statisticians to freely decide what the targets truly mean (MacFeely, 2020). The second problem is the absence of priority within complicated and sometimes confusing objectives. Politicians told statisticians to minimise the number of indicators per target to one if possible (MacFeely, 2020). The politicians' task is impossible, 232 indicators to 169 targets, meaning there is more than one indicator per target.

A range of tools exists to measure and visualize progress towards the goals to simplify monitoring. The goal is to make data more accessible and understandable. For instance, the online publication SDG Tracker, released in June 2018, provides data for all accessible indicators (SDG Tracker, n.d.). Multiple cross-cutting topics, such as gender equality, education, and culture, are addressed by the SDGs. In 2020, the Covid-19 pandemic will have significant effects and repercussions on all 17 SDGs (United Nations Economic and Social Council, 2018).

About half of member States identified the modernization of statistics processes as difficult for SDG measuring and monitoring. Still, it did not rank among the most pressing issues for nations (United Nations Economic Commission for Europe, 2020). It is unclear whether this is because countries mostly understand how to overcome the modernization obstacles they confront or because they do not view modernisation as a key priority in measuring and monitoring SDGs.

Regional and international organizations have articulated the benefits and necessity of modernization in the framework of measurement and monitoring.

Schwandt et al. (2016) described what is necessary to successfully measure SDGs. A strong emphasis has been put on evaluation, not only on measuring the SDGs. One can measure SDGs by numbers, but there should be an evaluation of each number to determine if the country is making progress or not. In addition, evaluation can address the complexity of the SDGs and their success since the SDGs are interconnected in complex ways (Schwandt et al., 2016).

2.4.3. SDGs as a Business Opportunity

On the one hand, SDGs have been seen as a problem due to their measurement; on the other hand, they can be perceived as a business opportunity. They are assigned on the national level, but at the same time, they are opportunities for businesses to implement new technologies in the production process, innovate business models etc. The following text will describe a detailed explanation of how companies can implement SDGs in their business and help achieve SDGs that are in the focus of this dissertation.

2.4.3.1. SDG 9. Industry, Innovation, and Infrastructure

The standard of living for the majority of the population is getting worse while the gap between rich and poor widens. People have difficulty meeting their most fundamental requirements. One in three people throughout the world do not have access to safe drinking water (WHO, 2019); 940 million people, or 13% of the global population, do not have access to the wonder that is electricity (Davies and Simons, 2020). By the year 2030, the WHO projects that five billion people would lack access to health care (Director-General of the WHO, 2018). This condition started to become considerably more perilous, particularly in nations that were either poor or still in the process of developing. As part of SDG 9 goal, industrialised countries have pledged to give developing and underdeveloped countries support in the form of development assistance (Küfeoğlu, 2021). Within the context of this SDG, developing and underdeveloped countries require innovative approaches, sustainable industrial breakthroughs, and long-term infrastructure investments in order to achieve sustainable economic growth, social and grassroots development, and climate change mitigation (Küfeoğlu, 2021).

Providing emerging countries with access to financial services and markets is of the utmost importance. For their economic development, many nations require loans and credit. In the region of sub-Saharan Africa, only one in five of small-scale enterprises has access to loans or credit (Sierra-Escalante and Lauridsen, 2018). The percentage of individuals who use the internet is rather high among OECD members, the United Nations ranks least developed countries as having an average Internet penetration rate of 17%. Access to the internet in the world's least developed countries is still extremely limited (International Telecommunication Union, 2022).

There are three primary focuses that make up SDG-9. The key to sustainable economic growth and raising the level of welfare in society is to develop industrialization, new technological developments and new skills in line with innovation. Transportation, information and communication infrastructures are important parts of development that are in line with these goals (Küfeoğlu, 2021).

The objective for sustainable development makes collaboration between industry and innovators an absolutely necessary component in the process of building environmentally friendly infrastructure. Industrialization and technological advancement should serve as the basis for growth, and all countries should industrialize in a way that is environmentally responsible. Putting money into new technologies and improving existing ones are both essential components of economic growth. There are currently more people living in cities than there are living everywhere else on the planet. It is currently more crucial than it has ever been to launch new businesses and advance public transit, renewable energy sources, and information and communication technology. Transformational innovation is required for long-term strategies to address financial and environmental challenges, such as increasing energy efficiency and employment opportunities. Fostering sustainable industries, financial support for technological research and development, and innovative investment are all potential drivers of sustainable growth.

2.4.3.2. SDG 13. Climate Action

On December 12, 2015, at COP21 in Paris, countries adopted the Paris Agreement to combat climate change. All nations agreed to work toward limiting the increase in global temperature to 1.5 degrees Celsius. This agreement illustrates the primary focus of SDG 13, which is mitigating and reducing the effects of climate change by reducing GHG emissions. Under SDG-13, the United Nations provides funding to developing countries so that they can build low-carbon development plans and adapt to the effects of climate change (UN DESA, n. d. b).

Many SDGs are interconnected; therefore, the connection is a clear two-way relationship: SDGs can mutually reinforce each other, allowing for the creation of a positive upward spiral. There is no nation on earth that is immune to the effects of climate change. Changing ecosystems (rising sea levels, drought, biodiversity loss) and health and safety damages, as well as the associated costs, are detrimental to society and businesses.

The effects of climate change can be seen in every aspect of how nature behaves. In the middle of the year 2021, Germany was hit by one of the deadliest and most destructive natural disasters in its history (Cornwall, 2021; Fekete and Sandholz, 2021). In addition, wildfires all around the world garnered a lot of attention in 2021, particularly those that occurred in Canada, Siberia, and countries in the Mediterranean (Labzovskii et al., n. d.; Kharuk et al., 2021). Humanity is not yet prepared to deal with frequent and extreme climate-related disasters, as evidenced by the number of lives lost, the amount of property damaged, the number of people forced to relocate within their own countries, the lack of access to clean water and electricity, deforestation, and high carbon emissions. By 2030, the UN plans to react to wild calamities in every country adaptively. It is important that as few people perish, become injured, lose their homes, or become internally displaced due to natural disasters as is humanly possible (The Global Goals, n. d.).

Directly or indirectly, the effects of climate change exert pressure on nearly every revenue stream of businesses. When the direct production process of a business or supplier is related to or dependent on agriculture or water, business models may be impacted. For instance, rising temperatures may diminish water resources and harm agricultural processes (Van den Breul et al., 2018). One could also imagine air pollution negatively impacting business processes via contaminated water or other natural substances. Especially for non-Western suppliers, natural disasters and extreme weather can impact their business operations.

New technological advances can assist businesses in reducing GHG emissions. In addition to other strategies, switching from fossil fuels to renewable energy can help reduce greenhouse gas emissions. Nonetheless, obstacles remain associated with this transition. Renewable energy’s current challenge is to provide energy in the same reliable manner as existing grids. This expands on the discussion of keeping coal and gas as a backup plan until a comprehensive solution is implemented. The technology exists to make the switch to renewable energy (Van den Breul et al., 2018). However, since this innovation is still in its infancy, it cannot be compared to the current, dependable energy supply. Therefore, adopting these new technologies requires courage. For businesses, this means that their contribution to the renewable energy experience can be found in establishing pilots within their organizations' ecosystems. Nonetheless, room for innovation must exist to achieve this breakthrough, and financial considerations play a crucial role.

If businesses want to make a stronger case for energy-saving technologies, they should view these investments as long-term exploitation and consider their long-term effects. To garner support for climate change decisions both inside and outside the business, it is necessary to raise awareness about this issue. First and foremost, it is crucial that businesses integrate climate change into their strategies with measurable targets. These objectives should align with the needs and preferences of the organization and its constituents. Thus, clear actions can be taken, and support for achieving the objectives is generated (Van den Breul et al., 2018). Second, it is essential to clarify the investment opportunities for both the business and its stakeholders. To create this clarity, risk-scenarios should be developed to illustrate the relationship between climate change and the business. Aligning the goals and objectives with the needs and ideas of the business and its stakeholders increases the opportunities for investments and the achievement of objectives, thereby making a clear contribution to SDG 13.

To fight against climate change, governments and businesses should develop new policies and programs that incorporate climate change mitigation strategies in order to meet future targets for limiting the effects of climate change. The indicators of this very targeted attention on decarbonization measures and the amount of greenhouse gas emissions. One example of a country's intention to fight against climate change is creating "nationally determined contributions" (NDCs). The main purpose of these documents is to indicate the plan for reducing GHG emissions and the effects of climate change. In addition to their NDCs, countries that have volunteered to do so, have begun adopting additional strategies to safeguard their citizens against the natural catastrophes brought on by climate change. Examples of such disasters include floods and cyclones (UN DESA, 2021). However, the proclaimed aims of certain countries are insufficient, which means that those targets can be met even without the implementation of new measures. In addition, another group of nations decided to implement policies that are unable to meet the insufficient requirements. This circumstance makes it more difficult to make progress toward the targets of 2030 and 2050. Therefore, it is important to model policies after those of nations who are making significant progress (Doni et al., 2020).

For decision-makers to be able to properly plan for the future, they require a knowledge base that is substantially broader. In order to achieve this goal, researchers and decision-makers need to work together to generate this information, which can then be applied to the development of successful policies to address climate change (Engineering and Physical Sciences Research Council, 2003). To fight climate change, certain strategies, as well as the knowledge and abilities to implement them are needed. Both scholars and policymakers have placed a strong focus on the significance of developing trustworthy frameworks that can be used as indicators of adaptive capacity (IPCC, 2007b). Due to the fact that adaptation is both context-specific and process-based, there is no template that can be used to determine what this should consist of. Because it is so closely connected to other aspects that have a role in decision making, it is considered essential to have an understanding of how to adapt (IPCC, 2014). The importance of learning and offering insights into what constitutes effective adaptation is growing. The "effective adaptation" is defined as changes that minimize sensitivity to current and future climate change.

The EU's long-term plans call for a significant increase in the use of nuclear power, which is another low-emissions form of energy technology. The utilization of diverse energy supply methods should prioritize the utilization of renewable energy sources. When it comes to all of these plans for the supply of energy, achieving great energy efficiency in the area of end-users is also an essential goal. In conclusion, carbon capture devices are being considered for implementation in the long run with the goal of reducing the amount of carbon gases that are unavoidably released into the environment (European Commission, 2011).

Individual or business carbon emissions may be subject to economic punishments, such carbon taxes and emission trading systems. Despite the fact that this method can ensure equitable compensation, low-income individuals may be disproportionately harmed by these policies (Gough et al., 2011).

Businesses and financial institutions are strongly encouraged to set their goals at the most aspirational level possible and to make a commitment to setting a long-term science-based target with the intention of achieving net-zero value chain greenhouse gas emissions as soon as possible and no later than 2050.

When it comes to offering proactive and constructive advice for governments to use in the development of effective climate policy, businesses play a vital role. While it is crucial to make a commitment to sustainability, it is even more important to connect the connections between this commitment and the views that your company takes on various policy issues. The climate action taken by businesses is an extremely important component in the process of providing market signals to nations to encourage them to improve their climate policies (UN Global Compact, n. d.). During a period of increased global unpredictability, the Covid-19 pandemic has exacerbated pre-existing disparities and poses a risk of rolling back advancements made toward achieving the SDGs and the Paris Agreement.

2.5. GHG Emissions in the EU Member States

The EU Member States are pioneers in the fight against climate change. The EU have numerous policies whose main purpose is to achieve all the targets for GHG emission reduction. Despite meeting its 2020 targets for GHG and increasing renewable energy use and energy efficiency in the unusual environment of the Covid-19 pandemic, and the pandemic recovery led to a surge in energy use and emissions in 2021 (Liselotte, 2021a). The European Climate Law aims to reduce net GHG emissions by “at least” 55% by 2030 compared to 1990. However, existing climate and energy legislation for the 2021-2030 era, as well as Member States’ national energy and climate plans (NECPs) for the 2021-2030 period, are still based on a lower 2030 objective of 40% emission reduction, as mandated by the Governance Regulation. The Commission intends to bring EU climate and energy legislation in line with the new targets with the “fit for 55” reform presented in July 2021. Member States need to harmonise their NECPs by June 2024. In 2019, the EU-27 GHG emissions were 3,743 Mt CO2e, representing a 19% decrease from 2005 and a 24% decrease from 1990 levels (Liselotte, 2021a).

Since 2020, three legislative pillars, the EU ETS Directive (2003/87/EC), the Effort-sharing Regulation (2018/842), and the LULUCF Regulation (2018/841), will cover emissions across the economy (Liselotte, 2021a). Prior to 2020, the Kyoto Protocol included LULUCF emissions and removals. The LULUCF sectors are vital to reaching the legally mandated EU goal of climate neutrality by 2050, since their GHG reductions will compensate for any emissions that cannot be reduced. The Just Transition Fund, established by Regulation 2021/1056, is important for assisting areas with emission-intensive sectors or coal-based economies in their transition. The Recovery and Resilience Facility, established to alleviate the epidemic’s economic impact, will allocate 37% of its revenues to climate action. The ‘fit for 55’ proposals of the European Commission include a substantial overhaul of the European climate action framework.

In 2019, the energy industries accounted for the greatest proportion (24%) of total EU emissions. This marked a decline from 2005 when they were responsible for 30% of the EU's emissions. Throughout this time, emissions from the energy industries were reduced by 35% (Liselotte, 2021a). Despite the fact that all sectors reduced their emissions between 2005 and 2019, only two sectors — transportation and agriculture — reduced their emissions by less than 2%. 19% of the total GHG emissions are accounted for by "other emissions" in third place. The majority of these emissions are attributable to business and residential structures. From 2005 and 2019, this category's emissions decreased by 15%, resulting in a modest rise in its percentage of the total. Although manufacturing industries and construction, as well as industrial processes and product use sectors, maintained the same proportion of overall emissions in 2019 as they did in 2005, emissions within the two sectors decreased by 23% and 21%, respectively. With its 3% share, the waste industry accomplished the second-largest decrease in emissions, with a 27% decrease, behind the energy sector over the same period. In 2019, around 45% of the EU's total emissions were covered by the EU ETS, which includes emissions from power generation and industries (Liselotte, 2021a). The EU ETS is a crucial instrument for decreasing the EU's emissions; continually reducing the available allowances guarantees that the cost of producing GHG grows, making mitigation activity more appealing. The industries covered by the EU ETS, particularly stationary electricity production, have demonstrated a strong tendency toward decarbonisation. From 2018 to 2019, the EU ETS sectors produced a 9% decrease. In contrast to the original goal of 21%, the EU ETS had achieved a 41% decrease in emissions by 2020, compared to 2005, despite the pandemic's impact on the economy. The proposed adjustment of the EU ETS as part of the 'fit for 55' package raises the 2030 EU ETS target from 43% to 61%. EU effort-sharing law establishes binding GHG emission objectives for each Member State, including emissions from non-ETS sectors such as transportation, buildings, agriculture, and waste. The Effort-sharing Decision spanned the years 2013-2020 and established a 10% (EU-28) overall emissions reduction objective, while the Effort-sharing Regulation covers the period 2021-2030 and sets a 29% (EU-27) reduction target (both compared with 2005 levels).

By 2020, the EU targeted a 20% share of renewable energy sources in gross final energy consumption. Five Member States fell short of their respective national renewable energy sources objectives. Due to the Covid-19 pandemic, the EU's overall energy usage drop in 2020 contributed to this accomplishment. Regarding the 2020 aim of 10% renewables share in total energy consumption for transport, demand changes and the overall reduction in transport energy use owing to Covid-19 pandemic limits had a significant influence.

According to the United Nations (1999), Europe is divided into four regions: Eastern Europe, Western Europe, Southern Europe and Northern Europe. There are six Member States in Eastern Europe (Bulgaria, Czechia, Hungary, Poland, Romania, Slovakia), seven Member States in Northern Europe (Denmark, Estonia, Finland, Ireland, Latvia, Lithuania, Sweden), eight Member States in Southern Europe (Croatia, Cyprus, Greece, Italy, Malta, Portugal, Slovenia, Spain), and six Member States in Western Europe (Austria, Belgium, France, Germany, Luxembourg, Netherlands). The author will briefly describe each Member State and its climate action in the following text.

2.5.1. Northern Europe

Morgado Simões and Victoria (2021a) reported Denmark's climate action progress. In 2019, Denmark accounted for 1.6% of total EU emissions. The report stated that Denmark recorded a 23% reduction in net GHG emissions between 2005 and 2018, outperforming the EU. 69% of the nation's emissions were concentrated in three sectors: transportation, energy, and agriculture. Two-thirds of the reduction in total emissions achieved since 2005 may be attributed to developments in the energy sector, which were particularly remarkable. Denmark's emissions reduction objective has increased from 20% by 2020 to 39% by 2030, and a 55% target has been established for 2030. In 2019, the transportation sector contributed the most to Denmark's emissions, decreasing only 0.2%. Agriculture, another large emitter, is responsible for 23% of Denmark's emissions. Energy industries are also responsible for a large share of emissions, with 18% of GHG emissions having more than halved since 2005. The energy business has significantly contributed to the decrease in global emissions, contributing a 21% decline. Through the energy and industry agreement and the waste strategy, the Danish government hopes to reduce emissions by 3,4 million tonnes of CO2 equivalent by 2030. The Danish Parliament passed the Climate Act in June 2020 mandates a 70% decrease in GHG emissions by 2030 and climate neutrality by 2050 at the latest. A climate action plan is being developed, with strategies for energy and industry, waste, road transport, green public procurement, sustainable building and green research.

Yougova (2021a) reported Estonia's climate action progress. The report stated that in 2019, Estonia's GHG emissions were generating 0.4% of total EU GHG emissions. Estonia plans to achieve a 70% decrease in GHG emissions between 1990 and 2030, with an 80% decrease by 2050. Between 2005 and 2019, energy industries were Estonia's primary source of GHG emissions. Oil shale was the primary raw material utilised in the energy sector for power generation and liquid diesel fuel manufacture. The new government's policy seeks to phase out oil shale power generation by 2035 and the usage of oil shale in the whole energy industry by 2040. Regarding decarbonisation, Estonia's NECP envisions a 25% decrease in GHG emissions between 2020 and 2030 through the use of current and new initiatives. Estonia also relies on cross-sectoral policies and actions with the potential to reduce GHG emissions, such as the production of bioenergy and the expansion of agriculture. The NECP aims to enhance farm biomethane production by converting manure and slurry into biogas as a substitute for fossil fuels in the energy and transportation sectors. It also aims to increase fuel efficiency and the proportion of biofuels in transport, electrify railways and ferries and impose time-based road charges on heavy-duty vehicles. The agriculture sector's GHG emissions are predicted to increase by 14% between 2020 and 2030. The Commission finds that the majority of its draft plan suggestions have been partially addressed and emphasises the need for the sustainable use of forest biomass. The NECP of Estonia emphasises synergies between policies and actions pertaining to energy efficiency, renewables, and building rehabilitation. By 2030, renewable energy should account for 63% of Estonia's gross final consumption of heat, 40% of its consumption of electricity, and 35% of "second generation" biofuels and 65% of electricity should be used to meet the 14% objective for transport. Estonia's long-term rehabilitation policy aims to completely renovate all pre-2000 structures by 2050, reducing CO2 emissions by 89% and energy consumption by 59%. Estonia intends to strengthen its current regional cooperation with the other Baltic countries by building cooperative infrastructure projects and offshore wind farms. The new government's platform calls for accelerating the building of Rail Baltic and expanding the Baltic Sea power grid.

Liselotte (2021b) reported Finland's climate action progress. The report stated that since 2005, Finland's GHG emissions have decreased at a quicker rate than the EU average. The energy industry and transportation are the largest emitters in Finland, accounting for 50% of total emissions in 2019. In accordance with EU effort-sharing regulations, Finland was obligated to cut non-ETS emissions by 16% by 2020 compared to 2005 and by 39% by 2030. Renovation of the building stock and voluntary energy efficiency agreements across industries and families are the focal points of energy efficiency efforts. All sectors of the Finnish economy have reduced their emissions, with the exception of agriculture. The transport sector accounted for one-fifth of Finland's total emissions, a proportion that has increased since 2005 despite a 12% decrease in emissions since 2005. As a result of emission reductions in other sectors, the agricultural sector's proportion of overall emissions grew by 30%, from 9% in 2005 to 12% in 2019. The NECP estimates that 90% of industrial process emissions in Finland are covered by the EU ETS, with efficiency gains expected to balance any emissions caused by increasing activity. With laws mandating the phase-out of coal in energy production by 2029 and the introduction of further nuclear power plants, emissions from the energy industry would fall dramatically. To accelerate replacement investments, Finland wants to halve its domestic use of mineral oil, including gasoline and diesel, by 2030 and increase the proportion of transport biofuels from 13.5% in 2020 to 30% in 2030. By 2028, a 10% bio-liquid quota will apply to heating and machinery light fuel oil. By 2025, a transmission line will connect northern Finland and Sweden, bolstering the regional power market and northern Finland's electrical supply security. The Finnish NECP emphasises the potential necessity to replace overhead transmission lines with subterranean cables. To address one-fifth of Finland's total emissions created by transportation, the government enacted a resolution on the fossil-free transportation plan as of May 2021. The objective is to attain net-zero emissions from transportation by 2045, with a benchmark of halving emissions relative to 2005 by 2030. To strengthen Nordic cooperation, lower transport emissions by establishing common indicators, and create a Nordic market for biofuels in transportation, Finland will develop its nuclear capacity and execute a program of disposing of its nuclear waste inside its borders during the next decade.

Liselotte (2021c) reported Ireland's climate action progress. The report stated that since 2005, Ireland's GHG emissions have decreased at a slower rate than the EU average. Ireland is responsible for 1.7% of total EU-27 GHG emissions. The agriculture sector is responsible for 31% of Ireland's emissions, a rise of 4.3% since 2005. Traditionally, energy sectors, manufacturing, and industrial processes account for the bulk of a country's emissions. But, in Ireland, they only account for 28% of total emissions and have cut their emissions by 33% since 2005. In 2019, Ireland attained a 12% share of renewable energy sources. The nation's 2030 aim of a 34% share of renewable energy is mostly centred on wind, solar and biomass. Agriculture is the largest contributor to Ireland's GHG emissions. Agriculture is responsible for an average of 10% of total emissions throughout the EU, compared to 31% in Ireland. Agriculture was the only industry to grow its emissions by 4.3% between 2005 and 2019. Energy industries only contribute 15% of emissions, compared to the EU average of 24%. Energy businesses have reduced their emissions by 41%. By 2030, Ireland aims to generate

70% of its power from renewable energy sources. The transportation industry has managed to lower its emissions by 7.5% since 2005, but this has stalled in recent years. The revised 2030 emissions reduction target is the most significant aspect of the updated Irish NECP, which promises to reduce total GHG emissions by an average of 7% each year until 2030, comparable to a 45% decrease between 1990 and 2030 or a 51% reduction from the baseline at the end of 2018. Waste management achieved the second-greatest reduction in emissions, 34%, but its minor contribution to overall emissions limits its influence. Retrofitting the Irish building stock and decarbonising household heating sources will be crucial to decreasing the proportion of "other emissions". The NECP outlines Ireland's goal to raise the carbon price to €80 per tonne by 2030, which is expected to generate over €6 billion for climate action over the decade.

Morgado Simões (2021a) reported Latvia's climate action progress. The report stated that between 2005 and 2019, Latvia's GHG emissions grew, accounting for 0.3% of total EU GHG emissions. The transportation sector accounted for 27.8% of total emissions, while the manufacturing industry and construction sector reduced their emissions by 42%. In accordance with EU effort-sharing regulations, Latvia was permitted to grow its emissions by 17% between 2005 and 2020. In 2019, Latvia attained a 41% share of renewable energy sources and aspired to reach 50% by 2030. The NECP of Latvia highlights three issues associated with power generation: energy security and the availability of producing capabilities, strengthening the transmission network and enhancing the connection with the European electricity market. The third obstacle is the unrealised potential of zero-emission power-producing technology. The NECP refers to the potential for solar energy to power large-scale solar electricity generation. The transportation sector, which must reduce emissions the most, is not assisting the country in reaching its projected goals because of the increasing age of the fleet and the continued import of old automobiles from other Member States. Latvia's long-term policy for building rehabilitation requires 8,100 residential apartment buildings to be rehabilitated by 2040. The national development plan for 2021-2027 is the principal instrument for medium-term development planning, with priorities such as enhancing the quality of the living environment and promoting regional growth. Several measures are identified, including reducing GHG emissions through climate change mitigation actions and technological advances, increased carbon sequestration, and introducing changes to the public transport network, with a particular emphasis on the railway system and the promotion of local mobility.

Liselotte (2021d) reported Lithuanian climate action progress. The report stated that since 2005, Lithuania's GHG emissions have decreased at a slower rate than the EU average, except for the transportation, agriculture, and "other emissions" sectors. Lithuania is responsible for 0.55% of the EU's total GHG emissions. Transportation and agriculture account for 52% of total emissions, while the energy business has decreased its emissions by 60%. Before 2020, EU ETS permitted Lithuania to grow its emissions by 15%. In 2019, the use of renewable energy in Lithuania was 25.5%. The country's 2030 goal of 45% renewable energy mostly focuses on wind, solar, and biofuels. The majority of energy efficiency initiatives focus on the building stock and transportation sector, although industry and home support programmes are also in place. Transportation accounted for 31% of all emissions in 2019, followed by agriculture. Since 2005, emissions from transportation have grown by 50%, while emissions from agriculture have remained consistent. The energy industry emissions have decreased by 60% due to increasing electricity and gas imports. The portion of overall emissions attributable to industrial processes and product consumption declined little, although the sector's emissions decreased by 20%. Over time, emissions from manufacturing industries and construction decreased by 12%. The waste industry has cut its emissions by 43%, resulting in a two-percentage point decrease in its proportion of overall emissions. The Lithuanian NECP estimates that EU ETS covered 30% of the country's total emissions in 2017, and they plan a further reduction of 37% compared to 2005. With electrification, train emissions are predicted to decrease by 29.9% by 2030 compared to 2005. Green public procurement will be crucial for car and bus fleets seeking to acquire 100% clean vehicles by 2030. Road transportation accounts for the majority of transportation emissions. Sustainable urban mobility planning, tariff incentives for alternative fuel cars, and a freight shift to inland waterways and rail are projected to reduce emissions. Lithuania aims to generate 100% of its power from renewable sources by 2050, including significant benchmarks for lowering imports.

Morgado Simões (2021b) reported Sweden's climate action progress. The report stated that Sweden's GHG emissions have decreased at a quicker rate than the EU average, accounting for 1.4% of total EU GHG emissions. From 2005 to 2019, the transport industry cut emissions by more than 23%, accounting for the largest percentage of overall emissions (30.3%). In accordance with the Effort-sharing Decision (2013-2020), Sweden must cut its non-EU ETS sector emissions by 17% from 2005 levels. In accordance with the Effort-sharing Regulation (2021-2030), the reduction objective for 2030 is 40%. The country's proportion of renewable energy sources was 56.4% in 2019 and is projected to reach 65.0% by 2030, primarily due to wind farms and solar energy. All sectors lowered their emissions between 2005 and 2019, with waste management having the greatest percentage drop in emissions (-56.4%). Emissions from manufacturing industries and construction (-35.7%), energy industries (-26.4%), "other emissions" (buildings and tertiary sector, -20.8%), industrial processes and product consumption (-8.6%), and agricultural (-3.6%) decreased. Sweden's final coal-fired power station ceased operations in 2020, two years earlier than originally scheduled. Nuclear energy production will continue as long as it is safe and viable, despite the nation's goal of generating 100% of its power from renewable sources by 2040. Yet, it is anticipated that by 2040, around 60% of nuclear power will be eliminated. The objectives for 2030 include climate neutrality, an 85% decrease in total domestic GHG emissions by 2045, and a 75% reduction in non-ETS emissions by 2040. Sweden is partnering with other Nordic nations to achieve climate neutrality, with wind energy playing a pivotal role. Technological advances in steelmaking have resulted in the world's first delivery of fossil-free steel samples. By 2026, the steel mill will be able to scale up production and provide the market with carbon-neutral steel.

2.5.2. Western Europe

Liselotte and Carvalho Fachada (2021) reported Austrian climate action progress. The report stated that since 2005, Austria's GHG emissions have decreased at a slower rate than the EU average, accounting for 2.2% of total EU emissions. In 2019, 30% of total emissions came from the transportation sector, and this share is growing. Austria aspires to reach carbon neutrality by 2040. Austria utilised 33.6% renewable energy sources in 2019, and the 46-50% renewable energy target for 2030 significantly focuses on reaching 100% renewable power generation. The transport sector is responsible for the majority of Austria's total emissions (30%) and has only decreased emissions by 1% from 2005 to 2019. The Austrian NECP identifies two primary causes: an increase in driving distances and the refuelling of transport traffic in Austria. Between 2005 and 2019, the energy industries sector cut emissions by 36%. The waste management business witnessed the biggest reduction in emissions, but its small total contribution restricted its effect. Agricultural, industrial, and product-use sector emissions increased by 2% and 7%, respectively. Austria aims to produce all of its electricity from renewable sources by 2030. In 2018, Austria launched the "Hydrogen initiative" and continues to promote hydrogen as a viable and essential energy source at the European and national levels. In January 2020, Austria's new government presented its program, reducing the carbon neutrality target from 2050 to 2040. This new objective and other new coalition efforts initiated a revision of the NECP. The administration has prioritised climate action, promising to enact a new climate protection law and increasing the ambition for existing measures. The National

Parliament passed the Renewable Expansion Act in July 2021, committing Austria to 100% renewable energy by 2030.

Morgado Simões (2021c) reported Belgium's climate action progress. The report stated that since 2005, Belgium's GHG emissions had fallen more slowly than the EU average, accounting for 3.3% of the EU's total GHG emissions. In compliance with EU effort-sharing laws, Belgium intended to reduce its emissions by 15% by 2020 and was on track to meet this objective in 2019. Belgium achieved a 9.9% share of renewable energy sources in 2019, and its target of reaching 17.5% by 2030 focuses on wind and solar energy, biofuels, and waste heat utilisation. From 2005 to 2019, all industries reduced their emissions, with the waste management business reducing its emissions by the most. Transport and agriculture experienced the lowest decreases in emissions over time, whereas the manufacturing industries and construction faced a 22.9% decline. The EU ETS encompasses energy generation and industrial emissions. It has predicted that energy-related emissions will grow until 2030, mostly due to the increased use of gas-fired power plants. If current policies are maintained, Belgium's total GHG emissions might increase by 4% by 2030 compared to 2019. Its seven nuclear reactors supply about 50% of the nation's electricity, although the share of electricity generated from natural gas is constantly increasing. Belgium aims to shut down its nuclear power reactors between 2022 and 2025, necessitating an increase in renewable energy production, improved interconnection with its neighbours, and an expansion of its natural gas infrastructure. To build a better-unified effort, the Commission's appraisal of Belgium's final NECP proposal urges greater national integration between the regional authorities and the federal government. The Walloon Climate Act of 2014 defined GHG emission reduction goals of 30% by 2020 and 80% to 95% by 2050, and the Flemish Regional Government encourages a 35% reduction by 2030 and an 80% reduction by 2050. By 2030, the Air Climate Energy Regional Plan of the Brussels Capital Area commits to a 32% decrease in GHG emissions. The federal government created a capacity payment system to prevent energy shortages and ensure a steady energy supply.

Yougova (2021b) reported French climate action progress. The report stated that France was responsible for 12% of the EU-27's total GHG emissions in 2019. Since 2005, the country's emissions have decreased at the same rate as the EU average. The transport, residential, industrial, and agricultural sectors accounted for around 60% of France's total emissions in 2019. The energy sector's contribution to emissions is minimal, with 29% of total emissions coming from the transportation industry and 16% from agricultural emissions. The residential buildings and tertiary sector were the second highest emitter, with a 22% share of total emissions. To reach carbon neutrality by 2050, the NECP identifies further initiatives to carbon-neutralize this sector, primarily through increased energy efficiency and renewable energy utilisation. France is implementing a mixture of renewable gas, electricity, and biofuels for freight transportation and a shift to biofuels in aircraft. In the agricultural sector, better management of fertilisers, a reduction in emissions from animal manure, the development of renewable energies of agricultural origin and bioenergy from forest wastes, and an increase in the energy efficiency of agricultural holdings are planned. In the forestry industry, wood products with extended lives and biomass from end-of-life wood products are predicted to grow by 2050. France wants to cut its GHG emissions by 40% between 1990 and 2030 and reach carbon neutrality by 2050. The plan establishes GHG caps over five-year intervals and a multiyear energy strategy to achieve this objective. France has prepared two main cross-sector initiatives and a variety of actions to reduce its energy consumption. The primary target is to cut GHG emissions from buildings by 49% by 2030 and reach carbon neutrality by 2050. The long-term remodelling strategy includes 10-year benchmarks to minimise residential and commercial energy use.

Morgado Simões (2021d) reported the climate action progress of Germany. The report stated that Germany is responsible for 24% of net EU-27 GHG emissions. Since 2005, emissions have declined gradually, in line with the EU's average trend. The energy sector is the greatest emitter, accounting for 29% of total emissions. Germany's 2030 emissions reduction target under the Effort-sharing Regulation is 38% below 2005. In 2019, renewable energy sources contributed 17.4% of gross final consumption, falling short by only 0.6% of the 2020 goal. The energy industry lowered its emissions by 35% between 2005 and 2019, with plans to eliminate coal by 2038 and develop energy production from onshore and offshore wind farms, improved photovoltaic capacity, and biofuels. Waste management is the sector with the greatest emission reductions; it was able to reduce its emissions by 56% between 2005 and 2019. The manufacturing industry and construction had the greatest rise in emissions, with an 8.7% increase from 2005 to 2019. In addition, the transportation sector increased its emissions during the same period by 1.5%. According to the NECP, Germany will handle grid optimisation and expansion, market integration, attempts to balance demand and supply, and power imports in order to ensure a stable energy supply. Germany is considering financial help to boost emission reductions in the heating and cooling industries to increase the proportion of renewable energy in this sector by 27% by 2030. The December 2019 approval of Germany's climate policy framework includes a comprehensive climate package aiming to reach both national and

European 2030 objectives. The Federal Climate Change Act defines a 55% reduction objective for 2030, gives yearly emissions budgets to certain sectors for 2020-2030, and creates an expert committee on climate-related issues. The Phase-out of the Coal-fired Power Stations Act sets the wheels in motion to eliminate coal from electricity generation by 2038.

Liselotte (2021e) reported Luxembourg's climate action progress. The report stated that Luxembourg's GHG emissions have declined at a slower rate than the EU average since 2005, accounting for 0.34% of the EU's total GHG emissions. 77% of Luxembourg's total emissions come from the transportation industry and the "other emissions" sector. The manufacturing and construction industry is the third largest emitter, accounting for 9% of total emissions. According to EU effort-sharing legislation, Luxembourg was required to cut emissions by 20% by 2020 and 40% by 2030. In 2019, Luxembourg attained a 7% share of renewable energy sources and aims to employ collaboration mechanisms to meet its 2030 goal of 25% of renewable energy sources. Energy efficiency methods include incentive and mandate programs for industry, building improvements, and electric transportation. Since 2005, transportation emissions have decreased by 14%, with almost all sectors' emissions falling in comparison to 2005 levels. The energy industry sector dropped emissions by 81% between 2005 and 2019. The proportion of overall emissions attributable to industrial processes and product consumption has remained consistent throughout the period in question, while the sector's emissions have fallen by 9%. Luxembourg implemented its climate law in December 2020, establishing a climate neutrality goal for 2050 and a 55% emission reduction goal for 2030. Luxembourg has the lowest environmental taxes among its European competitors, with just 4.4% of total tax income attributable to environmental taxes. In addition, Luxembourg has implemented a carbon price as part of a broader tax reform, setting the price at €20 per ton of CO2 with the expectation that it will rise over the following years. As a result of taxation based on the globally harmonised light vehicle test process, passenger automobile registration taxes will also increase. Luxembourg is heavily energy-reliant, importing electricity, gas, and mineral oil products from neighbouring nations, especially Belgium, Germany, France, and the Netherlands. Regional cooperation through the Pentalateral Energy Forum is key to ensuring energy security. The law reorganising the electricity market in Luxembourg was passed on 3 February 2021, with one of its primary goals being the facilitation and promotion of people's own renewable energy generation and use. In February 2021, Luxembourg unveiled its circular economy strategy to decrease and optimise the use of its scarce natural resources and support climate objectives.

Morgado Simões (2021e) reported the climate action progress of the Netherlands'. The report stated that the Netherlands is responsible for 5.2% of EU-27 total GHG emissions. The Netherlands' GHG emissions have decreased at a slower rate than the EU average. The Dutch energy industry emissions declined by 15%. The industry with the biggest percentage reduction in emissions from 2005 to 2019 was waste management, which decreased emissions by 55%. In 2019, 8.8% of the nation's energy came from renewable sources, and the objective for 2030 is 27%. In 2019, energy industries accounted for the greatest portion of the Netherlands' GHG emissions, at 29.7%. In 2020, the nation proposed a minimum carbon price for energy generation that would begin at €12.3/tCO 2 and increase by 159% by 2030, and in 2021, a carbon tax for the industry was established. The portion of the economy that is free from the carbon price will steadily decline. Between 2005 and 2019, emissions from industrial processes and product consumption, transportation, "other emissions", agriculture, and manufacturing industries and construction dropped. The Netherlands government has set a goal to cut overall GHG emissions by 49% by 2030 if policies remain unchanged. Measures include a coal ban beginning in 2030, a national grant for carbon emission reductions, and promotion and support for renewable energy. The Dutch government has committed to reducing GHG emissions to 95% of 1990 levels by 2050 through legally enforceable objectives. The government intends to establish a €22 million "coal fund" to solve job concerns caused by the coal phase-out. The national hydrogen strategy of the Netherlands calls for the generation of blue hydrogen from natural gas with carbon capture and storage. In addition, the northern region of the Netherlands plans to use 100% renewable hydrogen in future.

2.5.3. Southern Europe

Liselotte (2021f) reported Croatia's climate action progress. The report stated that since 2005, GHG emissions in Croatia have declined more slowly than the EU average. The transportation sector produced more than a quarter of Croatia's total emissions in 2019. The energy industry's emissions declined by 40%. Under EU effort-sharing regulation, Croatia was authorised to increase its emissions until 2020. Still, it must reduce them by 7% relative to 2005 by 2030, as its economy is significantly dependent on imported energy. Building stock renovation and energy efficiency requirement programs for energy providers is at the core of energy-efficiency-enhancing strategies. The Croatian NECP offers thirteen specific initiatives to reduce the high and constantly growing transportation-related emissions. The Croatian NECP promotes biofuels and electric mobility and aims for 2030 to include a 13.2% share of renewable energy sources in the final energy consumption of the transportation sector. By 2030, it is expected that hybrid, electric, and hydrogen-powered vehicles will account for 3.5% of all road passenger traffic. Yet, there is a lack of transparency on the implementation or impacts of planned policy measures and the sectorial aims and specificity of measures for rail, aviation, and shipping. The administration proposed to the Croatian Parliament in October 2019 a plan for an energy development strategy that includes a long-term goal of 65% renewables by 2050. Central to building stock measures is the long-term strategy developed in December 2020 to boost investment in the restoration of the national building stock by 2050. Croatia is constructing a new port for liquefied natural gas on the island of Krk as part of its efforts to limit and diversify its energy imports. Croatia initiated four sector-spanning technology and knowledge-sharing platforms in 2021. These platforms will provide options and possibilities for carbon collection, storage, and usage, circular economy, bioeconomy, and hydrogen technology.

Morgado Simões (2021f) reported Cyprus' climate action progress. The report stated that Cyprus' GHG emissions have fallen at a slower rate than the EU average since 2005, accounting for 0.26% of the EU's total GHG emissions. The percentage of renewable energy in Cyprus reached 13.8% in 2019. The energy industry accounted for 34.2% of all GHG emissions in Cyprus, a 0.4% rise over the previous year. Throughout the selected time period, the industrial and construction sectors reduced their contribution to total emissions from 8.9% to 5.5%. The EU ETS encompasses energy generation and industrial emissions, and it is estimated that by 2030, total GHG emissions in Cyprus will decline by 40%. Cyprus' Renewable energy roadmap plans to generate between 25% and 40% of its electricity from solar power by 2030. The NECP for the country's agriculture sector includes measures such as improving water management, reducing the intensity of natural resource use, optimising agricultural land use, decreasing fertiliser use, and strengthening animal waste management. CYnergy is a Cyprus plan to create a natural gas infrastructure on the island, with close to €290 million in funding from the EU. Notwithstanding fiscal and technological restrictions, the Long-term strategy for building rehabilitation predicts a plausible scenario in which 1% of the nation's building base is rehabilitated annually. To do this, the rate of refurbishment must be increased.

Morgado Simões (2021g) reported the climate action progress of Greece. The report stated that since 2005, Greece had lowered its GHG emissions at a faster rate than the EU average, accounting for 2.4% of the EU's total GHG emissions. Between 2005 and 2019, energy industry emissions decreased by 45%, and the manufacturing and construction industries had the highest reduction in emissions by 54%. The sectors with the lowest declines were transportation and agriculture. In 2019, the proportion of renewable energy sources in Greece reached 19%. In 2005, energy industries accounted for the greatest portion of Greece's GHG emissions, at 42%. According to the NECP, all existing lignite-fired power plants will be shut down by 2023, and those now under construction will have until 2028 to shut down or adapt to alternative fuel sources. Waste management-related emissions increased by 0.4%. The electricity industry is reducing the number of diesel-fired power plants, phasing out lignite as a power source, and increasing the usage of renewable energy sources. Agricultural and tertiary sector CO2 emissions fall under the "other emissions" category and will stay steady during the next decade. Sustainable food production and sustainable farm management are promoted to minimise emissions from the agricultural sector. Emissions will be decreased in the tertiary sector through improvements to lighting, street lighting, heat pump installation, and end-use appliances.

Liselotte (2021g) reported the climate action progress of Italy. The report stated that since 2005, Italian GHG emissions have decreased at a quicker rate than the EU average. Italy is responsible for 11.4% of the EU's total GHG emissions. All economic sectors have reduced their GHG emissions between 2005 and 2019. The transportation and "other emissions" sectors are responsible for over half of Italy's total emissions. In accordance with EU effort-sharing regulations, Italy lowered its emissions by 13% between 2005 and 2020, and the government intends to meet its 2030 goal of 33%. In 2019, Italy attained an 18% proportion of renewable energy sources. The focus of energy efficiency measures is primarily on the building stock and transportation sectors, with subsidies for businesses and families. The greatest emission reductions occurred in two industries: the energy industries sector was able to lower its emissions by 42%, while the manufacturing and construction sectors reduced their emissions by 47%. Agriculture only reduced emissions by 5.5%, while other sectors reduced emissions by 32%, causing agriculture's percentage of overall emissions to climb from 5.4% in 2005 to 7.2% in 2019. The Italian NECP imposes a 43% reduction objective for ETS sectors, but the nation expects to exceed its target and achieve a 55.9% reduction by 2030. To achieve this, Italy is enhancing its gas infrastructure and linkages for reliable and steady baseload electricity production, expanding freight transportation on canals and railroads, and promoting alternative fuels and charging infrastructures. Key modal shift projects include public transportation and cycling, with 85% of new public sector vehicle purchases for urban services must be electric or hybrid, and sustainable urban mobility plans will increasingly be required for financing access.

Erbach and Carvalho Fachada (2021) reported Malta's climate action progress. The report stated that Malta, which accounts for less than 0.1% of the EU-27's total GHG emissions, has decreased its emissions at a quicker rate than the EU average. However, the country's location, demography, and growing GDP make it impossible to sustain this trend, according to Malta's NCEP. The energy sector is responsible for 28% of Malta's overall emissions, and emissions from the transportation sector increased by 22%. The NECP of Malta includes strategies and initiatives to enhance the proportion of renewable energy and minimise emissions from transportation. The energy sector has strongly influenced The Maltese government intends to fulfil the increasing demand for electricity via renewable energy, efficient fossil power plants, and interconnection capacity. However, its NECP identifies constraints in terms of economies of scale that result in relatively high deployment costs for renewable energy. In contrast, emissions from industrial processes and product consumption increased more than six-fold between 2005 and 2019, accounting for 12% of Malta's GHG emissions in 2019. Its increase is nearly entirely attributable to rising home demand for refrigeration and air-conditioning owing to population and economic growth. Geographical isolation enhances Malta's reliance on fossil fuels and air transport, which accounts for 40% of the total energy required by the country's transportation industry. Malta wants to raise the proportion of renewable energy in heating and cooling by promoting solar and heat pump water heaters and deploying air-to-air reversible heat pumps. However, the increasing prevalence of high-rise and multi-unit buildings limits the technological potential of solar water heaters.

Morgado Simões and Fachada (2021) reported the climate action progress of Portugal. The report stated that Portugal accounts for 1.8% of all GHG emissions in the EU. Between 2005 and 2019, the transport industry lowered its emissions by 10.3%, while the energy sector decreased by 50%. Portugal was permitted to grow its non-ETS GHG emissions by 1% relative to 2005 under the EU effort-sharing law over the 2013-2020 period. In 2019, the proportion of renewable energy sources was 30.6%. The country's objective of 47% renewable energy by 2030 is one of the highest in the EU, with a target of 80% renewable energy in electricity by 2030. Transport accounted for 26% of total emissions in Portugal in 2019, making it the highest producer of GHG. The energy industries accounted for 19% of total emissions in 2019. The action strategy for the power generating sector promotes decarbonisation by terminating the production of electricity from coal on the mainland and from fuel oil and diesel in the south. The NECP projects that all coal-fired power stations will be shut down by 2025 and sets 2030 emission reduction objectives of 30% below 2005 levels for the waste management industry. The NECP's strengths include its consistent alignment of 2030 targets with the ambition of carbon neutrality and the significant interplay between climate and circular economy objectives. The hydrogen strategy of Portugal was adopted in 2020 and aims to decarbonise the natural gas network and electric power plants, as well as the transportation and industrial sectors. It anticipates a rise in hydrogen production and hydrogen-powered cars by 2030, the development of 50 to 100 hydrogen refuelling stations and electrolysers.

Morgado Simões (2021h) reported Slovenia's climate action progress. The report stated that since 2005, Slovenia's GHG emissions had been lowered at a slower rate than the EU average, accounting for 0.5% of total EU GHG emissions. Between 2005 and 2019, the country's energy industry emissions decreased by 29.5%. Extinction of coal and other measures are anticipated to reduce these emissions significantly. The industry with the highest percentage reduction in emissions from 2005 to 2019 was "other emissions", at 45.2%. According to the Effort-sharing Decision (2013-2020), Slovenia was permitted to raise emissions in sectors not included in the EU ETS by 4% compared to 2005. In addition, Slovenia is required by the Effort-sharing Regulation (2021-2030) to cut these emissions by 15%. In 2019, 32.3% of Slovenia's GHG emissions were attributable to transportation. Current methods to mitigate the sector's emissions include integrated transport planning, mobility management, incentives for using contemporary technology applied to mobility management, and public transportation subsidies. During 2005-2019, emissions from transportation increased by 10.8% of total emissions. The change from public to private transportation led to the sector's leadership position. Between 2005 and 2019, emissions decreased in waste management, energy industries, manufacturing industries and construction, and industrial processes and product consumption. In 2019, the proportion of renewable energy sources in the country reached 22%. The aim for 2030 is 27%, which will be achieved mostly by solar and water electricity and wood biomass. Slovenia has declared intentions to eliminate coal use completely by 2033. Slovenia intends to continue running its nuclear reactor, which it shares with Croatia and is contemplating the construction of a new one. The NECP estimates that the installed capacity of the nation's hydroelectric power facilities could reach a 42% increase compared to forecasts for 2040. Slovenia's policy for coal withdrawal and redevelopment of coal districts is imminent, and significant advancements in photovoltaic energy generation have occurred. Slovenia's long-term climate policy aims to cut emissions from transportation and buildings by 55-65% and 90-99% by 2050.

Morgado Simões and Victoria (2021b) reported Spain's climate action progress. The report stated that Spain produces 9% of total EU GHG emissions. The country lowered its emissions by 27% between 2005 and 2019, outperforming the EU average. The transportation industry is the greatest emitter, accounting for 27% of emissions, followed by the energy sector with 16%.

From 2005-2019, the energy sector reduced emissions by 57%, significantly contributing to the country's overall emission reduction, and the transportation industry decreased its emissions by 11.4%. From a 2020 aim of a 20% share of renewable energy in the energy mix to a 2030 target of 42%, Spain has significantly boosted its degree of ambition regarding the energy transition. The nation intends to prioritise the implementation of solar and wind energy. The proposed modifications are anticipated to increase energy efficiency by more than 3%. In 2019, 14% of emissions came from the industrial and construction industries, while agriculture's accomplishments were more modest, with a 4.6% reduction in emissions. Over time, waste management emissions rose by 1.8%. The EU ETS encompasses emissions from 900 industrial and electrical production units, which account for 40% of total emissions. ETS sectors are estimated to provide a 61% decrease in emissions relative to 2005. The NECP of Spain ranks electricity generation as one of the most crucial decarbonisation industries (together with transport). Deep emission reductions are anticipated in this sector as a result, firstly, of measures to deploy renewable energy, particularly solar and wind power, with a 2030 target of 74% renewables share in electricity generation and 100% by 2050, and, secondly, of the gradual phasing out of coal, induced by the ETS market mechanisms. The NECP recommends incentives for incorporating renewables – specifically biomass, biogas, and solar – into industrial processes and boosting research and innovation in low-carbon technologies, including waste heat recovery and carbon capture technology. The Spanish government has declared a climate emergency and established thirty lines of priority for its climate action agenda, with a 2030 target of 70% renewables share in electricity generation.

2.5.4. Eastern Europe

Yougova (2021c) reported Bulgaria's climate action progress. The report stated that Bulgaria submitted its final NECP in March 2020, incorporating Commission comments. The analysis concluded that the nation's overall GHG emissions were 37% lower in 2019 than in 1990 and 44% lower in 2020. This was due to structural changes in the industry, such as the demise of energy-intensive companies, an increase in hydro and nuclear electricity, the implementation of energy efficiency measures in the housing sector, and a transition from solid and liquid fuels to natural gas in energy consumption. The energy industry contributes to Bulgaria's GHG emissions. The NECP prioritises renewable energy sources, energy efficiency, the internal market, and energy security in order to decarbonise the energy industry. Unfortunately, the government has been unable to stop the growth in emissions from the transportation sector due to the high CO2 emissions from diesel, gasoline, and LPG consumption. Decarbonisation plans in Bulgaria aim to increase the share of electric public transportation, promote the use of electric and hybrid vehicles, construct low-emission zones in key cities, deploy intelligent transport systems, and incentivise modal shifts. Regarding decarbonisation, Bulgaria aims to reduce its GHG emissions by 49% compared to 1990 levels by 2030, mostly through energy sector policies, especially those that assist the development of the renewable energy sector. Bulgaria desires to increase the amount of power generated by wind, solar, and biomass, construct biomass-based cogeneration facilities, raise the share of biofuels in its energy mix, and introduce new generation biofuels and hydrogen. The NECP thinks that waste prevention, separate collection, reuse and recycling, and biodegradable waste recovery have room for improvement, particularly in municipal solid waste management. In addition to promoting grid integration and expanding the use of smart grids and storage systems, it lacks a coal phasing-out strategy. The Bulgarian NECP highlights the relationship between energy efficiency achievements and building rehabilitation strategies, including intermediate goals and estimations of energy and CO2 savings. Bulgaria has already set a goal to restore and improve the energy efficiency of more than 5% of its public buildings yearly.

Liselotte (2021h) reported Czechia's climate action progress. The report stated that since 2005, the Czech Republic had lowered its GHG emissions at a slower rate than the average EU member state. The energy sectors, manufacturing, and industrial processes account for 60% of overall emissions in the Czech Republic and have decreased by 20%. Coal plays a significant role in the Czech economy, and nuclear energy is viewed as an integral element of the transition process. The manufacturing and construction industries have lowered their percentage of total emissions by 5.2%. The waste and transportation industries saw the greatest growth in emissions throughout the time (24% and 23%, respectively). The industrial operations and product use-related emissions increased significantly. The Czech economy is dominated by energy-intensive sectors, such as iron, steel, and chemical manufacturing. The Czech Coal Commission has proposed eliminating coal by 2038. The cost of low-carbon technologies raises concerns for industry competitiveness. The NECP identifies a functional ETS and EU law on pollution control as major factors to facilitate the transition and cut ETS sector emissions. The foundational policies and initiatives were created between 2012 and 2017.

Morgado Simões (2021i) reported the climate action progress of Hungary. The report stated that since 2005, Hungary's GHG emissions had decreased more slowly than the EU average, accounting for 1.7% of the EU's total GHG emissions. Between 2005 and 2019, transportation emissions increased by 19%, which accumulated over a 22% increase in total emissions. Over time, the energy industries' share of total emissions declined by 37.6%. Between 2005 and 2019, the waste management, industrial processes, and product usage sectors lowered their emissions. Agriculture and the manufacturing and construction industries raised their emissions by 16% and 19%, respectively. The Effort-sharing Decision (2021-2030) permits Hungary to raise its emissions by 10% in sectors not included in EU ETS. The percentage of renewable energy sources in Hungary reached 12.6% in 2019. The nation's goal of a 21% renewable energy sources share by 2030 is predicated on reforms to the transportation and heating and cooling sectors, where district heating networks are predicted to be adjusted. Current subsidies and tax incentives are designed to increase the use of electric vehicles by 2030. The NECP describes the nation's objective to increase its nuclear capabilities by constructing additional nuclear reactors. The objective of the green district heating program in Hungary is to replace natural gas in the heating market with renewable energy sources and to provide individually heated homes. Hungary launched a "green bus" plan to replace 50% of its public bus fleet with low- or zero-emission vehicles to reduce emissions from the transportation sector.

Erbach (2021a) reported Poland's climate action progress. The report stated that Poland's GHG emissions have been stable, with slight annual fluctuations between 2005 and 2019. Poland accounts for 10.5% of total EU-27 GHG emissions in the observed time. The energy industries sector, which relies primarily on coal, emits 38% of the nation's total GHG emissions. Although emissions from the energy sector decreased by 17% from 2005 to 2019, emissions from the transportation sector surged by 84%, reaching a 17% proportion in 2019. In accordance with EU ETS, Poland was authorised to grow its emissions by 14% relative to 2005 levels by 2020 and must now achieve a 7% decrease by 2030. By focusing on biomass, offshore wind, and biofuels, Poland plans to obtain renewable sources share of at least 23% by 2030. In 2019, Poland achieved 12.2% in renewable sources. Coal constituted 41% of Poland's total energy supply in 2020 and 59% of energy-related CO2 emissions in 2019. In 2020, coal provided 69% of Poland's power. The coal proportion of the overall energy supply decreased by 17.6% between 2005 and 2019 and by 22% between 2005 and 2020 for electricity production. Throughout this time span, the usage of natural gas and oil has increased, while the use of biofuels has more than quadrupled to reach 9.4% by 2020. Just 1.7% of Poland's total energy supply comes from wind and solar power. The "other emissions" sector mostly accounts for 20% of overall emissions. The manufacturing and construction industries reduced emissions by 9%. Poland must reform its energy sector, particularly the coal mining industry to transition to a low-carbon economy. At COP24, the Polish government and miners' unions reached an agreement to phase down coal mining beginning in 2021, with the final mine closing in 2049. Poland intends to build six nuclear power stations to ensure its future electricity supply, with the first expected to begin operations in 2033.

Liselotte (2021i) reported Romania's climate action progress. The report stated that Romania is responsible for 3% of the EU-27's total GHG emissions and decreased emissions faster than the EU average from 2005 to 2019. Between 2005 and 2019, energy industry emissions decreased by 46%. In 2019, Romania attained a 24.3% proportion of renewable energy sources, mostly centred on the wind, hydro, solar, and biomass fuels. Energy efficiency measures are focused on heating supply, building envelopes, and industrial modernization. The industrial processes and product usage sector decreased its emissions by 40% between 2005 and 2019. The transportation sector's contribution to total emissions increased the greatest, from 8.2% in 2005 to over 16% in 2019. This was the result of a 40% rise in sector emissions. The percentage of manufacturing and construction businesses remained unchanged, but their emissions decreased by 27%. Agriculture sector emissions decreased by 11%. The waste sector's emissions climbed by 4%. Two locations in Romania are associated with coal mining, and both include other carbon-intensive sectors. Waste management measures and the desire to foster industrial symbiosis contribute to a more circular economy. The NECP identifies the broader European 20-20-20 climate and energy framework as the foundation for many of the country's primary national programs. Romania's recovery plan includes initiatives to commit to a complete coal phase-out by 2032, increase renewable energy objective from 30.7 to 34% of gross final energy consumption, prioritise transportation infrastructure and expedite green tax and budgeting principles.

Erbach (2021b) reported Slovakia's climate action progress. The report stated that between 2005 and 2019, Slovakia lowered its GHG emissions at the equivalent rate as the EU average, accounting for 1.1% of the EU's total GHG emissions. 37% of Slovakia's total GHG emissions are attributable to the industrial sector, while transportation and waste management emissions grew. In addition, emissions from agriculture stayed unchanged. According to EU effort-sharing regulations, Slovakia was permitted to grow its emissions by 13% by 2020 and is required to lower them by 12% by 2030. In 2019, Slovakia attained a 16.9% percentage of renewable energy sources, above its 2020 goal of 14%. With onshore wind, photovoltaics, and biofuels, the nation intends to meet its 2030 goal of a 19.2% share. The industry is the greatest contributor to Slovakia's GHG emissions, accounting for 21% of total emissions from industrial processes and product consumption and 16% from manufacturing sectors and construction.

Between 2005 and 2019, energy industry emissions decreased by 41%, accounting for 16% of Slovakia's emissions in 2019. In 2019, nuclear energy contributed 56% of power generation, while renewables accounted for 23%. In 2019, just 21% of Slovakia's power was derived from fossil fuels. By the end of 2023, Slovakia will no longer subsidise coal mining and the generation of power from coal. Slovakia's transport sector grew by 7% between 2005 and 2019, accounting for 20% of total emissions in 2019. To minimise emissions from transportation, the government plans to encourage biofuels in road transport, especially those derived from non-food crops, wood, organic waste, and food crop waste. Waste management emissions comprised 4% of the total and rose by 20% throughout the period. To address emissions in the waste industry, the waste management programme for 2016 to 2020 and the waste prevention programme for 2019 to 2025 include initiatives and national objectives. Other emissions, such as buildings and services, decreased by 25%. The "Greener Slovakia" environmental policy framework aims to safeguard natural resources, decrease pollution, and transition to a circular economy. It examines adaptation to climate change in connection to water, biodiversity, forestry, and agriculture.

2.6. Development of EU Environmental Governance

To understand environmental governance, it is important to understand what governance is. Scientists (Graham et al., 2003; Lockwood et al., 2010; Bennett and Satterfield, 2017) define governance as the institutions, structures, and processes that determine who makes decisions, how and for whom decisions are made, whether, how, and what actions are taken and by whom and to what effect; and who, how, and for whom actions are taken and what their consequences are. One can think that governance and management are the same, but there is a distinction between these two terms. Management refers to the resources, strategies, and actions that come from the operation of government (Lockwood, 2010). Particularly, the purpose of environmental governance is to manage individual or group actions in pursuit of public environmental values and associated societal results (Armitage et al., 2012; Termeer, et al., 2010). To comprehend environmental governance, one must comprehend how decisions pertaining to the environment are made and whether the policies and processes that follow are environmentally and socially sustainable (Bennett and Satterfield, 2017). According to the UNEP (n. d.), environmental governance encompasses the policies, laws, and conventions that regulate human conduct, as well as who makes decisions, how decisions are made and implemented, the scientific data required for decision-making, and how the public and significant stakeholders can engage in decision-making.

Europe was the first continent to embrace large-scale industrialization. The aggressive and exploitative use of labor and natural resources in overseas colonies, enabled European nations, especially the United Kingdom, to become global economic superpowers in the nineteenth century. Since the beginning of the 20th century, all EU member states have undergone industrialisation and integration into worldwide markets for products and services (Selin and VanDeveer, 2015). This aided in laying the economic groundwork for the broad European social welfare governments that arose in the latter half of the twentieth century. While European economic and social progress over the past century has been genuinely astounding, it has resulted in one of the most changed and misused environments on the planet.

The EU has greater control over its Member States than any other international system, making it the most authoritative form of international administration in the world (Selin and VanDeveer, 2015). The EU, as an intergovernmental arrangement of 27 member states (as of March 2020), is indisputably an international organisation with an important legal and political authority in the international institutions' system. Moreover, the environment is among the numerous policy domains where the EU has authoritative power, expanding over the national level. The EU has also been aligning its political and economic agendas across its member states with environmental priorities to implement the "sustainable development" paradigm. To make EU environmental governance successful, different stakeholders and decision-makers need to interact. EU environmental policy emerged in 1972 when nine EEC Member States called for developing the first Environmental Action Programme (EAP). The Environmental Action Programmes provide a broad policy framework for the European Union's environmental policy, in which the most important medium- and long-term objectives are identified and outlined in a fundamental strategy, where applicable incorporating concrete measures (Federal Ministry for Environment, Nature Conservation, Nuclear Safety and Consumer Protection, n. d.). The EU developed seven Environment Action Programmes, and their duration is between 3 and 10 years.

The emergence of the EU as a regional and global leader in environmental politics was brought to reality as a result of several amendments to the EU funding treaties but is also the outcome of a series of political and legislative measures across Europe (Selin and Vandeveer, 2015). Since the 1980s, continuous European policy reforms for the growing integration of environmental concerns resulted in a system of environmental governance in Europe that is broad in scope, extensive in detail and rather demanding, representing a complex, multi-level and evolving system.

The EU is one of the most advanced international organisations in the world, characterised by a relevant degree of supranationalism, meaning that decisions can be taken at the European level. In particular, just as for other policy domains, decisions within European institutions are taken in the framework of the European triangle, made by the European Commission, the European Parliament and the Council of the European Union (Orsini and Kavvatha, 2020). During the implementation phase of European policies, the European Court of Justice is also a key actor by making sure that EU law is implemented equally in all the member states and by interpreting any disputes between the member states and the European institutions.

For environmental governance, shared competencies apply, meaning that both the EU and its member states have the competencies to legislate and adopt binding environmental acts. Through time, European institutions have taken up more importance, and currently, most environmental objectives are shaped within European institutions rather than at the national level of policymaking (Orsini and Kavvatha, 2020). Regional governance is actually sometimes mobilised when international policies stagnate (Balsiger and Prys, 2016), and the European environmental efforts make it a laboratory to test policies at the multilateral level before their potential adoption by other governments and regions of the world. All the levels of EU action for environmental policy, being the national, European, transnational and international levels, are essential to the discussion of EU and global environmental governance. Moreover, the EU also sets the pace of international environment policymaking (Wurzel et al., 2016) under the consideration that internal EU environmental legislation is not sufficient to protect Europeans from the negative consequences of transboundary and global environmental degradation.

The role of the EU as a leading proponent of international action on the environment committed to promoting sustainable development throughout the world, and the limits of the such role are key elements to investigate (Orsini and Cobut, 2020). Studying the EU's position is also important to understand the potential for the concretisation of environmental processes, negotiations and agreements.

The Scientists for Future (2019) issued a statement based on scientific evidence regarding climate protection. The statement concludes that *"the current measures for protecting the climate, biodiversity, and forest, marine, and soil resources, are far from sufficient"* (Scientists for Future, 2019:79). The Statement consists of 24 alarming yet scientifically proven facts about the state of the world environment, and it contains clear evidence that human activity is at the origin of such alarming signs (Scientists for Future, 2019).

The EU, just as European scientists, is also becoming increasingly aware of environmental degradation. The European Green Deal, a comprehensive environmental policy plan presented in December 2019 by the European Commission, confirms that *"the atmosphere is warming and the climate is changing with each passing year. One million of the eight million species on the planet are at risk of being lost. Forests and oceans are being polluted and destroyed"* (European Commission, 2019: 2). With the Earth's oceans, terrestrial ecosystems, and atmosphere all connected, no state can avoid the global environmental crisis and multilateral action is essential (Morin et al., 2020). Moreover, environmental problems are not reduced to environmental degradation issues anymore but have been found to have impacts on many other important domains. For instance, climate security, defined as conflicts that can be created or exacerbated by climate change consequences, is a growing concern for the EU and for the United Nations Security Council (Dupont, 2019). Therefore, it has been found crucial for political entities to invest in the development of policies that could help mitigate worldwide environmental degradation and the EU has been particularly active in doing so.

2.6.1. EU Climate Policy

Experience and lessons acquired must inform the formulation and implementation of climate policies, as well as their evolution over time. This also applies to climate policy within the context of the EU (Delbeke and Vis, 2015). The research makes it very evident how much more must be done to prevent disastrous climate change from negatively hurting the Earth and its inhabitants. The rate of progress will be largely determined by the effectiveness and cost of policies. The EU is making its fair share of efforts to decrease GHG emissions and has implemented ambitious climate measures that will result in a true decoupling of economic development and emissions (Delbeke and Vis, 2015). The EU cannot solve the problem of climate change on its own. Fortunately, the EU's experience can also serve as a valuable learning-by-doing resource for other nations as they establish their climate policies and steer their economies toward prosperous, low-carbon development.

The EU has not been successful from the beginning with its climate policy since its first attempt to fight climate change was taxation in the 1990s. The development of a comprehensive climate strategy in the EU began in the 1990s, but accelerated around the year 2000, when the Kyoto Protocol was agreed but ratification efforts were still ongoing.

In 1992, the Commission introduced ecotax with the main purpose of being paid based on emitted GHG emissions from fossil fuel usage (Godet, 2020). The EU spent nearly a decade attempting to implement a carbon-energy tax. This failed for political reasons since the idea of introducing extra taxes was unpopular at a time when many individuals already felt overtaxed. This also failed for institutional reasons, as the adoption of European taxation requires the unanimity of all Member States, which proved unachievable. As an alternative to placing a fixed fee on pollution, the quantity of pollution was subsequently restricted.

One of the most remarkable examples of learning by doing is the EU ETS, in which the original allocation of allowances was primarily based on free handouts to private enterprises by the Member States (Delbeke and Vis, 2015). Although it was widely acknowledged that this was suboptimal, it was an essential step in establishing the system. Rapidly, based on the acquired experience, consensus arose that better solutions were required, and allocation is now based on auctions and EU-wide performance benchmarks.

The economic and technical preparation of policy, as well as broad interaction with stakeholders, are of the utmost importance. This is vital not just to achieve sufficient political understanding and support but also to ensure that the policy context, once established, stays as stable as feasible. Creating maximal openness has been an essential precondition for success, as there are frequently competing economic interests with substantial stakes. Policymaking based on facts and data, explicit consideration of costs and benefits to society, and an active engagement with stakeholders has been more fruitful than a short-sighted focus on what is deemed politically expedient.

Given the magnitude of the decarbonisation of Europe, fifteen years is an insufficient amount of time. Therefore, it is premature to offer a conclusive evaluation of the EU's climate change policy experience. Nonetheless, the emergence of the following crucial features has already begun (Delbeke and Vis, 2015):

1. The EU has proved that it is possible to lower emissions while maintaining economic growth.
2. The EU has successfully employed market mechanisms to cut emissions, specifically by instituting a carbon price.
3. The EU has been a leader in the deployment of low-carbon and energy-efficient technology in both new and more conventional industrial sectors.

4. Integration of the climatic dimension into the design of economic-relevant policies, such as energy, transportation, industry, and regional development, has been essential.
5. Businesses request a regulatory environment that is stable and focused on long-term structural reforms as opposed to short-term governmental interventions and regulatory adjustments.

The environmental policy will continue to adapt in light of experience and circumstances while attempting to offer businesses and consumers with the greatest amount of predictability possible. One of the initial policy initiatives was to establish a vastly improved statistical information system through the systematic monitoring, reporting, and verification of greenhouse gas emissions in the Member States and the various economic sectors. Today, the EU's Monitoring Mechanism Regulation is one of the best-developed tools in the world, releasing a thorough report every autumn (EEA, 2015). The availability of reliable statistical data is one of the fundamental pillars of EU climate policy.

The EU's GHG emissions declined in all major emitting sectors between 1990 and 2020, with the exception of transportation, refrigeration and air conditioning. The total CO_2-equivalent emissions of the 27 Member States decreased by 346 million tonnes CO2 equivalent between 2019 and 2020. In fact, global emissions declined by 19%, while the EU economy's GDP rose by 54% between 1990 and 2020 (EEA, 2022). Due to this successful decoupling, the intensity of the EU's greenhouse gas emissions decreased by 34% between 1990 and 2020. While absolute emissions decrease more during periods of low economic growth, the consistent reduction of greenhouse gas intensity over more than two decades illustrates that decoupling is advancing regardless of economic cycles. Decoupling occurred in every Member State, notwithstanding population growth. Similarly, energy consumption (gross final energy consumption) peaked in 2005 and was just 1% more in 2012 than it was in 1990 (Eurostat, 2018).

The largest significant category in the EU-KP, accounting for 18.9% of all greenhouse gas emissions in 2020 and 82% of emissions from the Energy Industries Sector, is CO_2 emissions from the production of electricity and heat. In the EU-KP, CO_2 emissions from the production of electricity and heat fell by 51.2% between 1990 and 2020. Between 1990 and 2020, the fuel used to provide public power and heat dropped by 32.8% in the EU-KP. Solid fuels make up 35.3% of the fuel utilized in public conventional thermal power plants, and between 1990 and 2020, their combustion will have decreased by 66.5%. Between 1990 and 2010, the usage of gaseous fuels climbed by a factor of almost 3, fell until 2014, and has since increased again in recent years. With a share of 39.2% of all the fuels used to produce heat and electricity in the EU-KP, 2020 will mark the first year in which natural gas consumption surpasses solid fuel usage. Although their use has significantly decreased over the past 30 years, liquid fuels still make up about 2.7% of total energy use. The use of biomass has grown even more quickly than the use of gas; it now makes up 17.5% of the fuel mix. Finally, between 1990 and 2020, the use of other fossil fuels increased by 4.5, accounting for 4.8% of total consumption. Peat will still have a meager 0.4% share in 2020 (EEA, 2022).

98.8% of the GHG emissions from the production of heat and electricity in the public sector are carbon dioxide emissions. Compared to 1990, these emissions decreased in 27 countries while rising in two of them. Cyprus alone was responsible for 88% of the increase in emissions from the two nations where emissions were higher in 2020 than they were in 1990. Out of the nations whose emissions decreased, the United Kingdom (21.3%), Germany (21.9%), Poland (13.3%), Romania (7.1%), and Italy (6.8%) accounted for 70.3% of the overall drop. Between 1990 and 2020, there was a net reduction of 732.2 Mt CO_2 and a 51% increase in the EU-KP, respectively. N2O emissions currently account for 0.7% of the greenhouse gas emissions from the generation of public power and heat. Emissions reduced by 26% between 1990 and 2020. Germany and the United Kingdom both reported significant decreases in emissions from this source category (-811 kt CO_2eq and -721 kt CO_2eq, respectively). Spain saw the largest rise (+120 kt CO_2eq). Finally, the production of public energy and heat currently accounts for 0.5% of global greenhouse gas emissions. The amount of emissions increased by 384% from 1990 to 2020. Germany (2040 kt CO_2eq), which was also in charge of 66.7% of the EU-KP emissions in 2020, showed the largest increase (EEA, 2022).

In accordance with the Kyoto Protocol, the 15 nations that were EU Member States in 1997 (the “EU-15”) promised to cut their combined emissions of six GHGs by 8% below 1990 levels between 2008 and 2012. Throughout the time, these Member States significantly outperformed their target and lowered their emissions by up to 18.5%. With existing legislation in place, it is anticipated that energy usage will continue to decline through 2035. (Capros et al., 2014).

The aforementioned numbers do not include the amount of carbon anticipated to be stored in the EU’s forests and crops. The amount of carbon emitted by the land use, land-use change, and forestry (LULUCF) sector in the European Union has remained relatively stable: the carbon sink, which is carbon fixed in soil and vegetation.

2.6.2. EU-ETS

Pricing carbon emissions is of utmost importance to guide investments in the carbon-free energy and processing industry. Under emissions trading schemes, the price of carbon spreads through the whole economy via electricity price, thus changing relative prices in favor of carbon-free solutions in both consumption and production (Lise et al. 2010; Aatola et al. 2013).

The EU ETS is the cornerstone of EU climate policy and embodies its ideological principles, being a market that fosters the decarbonisation of the economy. The EU ETS is the largest GHG emissions trading programme in the world with the simple "cap and trade" system. The "cap and trade" system underlies how the EU ETS operates. The total amount of particular GHGs that the installations covered by the system are allowed to emit is limited. Over time, the cap is lowered to reduce overall emissions. Installations purchase or receive emissions allowances within the cap, which they can exchange with one another as necessary (European Commission, n. d. a). The restriction on the overall amount of available allowances makes sure that they have a purpose. An installation must surrender enough credits each year to fully cover its emissions, or else stiff penalties would be assessed. When an installation lowers its emissions, it can either keep the extra allowances for future use or sell them to another installation that needs them. Trading provides flexibility that guarantees emissions are reduced where doing so would cost the least. A strong carbon price encourages investment in cutting-edge, low-carbon technology as well.

The subsequent developing "carbon market" encourages operators to look for the cheapest option to reduce their emissions, whether investing in greener production methods or buying more allowances. The two main objectives are to limit GHG emissions and to encourage the development of an "environment-friendly" economy. The Commission's change of heart during the Kyoto negotiations did not commit the EU to implement an ETS; the trading scheme was simply one of several possible options for reaching the reduction target. However, after the failure of the ecotax, a market-based instrument seemed the most cost-effective option (Anderson and Di Maria, 2011).

The EU ETS has been the principal market for CERs and other credits from the UNs flexibility mechanisms (Watt, 2018). In 2014, emissions in the sectors covered by the ETS were already below the cap for 2020 (EEA, 2015). However, in recent years the EU ETS has been over-supplied with carbon credits. There were multiple causes of over-supply in relation to the ETS.

First, the post-2008 European recession and economic slow-down reduced the amount of carbon-intensive activity on the continent (Declercq et al., 2011). Indeed, this reduction highlights the importance of planned economic de-growth strategies in richer countries, if climate targets are to be met in an internationally equitable manner (Anderson and Bows, 2011). Second, the success of renewable energy technologies and other climate change mitigation efforts, such as energy efficiency targets, have reduced emissions in sectors covered by the ETS (EEA, 2015). Third, the weak ambition of the ETS means that the emissions cap is set very generously, putting only a marginal constraint on the continuation of activities that cause climate change.

At the very beginning, the EU ETS covered only CO_2 emissions in energy-intensive power and manufacturing industries in the 25 member states, which at the time accounted for 46% of the EU's overall CO_2 emissions (e.g. electric power; direct emissions from oil refineries; glass, cement and paper production) (Godet, 2021). According to European Commission (2015) it covers six gases (CO_2 emissions; N_2O emissions from all nitric, adipic and glyoxylic acid production; and four types of PFC emissions from aluminium production) and 11,000 installations in the entire European Economic Area (28 Member States plus Norway, Iceland and Lichtenstein), impacting 502 million people. The sectoral scope includes the aviation sector, aluminium production, carbon capture and storage, the petrochemicals industry and the production of other chemicals.

The ETS has developed across multiple phases, and substantial systemic changes have been adopted at each phase of the system's evolution. On the one hand, the goals of these reforms have been to improve the motivation to restrict emissions and invest in environmentally friendly technologies. On the other hand, the goals of these reforms have been to limit the likelihood of fraud and greenwashing.

The scope of the ETS has expanded over the years. Table 3 presents the EU ETS evolutions through time.

Table 3 Development of the EU ETS

	Phase I (2005 – 2007)	Phase II (2008 – 2012)	Phase III (2013 – 2020)	Phase IV (2021 – 2030)
Goal	Pilot the system to demonstrate proof of the concept.	Reduction of -8% GHG emissions relative to 1990 levels.	Reduction of -21% GHG emissions relative to 2005 levels.	Reduction of -43% GHG emissions relative to 2005 levels.
Countries	EU27	EU27 + Norway, Iceland, Lichtenstein	EU28 + Norway, Iceland, Lichtenstein	EU28 + Norway, Iceland, Lichtenstein
GHGs	• Carbon dioxide (CO_2)	• CO_2 • Nitrous oxide (N_2O) via voluntary opt-in by Member States	• CO_2 • N_2O) • Perfluorocarbons (PFC) from aluminium production	• CO_2 • N_2O • PFC
Sectors	• Power generation installations • Energy-intensive industries	• Power generation installations • Energy-intensive industries • Aviation	• Power generation installations • Energy-intensive industries • Aviation in EEA • Aluminium • Petrochemicals	• Power generation installations • Energy-intensive industries • Aviation in EEA • Aluminium • Petrochemicals
Cap	• Cap set at national level through National Allocation Plan (NAP) • Sum of NAP = total EU-wide cap • Emissions registered in national registries	• -6,5% allowances compared to Phase I • Guidance on how to establish NAP • Sum of NAP = total EU-wide cap • Emissions registered in a EU registry	• Single EU-wide cap replaces sum of NAP • Linear annual reduction of allowances of -1.74%	• Single EU-wide cap replaces sum of NAP • Linear annual reduction of allowances of -2.2%

	Phase I	Phase II	Phase III	Phase IV
Allowance management	• Allocation through NAPs. • Free allocation of nearly all allowances. • Penalty for non-compliance at 40€/t CO2.	• Free allocation reduced to 90% of Phase I. • Free allocation through harmonized NAP. • Auctioning introduced in some countries. • Penalty for non-compliance raised to 100€/t CO2.	• Auctioning and free allowance allocation according to National Implementation Measures (NIM) for each Member State. • Introduction of a Market Stability Reserve (MSR) and new market entrants reserve. • Introduction of international credits. • Penalty for non-compliance at 100€/t CO2 increasing with inflation.	• MSR doubles the number of allowances to be put in the reserve to 24% of the allowances in circulation between 2019 and 2023. The regular feeding rate of 12% will be restored as of 2024. • 100% free allowances will continue to be given to sectors with the highest risk of carbon leakage, and thus of relocating their production outside the EU • Free allocation for sectors with lower risks of carbon leakage is foreseen to be phased out after 2026 from a maximum of 30% to 0% at the end of Phase IV (2030).
Tradable units	• EU Emissions Allowances (EUAs)	• EUAs • CERs • ERUs	• EUAs • CERs • ERUs	• EUAs • CERs • ERUs

Source: author according to European Commission (2015) and Trauffler (2019)

The “central bank” of the carbon market, the Market Stability Reserve (MSR), was established in January 2019, marking a significant reform. This mechanism is intended to reduce the carbon market’s surplus of emission allowances and strengthen the ETS’s resilience to future shocks. It absorbs or releases allowances depending on whether the market is in surplus or deficit. From 2023 onwards, the MSR will be supplemented by a cancellation mechanism that will allow the surplus of allocations held in reserve to be cancelled if it exceeds the previous year’s auction volume.

However, many observers continue to view the ETS with scepticism, despite the changes that have been made. Some think a market-based instrument is the most effective answer, but they point out the current system’s flaws and want to see it reformed even more (Godet, 2021). Energy-intensive, trade-exposed (EITE) businesses have competitiveness concerns due to the nature of their products and the greenhouse gas-intensive methods required to manufacture them, and their limited capacity to reduce carbon emissions from their operations (Carbon Pricing Leadership Coalition, 2016). Moreover, implementation challenges include worries about the potential decline in consumer purchasing power, economic competitiveness, and social equality. Regulations governing carbon pricing may or may not have immediate, obvious effects on the final consumer, depending on how they are constructed (Engin et al., 2022). Consumers typically pay the price because businesses typically pass on the costs. Companies who promote their goods internationally may also experience lower cost competitiveness than unregulated competitors.

2.6.3. EU Green Deal

The European Green Deal (EGD) is the EU’s new growth plan, which *“presents an initial roadmap of the key policies and measures needed to achieve the European Green Deal. It will be updated as needs evolve and the policy responses are formulated. All EU actions and policies will have to contribute to the European Green Deal objectives. The challenges are complex and interlinked. The policy response must be bold and comprehensive and seek to maximise benefits for health, quality of life, resilience and competitiveness. It will require intense coordination to exploit the available synergies across all policy areas”* (European Commission, 2019). In addition, it is a vital component of the EU’s ambition to accomplish the 2030 Agenda for Sustainable Development. In addition, it promises to safeguard citizens from environmental hazards and repercussions, as well as to be inclusive and fair. To place well-being at the centre of economic policy.

On December 11, 2019, the European Commission presented the EGD to EU institutions and the public. In January 2020, following a parliamentary debate, the European Parliament voted to support the EGD, but emphasized that more work was required to create a just transition that would leave no one behind. In terms of carbon emissions, the European Parliament has also advocated for greater interim targets. Figure 3 illustrates main elements of the EGD.

Figure 3 The European Green Deal

Source: European Commission (2019)

The EGD's primary objectives are reducing carbon emissions by 55% in 2030 and becoming a zero-carbon economy by 2050 (Sikora, 2021). The EGD is not a legislation, but rather a comprehensive policy framework that outlines the intentions and objectives of many policy sectors. Existing regulations and standards will be changed and new laws and directives will be drafted and implemented over the next few years to facilitate its implementation. The Green Deal consists of eight essential components (European Commission, 2019):

1) Increasing the European Union's climate goals for 2030 and 2050
2) Supplying clean, affordable, and secure energy;
3) Mobilizing business for a clean and circular economy
4) Constructing and rebuilding in a manner that conserves energy and resources

5) An objective of zero pollution for a toxin-free environment
6) Conserving and restoring biodiversity and ecosystems
7) Farm to Fork: an equitable, healthful, and ecologically sound food system
8) Accelerating the transition to smart and sustainable mobility.

To accomplish all components of the EGD, all Member States need to act together because climate change and biodiversity loss are common problems for the world together.

2.6.3.1. Designing a Set of Deeply Transformative Policies

The formality and intention to carry out the goals of policies and laws are ensured by these guiding documents. Policies will have been put in place to increase the EU's climate ambition for 2030 and 2050, as outlined in the roadmap for the EGD objectives. According to the EGD, Climate Law was supposed to be implemented in 2020. However, it was published on July 9, 2021, and went into effect on July 29, 2021 (European Commission, 2021). To implement the EGD, clean energy supply policies across the economy, industry, production and consumption, large-scale infrastructure, transportation, food and agriculture, construction, taxation, and social security must be rethought (European Commission, 2019). To achieve carbon neutrality by 2050, the Climate Law sets a target of reducing net emissions by 55% from the overall GHG emission rate in 1990. Additionally, the Law mentioned the establishment of a European Scientific Advisory Board on Climate Change, rules on adaptation to climate change, and a commitment to establishing sector-specific roadmaps to establish a circular economy through communication with key stakeholders. The green pledge that guides the implementation of the Just Transition is "Do no harm," which will take into account the sustainability of the environment, economy, and society.

New measures alone will not be sufficient to meet the goals of the EGD. In addition to initiating new initiatives, the Commission will collaborate with the Member States to intensify EU efforts to ensure that existing legislation and policies related to the EGD are enforced and implemented effectively.

2.6.3.1.1. Increasing the EU's Climate Ambition for 2030 and 2050

It's becoming clear that the national plans aren't enough to significantly boost the European Union's emission reduction targets for 2030. As such, the current updates aim to enhance and clarify the national plans (Oei et al., 2019). The European Union has already begun to modernize and alter the economy in order to achieve carbon neutrality. Between 1990 and 2018, GHG emissions were cut by 23% while the economy expanded by 61%. Nevertheless, present plans will reduce GHG emissions by only 60% by 2050 (European Commission, 2019).

Evaluation and revisions of all relevant climate-related policy instruments such as the EU ETS, including a possible extension of European emissions trading to new sectors, Member State objectives to cut emissions in areas outside the Emissions Trading System, and the land use, land use change, and forestry regulation. These policy improvements contributed to the implementation of effective carbon pricing across the economy (Euroepan Commission, 2019). This promoted alteration in consumer and business behaviour and support an increase in sustainable public and private investment. The various pricing mechanisms must complement one another and form a coherent policy framework. Also vital is ensuring that taxation is consistent with climate aims.

2.6.3.1.2. Supplying Clean, Affordable and Secure Energy

One of the most important factors to consider in order to achieve net-zero emissions is energy usage. Efficiency in energy use is a top priority for the EGD. Following the completion of the industrial revolution, there was a sharp spike in the amount of coal used in production. With that in mind, the rate of CO_2 emissions around the globe has recently begun to increase. The increasing rate of CO_2 emissions has been a contributing factor to the rise in temperature. Therefore, energy resources, their emission rate, the manner in which they are consumed, and their potential to be sustainably used are essential components of an eco-friendly economy and environment. Within the parameters of the EGD, it is indicated that coal mining will be phased out and replaced by renewable energy resources. This will be beneficial to consumers as the cost of their energy bills will be reduced as a result of the usage of renewable resources. Renovating the homes of individuals will, in addition, result in lower monthly expenditures. Moreover, the EU's energy supply must be affordable and safe for consumers and businesses.

The shift to renewable energy should involve and benefit customers. Renewable sources of energy will play a crucial role. Increasing offshore wind output will be vital, with regional collaboration between Member States serving as a foundation. The intelligent integration of renewables, energy efficiency, and other sustainable solutions across sectors will aid in achieving decarbonisation at the lowest cost possible. The rapid fall in the cost of renewables, in conjunction with the improved design of support programs, has already lowered the impact of renewables deployment on household energy costs. By mid-2020, the Commission offered measures to facilitate intelligent integration. In parallel, the decarbonisation of the gas sector was facilitated, including by enhancing support for the development of decarbonised gases, creating a forward-looking design for a competitive decarbonised gas market, and by addressing the issue of methane emissions related to energy production.

Households that cannot afford essential energy services to maintain a minimum level of living must be protected against the risk of energy poverty. Effective programs, such as funding schemes for residential renovations, can reduce energy costs and benefit the environment. In 2020, the Commission proposed guidelines to help Member States in combating energy poverty.

In 2018, more than 75% of the European Union's GHG emissions were attributed to the production and use of energy across all economic sectors (European Commission, 2018). The Clean Energy policy area aims to bring down that high percentage by creating a power sector that relies heavily on renewable sources and an integrated, interconnected, and digitalized energy market in the EU. The European Union's Hydrogen Strategy examines the possibility that the use of clean hydrogen could help to the process of decarbonisation (European Commission, 2020a). The Clean energy for all Europeans package will make it easier to implement the strategy for energy system integration. This strategy aims to improve the coordination of planning and operation of the energy system "as a whole," spanning a variety of energy carriers, infrastructure, and end uses.

Additionally, a proposal has been made for a reform of the Trans-European Networks for Energy Regulation, often known as the TEN-E Regulation (European Commission, 2020b). The revised framework reflects the accelerated take-up of renewable energy sources, smart sector integration, the modernization of the EU's cross-border energy infrastructure, and mandatory sustainability criteria for all projects.

2.6.3.1.3. Mobilising Industry for a Clean and Circular Economy

To achieve a climate-neutral and circular economy, the industry must be fully mobilized. It takes a generation, or twenty-five years, to restructure an industrial sector and all of its value chains. To be prepared for the year 2050, decisions and actions must be made within the next few years.

From 1970 to 2017, the yearly global extraction of resources increased by a factor of three, posing a significant global risk. More than 90%of biodiversity loss and water stress are attributable to the exploitation and processing of minerals, energy, and food resources. The EU’s industry has begun the transition, but it is still responsible for 20% of the GHG emissions (European Commission, 2019). It remains too “linear” and dependent on the extraction, exchange, and processing of fresh materials into things, which are then disposed of as trash or emissions. Only 12% of the materials used are recycled. The shift presents a chance to expand economically viable and employment-intensive endeavours. There is an enormous opportunity for low-emission technologies, sustainable products, and services on global markets. Similarly, the circular economy offers enormous potential for the creation of new activity and jobs. However, transition is occurring too slowly, with neither widespread nor uniform progress. The EGD will promote and expedite the transition of EU industries to a paradigm of inclusive, sustainable growth.

The transition toward a circular economy, which is a model of sustainable inclusive growth makes industrial strategies of the utmost significance. According to the EGD, an eco-friendly economy will receive support in the form of sustainable products that can recycle or reuse existing materials, supply chain laws, and trade regulations. Therefore, we will begin our efforts by focusing on resource-intensive industries like textiles, construction, electronics, and plastics as a first priority. A supplementary sum of money is required in order to realise the climate goal. Therefore, on January 14, 2020, the Commission established and declared "The European Green Deal Investment Plan" as having a minimum value of one trillion euros. In addition, evaluations for The Just Transition Fund are scheduled to take place between the years 2021 and 2027. These funds are going to be put toward a sustainable project that will facilitate the transition to a circular economy while adhering to the carbon neutrality in the EU. On the other hand, none of this can be accomplished unless the various areas of Europe take into account and act in accordance with the EGD’s best practices.

The EGD encompasses a variety of initiatives, ranging from product sustainability to the procurement of raw materials, that are intended to increase efforts to reduce carbon emissions. In order to reduce the strain that is placed on natural resources, the recently enacted Circular Economy Action Plan outlines a number of projects that will lengthen the lifespan of products (European Commission, 2020c). It includes a Sustainable Products Policy, which controls the enhancement of product reusability, reparability, and integration of recycled contents.

Additionally, it includes a Sustainable Products Policy. The recently enacted EU Industrial Strategy has as its primary objective the development of markets for climate-neutral and circular products, as well as the promotion of digital transformation throughout the EU (European Commission, 2020d). According to the EGD, these actions are required in order to guarantee a sufficient supply of the essential raw materials that are essential for the development of environmentally friendly technologies such as clean hydrogen, fuel cells and other alternative fuels, energy storage, and carbon capture, storage, and utilization.

While the circular economy action plan will lead the transition of all sectors, specific attention will be paid to resource-intensive industries including textiles, construction, electronics, and plastics. The Commission will follow up on the 2018 plastics plan by focusing on measures to combat intentionally introduced micro plastics and unintended releases of plastics, such as through textiles and tire wear. The Commission will adopt standards to ensure that all packaging on the EU market is economically reusable or recyclable by 2030, will build a regulatory framework for biodegradable and bio-based plastics, and will take actions regarding single use plastics.

A sustainable product policy has the ability to drastically minimize waste. Where waste cannot be avoided, its economic value must be recovered and its impact on the environment and climate change must be avoided or reduced. This calls for new regulations, including targets and steps to combat excessive packaging and waste production. Concurrently, EU enterprises should have access to a robust and integrated single market for secondary raw materials and by-products. This necessitates a deeper level of collaboration across value chains, similar to the Circular Plastics Alliance. Access to resources is also a strategic security concern for the Green Deal ambitions of Europe. Ensuring the availability of sustainable raw materials, especially essential raw materials required for clean technologies, digital, space, and defence applications, by diversifying supply from both primary and secondary sources is therefore one of the prerequisites for this shift to occur.

2.6.3.1.4. Building and Renovating in an Energy and Resource Efficient Way

Significant amounts of energy and mineral resources are needed for the construction, usage, and renovation of structures (e.g. sand, gravel, cement). Additionally, buildings account for 40% of the energy consumed and 36% of GHG emissions. Currently, the yearly refurbishment rate of the building stock in the Member States ranges from 0.4% to 1.2%. To meet the EU's energy efficiency and climate objectives, this pace will need to at least double. In parallel, 50 million people struggle to appropriately heat their houses. EU and the Member States should participate in a renovation of public and private buildings to meet the dual challenges of energy efficiency and cost. Renovation reduces energy bills and helps reduce energy poverty, while boosting renovation rates is difficult. It is an opportunity to help small and medium-sized enterprises (SMEs) and local jobs. The Renovation Wave is a strategy to renovate buildings to increase their energy efficiency (European Commission, 2020e). Buildings that are more energy efficient will be the most significant, following the feasibility of incorporating emissions from buildings in the EU ETS.

The Commission collaborated with stakeholders in 2020 on a new rehabilitation program. This comprised an open platform that brings together the buildings and construction industry, architects and engineers, and municipal governments to solve rehabilitation hurdles. Under InvestEU, this effort will also incorporate new financing methods. These might target housing associations or energy service firms that could implement renovations, including those based on energy performance contracts. An important objective would be to organize renovation efforts into larger blocks to take advantage of more favourable financing conditions and economies of scale. In addition, the Commission will endeavour to remove national regulatory hurdles that impede investments in energy efficiency in rented and multi-ownership properties. A focus will be placed on the refurbishment of social housing in order to assist households that struggle to pay their energy costs. Renovating schools and hospitals should also be a priority, as the money saved via building efficiency may be used to enhance education and public health.

2.6.3.1.5. Accelerating Shift to Sustainable and Smart Mobility

The Sustainable Mobility policy domain includes initiatives to reduce transportation emissions, which account for 25% of EU greenhouse gas emissions (European Commission, 2019). The adopted Strategy for Sustainable and Smart Mobility lays the groundwork for action to transform the EU transportation sector, with a goal of achieving a 90% reduction in emissions by 2050 through a smart, competitive, safe, accessible, and affordable transportation system. Increased capacity, reduced congestion, and reduced pollution could all be achieved as a result of efforts to promote more sustainable modes of transportation. The strategy establishes a number of goals for 2030, including (Patel and Robinson, 2021):

- At least 30 million zero-emission cars will be on European roads;
- 100 European cities will be climate neutral; and high-speed rail traffic in Europe will double.
- Scheduled collective travel under 500 km should be carbon neutral;
- automated mobility will be widely deployed at large scale
- zero-emission marine vessels will be ready for market, with additional targets set for 2035 and 2040.

A number of legislative revision proposals are being considered in order to achieve these goals. One aspect is the review of the Directive on the Deployment of Alternative Fuel Infrastructure (European Commission, 2021a), which establishes the requirements for expanding the EU's network of charging and refuelling stations for alternative vehicle fuels like electric batteries and hydrogen (European Commission, 2020f). In light of the EU carbon neutrality target, the Regulation establishing CO2 emission performance standards for new passenger cars and light commercial vehicles may also be revised. The revision would result in stricter emissions standards for automobiles. The EU Commission also intends to revise the Trans-European Transport Network Regulation (TEN-T Regulation) and the Intelligent Transport Systems Directive. This aims to increase the adoption of zero-emission vehicles, develop sustainable alternatives, and support digitalization and automation (European Commission, 2021b).

Together with digitally-enabled intelligent traffic management systems, automated and interconnected multimodal mobility will play an increasing role. The EU's transport system and infrastructure will be adapted to accommodate new sustainable mobility services that can reduce urban congestion and pollution. Through its financing mechanisms, such as the Connected Europe Facility, the Commission will assist in the development of intelligent systems for traffic management and "Mobility as a Service" solutions. The price of transportation must reflect its impact on the environment and on public health. Subsidies for fossil fuels should end, and as part of the revision of the Energy Taxation Directive, the Commission will examine the present tax exemptions, including those for aviation and maritime fuels, to determine how best to address loopholes. Similarly, the Commission will propose extending European emissions trading to the marine sector and reducing the free allowances provided to airlines under the EU Emissions Trading System. This will be coordinated with worldwide efforts, particularly at the International Civil Aviation Organization and the International Maritime Organization. Throughout addition, the

Commission will give fresh political attention to how effective road pricing may be implemented in the EU.

The EU should simultaneously increase production and deployment of sustainable alternative fuels for transportation. There will be a demand for around 1 million public charging and refuelling stations by 2025 to accommodate the 13 million zero- and low-emission vehicles anticipated on European roads. The Commission will encourage the deployment of public charging and refuelling stations where persistent gaps remain, particularly for long-distance travel and in less densely inhabited areas, and will issue a new financial call as soon as possible to assist this initiative. These measures will supplement those adopted at the national level. The Commission will evaluate legislative measures to increase the development and adoption of sustainable alternative fuels for the various modes of transportation. Transport should become far less polluting, particularly in urban areas. A mix of actions should be implemented to address pollution, urban congestion, and the improvement of public transportation. The Commission will propose stricter pollution rules for vehicles using internal combustion engines.

2.6.3.1.6. From 'Farm to Fork': Designing a Fair, Healthy and Environmentally-friendly Food System

Food systems account for approximately 21% to 37% of global GHG emissions and consume significant natural resources (Climate Diplomacy, n. d.). The Farm to Fork strategy aims to address these environmental concerns, as well as fairness, the sustainability of the food system, and Europeans' health. The strategy will emphasize waste reduction and the transformation of food manufacturing, processing, retailing, packaging, and transportation.

The Farm to Fork strategy proposes spending €10 billion on food, bioeconomy, natural resources, agriculture, fisheries, aquaculture, and the environment, as well as digital technologies and nature-based solutions for agri-food, through Horizon Europe, the EU's research and innovation framework program. EU policies and legislation will emphasize trade policy in order to obtain commitments from third countries in areas such as animal welfare, pesticide use, and antimicrobial resistance. The Commission and food-chain stakeholders are working on an EU Code of Conduct for Responsible Business and Marketing Practice, as well as obtaining commitments from food companies and organizations to begin taking steps to improve health, sustainability, and the environment. The common agricultural policy (CAP) is also being reformed.

Separately, the EU Commission has proposed a methane reduction strategy. Methane is the second most significant contributor to climate change after CO_2, and it contributes to air pollution. Reducing methane emissions requires a multi-sector approach: agriculture accounts for 53% of anthropogenic methane emissions in the EU, waste accounts for 26%, and energy accounts for 19%. The Methane strategy prioritizes adequate reporting and biogas production opportunities, as well as specific measures in the energy, agriculture, and waste sectors.

European cuisine is renowned for its safety, nutritional value, and high quality. It should now also become the worldwide sustainability norm. Although the move to more sustainable systems has begun, feeding a rapidly expanding global population with current production patterns remains a challenge (European Commission, 2019). Food production still causes air, water, and soil pollution, contributes to biodiversity loss and climate change, consumes excessive amounts of natural resources, and wastes a significant amount of food. In addition, poor diets contribute to obesity and diseases such as cancer. There are new prospects for all food value chain participants. New technologies and scientific discoveries, together with rising public awareness and demand for sustainable food, will be advantageous for all parties involved.

European farmers and fishers are essential to transition management. The Farm to Fork Strategy will enhance their efforts to combat climate change, safeguard the environment, and preserve biodiversity. The common agricultural and fisheries policies will continue to play a vital role in supporting these efforts and guaranteeing a reasonable standard of life for farmers, fishermen, and their families. According to the Commission's plans for the common agricultural policy for 2021 to 2027, at least 40% of the overall budget for the common agricultural policy and at least 30% of the Maritime Fisheries Fund would be allocated to climate change.

By moving the emphasis from compliance to performance, eco-schemes should reward farmers for improved environmental and climatic performance, such as controlling and storing carbon in the soil and enhancing fertilizer management to improve water quality and cut emissions. Together with the Member States, the Commission will explore the potential of sustainable fish as a source of low-carbon food. The strategic plans will need to reflect an elevated level of ambition to dramatically reduce the usage and risk of chemical pesticides, fertilizers, and antibiotics. On the basis of a consultation with key stakeholders, the Commission will determine the necessary actions, including legislative ones, to achieve these reductions. In Europe, organic farming must also expand in terms of land coverage. The EU must develop innovative approaches to safeguard crops from pests and diseases and evaluate the potential role of new inventive techniques in enhancing the sustainability and safety of the food system.

Additionally, the Farm to Fork Strategy will help to realise a circular economy. It aims to reduce the environmental effect of the food production and retail industries by addressing transit, storage, packaging, and food waste. This will include efforts to prevent food fraud, such as enhancing enforcement and investigative capacity at the EU level, and launching a procedure to identify new innovative food and feed items, such as seafood based on algae.

2.6.3.1.7. Preserving and Restoring Ecosystems and Biodiversity

Human activities have reduced the population of wild species by 60% in the last 40 years. The EU Biodiversity Strategy for 2030 identifies changes in land and sea use, overexploitation, climate change, pollution, and invasive alien species as key drivers of biodiversity loss (Patel and Robinson, 2021). Climate change and biodiversity loss are inextricably linked, and nature-based solutions will play an important role in mitigating and adapting to climate change. According to the European Commission, the construction, agriculture, and food and beverage industries are the most reliant on biodiversity. The EU Biodiversity strategy will complement the Farm to Fork strategy by focusing on the restoration of forests, soils, and wetlands, as well as the creation of green spaces in cities. The EU will implement a new biodiversity governance framework to address legislative gaps that are impeding the improvement of biodiversity standards across the EU. This framework includes imposing legally binding nature-restoration targets to restore degraded ecosystems, which will be accomplished through full implementation of the EU Pollinators initiative, the Habitats Directive, and the CAP.

The European Commission estimates that funding the biodiversity strategy will require €20 billion per year. This will necessitate the use of a mix of public and private funding at the national and EU levels, as well as funds from the EU budget. Part of the Renewed Sustainable Finance Strategy will be devoted to ensuring that the financial system contributes to mitigating current and future biodiversity risks, recognizing the threat that biodiversity loss poses to the financial prospects of many sectors of the economy.

Ecosystems provide vital services such as food, clean air and water, and shelter. They minimize natural disasters, pests, and diseases and contribute to climate regulation (European Commission, 2019). The EU and its worldwide allies must stop the loss of biodiversity. According to the 2019 Global Assessment Report of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services, changes in land and sea use, direct exploitation of natural resources, and climate change are the three most major drivers of biodiversity loss worldwide.

The biodiversity strategy outlines concrete ways to achieve goals such as expanding the scope of protected land and sea regions rich in biodiversity, building on the Natura 2000 network. Member States should also strengthen cross-border collaboration in order to safeguard and restore Natura 2000 habitats more efficiently. The Commission will determine which measures, including legislation, will assist Member States in improving and restoring degraded ecosystems, especially carbon-rich ecosystems, to good ecological status. In addition to ideas to green European cities and boost biodiversity in urban settings, the strategy for biodiversity will also include initiatives to green European cities. The Commission will consider establishing a plan for nature restoration and will investigate ways to offer money to assist Member States in achieving this objective.

Climate change is exerting growing pressure on forest ecosystems. In order for the EU to achieve climate neutrality and a healthy ecosystem, both the quality and quantity of its wooded land must increase. Sustainable reforestation and afforestation, as well as the restoration of degraded forests, can improve CO_2 absorption while enhancing forest resilience and supporting a circular bioeconomy. On the basis of the Biodiversity Strategy for 2030, the Commission will develop a new EU forest strategy embracing the entire forest cycle and promoting the many services provided by forests. The key objectives of the new EU forest strategy will be effective afforestation, forest preservation, and restoration in Europe in order to increase the absorption of carbon dioxide, reduce the incidence and extent of forest fires, and promote the bio-economy in accordance with ecological principles favourable to biodiversity.

A sustainable “blue economy” will play a major role in mitigating the many demands on the land resources of the EU and combating climate change. Increasingly, the significance of oceans in reducing and adapting to climate change is acknowledged. The sector may help through enhancing the utilization of aquatic and marine resources, as well as by promoting the development and consumption of novel protein sources that can alleviate strain on agricultural land.

2.6.3.1.8. A Zero Pollution Ambition for a Toxic-free Environment

To create a non-hazardous environment, it is necessary to take further steps to prevent pollution and to clean and eliminate it. To protect Europe's population and ecosystems, the EU must improve its monitoring, reporting, prevention, and remediation of air, water, soil, and consumer product pollution. To accomplish this, the EU and Member States will need to examine all policies and regulations more methodically. In 2021, the Commission established a zero-pollution action plan for air, water, and soil in order to address these interrelated concerns.

It is necessary to restore the natural functions of ground and surface water. This is crucial for preserving and restoring biodiversity in lakes, rivers, wetlands, and estuaries, as well as preventing and limiting flood damage. The Commission will consider the findings of the examination of the air quality legislation. In addition, it will recommend strengthening measures on monitoring, modelling, and air quality strategies to assist local governments in achieving cleaner air. Significantly, the Commission will suggest revising air quality standards to better align them with World Health Organization recommendations.

2.6.3.2. Mainstreaming Sustainability in all EU Policies

The EU Treaties recognize the economic, social, and environmental components of sustainable development, all of which must be addressed simultaneously. Sustainable development has been at the centre of the European project for a very long time. The key to achieving sustainable development is to strike a balance between maximising economic productivity, fostering social inclusion, and being responsible stewards of the planet's resources. This will allow for the provision of a dignified existence for all people within the bounds of the planet.

Sustainable development has been included into the policies and regulations of the EU. This has been accomplished through the implementation of the EU Sustainable Development Strategy, the EU 2020 Strategy, and the EU Better Regulation Agenda. This can be seen in sectoral plans such as the 7th Economic Action Plan. These measures have been followed by a significant level of engagement on the part of Member States and other stakeholders, which is a prerequisite for their implementation.

The EU had a considerable impact on the development of the global Agenda 2030. The Agenda is completely compatible with the goals of the European Union and has become the paradigm for the overall progression toward sustainable global development. In accordance with the principle of subsidiarity, the European Union and its Member States will continue to take the initiative in putting the Sustainable Development Goals and the 2030 Agenda into action. The 2030 Agenda will further accelerate a coordinated approach between the internal and external components of our policies and the coherence of EU financial tools.

The EGD was succeeded by the European Green Deal Investment Plan (EGDIP) in January of 2020. The EGDIP is the "investment pillar" of the EGD, and its goal was to "*mobilise at least €1 trillion of sustainable investments over the next decade*" (European Commission, 2020g). This was the goal of the EGDIP because the Commission wanted to *"enable a framework to facilitate public and private investments needed for the transition to a climate-neutral, green, competitive, and inclusive economy"* (European Commission, 2020g).

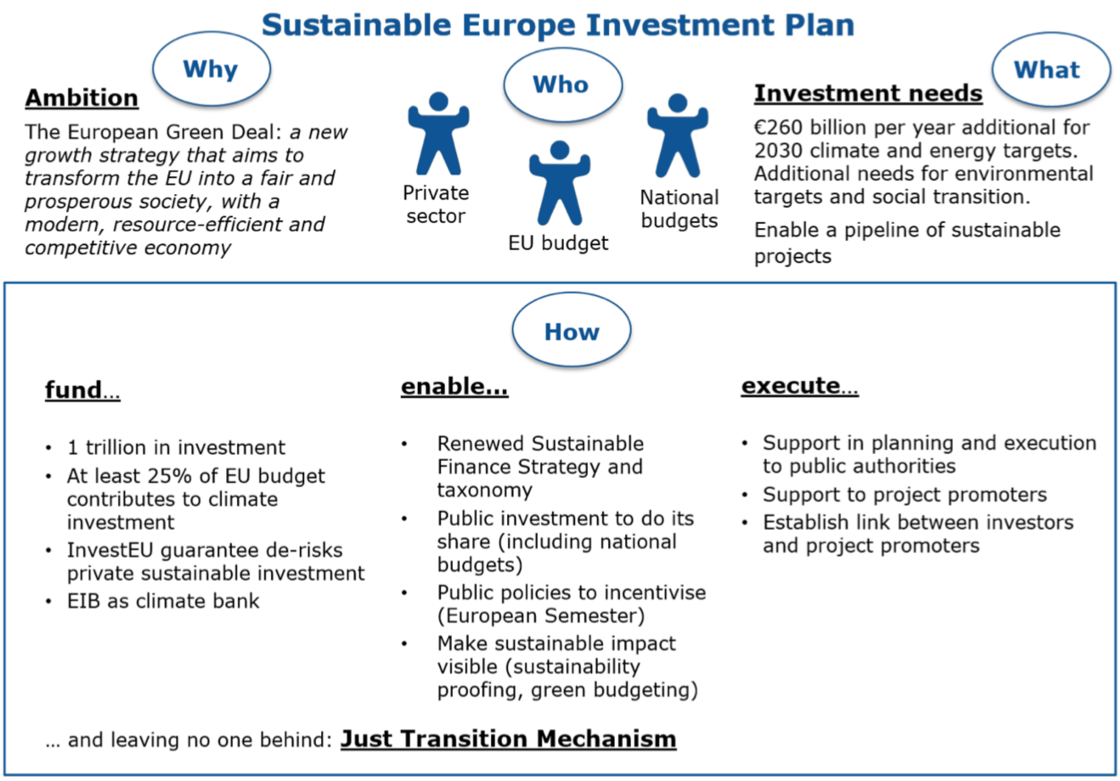

Figure 4 The Sustainable Europe Investment Plan

Source: European Commission (2020g: 3)

Figure 4 shows who is responsible for maintaining the Sustainable Europe Investment Plan and how much money Member States need to achieve a net-zero economy. In addition, it describes the main motivation for why it exists and how it can be achieved.

3. Methodology

Further to the theoretical background, which explained the main terms, the history of climate change and international agreements on climate change, with emphasis on the UN SDGs and environmental governance in the EU, the dissertation will now move to the methodology. Based on the aims and hypotheses set, the methods used to collect and analyse data and test the set hypotheses are explained in the following text. Testing set hypotheses is based on applying the quantitative methodology common in social sciences. The importance of quantitative analysis in environmental studies dates back to 1928, when Chapman analysed environmental factors by quantitative analysis. In addition, Chapman (1928) mentioned that throughout history, various branches of science used relatively inexact description methods and relative exact quantitative methods and mathematical calculations. Thus, in accordance with the stated research questions and research aims, it is necessary to choose a research strategy that will be consistently applied during the research process. The research process consists of six main steps (Saunders et al., 2019): research philosophy, research logic, research strategy, research approach, time sequence and data collection methods.

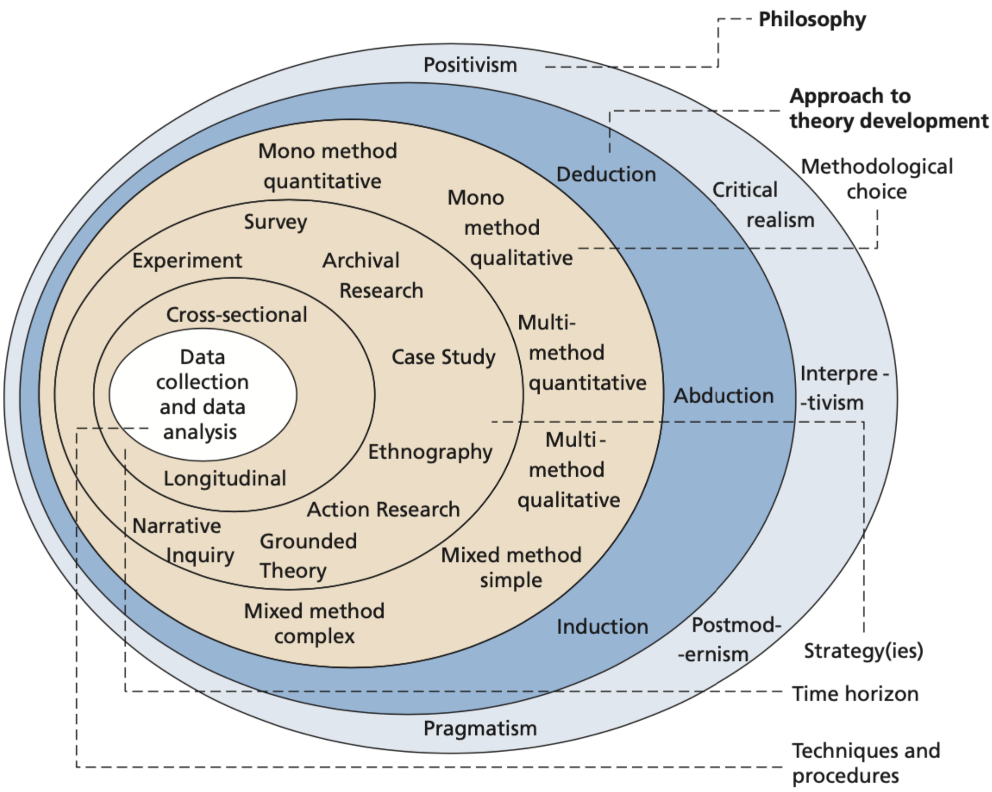

Figure 5 The "research onion"

Source: Saunders et al. (2019:130)

Figure 5 is often called the “research onion” and is used to determine the six steps of the research process. Saunders et al. (2019) introduced the “research onion” to help researchers in their decision-making process to find appropriate methods for their research.

Furthermore, to test the set hypotheses, the collected data was analysed using the statistical program IBM Statistical Package for the Social Science (SPSS) version SPSS 25.0, Stata 14 MP and EViews 12.

3.1. Research Design

For several decades, the research methodology traditionally used in the social sciences was quantitative methodology, which originated in natural sciences such as biology, chemistry, physics, and geology and was concerned with exploring things that could be observed and measured in some way (Antwi and Hamza, 2015). According to Antwi and Hamza (2015), Kuhn first mentioned the term paradigm in 1962, which comes from the Greek word *paradeigma*, and means a pattern. According to Kuhn (1977), a paradigm is a research culture comprised of a set of beliefs, values, and assumptions shared by a community of researchers regarding the nature and conduct of research.

Research paradigms are the philosophies of science, as stated by Varpio and MacLeod (2020), and they serve as a compass for directing scientific discoveries through the assumptions and values they uphold (Park et al., 2020). Scientists (Lincoln and Guba, 2000; Patton, 2002; Bagele, 2011; Scotland, 2012; Park et al., 2020) differentiate research paradigms by core elements: ontology, epistemology, axiology and methodology[3]. In this section, the paradigm discussion will be limited to the one chosen for this research.

This dissertation uses positivism based on an epistemological approach as a research philosophy. The goal of the positivist methodology is to explain relationships (Scotland, 2012). Positivists seek to identify the factors that influence outcomes (Creswell, 2009). Their goal is to create laws that can be used for prediction and generalization, and a deductive approach is used (Scotland, 2012). From an epistemological standpoint, the researcher would concentrate on discovering observable and measurable facts and regularities, and only phenomena that can

[3] For a description of research paradigms in business and managerial research, see Saunders et al. (2019: 133 - 134), Park, Konge and Artino (2020:690), Bagele (2011:40 – 41).

be observed and measured would result in the generation of credible and meaningful data (Crotty, 1998).

A positivist researcher would view businesses and other social entities as real, like physical objects and natural events. Positivists would look for causal correlations in data to develop scientific generalizations. These universal norms and laws help explain and anticipate businesses' behaviour and occurrences. Positivists employ current theory to develop hypotheses. These assertions provide hypothetical explanations that can be examined, confirmed, or denied, leading to the development of a theory that can be tested by additional research. Positivists avoid influencing their study and data by being neutral and detached. This includes conducting value-free research wherever possible. Positivists believe this is based on measurable, quantifiable data. They claim to be external to data collecting because they can't change the collected data (Saunders et al., 2019: 145 – 146).

After choosing the research philosophy, the next layer of the "research onion" is choosing an approach to theory development. As Saunders et al. (2019) described, there are three options to choose between (deductive, abductive and inductive approach). The author chose the deductive approach since it is associated with positivism, and it is applied as a research approach in this dissertation. The deduction is commonly associated with scientific research, and it tests theory through rigorous tests with a sequence of propositions (Saunders et al., 2019).

The third step of the research process is the methodological choice. The researcher can choose between six different types of methodology (mono-method quantitative study, mono-method qualitative study, multi-method quantitative study, multi-method qualitative study, mixed method simple study and mixed method complex study). The author chose a quantitative research design with a multi-method quantitative study design to use in the dissertation. As Saunders et al. (2019) describes, a multi-method quantitative study consists of more than one quantitative data collection technique and corresponding analytical procedure. The quantitative approach is used in the dissertation due to the numerical data required to test all the hypotheses. Market efficiency of EU ETS, UN SDGs, ESG ratings and GHG emissions are all measured quantitatively; therefore, the author chose a quantitative approach.

The fourth step in the research process is to choose a research strategy. There are eight research strategies (experiment, survey, archival and documentary research, case study, ethnography, action research, grounded theory and narrative inquiry). The author chose archival and documentary research as well as case study to use in this dissertation. Archival and documentary research includes secondary data that are published and available in some form, such as data and documents published on the websites of different businesses and organisations, audio-visual content, photographs, etc. The application of archival research in this dissertation refers to the EU ETS data, which was used to create a database for analysis. The case study is, according to Yin (2018), an in-depth inquiry into a topic or phenomenon in its real-world context. The application of the case study in this dissertation refers to the data of EU countries and companies, which was used to create a database for another analysis.

The time horizon constitutes the fifth step of the research process in which there is a choice between longitudinal and cross-sectional research. Longitudinal research involves more time series, which enables the author to study change and development. Accordingly, the research in the dissertation is longitudinal because it includes the analysis of five years (2008-2012) in Phase II and eight years (2013-2020) in Phase III of the EU ETS market efficiency, seven years (2013-2019) of the UN SDGs, and five years (2016-2020) of the ESG ratings.

The final step of the research process involves data collection and analysis. Based on all the mentioned steps, for an easier and shortened overview, the research design is shown schematically in Figure 6.

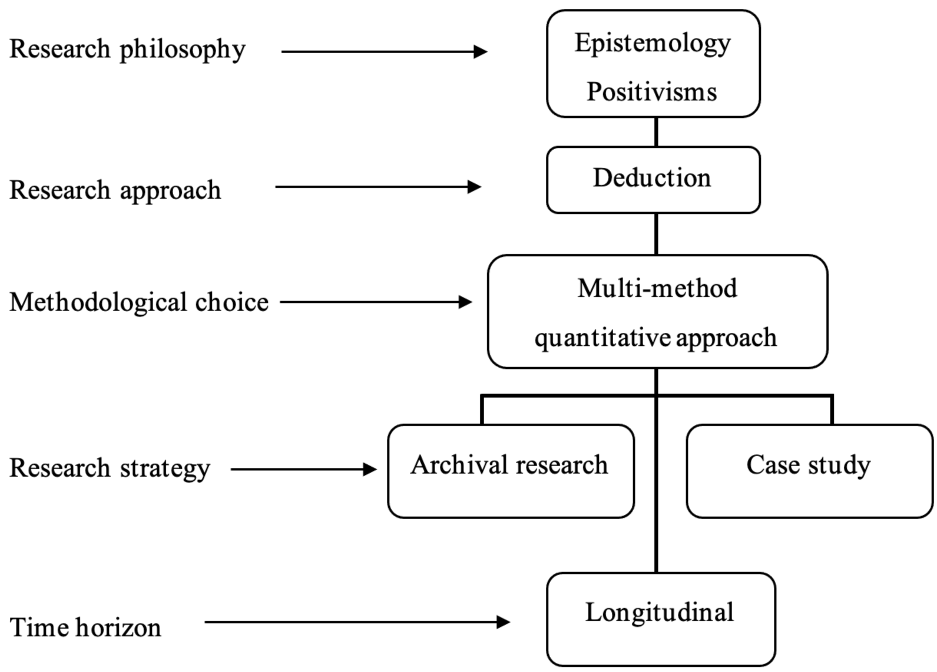

Figure 6 Research design according to the research process

Source: author based on Figure 5

3.2. Research Sample

To test all the hypotheses, the author needs to analyse different datasets. Therefore, there are three samples to conduct the analysis. Table 4 describes all three datasets with information about databases used to retrieve the data, time frames and variables used to test all the hypotheses.

Table 4 Systematic overview of analysed data

Dataset	Database	Time frame	Variables
EU ETS	Refinitiv Eikon	Daily: Phase II (2008-2012) Phase III (2013-2020)	EUA Futures 2012 EUA Futures 2020
EU Member States	UN DESA	Yearly (2013-2019)	UN SDG indicators: 9.4.1 emissions from fuel consumption 9.4.1 emissions per unit GDP PPP 13.2.2 total GHG emissions per year
EU companies	Refinitiv Eikon	Yearly (2016-2020)	Industry Company size GHG emissions Environmental ratings Environmental innovation Resource use

Source: author's own interpretation based on retrieved data

Table 4 is a systematic overview of the presented data. As the author already explained, the dissertation analysis three levels of the EU (macro, mezzo and micro level). Each level helps the author to give further recommendations and conclusions based on the conducted analysis. The retrieval date of each data set has been different, and it is important to include that information for potential comparative studies. The EU ETS dataset was retrieved from Refinitiv Eikon on June 17th, 2022. The EU Member States dataset was retrieved from UN DESA on October 21st, 2022. The EU companies' data set was retrieved from Refinitiv Eikon on multiple days as follows: June 11th (Austria, Belgium, Cyprus, Czechia, Denmark), June 12th (Finland, France, Germany, Greece, Hungary, Ireland, Italy), June 13th (the Netherlands), June 14th (Luxembourg, Malta, Sweden) and June 15th (Poland, Portugal, Romania, Slovenia, Spain) due to a large number of companies. In the following text, the author explains each dataset in detail. The first explained is the EU ETS sample, the second is the UN SDGs sample, and the third is the ESG rating sample.

3.2.1. EU ETS

The author will use carbon futures data to analyse EU ETS market efficiency. As Ibikunle et al. (2016) state, emissions permits have to be surrendered on an annual basis. In principle, therefore, futures contracts on emissions permits offer significant benefits, both as instruments for hedging price risk and as mechanisms to assist in the smooth operation of the system as a whole. Understanding the microstructure of these markets, therefore, goes a long way in helping to inform global climate change policy. There are several reasons for focusing on the carbon futures market instead of the spot, according to Daskalakis (2013). According to Chevallier (2010), this is the obvious choice because price discovery of carbon permits occurs on the futures market in the same way as it does on other commodity markets. Moreover, the majority of the liquidity in the EU ETS comes from the futures market. Specifically, in Europe in 2011, 88% of all carbon transactions were made in futures, 2% in spot emission allowances, and 10% in options (Kossoy and Guigon, 2012). In addition, through the cost-of-carry relationship with no convenience yield and no storage expenses, the value of carbon futures are directly correlated with those of spot ones (Daskalakis et al., 2009)

As a comparison, EUA Futures 2012 and EUA Futures 2020 will be analysed because EUA Futures 2012 represents historical prices for futures with an expiration date in December 2012, and EUA Futures 2020 represents historical prices for futures with an expiration date in December 2020. Therefore, the author can compare Phase II and III of EU ETS and its market efficiency. By comparing the two phases, the author can present evidence of EU ETS's progress towards market efficiency. Analysis of the EU ETS connects the first hypothesis and the first aim of the dissertation to estimate market efficiency.

3.2.2. UN SDGs

The UN SDGs have already been discussed in Chapter 2 from a theoretical standpoint. In the following text, the author explains which indicators have been used to test the differences between the EU Member States and their progress towards reducing GHG emissions. The Inter-Agency and Expert Group on SDG Indicators (IAEG-SDGs) created the global indicator framework for the Sustainable Development Goals, which was approved at the United Nations Statistical Commission's 48th session in March 2017 (UN DESA, n.d. c).

The global indicator framework was later adopted by the General Assembly on 6 July 2017 and is included in the Annex to the General Assembly Resolution on the Work of the Statistical

Commission in relation to the 2030 Agenda for Sustainable Development (A/RES/71/313) (UN DESA, n.d. c). The Resolution states that the indicator framework will be refined annually and thoroughly reviewed by the Statistical Commission at its fifty-first session in March 2020 and its fifty-sixth session in 2025. The global indicator framework will be supplemented by indicators developed at the regional and national levels by the Member States.

Annual indicator refinements are incorporated into the indicator framework as they occur. As part of the 2020 Comprehensive Review, the IAEG-SDGs proposed 36 major changes to the framework in the form of replacements, revisions, additions, and deletions in accordance with the group's mandate, which were approved by the 51st Statistical Commission in March 2020 (UN DESA, n.d. c). The global indicator framework contains 231 distinct indicators. Even though there are 248 indicators listed in the global indicator framework of SDG indicators, thirteen indicators appear again and again under two or three different targets.

The time frame for the UN SDGs analysis is seven years (2013-2019) due to the available data from the UN DESA. The sample consists of twenty-seven Member States since the author did not include the UK. The UK has been exempted from the sample because the focus of the dissertation is on Phase III of the EU ETS (2013-2020). Table 5 shows the most important information regarding the UN SDGs sample.

Table 5 UN SDGs sample

SDG indicator	N	Minimum	Maximum	Mean	Std. deviation
9.4.1 emissions from fuel consumption	189	1.35	763.65	103.8875	153.31657
9.4.1 emissions per unit GDP PPP	189	0.062	0.484	0.16506	0.066700
13.2.2 total GHG emissions per year	189	1.90248	940.41954	140.656952	197.549884

Source: author's own calculation based on UN DESA data

As Table 5 shows, three indicators have been analysed, and the number of observations is 189 instead of 27. The collected data was in a wide format, and the author restructured it in a long format so it could be analysed. The Member States emitted an average of 103.89 million tonnes of carbon dioxide from fuel combustion. In addition, they emitted an average of 140.66 metric tonnes per year in total. Analysis of the UN SDGs connects the second hypothesis and the second aim of the dissertation to statistically confirm the differences between EU Member States and GHG emissions.

3.2.2.1. UN SDG 9

The author tested differences between the EU Member States and their distribution of percentage change of GHG emissions. Based on the UN SDGs indicators, the author used three indicators to test the differences. SDG Goal 9 is to *"build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation"* (UN DESA, n.d.), with target *9.4 "to upgrade infrastructure and retrofit industries to make them sustainable, with increased resource-use efficiency and greater adoption of clean and environmentally sound technologies and industrial processes, with all countries taking action in accordance with their respective capabilities by 2030"* (UN DESA, n.d.) has been the focus of this dissertation. The author used indicator *9.4.1 CO_2 emissions per unit of value added* (UN DESA, n. d. d) to test the differences. Indicator 9.4.1 is measured by three methods (UN DESA, n. d. d):

- *"Carbon dioxide emissions from fuel combustion (millions of tonnes)*
- *Carbon dioxide emissions per unit of manufacturing value added (kilograms of CO2 per constant 2015 United States dollars)*
- *Carbon dioxide emissions per unit of GDP PPP (kilograms of CO2 per constant 2017 United States dollars)"*.

For the purpose of the analysis, the author chose the first and the third option for measuring GHG emissions among countries. The International Energy Agency (IEA) collects national energy data in accordance with generally accepted criteria for energy statistics. It calculates CO_2 emissions using Tier 1 of the 2006 IPCC Guidelines for National GHG Inventories, resulting in globally comparable CO2 emissions data for more than 150 nations and areas. The IEA reported data for the indicators in 2021. According to UN DESA (2022), *"GDP represents the sum of gross value added from all institutional units resident in the economy",* and the overall CO_2 emissions intensity of the economy is calculated using GDP based on purchasing power parity (PPP), to be able to compare countries across time.

3.2.2.2. UN SDG 13

In addition, the author analysed SDG goal 13, *"take urgent action to combat climate change and its impacts"*, with target 13.2, *"Integrate climate change measures into national policies, strategies and planning"* (UN DESA, n.d. d). Target 13.2 has been measured by two indicators, and the author chose to use indicator 13.2.2, *"total greenhouse gas emissions per year"* (UN DESA, n.d. d). Indicator 13.2.2 consists of *"total GHG emissions without land use, land-use* *change and forestry (LULUCF) for Annex I Parties"* and is measured in Mt CO_2 equivalent (UN DESA, 2021). The UNFCCC collects annual data on GHG inventory from Annex I Parties at the country level. According to UN DESA (2021), total GHG emissions are computed as the sum of direct GHG emissions, including carbon dioxide, methane, nitrous oxide, perfluorocarbons, hydrofluorocarbons, sulphur hexafluoride, and nitrogen trifluoride, all quantified in units of CO2-equivalent known as Global Warming Potentials (GWP).

3.2.3. ESG Ratings

As a risk management concern, managing environmental, social, and governance (ESG) issues have gained popularity among investors, shareholders, and governments while becoming an increasingly important component of enterprises' competitive strategies (Galbreath, 2013; Tarmuji et al., 2016). Eccles and Viviers (2011) published a study on ESG issues in academic literature. They concluded that ESG issues are very important, and they have been part of different studies since 1975. ESG data has recently been used by stakeholders, particularly investors, to a greater extent. As stakeholder pressure on environmental concerns like climate change, pollution, and waste increases considerably, businesses are transitioning to data stream-based systems in order to remain competitive. ESG information played a significant and positive impact on the business's transformation (Tarmuji et al., 2016). Companies are conscious that ESG disclosure is essential to presenting a positive reputation and image to stakeholders while addressing the challenge of environmental issues. The trend of exposing ESG practices in the global data stream has dramatically increased over time as businesses strive to be sustainable.

There are numerous data providers on ESG ratings, such as Bloomberg, FTSE Russell, Institutional Shareholder Services, Moody's, MSCI, Sustainalytics, S&P, Refinitiv (Thomson Reuters former Financial & Risk business), etc. To analyse the ESG data, the author collected data through Refinitiv.

There are currently three major worldwide financial service providers: Thomson Reuters, MSCI, and Bloomberg. These three systems offer combined ESG scores that show businesses who perform well in terms of ESG standards are primarily concerned with maximising long-term shareholder value. ESG data, however, continues to be widely disregarded by many businesses and investors, and it offers an untapped resource for staying competitive (Greenwald, 2010). Companies with strong ESG performance disclose more information about management policies, practices, and performance, which reflects the transparency of the management of financial and non-financial data (Greenwald, 2010).

Numerous current research isolates or concentrates on a certain ESG dimension (Ponnu, 2008; Barnett and Salomon, 2012; San Ong et al., 2014). Only a small amount of ESG research has been done on all three dimensions—environmental, social, and governance—in one location (Ioannou and Serafeim, 2010; Zuraida, et al. 2014). The effects of environmental actions will be felt by society. As a result, the business needs a socially responsible governance system. Combining these three factors could make management practices stronger and improve business performance. Even empirical research supports the idea that ESG practices significantly improve financial performance.

ESG metrics strive to assess additional aspects of a company's performance that are hidden from view in accounting data (Bassen and Kovacs, 2020). Moreover, Bassen and Kovacs (2020) argued that the value of reputation, quality, brand equity, safety, workplace culture, strategies, know-how, and a host of other assets, which are more important than ever in a knowledge-based global economy, cannot be adequately conveyed to management and investors by corporate financial statements. ESG indicators can be used to assess a company's management's capabilities and to enhance risk management since they capture a wider range of non-financial data on environmental, social performance, and corporate governance (Galbreath, 2013).

ESG data is critical, especially for managerial objectives. Managers must have comprehensive and current information about their global operations. As a result, management can adapt its business planning as necessary and is able to foresee and proactively communicate important changes in its projections with analysts. This point of interest makes analysts' estimations more accurate and practical, and it gives management more precise knowledge to deal with the outcomes to regularly meet or exceed market expectations (Greenwald, 2010).

Additionally, managers at organizations with good ESG performance are able to manage by long-term goals and have a keen understanding of the long-term strategic concerns in their industry. These businesses take the essential long-term measures to guarantee their business success over longer time periods in order to be viable (Greenwald, 2010).

Analysis of the ESG ratings connects the third, fourth and fifth hypotheses to the third aim of the dissertation to test the relationship between company size and industry on GHG emissions between EU companies. As a part of ESG reporting, companies report on their GHG emissions; therefore, the author uses reported values to conduct the analysis.

3.2.3.1. Environmental Ratings

Due to the effects of the pollution that is being produced, internal and external stakeholders have recently shown a greater interest in the environmental performance of commercial firms (Jasch, 2006). Employees may be impacted by pollution in the workplace, whereas communities impacted by local pollution, environmental activist groups, government regulators, shareholders, investors, customers, and suppliers are examples of external stakeholders (Jasch, 2006). In order to reduce air emissions (such as greenhouse gases, ozone-depleting compounds, carbon dioxide, etc.), waste, hazardous waste, water discharges, spills, or its effects on biodiversity, a corporation must employ the best management practices.

The management of the organization must also make sure that natural resources are utilised wisely during the production process. A company's ability to reduce environmental costs and burdens for its customers and thereby open up new market opportunities through new environmental technologies and processes or eco-designed, dematerialized products with increased durability could be improved with the support of advanced technology and product innovation (Tarmuji et al., 2016). Stronger environmental performance, according to reference (Melnyk et al., 2003), can raise the firm's worth and draw in new stakeholders. In addition to producing reasonable cost savings, strong environmental practices in operational activities can prevent the negative commercial effects of pollution issues (IFAC, 2005).

In response to the aforementioned problems, the accounting literature has seen a dramatic surge in study on environmental performance. Al-Tauwaijri et al. (2004) examined the environmental effects brought about by corporate operations, such as hazardous waste recycling toxic release, water pollution level, non-compliance with environmental laws, or environmental ratings of companies created by outside organizations. Scientists (Wagner and Schaltegger, 2004; Jalaluddin et al., 2010; Henri and Journeault, 2010) have examined a variety of techniques for evaluating the environmental performance of the effectiveness of pollution control and how it affects organizational performance. On the other hand, Elsayed and Paton (2005) utilize Tobin's q, return on assets, and return on sales as three additional indicators of company profitability or economic performance. Their research shows that the relationship between environmental performance and financial performance is weaker.

Analysis of the environmental ratings connects the sixth, seventh and eighth hypotheses to the fourth aim of the dissertation to find the differences between companies in the EU and their environmental ratings and test the relationship of determinants of environmental ratings.

3.2.3.2. Social Ratings

Businesses should practice social responsibility because environmental operations that are not properly controlled will harm the environment, people, and revenue. The corporate social performance (CSP) has been envisioned as a three-dimensional notion by (Carroll, 1979). Corporate social responsibilities fall into three categories: (1) economic, legal, ethical, and discretionary; (2) responsiveness to social concerns; and (3) social issues (consumers, the environment, product safety, employee discrimination/safety, and shareholders). Performance demonstrates that what counts are the results and outcomes that businesses may achieve as a result of their acceptance of social responsibility and adoption of a responsiveness mindset (Carroll, 2012).

While CSP was described by Wood (1991) as a business organization's configuration of social responsibility principles, social responsiveness procedures, and tangible socially relevant policies, initiatives, and outcomes as they relate to the social relationships of the enterprise. In addition to the company's usual duties to economic shareholders, CSP highlights the company's obligations to a variety of stakeholders, including its workers and the community at large (Turban and Greening, 1997). As a result, businesses with strong social performance have an easier time luring qualified candidates (Turban and Greening, 1997).

Thus, the corporation should be socially responsible and attentive to social issues in order to foster trust and loyalty toward its workers, consumers, and society. Product responsibility, community, human rights, diversity and opportunity, employment quality, health and safety, and training and development are all indicators of a company's social responsibility (Carroll, 2012).

Barnett and Salomon (2012) argued that although organizations with high CSP had the best financial performance, those with low CSP have higher financial performance than those with moderate CSP. This lends credence to the theoretical claim that stakeholders can convert social responsibility into financial gain.

While looking at CSP and economic success, Wagner (2010) discovered that there is no clear correlation between the two. Advertising seems to be the sole avenue by which corporate social performance and economic performance are favourably correlated. It demonstrates how important it is for the corporation to keep up its competitiveness to communicate socially relevant actions to pertinent stakeholders like customers, non-governmental organizations, or a regulatory body.

3.2.3.3. Governance Ratings

Limiting agency costs, promoting firm survival, and improving business performance in the best interests of shareholders all depend on a sound corporate governance framework (Fama and Jensen, 1983). Corporate governance was defined as the process and framework used to plan, manage, and advance the organization's operations and corporate responsibility with the specific aim of recognizing long-term shareholder value while taking into consideration the interests of other stakeholders (OECD, 1999).

The essential role of corporate governance is to support the board's performance in managing the organization's business operations (Ponnu, 2008). One of the most crucial components of the corporate governance system for regulating how the business of the firm is conducted is the board of directors (Cadbury, 2000). The finest company governance practices focus on fair and competitive management compensation to entice and keep board members and executives. The shareholders should receive equal treatment and special benefits. The vision and strategy should be communicated to all stakeholders and integrated into daily decision-making processes together with economic (financial), social, and environmental measurements.

The business adheres to the guidelines and standards to guarantee sustainability and advancement. Corporate governance responsibility denotes the existence of specialized sustainability management processes within the organization (Klettner et al., 2014). Different authors (Aggrawal, 2013; Achim, et al., 2016; Bhagat, et al., 2019) state that corporate governance has an impact on business performance. O'Connel and Cramer (2010) discovered evidence that board size had a significant negative correlation with business performance. Additionally, they discovered a strong and positive correlation between firm success and the proportion of non-executives on the board, as well as a significantly less negative correlation between board size and firm performance for smaller firms.

Corporate environmental management procedures frequently connect to financial results. Adopting innovative environmental practices, such as reducing pollution sources and operating in a more ecologically friendly manner, can lower trash disposal costs and penalties, which has a positive economic impact on businesses (Aragon-Correa et al., 2008).

3.2.3.4. Refinitiv ESG Ratings

With data going back to 2002 and encompassing more than 80% of the global market value over more than 630 different ESG variables, Refinitiv has one of the most complete ESG databases in the business. Refinitiv's ESG scores are made to measure a business's relative ESG performance, commitment, and effectiveness based on information provided by the company. Additionally, Refinitiv gives a total ESG combined (ESGC) score that is adjusted to account for important ESG disputes that have an effect on the covered businesses. Over 12,000 public and private businesses around the world have ratings available, with time series data dating back to 2002 (Refinitiv, 2022). The percentile rank results (available in percentages and letter grades from D- to A+) are easy to interpret. They are compared to The Refinitiv Business Classifications (TRBC - Industry Group) in order to determine how well they perform in terms of the environmental, social, and controversies categories (Refinitiv, 2022). All governance criteria are also evaluated in relation to the nation of incorporation.

Every week, data is updated on products and a new computation of the ESG ratings happens. The database is updated continuously in accordance with company reporting trends. Updates might include a brand-new company being added to the database, the most recent fiscal year update, or fresh controversial events. In keeping with firms' own ESG disclosure, reported ESG data is typically updated once a year (Refinitiv, 2022).

The results are based on the sector (for environmental and social considerations) and country of incorporation of the company, as well as the relative performance of ESG elements (for governance). Refinitiv does not assume to define what "excellent" looks like; instead, they allow the data to reveal industry-based comparative performance within the framework of their standards and data architecture. Figure 7 shows how Refinitiv calculates the ESG and ESGC scores.

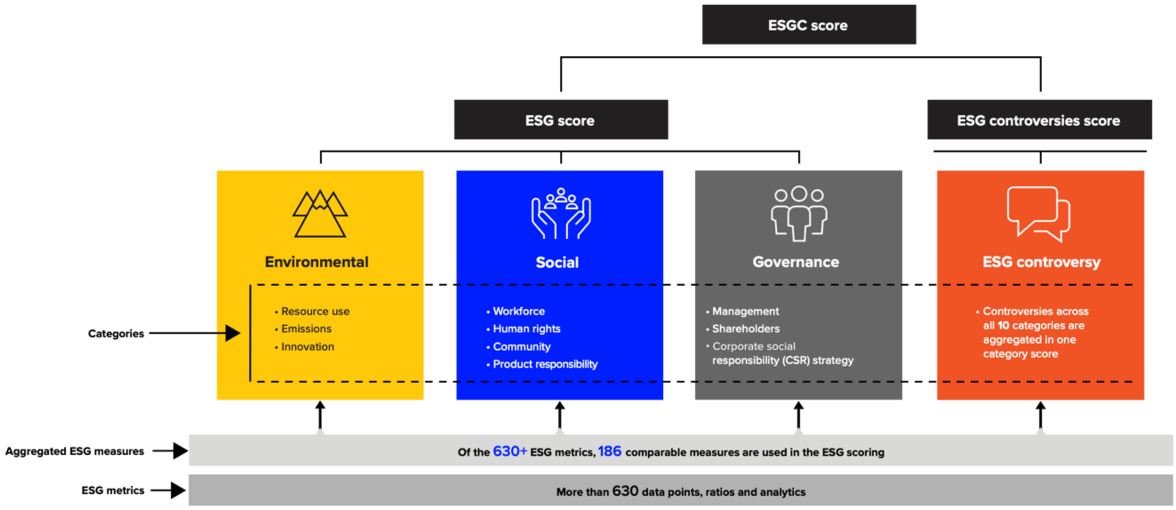

Figure 7. Refinitiv ESGC score overview
Source: Refinitiv (2022:3)

Refinitiv ESG ratings integrate and take into consideration industry materiality and business size biases, reflecting the underlying ESG data methodology and providing a transparent, data-driven evaluation of companies' relative ESG performance and capability. The ESG scoring system used by Refinitiv adheres to a number of important calculating principles (Refinitiv, 2022). Additionally, a total ESGC score is computed, which deducts points for news controversies that have a significant effect on firms from the ESG score. The underlying metrics are specific enough to distinguish between firms that don't publish much, are opaque, or provide meagre implementation and execution from firms that "walk the walk" and become leaders in their particular fields or regions.

As Figure 7 shows, ESG scores are based on 10 different categories. Three factors are used to calculate the ESG controversy score and the 10 category scores using a percentile rank ranking system (Refinitiv, 2022). The following equation represents three factors used for the score calculations.

$$\text{score} = \frac{\text{no. of companies with a worse valute} + \frac{\text{no. of companies with the same value included the current one}}{2}}{\text{no. of companies with value}}$$

Based on the calculations, the company is given a specific ESG score in the range from D- to A+. Figure 8 displays a thorough breakdown of the scores within the given ranges, grades and description of grades.

Score range	Grade	Description
0.0 <= score <= 0.083333	D -	'D' score indicates poor relative ESG performance and insufficient degree of transparency in reporting material ESG data publicly.
0.083333 < score <= 0.166666	D	
0.166666 < score <= 0.250000	D +	
0.250000 < score <= 0.333333	C -	'C' score indicates satisfactory relative ESG performance and moderate degree of transparency in reporting material ESG data publicly.
0.333333 < score <= 0.416666	C	
0.416666 < score <= 0.500000	C +	
0.500000 < score <= 0.583333	B -	'B' score indicates good relative ESG performance and above-average degree of transparency in reporting material ESG data publicly.
0.583333 < score <= 0.666666	B	
0.666666 < score <= 0.750000	B +	
0.750000 < score <= 0.833333	A -	'A' score indicates excellent relative ESG performance and high degree of transparency in reporting material ESG data publicly.
0.833333 < score <= 0.916666	A	
0.916666 < score <= 1	A +	

ESG laggards

ESG leaders

Figure 8 ESG score indicator range, grade, and description

Source: Refinitiv (2022:7)

When there are controversies throughout the fiscal year, the ESG score and ESG controversies score are averaged to determine the ESGC score (Refinitiv, 2022).

The author used Refinitiv ESG scores for 1457 businesses in the EU during a five-year period (2016-2020). The time period for each business and its ESG scores differs; therefore, some businesses have ESG scores from 2012 onwards, while others have only one reported year (2020). The author chose a five-year time period since the EU presented Directive 2014/95/EU in 2014, indicating businesses should report non-financial information regarding their environmental protection policies, social responsibility strategies or anti-corruption and bribery tactics. To answer that Directive, companies started with their reporting process, and the author chose 2016 as a starting point in the analysis of ESG ratings. In addition, the author used secondary data, which due to limited data availability, only consists of data from a five-year time period.

The Refinitiv ESG magnitude matrix was designed as a proprietary model and is applied at the category level to provide an objective, impartial, and reliable assessment of the importance of each ESG issue to different industries (Refinitiv, 2022). Importantly, when ESG corporate disclosure develops and grows, the magnitude values are automatically and dynamically modified. The environmental rating that author analyses is divided into three categories: emissions, innovation, and resource use. Category weights serve as a definition of materiality for Refinitiv ESG. To identify the relative importance of each theme to each distinct industrial group, category weights are computed using an objective and data-driven methodology. Data points with appropriate disclosure are utilized as a proxy for industry magnitude based on the themes covered in each category. There is one data point per topic, hence there is a one-to-one correspondence between themes and data points. Due to incomplete disclosure, there aren't any data points for some themes that may be used to determine their relative importance (Refinitiv, 2022). Although these topics are featured in corporate ESG reporting and the Refinitiv ESG database, they are not part of the scoring system used to determine the materiality matrix. Refinitiv can locate crucial data points across all of the distinct themes where reporting is enough to use as a stand-in for materiality by compiling a list of all the individual themes. Figure 9 provides detailed view on the environmental themes covered in each category, with respective data points evaluated as proxies of ESG magnitude per industry group.

Pillars	Catagories	Themes	Data points	Weight method
Environmental	Emmission	Emissions	TR.AnalyticCO2	Quant industry median
		Waste	TR.AnalyticTotalWaste	Quant industry median
		Biodiversity*		
		Environmental management systems*		
	Innovation	Product innovation	TR.EnvProducts	Transparency weights
		Green revenues, research and development (R&D) and capital expenditures (CapEx)	TR.AnalyticEnvRD	Quant industry median
	Resource use	Water	TR.AnalyticWaterUse	Quant industry median
		Energy	TR.AnalyticEnergyUse	Quant industry median
		Sustainable packaging*		
		Environmental supply chain*		

Figure 9 Detailed view on the environmental themes covered in each category

Source: Refinitiv (2022:10)

Analysed data could be Boolean or numeric. Answers to Boolean questions typically consist of "Yes", "No", or "Null". For the purpose of calculating the percentile score, Boolean data points are translated to numeric values based on the polarity of the data point. A relative percentile ranking is only used when a company reports a numeric data and all the companies within an industry group do the same (Refinitiv, 2022).

The following two approaches are used to compute the magnitude matrix, which is utilized as a proxy for magnitude for the environmental and social pillars, given numeric and Boolean data values. The first approach is industry median that utilize primarily for numerical data points that have an influence on the environment and society. The proportionate percentage that a certain sector contributes to the aggregate gross number across the whole ESG universe should serve as the basis for materiality weighting (Refinitiv, 2022). The relative median value for a company within that industry group determines the issue of materiality, or in other words, the relative weight. Decile ranks are assigned after comparing the relative median values for each industry group to which the data item is relevant. The relative weight given to that data point in calculating the industry weight is determined by the decile rank, which ranges from 1 to 10. The second approach is transparency weights, mostly applied to Boolean data elements. The degree of disclosure for each data point within a certain industry group determines the magnitude weights. The relative weight, or question of materiality, is established based on the disclosure of relative level within that industry group. Decile ranks are assigned together with the disclosure percentage for each industry group to whom the data point is relevant. The relative weight given to that data point in calculating the industry weight is determined by the decile rank, which ranges from 1 to 10. By the Refinitiv (2022) definition, the resource use score demonstrates a company's performance and ability to consume less energy, water, and other resources, as well as to discover more eco-friendly solutions by enhancing supply chain management. In addition, environmental innovation score demonstrates a company's ability to lower the costs and burdens associated with the environment for its clients, resulting in the creation of new market opportunities through new environmental technology, processes, or eco-designed products.

Table 6 shows changes in the number of businesses that reported ESG in the time frame. A detailed number of businesses that reported ESG based on the EU Member State through analysed years is presented in Appendix 1. Since the analysed time period is five years, and it started in 2016, the author excluded the UK due to "Brexit"[4], which happened in 2020, and the UK is not included in the analysis. Moreover, since the author uses secondary data provided by Refinitiv, all Member States could not be analysed due to their data availability. Countries that were not included in the analysis are Bulgaria, Croatia, Estonia, Latvia, Lithuania and Slovakia.

[4] The United Kingdom's process of leaving the European Union is known as "Brexit".

Table 6 Number of businesses reported ESG (2016-2020)

Year	Number of businesses
2016	555
2017	634
2018	945
2019	1074
2020	1457

Source: author’s own calculation based on Refinitiv data

As Table 6 shows, there is a constant increase in the observed data. In five years, the number of businesses almost tripled, which shows that the ESG ratings are important for businesses, and the author expects a further increase in the future, with more rapid change. All the businesses are divided into thirteen industry groups by Refinitiv. Industry sub-sectors are presented in Appendix 2. Table 7 represents the number of companies by each industry group within the observed time periods.

Table 7 Businesses according to the industry group over the years

	Number of businesses				
Industry group	2016	2017	2018	2019	2020
Academic and educational services	0	0	0	1	1
Basic materials	59	62	85	95	110
Consumer cyclicals	79	90	143	162	216
Consumer non-cyclicals	34	37	60	69	85
Energy	34	35	40	43	59
Financials	87	94	114	122	132
Government activity	0	0	0	0	0
Healthcare	43	54	91	104	159
Industrials	99	119	186	215	307
Institutions, associations and organizations	0	0	0	0	0
Real estate	47	55	85	96	110
Technology	44	55	100	123	232
Utilities	29	33	41	42	46
Total	555	634	945	1072	1457

Source: author’s own calculation based on Refinitiv data

As table 7 represents, companies included in energy and utilities industry groups showed slow progress toward ESG reporting, while companies in industry groups such as technology, industrials and healthcare showed better progress. In this section, progress means that the number of companies with ESG reporting has increased during the observed time, while slow progress means that the number of companies is increasing at a lower rate.

Furthermore, businesses are divided into categories based on their size. The author used the Eurostat (n.d.) classification:

- Microenterprise: less than 10 employees
- Small enterprise: 10 - 49 employees
- Medium-sized enterprise: 50 - 249 employees
- Large enterprise: equal to or more than 250 employees.

According to the Eurostat classification, the author divided businesses into each category every year. Table 8 presents how businesses are distributed based on their size. For data analysis the author merged micro and small businesses into one category, hence the analysis is actually conducted on three categories: micro and small, medium, and large businesses.

Table 8 Businesses according to the industry group over the years

Company size	Number of businesses				
	2016	2017	2018	2019	2020
Micro	0	0	1	2	3
Small	1	3	12	12	18
Medium	8	11	24	32	64
Large	436	532	741	833	1028
Total	445	546	778	879	1113

Source: author’s own calculation based on Refinitiv data

As previously discussed, the author analyses the environmental ratings of businesses as well as GHG emissions, resource use and environmental innovation. The main purpose is to analyse how resource use and environmental innovation impact environmental ratings and how GHG emissions impact the same rating.

GHG emissions are significant for the analysis; therefore, the author uses data provided by Refinitiv. As Refinitiv (2021) states, there are four ways in how CO_2 emissions have been modelled:

- Reported
- CO_2 model
- Energy model
- Median model.

If the CO_2 emissions have been reported, Refinitiv collects data directly from the company, and the reported value does not need to be modelled. If the CO_2 emissions are not reported, then Refinitiv uses one of three models to compute the missing value.

The first solution is the CO_2 model; Refinitiv takes the last available total CO_2 and divides that number by the number of employees for the same year. The next step is to multiply the calculated number by the number of employees from the current year. In addition, the whole process is repeated using net sales instead of the number of employees (Refinitiv, 2021). As an estimate, Refinitiv calculates the average of both calculations, or it uses only one if both are not available.

The second solution is the Energy model; Refinitiv takes the last available total energy consumed (or produced, depending on the industry) and divides that number by the number of employees for the same year. The next step is to compute the same ratio for all other businesses in the same industry. In addition, it calculates the percentile rank of the main business within the ratios of other businesses. Furthermore, it repeats the process but with CO_2 emissions instead of energy. After the CO_2 ratio is computed, both ratios should be multiplied by the number of employees in the targeted year (Refinitiv, 2021). Moreover, both ratios should be multiplied by net sales and an estimate, Refinitiv calculates the average of both calculations, or it uses only one if both are unavailable.

The third solution is the Median model, which starts by computing the CO2/ number of employees ratio for all the companies in the same industry. After all the numbers are calculated, the median should be computed. The same calculation is repeated using net sales instead of the number of employees (Refinitiv, 2021). And the final estimate is the average of both calculations, or only one if both are unavailable.

Table 9 presents the main characteristics of analysed businesses, and the author uses descriptive statistics to describe the businesses.

Table 9 Main characteristics of the businesses in the sample

		N	Minimum	Maximum	Mean	Std. deviation
2016	Number of employees	445	39	6266715	45452.55	79025.929
	Environmental rating	555	1	12	5.57	3.124
	GHG emissions	555	0	190000000	3315878.03	14574389.0
	Resource use	555	1	12	5.13	3.598
	Environmental innovation	554	1	12	7.68	3.829
	ESG score	555	1	12	5.71	2.401
2017	Number of employees	546	18	642292	40231.43	74648.089
	Environmental rating	634	1	12	5.88	3.237
	GHG emissions	634	0	194800000	2904474.31	13075268.1
	Resource use	634	1	12	4.99	3.555
	Environmental innovation	633	1	12	7.71	3.847
	ESG score	634	1	12	5.56	2.351
2018	Number of employees	778	7	664496	30031.30	64698.988
	Environmental rating	945	1	12	6.64	3.307
	GHG emissions	945	0	188800000	1971857.71	10136721.3
	Resource use	945	1	12	5.85	3.698
	Environmental innovation	943	1	12	8.23	3.761
	ESG score	945	1	12	5.98	2.448
2019	Number of employees	879	5	671205	27763.37	61807.184
	Environmental rating	1074	1	12	6.49	3.274
	GHG emissions	1072	0	181900000	1659343.46	8670850.35
	Resource use	1074	1	12	5.79	3.683
	Environmental innovation	1074	1	12	8.08	3.764
	ESG score	1074	1	12	5.97	2.440
2020	Number of employees	1113	3	662575	22207.71	54531.145
	Environmental rating	1454	1	12	7.10	3.402
	GHG emissions	1457	0	150800000	1106569.84	6450287.89
	Resource use	1454	1	12	6.48	3.856
	Environmental innovation	1453	1	12	8.60	3.690
	ESG score	1457	1	12	6.31	2.643

Source: author's own calculation based on Refinitiv data

As a Table 9 shows, the mean value of GHG emissions in 2020 was almost three times lower than one in 2016. Lower GHG emissions, and greater number of companies in 2020 in comparison to 2016 showed that EU companies are transitioning toward a low-carbon economy.

3.3. Methods for Data Analysis

After the samples are described, the author describes the statistical methods that have been used to test all the hypotheses.

3.3.1. Estimation of Market Efficiency

Efficiency describes a market where useful knowledge is priced into financial assets (Dimson and Mussavian, 1998). Economists sometimes use this word to refer to operational efficiency, highlighting how resources are used to facilitate market operation. If capital markets are competitive, microeconomics says investors can't expect high returns from their tactics.

Bachelier's dissertation in 1990 foresaw market efficiency. He stated that *"past, present, and even discounted future events are reflected in market price, but sometimes exhibit no apparent relation to price fluctuations"* (Dimson and Mussavian, 1998:92 as in Bachelier,1990). This awareness of the market's informational efficiency prompts Bachelier to state, *"If the market doesn't forecast its fluctuations, it assesses their likelihood, and this likelihood can be evaluated statistically"* Dimson and Mussavian, 1998:92 as in Bachelier,1990). Bachelier's work was neglected until Samuelson communicated it to economists in the late 1950s (Bernstein, 1993), and Cootner (1964) published it in English. In the first part of the 20th century, a speculative markets theory could have emerged. Early literature accumulated empirical observations that didn't fit with economic frameworks or practitioner views. Bachelier found that commodity prices change randomly and following research by Working (1934) and Cowles and Jones (1937), confirmed this.

Kendall (1953) studied stock and commodities price series in the UK. He concluded that in price series recorded at close intervals, random changes swamp any systematic influence, and the data seem to wander. These empirical observations were dubbed the "random walk model" or "random walk theory". With a greater understanding of price creation in competitive marketplaces, the random walk model became consistent with the efficient markets hypothesis. Samuelson (1965) stated that *"in competitive markets there is a buyer for every seller"*. Fama (1970) reviewed the theory and evidence of market efficiency using Samuelson's microeconomic approach and Harry Roberts' taxonomy. A market is efficient if trading on available information doesn't yield an abnormal profit (Dimson and Mussavian, 1998).

The efficient market hypothesis (EHM), also known as Fama's concept of informational efficiency or capital market efficiency, is an economic theory that deals with the processing of information in capital markets (Fama, 1970). An information-efficient market, price formation takes into account not only current and historical data, but also anticipated developments. With regard to the EU ETS, this implies that market participants are aware of the relevant CO_2 price data as well as the processes that generate CO_2 price data. When new information becomes available, market participants re-evaluate shareholder values, resulting in new CO_2 price levels. Because information is only classified as new if a market participant fails to anticipate it, shocks that directly affect investment behaviour or data generation processes can influence the price level. In further text, the author also uses the term "informational efficiency" as a synonym for "market efficiency".

There are three distinct categories of information that result in three different forms of the EHM (Fama, 1970, Dimson and Mussavian, 1998). In strong informational efficiency, the CO_2 price reflects all available information. This assumption results in the price analysis taking into account both publicly available and non-publicly available information (e.g., executive board development, mergers). The semi-strong informational efficiency category advocates that actual CO_2 price levels fully reflect publicly available information. As a result, all historical and fundamental data (for example, the economy, weather, and fossil fuel prices) is incorporated into the price signal. As a result, only the use of non-publicly available information or inside information allows for above-average returns. To test this type of market efficiency, event studies measuring the velocity of price changes due to new information can be used. Finally, the weak form of the EHM declares that the actual price fully includes historical price and return information that has no influence on future price developments. This implies that, due to the EU ETS's low informational efficiency, an analysis of past CO_2 price behaviour using technical analysis does not result in above-average returns. Only the availability of more information allows for higher returns. This type of efficiency is tested in the dissertation by analysing the predictability of future returns using historical price data. The weak form of the informational efficiency test implies that the effects of other variables other than historic price levels on the CO_2 price are ignored (Dimson and Mussavian, 1998). If the effects of other variables are not directly reflected in the actual price level but rather influence the price level gradually, market participants will be alerted to impending smaller increases. As a result, the reason for the CO_2 price change is redundant within this framework because the question is whether and to what extent past price changes are informative for future price changes.

The EHM's weak form is related to the statistical concept of a random walk, which states that all subsequent price changes represent random deviations from previous prices. The random walk hypothesis assumes that information flows freely and is directly integrated into market prices, implying that future prices will be independent of current price changes (Goers, 2014). Newly arriving information cannot be predicted, resulting in price changes that are unpredictable and random. A random walk is defined as an autoregressive stochastic process, $p_t = p_{t-1} + \beta + \varepsilon_t$, where p_t represents the natural logarithm of the EUA price at time t, β denotes a drift parameter, and ε_t represents the random increment and is independent and identically distributed with mean zero and variance (Goers, 2014). The random term represents the effect of arriving information on the actual CO_2 price. The first difference is shown by $\Delta p_t = \beta + \varepsilon_t$ (Goers, 2014). Moreover, according to this model, the expected value of the CO_2 price is the same as the expected value in previous periods adjusted for unanticipated information.

To test the market efficiency of the EU ETS in Phase III, the author will test the EUA Futures prices to a weak form of EHM. The test would include unit root tests, autocorrelation coefficients, and variance ratio tests.

3.3.2. Panel Regression Model

Linear regression is a statistical approach that may be used for both causal inference and prediction. The multiple regression model is:

$$Y_i = \beta_0 + \beta_1 X_{1i} + \beta_2 X_{2i} + \ldots + \beta_k X_{ki} + u_i, \qquad i = 1, \ldots, n,$$

where Y_i represents the i^{th} observation on the dependent variable; $X_1, X_2, \ldots, X_{ki}$ represents the i^{th} observation on each of the k regressors; and u_i represents the error term. The population regression line is the relationship that holds between Y and X's, on average, in the population:

$$E(Y|X_{1i} = x_1, X_{2i} = x_2, \ldots, X_{ki} = x_k) = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \ldots + \beta_k x_k.$$

β_1 represents the slope coefficient on X_1, β_2 represents the slope coefficient on X_2 and so on. The coefficient β_1 is the expected change in Y_i associated with a unit difference in X_1, holding constant other regressors, $X_2, \ldots, X_k$. The coefficients on the other X's are interpreted similar manner. The intercept β_0 represents the anticipated value of Y when all the X's equal 0. The intercept can be thought of as the coefficient on a regressor, X_0, that equals 1 for all i. In certain econometric applications, the intercept has a meaningful economic interpretation. In other applications, the intercept has no real-world meaning (Stock and Watson, 2019).

Kennedy (2008:281) states that longitudinal data consists of *"observations on the same units in numerous different time periods"*. A panel data set consists of several entities, each with repeated measurements made at various time intervals. As Kennedy (2008) stated, panel data became available since the longitudinal data has more variability and enables the exploration of more issues than cross-sectional or time-series data alone. *"Panel data give more useful data, greater variety, less collinearity among the variables, more degrees of freedom, and more efficiency,"* asserts Baltagi (2001:6). Panel data models offer strategies for addressing heterogeneity and look at fixed and/or random effects in the longitudinal data (Park, 2011).

In order to deal with heterogeneity or individual effects that may or may not be detected, panel data models look at group (individually specific) effects, time effects, or both. These impacts can either be random or fixed. While a random effect model looks into differences in the components of error variance across individuals or time periods, a fixed effect model investigates whether intercepts vary between groups or time periods (Park, 2011). A two-way model takes into account both sets of dummy variables, while a one-way model only takes into account one set.

3.3.2.1. OLS

The ordinary least squares (OLS) model produces accurate and reliable parameter estimations if there is no individual impact. OLS is based on five fundamental presumptions (Greene, 2008: 11-19; Kennedy, 2008: 41-42):

1. The dependent variable is expressed as a linear function of a number of independent variables and the error (disturbance) term, according to the concept of linearity.
2. Exogeneity states that a disturbance's anticipated value is zero or that it has no correlation with any regressors.
3. Disturbances are unrelated to one another and have the same variance.
4. In repeated samples without measurement mistakes, the observations on the independent variable are fixed rather than stochastic.

5. According to the full rank assumption, independent variables do not have a perfect linear connection (no multicollinearity).

In longitudinal data, heterogeneity may have an impact on assumptions 2 and 3 if the individual effect is not zero. For example, disturbances may not all have the same variance but instead vary amongst individuals (heteroscedasticity) or are connected to one another (autocorrelation).

3.3.2.2. Fixed Effect Model

Models for panel data look at the random and/or fixed effects of people or time. The function of dummy variables plays a key role in distinguishing fixed effect models from random effect models. In a fixed effect model, a parameter estimate of a dummy variable is a part of the intercept, and in a random effect model, it is a part of the error component (Park, 2011). Regardless of whether a model is fixed or random, slopes remain constant between groups or over time.

In a fixed group effect model, individual variations in intercepts are investigated while assuming identical slopes and constant variance (group and entity). OLS assumption 2 is not violated since an individual-specific effect is time-invariant and treated as a component of the intercept, which permits the intercept to be correlated with other regressors. By using least squares dummy variable (LSDV) regression (OLS with a set of dummies) and internal effect estimation techniques, this fixed effect model is estimated (Park, 2011).

The fixed effect model is written as follows:

$$Y_{it} = \beta_0 + \beta_1 X_{1i} + \beta_2 X_{2i} + \ldots + \beta_k X_{ki} + a_i + u_i$$

where $\beta_1, \ldots, \beta_i$ represent characteristic that is common to all observed units over several periods, x_{it} are independent variables, i.e. a_{it} represents a fixed effect because it is time-invariant, and u_{it} is a random error estimate.

A random effect model estimates error variance specific to groups on the premise that individual effect (heterogeneity) is not correlated with any regressor (or times). Consequently, the intercept is a component of the composite error term or an individual-specific random heterogeneity. Because of this, an error component model is another name for a random effect model. Each individual's regressors have the same intercept and slope (Park, 2011). Individual-specific errors, not intercepts, determine how different individuals (or times) are from one another.

With the Hausman specification test, a random effect model is put up against its fixed equivalent (Hausman, 1978). A random effect model is preferred over a fixed one if the null hypothesis—that the individual effects are uncorrelated with the other regressors—is not disproved. Random effects have the same form as fixed effects with the additional assumption that the unobserved effect is uncorrelated with any explanatory variable, so the Hausman test questions just that. Therefore, the hypotheses are:

H0: The unobserved effect is uncorrelated with the explanatory variables.

H1: The unobserved effect is correlated with the explanatory variables.

This implies that the fixed effects model is used when the null hypothesis is rejected. The author used Hausman specification test to determine whether the fixed or random effects model should be used to test the eighth hypothesis (H8: *GHG emissions have a greater effect on the environmental ratings of European Union companies than resource use and environmental innovation.*).

The representativeness of the applied panel regression model is measured by the coefficient of determination (R^2), which represents the share of variance in the dependent variable that can be predicted from the independent variables. Its value varies from 0 to 1. If the regression model is a good predictor, then the coefficient of determination will be close to 1. In addition to the coefficient of determination, important information about the quality of the estimated model is provided by information about the corrected value of the coefficient of determination, that is, about the adjusted coefficient of determination (Adjusted R Square), which, according to Newbold et al. (2022), accounts for the fact that non-relevant independent variables result in a slight reduction in the error sum of squares. As a result, the Adjusted R Square allows for a more accurate comparison of several regression models with varying amounts of independent variables. To test the differences between the environmental ratings of European companies, the author will use panel linear regression since the environmental ratings consist of multiple variables observed over 5 years. In addition, the author will use panel linear regression to conclude if GHG emissions have a greater effect on environmental ratings than the businesses' resource use or environmental innovation.

3.3.3. Kruskal-Wallis test

Woodrow (2014) states that analysis of variance (ANOVA) is used when a researcher wants to compare more than two observed group scores. The ANOVA F-test is used to determine whether two or more population means are equal. However, the F-test relies on many assumptions routinely disregarded and broken in real-world applications. These assumptions include that the data in each group are drawn from a normal distribution, the population variances in each group are equal (homoscedasticity), and the data are independent. If these assumptions are met, the F-test of ANOVA is an effective tool for assessing if the means of many populations are equal. When comparing the means of k populations, the Kruskal-Wallis nonparametric test is applied when it is known that the populations do not have equal variances or are not normal.

Nonparametric approaches necessitate less rigorous assumptions than their parametric equivalents; they utilise less data information (Ostertagova et al., 2014). When the assumptions of parametric tests are violated, nonparametric testing should be utilised.

The Kruskal-Wallis test (Kruskal and Wallis, 1952) is the nonparametric equivalent of a one-way ANOVA and is utilised to determine if samples come from the same distribution. This test extends the Wilcoxon-Mann-Whitney two-sample test to more than two independent samples.

The Kruskal-Wallis test makes no assumptions about the existence of normality. Nevertheless, it assumes that the observations in each group come from populations with the same distribution shape and that the samples are independent and random. The test statistic for a one-way analysis of variance is the ratio of the sum of squares for the treatment to the sum of squares for the residuals (Ostertagova et al., 2014). The Kruskal-Wallis test utilises the same procedure, but as with many nonparametric tests, the ranks of the data are utilised in place of the raw data.

Mathematical aspects of the Kruskal-Wallis test are as follows. If there are no mean ranks or if there is a limited number of them, the Kruskal-Wallis test is defined as (Kruskal and Wallis, 1952):

$$H = \left(\frac{12}{N(N+1)} \sum_{i=1}^{k} \frac{R_i^2}{n_i} \right) - 3(N+1)$$

where n_i is the dimension of the sample i for $i = 1, \ldots, k$; N is total number of observations; R_i is the sum of the ranks given to the observations of sample i. The coefficient $\frac{12}{N(N+1)}$ is a normalization factor. In addition, if there are many mean ranks, it is necessary to make a correction and calculate Kruskal-Wallis test as (Kruskal and Wallis, 1952):

$$\widetilde{H} = \frac{H}{1 - \frac{\sum_{i=1}^{g}(t_1^3 - t_i)}{N^3 - N}}$$

where the g is the number of groups of mean ranks and the t_i is the dimension of ith group.

The author will use the Kruskal-Wallis test to test EU companies and their GHG emissions as well as industry and company size during the five-year time frame, from 2016 until 2020.

4. Empirical analysis

This chapter provides the results of the analysis of EU ETS, ESG ratings, and UN SDGs. After the test results are described, the author concludes whether or not to reject the set hypotheses. The first subchapter describes the decision regarding the first hypothesis. The second sub-chapter describes the decision-making process for the second, third and fourth hypotheses. The third subchapter describes the decision regarding the sixth, seventh and eighth hypotheses. The fourth subchapter describes the decision for the fifth hypothesis.

4.1. EU ETS Market Efficiency

The focus of EU ETS efficiency analysis is on analysing random walks, which are distinguished by dependent and not equally distributed random increments, in accordance with prior techniques (Albrecht et al., 1976; Aatola et al., 2014). In order to study informational efficiency, unit root tests and autocorrelation coefficients are included in the empirical analysis of the EU ETS.

The second and third trading phases were used to structure the data, and the second trading phase sample has 1243 observations from February 4th 2008 to December 17th 2012, while the third trading phase sample contains 2052 observations from January 2nd 2013 to December 14th 2020. The price levels of EUA Futures 2012 during the second trading phase are shown in Figures 11 - 13.

Figure 10 EUA Futures 2012 prices

Source: author’s own calculation

Figure 11 Natural logarithm of EUA Futures 2012 prices

Source: author’s own calculation

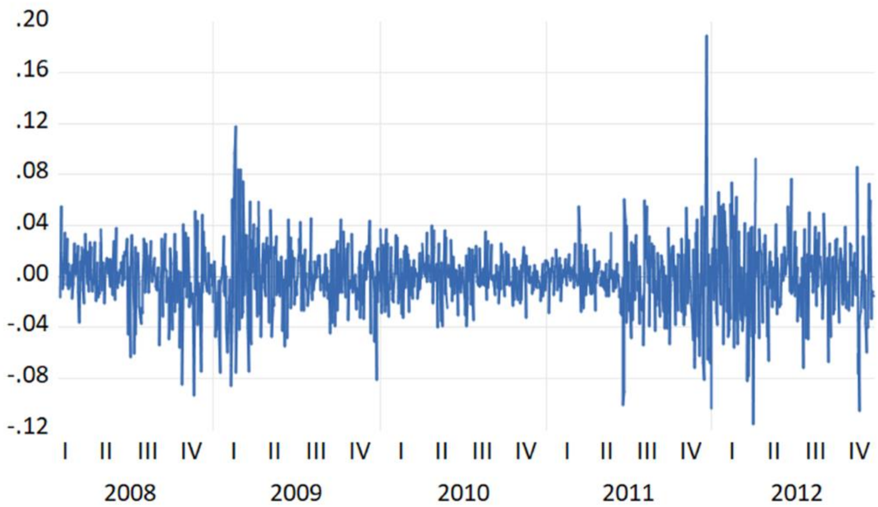

Figure 12 Differentiated natural logarithm of EUA Futures 2012 prices

Source: author’s own calculations

The price levels of EUA Futures 2020 during the third trading phase are shown in Figures 14 – 16.

Figure 13 EUA Futures 2020 prices

Source: author's own calculation

Figure 14 Natural logarithm of EUA Futures 2020 prices

Source: author's own calculation

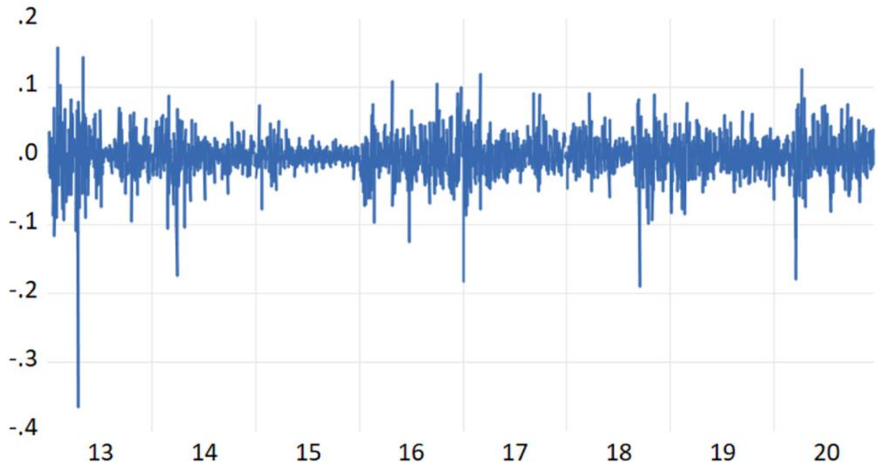

Figure 15 Differentiated natural logarithm of EUA Futures 2020 price

Source: author's own calculation

In this analysis, EUA prices at time *t* are represented by the symbol P_t. Its natural logarithm series, $p_t = ln(P_t)$, and differentiated natural logarithm series, $\Delta p_t = p_t - p_{t-1}$, which shows proportionate deviations from the original price series, are both analysed. The logarithmic EUA Futures price returns at point *t* are thus expressed by the expression Δpt. Figures 12, 13, 15 and 16 display the price development of p_t and Δp_t, and Table 10 provide descriptive statistics for the EUA Futures 2012 series.

Table 10 Descriptive statistics for p_t and Δp_t EUA Futures 2012 series

	p_{2012}	Δp_{2012}
Mean	2.652549	-0.000976
Median	2.727199	-0.000605
maximum	3.537475	0.189522
Minimum	1.743969	-0.116029
St. dev.	0.417203	0.026344
Skewness	-0.195534	0.040101
Kurtosis	2.446270	6.897214
Observation	1243	1242

Source: author's own calculation

Table 11 provides descriptive statistics for the EUA Futures 2020 series.

Table 11 Descriptive statistics for p_t and Δp_t EUA Futures 2020 series

	p_{2020}	Δp_{2020}
Mean	2.324997	0.000563
Median	2.087534	0.000000
maximum	3.430756	0.158960
Minimum	1.410987	-0.365371
St. dev.	0.611513	0.030931
Skewness	0.506905	-1.129860
Kurtosis	1.687974	16.01363
Observation	2052	2051

Source: author's own calculation

The following text summarizes the results and provides an interpretation regarding the amount of informational efficiency of the scheme in the targeted periods based on the statistical approach outlined.

To determine whether a time series represents a non-stationary stochastic process, unit root tests are performed. Since a random walk is a stationary first difference process, the CO2 pricing produced by the EU ETS must have a unit root, unlike the first difference of the series. The Dickey-Fuller Test (DF) has an enhanced version, the Augmented Dickey-Fuller Test (ADF), which reacts to longer and more intricate time series models (Dickey and Fuller, 1976). It expands the DF framework by assuming that p_t is subject to an autoregressive process of order k, where $k > 1$ and c denotes a constant.

$$p_t = c + \delta_t p_{t-1} + \cdots + \delta_k p_{t-k} + \varepsilon_t$$

This operation equals:

$$\Delta p_t = c + \Theta p_{t-1} + \beta_1 \Delta p_{t-1} + \cdots + \beta_{k-1} \Delta p_{t-(k-1)} + \varepsilon_t$$

where: $\Theta = \delta_1 + \cdots + \delta_{k-1}$. $\Theta < 0$ holds for a stationary process while $\Theta = 0 \Leftrightarrow \delta{:}\sum \delta_i = 1$ indicates a non-stationary process. Consequently, the null hypothesis, which states that p_t is non-stationary and contains a unit root is given by H_0: $\Theta = 0$. H_1: $\Theta < 0$ is the alternative hypothesis indicating that p_t is a stationary process (Goers, 2014).

The homoscedastic and independent error terms ε_t are necessary for the ADF. In order to prevent model misspecification, the lag-length of the autoregressive model should be chosen to be suitably large. On the other hand, a k value that is too large could result in the null hypothesis not being rejected. In fact, k should be chosen so that it satisfies a predetermined informational condition that permits comparing the validity of nested models. The Akaike-Information criterion (AIC) is used in this situation (Goers, 2014). The results of the AIC test for EUA Futures 2012 and EUA Futures 2020 are presented in Appendix 3.

The Phillips-Perron Test (PP) offers another method for detecting unit roots (Philips and Perron, 1988). Through an adaptation of the DF test statistics, the PP accounts non-parametrically for serial correlation and heteroscedasticity in the errors terms (Goers, 2014).

Finally, the testing for unit roots also includes the Kwatkowski-Phillips-Schmidt-Shin Test (KPSS) technique (Kwiatkowski et al., 1992). The KPSS proposes stationarity as the null hypothesis and non-stationarity as the alternative hypothesis, in contrast to the methods of the ADF and the PP (Goers, 2014). The time series is represented mathematically as the total of a deterministic trend, a random walk, and white noise, and the KPSS determines if the random walk exhibits zero variation by applying a set of critical values.

Since random walks are the first difference in stationary processes, if p_t contains unit-root, it is non-stationary. If Δp_t does not contain a unit root, it is stationary. According to Table 12, the unit root tests show non-stationarity for p_t for both EUA Futures.

Table 12 Unit root tests for natural logarithm EUA Futures 2012 and EUA Futures 2020

	p_{2012}	p_{2020}
ADF (constant)	-0.550668	-0.436352
ADF (constant + trend)	-2.251208	-2.356001
ADF	-1.375165	0.686227
PP (constant)	-0.569307	-0.402715
PP (constant + trend)	-2.287631	-2.316251
PP	-1.365980	0.710049
KPSS (constant)	3.127042	4.112116
KPSS (constant + trend)	0.349231	0.980138

Source: author’s own calculation

According to Table 13, the unit root tests show stationarity for Δp_t for both EUA Futures.

Table 13 Unit root tests for differentiated natural logarithm EUA Futures 2012 and EUA Futures 2020

	Δp_{2012}	Δp_{2020}
ADF (constant)	-33.08334***	-45.71864***
ADF (constant + trend)	-33.08235***	-45.74203***
ADF	-33.05507***	-45.71203***
PP (constant)	-33.02625***	-45.72556***
PP (constant + trend)	-33.02432***	-45.74216***
PP	-33.00009***	-45.73567***
KPSS (constant)	0.086360***	0.233398***
KPSS (constant + trend)	0.049604***	0.057691***

*** refer to significance at 1%, 5% and 10% levels.
Source: author's own calculation

As a result of unit root tests, ADF; PP and KPSS tests show that differentiated natural logarithm prices for both EUA Futures are stationary, while the test showed both EUA Futures have been non-stationary when prices have been converted to natural logarithm. Based on the unit root tests, the EUA Futures prices for the second and third period may have followed random walk.

To test the random walk hypothesis, autocorrelation coefficients need to be analysed. The correlation between the lags p_t and p_{t-k} is referred to as the autocorrelation of a series regarding the *k-th* lag. The autocorrelation coefficients between Δp_t and Δp_{t-k} for the random walk model with dependent and non-identically distributed random increments must all be equal to zero for any $k>0$ (Goers, 2014). The *k-th* autocorrelation coefficient, denoted by the symbol $\rho(k)$, can be described as follows:

$$\rho(k) = \frac{cov(p_t - \Delta p_{t-1})}{\sqrt{var(p_t)var(p_{t-1})}}$$

An autoregressive model of order *j* shows p_t as a linear function of the lagged variables p_{t-1},..., p_{t-j} in the situation of serial autocorrelation (Goers, 2014). While an abrupt reduction of the autocorrelation coefficients to zero in the case of a growing *k* shows a moving-average process, autocorrelation coefficients that go to zero continuously with a growing *k* indicate autoregressive characteristics of the process. The Ljung-Box Q-statistic at lag *k* can be used to examine the significance of the autocorrelation coefficients as well as the null hypothesis that there is no autocorrelation up to order *k* (Goers, 2014).

The autocorrelation between p_t and p_{t-k} must be equal to zero for any $k > 0$ in order for the random walk hypothesis to be accepted. Tables 14 and 15 list the outcomes of the autocorrelation study together with the significance determined by the Ljung-Box Q(k)-statistic.

Table 14 Autocorrelations for Futures 2012

	p_{2012}		Δp_{2012}	
Lag *k*	Autocorrelation	Q(k)	Autocorrelation	Q(k)
1	0.996	1236.4***	0.062	4.7737**
2	0.992	2464.0***	-0.039	6.6315**
3	0.988	3682.8***	0.025	7.3896*
4	0.984	4892.7***	-0.025	8.1546*
5	0.980	6094.1***	-0.045	10.637*

*, ** and *** refer to significance at the 10%, 5% and 1% levels.

Source: author's own calculation

Table 15 Autocorrelations for Futures 2020

	p_{2020}		Δp_{2020}	
Lag *k*	Autocorrelation	Q(k)	Autocorrelation	Q(k)
1	0.998	2046.5***	-0.010	0.2058
2	0.996	4085.6***	-0.035	2.6805
3	0.994	6117.7***	-0.024	3.8344
4	0.992	8143.2***	0.073	14.778***
5	0.990	10161***	0.010	14.983**
6	0.988	12172***	-0.037	17.791***
7	0.986	14176***	0.009	17.970**

*, ** and *** refer to significance at the 10%, 5% and 1% levels.

Source: author's own calculation

Strong positive autocorrelation can be seen with regard to the autocorrelation of p_t in the second and third trade periods by steadily decreasing coefficients with increasing number of lags. The null hypothesis that there is no autocorrelation has to be rejected at 5% and 10% significance levels, according to research on the autocorrelation of Δp_t during the second trading period. Autocorrelation coefficients close to zero and changing Ljung-Box Q(k)-statistics from very small numbers to greater numbers during the third trading period (2013-2020) show that lagged change in the logarithmic CO2 price cannot fully explain the present change. As a result, the third trading period partially satisfies the condition that the EUA futures prices followed a random walk.

Based on the conducted analysis, the author partially confirms the first hypothesis (*H1: The EU ETS is market efficient during Phase III*). Results showed that the EU ETS is partially market efficient during Phase III when it confronts negative shocks such as the Covid-19 pandemic. This result helps the companies obligated to trade at EU ETS to anticipate possible future shocks and trade carefully.

4.2. GHG Emissions in the European Union Member States

The second hypothesis (*H2: There are statistically significant differences in the distribution of percentage change of GHG emissions of the European Union Member States*) has been analysed using a non-parametric Kruskal-Wallis test.

Differences between the Member States have been tested by three indicators measured by UN SDGs. Indicator 9.4.1 has been measured as emissions from fuel consumption and per GDP PPP, while indicator 13.2.2 has been measured as total GHG emissions per year. The first indicator is measured by millions of tonnes, the second indicator is measured by kilogrammes of CO2 per constant 2017 United States dollars, and the third indicator is measured by millions of tonnes of CO2 equivalent. All indicators are measured by absolute numbers; therefore, the author recalculated indicators to the relative numbers. With recalculated indicators, the comparison between EU Member States can be estimated more precisely. Each country was observed for 7 years. The author recalculated indicators as a percentage change between the second and the first year, the third and the second year, etc. Recalculated indicators show the percentage change between years and the country's progress towards a low-carbon economy.

The author tested recalculated indicator 9.4.1 emissions from fuel consumption first. Based on the Kruskal-Wallis test (df = 26, H = 19.891, p > 0.797), the differences in distribution of percentage change of emissions from fuel consumption among EU Member States are statistically insignificant. Figure 17 shows how the Member States differentiate. The percentage change of total emissions from fuel consumption during the observed time is represented on the y-axis, while each country is on the x-axis. Appendix 5 shows the country according to the country code used to conduct the analysis. Estonia has the greatest reduction in average percentage change, while Cyprus has the greatest increase in average percentage change.

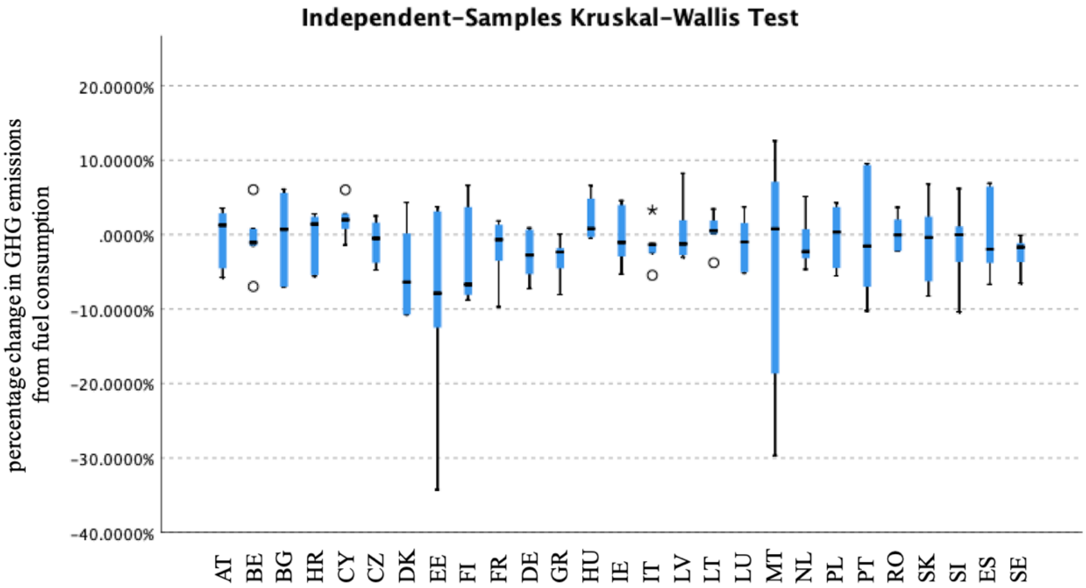

Figure 16 Differences between the Member States in the percentage change of emissions from fuel consumption
Source: author's own calculation

The indicator 9.4.1 (emissions per GDP PPP) was tested second. Based on the Kruskal-Wallis test (df = 26, H = 20.153, p > 0.784), the differences in distribution of percentage change of emissions per GDP PPP among EU Member States are statistically insignificant. Figure 18 shows how the Member States differentiate in the percentage change of emissions per GDP PPP. The percentage change of emissions per GDP PPP during the observed time is represented on the y-axis, while each country is on the x-axis. Appendix 5 shows the country according to the country code used to conduct the analysis. Denmark has the greatest reduction in average percentage change, while Austria has the greatest increase in average percentage change.

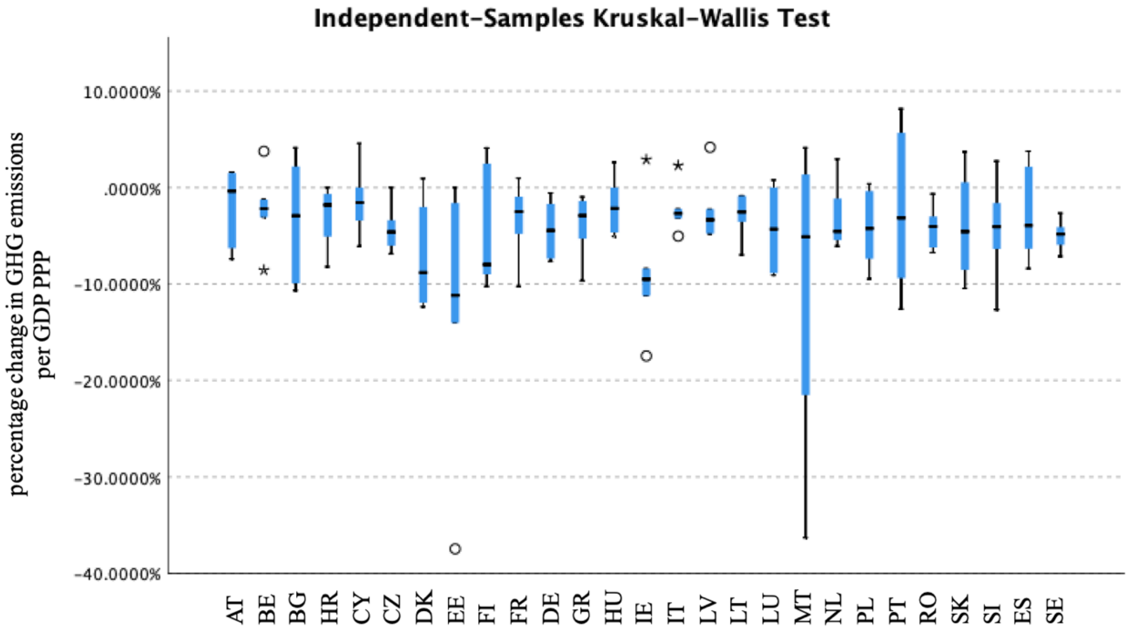

Figure 17 Differences between the Member States in the percentage change of emissions per GDP PPP
Source: author's own calculation

The indicator 13.2.2 total GHG emissions per year without LULCF was the third to be tested. Based on the Kruskal-Wallis test (df = 26, H = 19.669, p > 0.807), the differences in distribution of percentage change of emissions per GDP PPP among EU Member states are statistically insignificant. Figure 19 shows how the Member States differentiate in the percentage change of GHG emissions without LULCF. The percentage change in total GHG emissions per year without LULCF during the observed time is represented on the y-axis, while each country is on the x-axis. Appendix 5 shows the country according to the country code used to conduct the analysis. Finland has the greatest reduction in average percentage change, while Austria has the greatest increase in average percentage change.

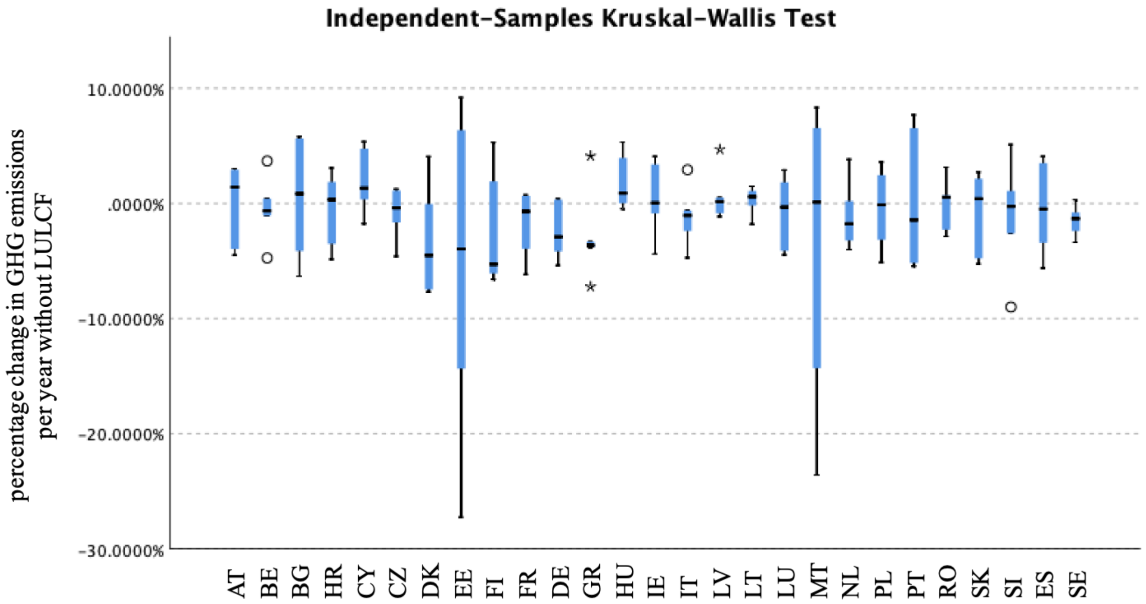

Figure 18 Differences between the Member States in the percentage change in total GHG emissions per year without LULCF

Source: author's own calculation

The results of the Kruskal-Wallis test for both the 9.4.1 indicator and 13.2.2 indicator show statistically insignificant differences between the Member States, so the author does not confirm the second hypothesis. Based on the first test, on average, eight countries (Austria, Bulgaria, Croatia, Cyprus, Hungary, Lithuania, Malta, and Poland) have increased their emissions over the observed time. On the other hand, seventeen countries managed to reduce their emissions (Belgium, Czechia, Denmark, Estonia, Finland, France, Germany, Greece, Ireland, Italy, Latvia, Luxembourg, the Netherlands, Portugal, Slovakia, Spain, and Sweden) on average. In comparison, two countries (Romania and Slovenia) had a stable average change in emissions.

Based on the second and the third test, on average, eight countries (Austria, Bulgaria, Croatia, Cyprus, Hungary, Lithuania, Romania, and Slovakia) have increased their emissions over the observed time. On the other hand, fifteen countries managed to reduce their emissions (Belgium, Czechia, Denmark, Estonia, Finland, France, Germany, Greece, Italy, Luxembourg, the Netherlands, Portugal, Slovenia, Spain, and Sweden) on average. The four countries (Ireland, Latvia, Malta, and Poland) had a stable average change in emissions.

4.3. GHG Emissions in the European Union Companies

The author tested two hypotheses that included GHG emissions in European Union companies. The first tested hypothesis was the third (*H3: According to industry, there are statistically significant differences in distribution of GHG emissions of the European Union companies*). The author conducted a Kruskal-Wallis test to test the third hypothesis, and the results are presented in Table 16.

Table 16 Differences between companies and their GHG emissions based on industry – Kruskal-Wallis test

Industry	N	Mean Rank	Kruskal-Wallis test
Technology	554	1235.91	df = 9 H = 1548.736 $p < 10^{-60}$*
Healthcare	451	1625.23	
Financials	549	1645.77	
Real estate	393	1923.32	
Consumer cyclicals	690	2319.78	
Industrials	926	2585.88	
Consumer non-cyclicals	285	2946.96	
Energy	211	3287.04	
Basic materials	411	3647.21	
Utilities	191	3989.55	

* refers to significance at the 5% level.

Source: author's own calculation

The Kruskal-Wallis test showed statistically significant differences between EU companies and their median of GHG emissions based on their industry. In addition, companies are divided among 13 different industries, but this analysis showed that among 1457 companies, none of them were part of the two industries (Institutions, associations and organisations; Government activity) and one industry had included only two companies (Academic and educational services) that were excluded from the test. Based on the conducted analysis, the author confirms the third hypothesis. The differences in median of GHG emissions between EU companies based on the industry exist. Utilities have the highest mean rank, which means that companies in utilities emit more GHG emissions than companies in other industries. Technology shows the lowest mean rank results, which means that companies that are part of technology industry emit the lowest GHG emissions among analysed sample.

The author conducted a Kruskal-Wallis test to test the fourth hypothesis (*H4: According to company size, there are statistically significant differences in distribution of GHG emissions of the European Union companies*). Results of the Kruskal-Wallis test are presented in Table 17.

Table 17 Differences between companies and their GHG emissions based on company size – Kruskal-Wallis test

Company size	N	Mean Rank	Kruskal-Wallis test
Small	52	562.13	df = 2 H = 256.422 $p < 2.0828 \times 10^{-56}$*
Medium	139	691.35	
Large	3568	1945.51	

* refers to significance at the 5% level.

Source: author's own calculation

The Kruskal-Wallis test showed statistically significant differences between EU companies and their median of GHG emissions based on their size. Based on the conducted analysis, the author confirms the fourth hypothesis. The differences in distributions of GHG emissions between EU companies based on the company size exist. The large companies have the highest mean rank and they emit more GHG emissions than medium and small companies.

To test the fifth hypothesis (*H5: Industry and company size influence the GHG emissions of the European Union companies*), the author conducted a fixed effect panel regression model with the least square dummy variable approach. Since both independent variables are categorical, the author computed both as dummy variables.

The Adjusted R Square of the tested model showed a very small percentage of variance in the target field (Adjusted R Square = 0.162), and therefore the model has no predictive value. On the other hand, the results of the coefficient of industry and company size can be compared, and they are presented in Table 18.

Table 18 Influence of industry and company size on GHG emissions among EU companies

Variable	Unstandardized coefficient		Standardized coefficient	VIF
	(β)	St. dev.	(β)	
Constant	-750487.864	457983.967		
Medium size	-199268.483	862761.545	-.003	1.196
Large size	1215553.570	340967.034	.052	1.160
Energy	4437266.094	742235.476	.092	1.322
Basic materials	6444098.067	603538.052	.181	1.590
Industries	736575.255	493327.411	.029	2.150
Consumer cyclical	170246.246	525013.332	.006	1.930
Consumer non-cyclical	325961.889	670070.660	.008	1.431
Finance	-161161.083	552675.061	-.005	1.762
Health	173210.874	581438.726	.005	1.640
Utilities	18.329819.028	772080.820	.364	1.301
Real estate	261339.534	617698.948	.007	1.635

Source: author's own calculation

As already discussed, the regression model does not have predictive value, but the coefficients of two variables can be defined. Variance inflation factor (VIF) is an indicator of multicollinearity, and VIF results for observed variables show that industry and company size do not violate the multicollinearity assumption of the regression model since the VIF value is lower than 2.5. According to Johnston et al. (2018), a VIF threshold greater than 2.5 indicates considerable collinearity. In addition, other scientists (Menard, 2002; Gareth et al., 2013) consider a VIF threshold of 5 or 10 or even higher than 10 to be problematic. When the standardised coefficients have been compared, both variables, industry and company size have a positive effect on the GHG emissions of the EU companies; therefore, the author confirms the fifth hypothesis.

A positive standardised coefficient for a dummy variable indicates that a company being in that category is associated with higher GHG emissions, compared to the reference category. The author chose small companies as reference category for company size and technology as a reference category for industry. Regarding the company size, dummy variable medium size with negative standardised coefficient mean that medium companies have lower GHG emission than small companies. Moreover, dummy variable finance, has negative standardised coefficient and it means that companies in finance have lower GHG emissions than companies in technology.

4.4. ESG Ratings in the European Union Companies

Analysis of ESG ratings involves three hypotheses. The focus of the analysis is the environmental ratings of the EU companies and their differences based on GHG emissions, resource use and environmental innovation since the environmental ratings of the Refinitiv database are measured by three categories: resource use, emissions and environmental innovation. All three categories have been included in the analysis. Categories have ratings based on metrics used to measure them. The author chose metrics that are reported by companies. Even though more than 170 metrics are used to measure these categories, not all have been reported; therefore, they have been excluded from the analysis.

The sixth hypothesis (*H6: There are statistically significant differences in the distribution of environmental ratings between European Union companies according to their size*) has been analysed using a non-parametric Kruskal-Wallis test due to the violated assumption of homogeneity of covariance ($p < 0.05$).

Based on the Kruskal-Wallis test ($df = 2$, $H = 77.155$, $p < 1.7618 \times 10^{-17}$), the author confirms the sixth hypothesis. The differences in the distribution of environmental ratings among EU companies based on their size exist and are statistically significant. Figure 20 shows differences in environmental ratings.

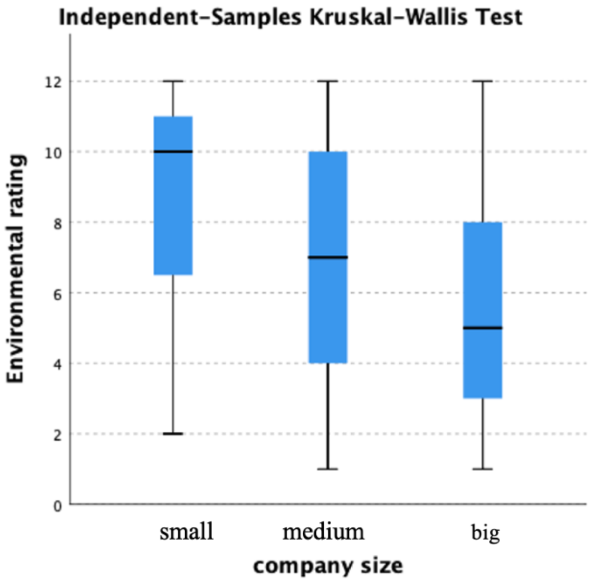

Figure 19 Environmental ratings of EU companies based on their size

Source: author's own calculation

Environmental ratings have been measured on a scale from one to twelve, where one represents an A+ rating, and twelve represents D- rating. Small companies have the worst ratings, as Figure 20 shows, with an average of ten (D+). Medium companies have better ratings than small companies, and their average rating is seven (C+), while large companies have the best ratings, and their average rating is five (B). Based on the Kruskal-Wallis results, the author confirms the sixth hypothesis.

The author conducted Hausman test using Stata 14, and the result showed that p-value is less than 0.05 ($p < 10^{-60}$). Based on the Hausman test result, the author uses fixed effects model. Fixed effect panel linear regression with the least square dummy variable approach model has been used to test the seventh (*H7: Resource use and environmental innovation have a positive effect on the environmental ratings of European Union companies*) and eighth (*H8: GHG emissions have a greater effect on the environmental ratings of European Union companies than resource use and environmental innovation*) hypotheses. Seventh hypothesis tests a positive effect of resource use and environmental innovation on environmental ratings. Positive effect is present when an increase by one point in resource use and environmental innovation increases environmental rating. All tested variables are measured by ratio scale. Company size has been used as a dummy variable.

The regression equation is:

$$Environmental\ ratings_i = \beta_0 + \beta_1 RU_i + \beta_2 EI_i + \beta_3 GHG_i + \beta_4 x_i + \beta_5 z_i$$

The regression equation consists of the following parameters Ru_i is the resource use rating, EI_i is the environmental innovation rating, GHG_i is the GHG emissions, x_i is the dummy variable for company size where 1 = medium and 0 = other sizes. In addition, z_i is the dummy variable for company size where 1 = large and 0 = other sizes. The time period (2016-2020) has been represented by *i*. Table 19 represents the results from the panel data analysis, and there are unstandardized and standardised coefficients presented. The author gives the regression equation with standardised coefficients to emphasise the differences in how each observed variable influences the environmental ratings of the EU companies. All the coefficients have been statistically significant ($p < 2.7863\times10^{-32}$); therefore, they are valid for further discussion.

Table 19 Regression analysis of GHG emissions, environmental ratings, resource use and environmental innovation of EU companies

Variable	Unstandardized coefficient		Standardized coefficient	VIF	Regression
	(β)	St. dev.	(β)		
Constant	0.820	0.069			Adjusted R^2 = 0.889 df = 5 F = 46071.650 $p<2.7863\times10^{-32}$*
Resource use	0.575	0.006	0.646	1.726	
GHG emissions	-0.000000007761	0.000	-0.023	1.025	
Environmental innovation	0.342	0.005	0.387	1.345	
Dummy medium size	-0.484	0.102	-0.025	1.147	
Dummy large size	-0.549	0.048	-0.070	1.580	

* refers to significance at the 5% level.

Source: author's own calculation

Fixed effect panel regression results in Table 19 show that the regression model has an excellent predictive value since the Adjusted R square is equal to 0.889. In addition, VIF values show that variables included in the regression equation do not violate the assumption of multicollinearity since all the VIF values are lower than 2.5.

The regression equation based on the results and standardised coefficients is:

$$Env.ratings_i = 0.646RU_i + 0.387EI_i - 0.023GHG_i - 0.025x_i - 0.048z_i$$

The company's environmental rating increases by 0.646 with each additional resource use rating point change, and it increases by 0.387 with each additional environmental innovation point change. The author confirms the seventh hypotheses since resource use and environmental innovation both have a positive influence on environmental ratings and increasing one of these two categories increases the environmental rating. Moreover, the environmental rating decreases by 0.023 when additional GHG emission is emitted. The author concludes when the absolute values of the standardised coefficients have been observed that GHG emissions do not have a greater effect on the environmental ratings than resource use and environmental innovation. The author does not confirm the eighth hypothesis since GHG emissions do not have a greater impact on environmental ratings than resource use and environmental innovation. The absolute values of GHG emissions are very low in comparison to absolute values of resource use and environmental innovation, therefore GHG emissions effect is lower than the effect of other two variables.

4.5. Overview of the Empirical Analysis

Based on the conducted analysis on three levels, the author presents a conclusion for each hypothesis in Table 20. There is one main aim of the dissertation, which is to fill the research gaps. Four additional aims help the author describe the results better and give a conclusion; after the following Table 20, the author will, in short, describe the most important results discussed in Chapter 5. The first hypothesis is connected to the first additional aim. The second hypothesis is connected to the second additional aim. The third additional aim is connected to the third, fourth and fifth hypotheses. The fourth additional aim is connected to the sixth, seventh and eighth hypotheses.

In addition, discussing obtained results will help researchers who intend to conduct potential comparative studies. Moreover, it will help all parties involved in the dissertation to make better business decisions or improve their progress toward a low-carbon economy.

In regard to the aims of the dissertation, the main aim, to fill the research gaps, has been achieved since the analysis shows:

1. how market efficient the EU ETS is in Phase III;
2. how EU Member States and companies differ in GHG emissions;
3. how EU companies differ in GHG emissions;
4. how EU companies differ in environmental ratings.

The first aim has been achieved with the results of the first hypothesis and the EU ETS is partially market efficient. The second aim of the dissertation has been achieved by testing the second hypothesis, and the differences between the EU Member States have not been statistically confirmed. The third aim of the dissertation has been achieved by testing the third, fourth and fifth hypotheses and the differences in environmental ratings between EU companies have been confirmed. The fourth aim has also been achieved by testing the sixth, seventh and eighth hypotheses and the impact of environmental innovation and resource use, as well as GHG emissions impact on environmental ratings have been determined.

Table 20 Overview of the status of hypotheses

Hypothesis	Status
H1: The EU ETS is market efficient during Phase III.	Partially confirmed
H2: There are statistically significant differences in distribution of percentage change of GHG emissions of the European Union Member States	Not confirmed
H3: According to industry, there are statistically significant differences in distribution of GHG emissions of the European Union companies	Confirmed
H4: According to company size, there are statistically significant differences in distribution of GHG emissions of the European Union companies	Confirmed
H5: Industry and company size influence the GHG emissions of the European Union companies	Confirmed
H6: There are statistically significant differences in the distribution of environmental ratings between European Union companies according to their size	Confirmed
H7: Resource use and environmental innovation have a positive effect on the environmental ratings of European Union companies	Confirmed
H8: GHG emissions have a greater effect on the environmental ratings of European Union companies than resource use and environmental innovation	Not confirmed

Source: author's interpretation

Table 20 lists all the authors' hypotheses and whether or not they have been confirmed. Based on the conducted analysis, the author confirmed five hypotheses, while two hypotheses were not confirmed, and one was partially confirmed.

The first hypothesis was partially confirmed since it cannot be fully confirmed or not confirmed. The EU ETS happens to be partially market efficient, which means that it is still developing and cannot reflect all the available information to all market participants simultaneously. Since the EU ETS is only partially market efficient, there can be opportunities for market participants to arbitrage. The second hypothesis was not confirmed, meaning that

EU Member States do not differ in distribution of GHG emissions. Moreover, the author confirms that EU companies differ based on industry and company size in the median of GHG emissions. Furthermore, EU companies differ in the median of environmental ratings based on the size of the company. In addition, industry and company size have a positive effect on GHG emissions. Moreover, resource use and environmental innovation positively affect environmental ratings, and GHG emissions do not have a greater effect on environmental ratings than resource use and environmental innovation. Further discussion on the obtained results is part of the next chapter.

5. Discussion

This dissertation aimed to fill the research gaps defined in the first chapter. It aimed to test the EU ETS market efficiency, to find the differences between the EU Member States and their GHG emissions based on UN SDGs indicators, and to find the differences between EU businesses and their environmental ratings and GHG emissions. The research results were obtained in the prior chapter, and the purpose of this chapter is to elaborate on the findings presented in the previous chapter.

5.1. Analysis of Research and Comparison to Previous Research

Obtained results have been compared to previous research and are discussed in detail in the following text. Where previous research did not find similar studies, the results are compared to generally available data. The following text is divided into three sub-chapters, where the first sub-chapter discusses the macro level of the dissertation – the EU ETS. The second sub-chapter discusses the mezzo level of the dissertation – the EU Member States and the GHG emissions. The third and fourth sub-chapters discuss the micro level of the dissertation – the EU companies and their GHG emissions and environmental ratings.

5.1.1. EU ETS

The EU ETS is the most important carbon market in the world, which is artificial and dependent on environmental policy and regulation; therefore, it is exposed to greater uncertainty than is the case for most ‘natural’ commodities (Ibikunle et al., 2016). Companies subject to the EU ETS are faced with ambiguity regarding their investment and production activities, which suggests that competitive disadvantages may develop compared to companies that are not regulated or that encounter realistic CO_2 signals. As a result, the absence of informational efficiency places limitations on the objective of cost efficiency, which stipulates that emission reductions be accomplished at the lowest possible cost. The weak type of informational efficiency is the one that is being emphasised in the dissertation. This kind of informational efficiency proposes that prices completely reflect the information of historical prices and returns, even though these do not have any bearing on how prices will evolve in the future. The effectiveness of the EU ETS is essential for emission-intensive businesses, decision-makers and policymakers, risk managers, and investors.

Based on the research conducted on EU ETS market efficiency, the author concluded that EU ETS partially shows weak information efficiency during Phase III. The author analysed Phase II (2008 – 2012) and Phase III (2013 – 2020) futures prices. Montagnoli and de Vries (2010) published a study and concluded that after Phase I was market inefficient, the second phase showed signs of restoring market efficiency. Goers (2014) applied unit root, autocorrelation and variance ratio tests to analyse the informational efficiency of the first two phases of EU ETS. He concluded that in the first trading period, EU ETS did not operate with informational efficiency, while in the second period, it did. Results presented in Chapter 4 showed that the EU ETS did not operate with informational efficiency in the second trading phase. The author's analysis observes the whole second trading period, contrary to Montagnoli and de Vries (2010), who observed only part of the period but came to the same conclusion. In addition, Charles et al. (2013) studied market efficiency in the second phase by modelling the relationship between futures and spot prices using the cost-of-carry hypothesis. They found out that the cost-of-carry pricing approach is invalid for the carbon markets across all maturities; hence, it appears that neither contract is priced in accordance with what is indicated by this pricing method. The absence of a link between the two variables in the cost-of-carry model might be interpreted as a symptom of inefficiency in the market, and it may present chances for arbitrage in the carbon market. The arbitrage opportunity for the investor is when the cost of buying the right to emit carbon dioxide is lower than the price at which that emission can be sold in the future and when the investor has the ability to lock in that sale price by selling a futures contract. Daskalakis (2013) analysed the market efficiency of the futures market and concluded that EU ETS shows a weak form of market efficiency.

Sattarhoff and Gronwald (2018) suggested that an intermittency multiplier should be used for assessing EU ETS market efficiency. They provide evidence that demonstrates how, over time, the EU ETS market evolves towards a more efficient state. The characteristics of the EU ETS have been investigated and analysed by Yang et al. (2018) using Lo MacKinlay's various variance ratio tests. The findings of their study reveal that the returns in Phase II are following the Martingale Process, and therefore EU ETS is an efficient market in the weak form. On the other hand, prices in phase III do not follow the Martingale Process, and the EU ETS is inefficient. Ghazani and Ali Jafari (2021) used an adaptive market hypothesis (AMH) approach for the third trading phase. They concluded that the EU ETS is more mature, and as the years pass, there is an increase in market efficiency.

The first research gap was to estimate market efficiency of the EU ETS Phase III. As the author confirmed that EU ETS is partially market efficient in Phase III, it makes it possible for market participants to exploit the situation. The following situations are possible for various sorts of market participants. Speculators may attempt to benefit from short-term price volatility by buying low and selling high. They may also attempt to take advantage of market inefficiencies by capitalising on price differences between EUA futures contracts or between the EUA futures market and other markets. Compliance buyers are the businesses subject to EU ETS emission restrictions that must purchase EU allowances to cover their emissions. With an inefficient EU ETS, the price of EUAs may not represent the genuine cost of emissions, allowing compliance purchasers to acquire EUAs at a price lower than their true worth. Compliance Sellers are in a similar position as compliance buyers, and they may be able to offer EUAs at inflated pricing, generating a possible profit opportunity. Moreover, the market makers offer market liquidity by purchasing and selling EUA futures contracts. In an inefficient EU ETS, market makers may benefit from setting bid and ask prices for EUA futures contracts that deviate from their genuine market value. Finally, market participants' possible results in an inefficient EU ETS depend on their ability to recognise and exploit market inefficiencies. Yet, an ineffective EU ETS might also result in market uncertainty and volatility, creating risks for market participants.

If the EU ETS is not market efficient, all market participants may be exposed to numerous risks. Potential risks include regulatory, price, counterparty, and liquidity risks. Since the EU ETS is a framework for regulating GHG emissions reductions, there is a potential regulatory risk. If the system is inefficient, policymakers may introduce new laws or modify the carbon price to solve the inefficiencies. These modifications might induce uncertainty among market participants and affect the value of their positions. Moreover, there is a price risk when the price of carbon may not accurately represent the real cost of carbon emissions, posing a threat to market participants exposed to the carbon price. For instance, if a company has acquired EUAs to cover its emissions and the carbon price declines as a consequence of market inefficiency, the value of their EUAs may fall, resulting in a financial loss. Likewise, a counterparty risk arises if EU ETS market participants enter into contracts with other market players, such as over-the-counter derivative contracts. In an inefficient market, it is possible that counterparties would be unable to fulfil their contractual commitments, resulting in significant financial losses for market players. Besides, there is a liquidity risk if EU ETS have less liquidity than an efficient market, making it more challenging for market participants to purchase or sell EUAs or other contracts at a reasonable price. This might pose problems for market participants who need to trade EUAs or other contracts to limit their exposure to emissions.

Overall, a partially market-efficient EU ETS might pose risks for market participants and have a negative effect on the value of their assets. Participants in the market should closely monitor the market for inefficiencies and consider applying risk management methods to mitigate their exposure to these risks.

5.1.2. GHG Emissions between European Union Member States

Many authors (Adams, 2015; Mair et al., 2018; Andries et al., 2019; MacFeely, 2019) state that UN SDGs are overlapping, interconnected, and opposite to one another. The second aim of the dissertation was to test the differences between EU Member States and their progress toward GHG emissions reduction. The author's results show that based on two different methods to measure indicator 9.4.1, EU Member States do not differ. In addition, indicator 13.2.2 showed that differences between the Member States do not exist. If all three analysed indicators are observed, the only differences that can be visually identified are between Estonia and Malta in comparison to other Member States. The percentage change of Estonia and Malta measured the biggest variability between the highest and the lowest values among all Member States. The biggest variability means the two countries faced many difficulties maintaining positive progress toward a low-carbon economy. As the author already analysed all the Member States and their progress toward a low-carbon economy as a part of Chapter 2, the following conclusion can be made based on the literature review and conducted the analysis.

Malta has the highest variability in UN SDGs indicators 9.4.1 and 13.2. among EU Member States because of its high material footprint and relatively small economy. This is largely due to Malta's heavy reliance on imports for its domestic consumption, particularly of fossil fuels, which are the largest contributor to its material footprint. In addition, Malta has limited renewable energy resources and relies heavily on imported oil for its electricity generation and transportation needs. At the same time, Malta has a relatively small economy, which means that its high material footprint significantly impacts its resource efficiency ratio. When calculating the ratio of material footprint to GDP, Malta's score is consequently the lowest among the EU Member States. Other factors that contribute to Malta's low resource efficiency include its high population density, limited natural resources, and the challenges associated with waste management in a small island nation. Malta faces significant challenges in achieving resource efficiency due to its high material footprint, small economy, and other unique characteristics. However, the Maltese government has recognised the importance of improving resource efficiency and has committed to developing policies and initiatives to address these challenges, such as promoting renewable energy and improving waste management. Moreover, the Maltese government has recognised the need to address climate change. It has committed to reducing its GHG emissions by transitioning to renewable energy sources and improving energy efficiency. The government has implemented policies to promote energy efficiency in buildings and transport. However, much work must be done to reduce Malta’s carbon footprint and contribute to global efforts to combat climate change.

The second country that has the highest variability in UN SDGs indicators 9.4.1 and 13.2. among the EU Member States is Estonia. This is primarily due to the country’s heavy reliance on oil shale for energy production. Oil shale is a sedimentary rock that contains kerogen, a type of organic matter that can be converted into oil and gas. Estonia has large deposits of oil shale and has been producing oil and gas from this resource since the early 20th century. The oil shale still accounts for a significant portion of Estonia’s energy mix, with about two-thirds of electricity production and nearly all heating produced from burning oil shale. Burning fossil fuels like oil shale releases large amounts of carbon dioxide and other GHG emissions into the atmosphere, contributing to climate change. Additionally, oil shale production and processing can also have other negative environmental impacts, such as air and water pollution. The Estonian government has recognised the need to transition to more sustainable energy sources. The government has also invested in renewable energy sources such as wind and solar power and has implemented policies to improve energy efficiency in buildings and transportation. However, transitioning from oil shale will require significant investment and may take time due to the country’s historical reliance on this resource.

Among the EU Member States, eight countries (Austria, Bulgaria, Croatia, Cyprus, Hungary, Lithuania, Romania, and Slovakia) have all experienced an increase in GHG emissions in recent years, despite the EU’s ambitious targets for reducing emissions. One of the main reasons for the increase in GHG emissions in these countries is their heavy reliance on fossil fuels, particularly coal. Coal is a significant contributor to GHG emissions and is the primary source of energy in many of these countries, particularly Bulgaria, Poland, and Romania. While there has been some progress in shifting towards cleaner energy sources such as wind and solar power, the transition away from coal has been slow in these countries due to factors such as the cost of alternative energy sources and the influence of the coal industry. Another factor contributing to the increase in GHG emissions in these countries is the growth of their economies. Many of these countries have experienced significant economic growth in recent years, particularly in the industrial and manufacturing sectors. This growth has led to increased demand for energy and has put pressure on these countries to expand their energy infrastructure. In many cases, it meant building new power plants and other energy-intensive facilities, which has contributed to the increase in GHG emissions. Transportation is also a significant contributor to GHG emissions in these countries. Many of them have seen a significant increase in car ownership and road traffic in recent years, particularly in urban areas. This has led to an increase in emissions from transportation, particularly from private vehicles. In addition, public transportation infrastructure in many of these countries is inadequate, which has made it difficult to reduce the use of private vehicles. Agriculture and forestry are also significant contributors to GHG emissions in these countries. Finally, some of these countries have experienced a decrease in GHG emissions from certain sectors but an increase in emissions from others. For example, Lithuania has seen a significant decrease in emissions from the electricity sector due to the transition away from coal but an increase in emissions from the transport sector due to the growth in car ownership. In conclusion, the increase in GHG emissions in Austria, Bulgaria, Croatia, Cyprus, Hungary, Lithuania, Romania, and Slovakia can be attributed to a range of factors, including their heavy reliance on fossil fuels, economic growth, transportation emissions, agriculture and forestry emissions, and changes in emissions from different sectors. Addressing these challenges will require a coordinated effort from governments, businesses, and individuals to transition towards cleaner energy sources, reduce emissions from transportation, improve agricultural and forestry practices, and implement other measures to reduce GHG emissions.

In contrast to the EU Member States that have experienced an increase in GHG emissions, other countries (Belgium, Czechia, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Latvia, Luxembourg, the Netherlands, Portugal, Slovakia, Spain, and Sweden) have managed to decrease their emissions in recent years. One of the main reasons for these countries' decrease in GHG emissions is their strong focus on renewable energy. These countries have implemented policies and incentives to promote the use of renewable energy sources such as wind, solar, and hydropower. For example, Denmark has set a target of 100% renewable electricity by 2030 and has already achieved a significant proportion through wind power.

Germany has also been a leader in renewable energy, particularly in solar and wind power. The focus on renewable energy has helped reduce electricity sector emissions, which is a significant contributor to GHG emissions. Another factor contributing to the decrease in GHG emissions in these countries is energy efficiency measures. Many countries have implemented policies and initiatives to improve energy efficiency in buildings, transportation, and industry. In addition, these countries have implemented measures to promote the use of public transportation, cycling, and walking, which has helped to reduce emissions from transportation. Changes in industrial processes and practices have also contributed to these countries' decrease in GHG emissions. For example, in Ireland, introducing a carbon tax has helped reduce emissions from the cement and lime industries. The adoption of circular economy principles, which focus on reducing waste and increasing the reuse and recycling of materials, has also helped to reduce emissions in some countries. Finally, some of these countries have experienced a decrease in emissions due to changes in their energy mix. For example, France has reduced emissions by increasing its use of nuclear power, while Sweden has reduced emissions by increasing its use of hydropower. In addition, some countries, such as Portugal, have experienced a decrease in emissions due to the increased use of natural gas, which has lower emissions compared to coal and oil. In conclusion, the decrease in GHG emissions can be attributed to a range of factors, including their focus on renewable energy, energy efficiency measures, changes in industrial processes, and changes in their energy mix. These countries serve as a model for other countries seeking to reduce their GHG emissions and transition towards a low-carbon economy. However, the challenge of mitigating climate change is global, and it will require sustained efforts from all countries to achieve the targets set by the Paris Agreement and ensure a sustainable future for generations to come.

The EU Member States (Ireland, Latvia, and Poland) have experienced a stable average change in their GHG emissions in recent years. One factor contributing to the stable average change in GHG emissions in these countries is their reliance on fossil fuels. These countries have a significant proportion of their energy mix coming from coal, oil, and gas, which are high in emissions. The reliance on fossil fuels has made it challenging for these countries to reduce their GHG emissions, as any attempts to transition to renewable energy will require significant investment and infrastructure changes. Another factor contributing to the stable average change in GHG emissions in these countries is their economic development. These countries are still transitioning to a more service-oriented economy, and their industries and transport sectors are still growing. This growth has led to an increase in energy demand, which has led to an increase in GHG emissions. In addition, these countries have faced challenges in implementing policies and measures to reduce GHG emissions. Furthermore, these countries have also faced challenges accessing funding and support for renewable energy and energy efficiency measures. It is worth noting that while these countries have a stable average change in GHG emissions, they still contribute to the overall emissions of the EU. As such, these countries still need to take action to reduce their emissions and contribute to the EU's goal of becoming climate-neutral by 2050.

5.1.3. GHG Emissions between European Union Companies

The third aim of the dissertation was to test the relationship of company size and industry on GHG emissions between EU companies. The press release from The Conference Board (2022) states that large firms disclose GHG emissions at a 2.5 higher rate than small companies. As discussed, 100 large companies are responsible for 71% of global GHG emissions (Griffin, 2017). Therefore, the author's result is that there are differences among observed EU businesses and their GHG emission based on their company size. The author's result confirms the Carbon Majors Report by Griffin (2017) and The Conference Board's statement (2022). Large companies typically have more resources and can invest in clean energy technologies to help reduce their emissions. However, they may also face greater scrutiny from stakeholders and regulators and be subject to more stringent emissions reporting requirements. Medium-sized companies have fewer resources than larger companies and may still be able to invest in energy efficiency measures or renewable energy sources. However, they may face more challenges in accessing financing for such investments. On the other hand, the Green Business Bureau (2022) states that small businesses are also harmful to the environment and emit GHGs. Small companies typically have lower emissions than larger companies. However, they still contribute to GHG emissions in the EU and may face different challenges in reducing their emissions. For example, they may have limited resources to invest in energy efficiency measures and less access to financing for renewable energy projects. In addition, larger companies tend to disclose the GHG emissions information together with other information relevant to ESG ratings. At the same time, small and medium companies have not been obligated to report their GHG emissions. Differences in disclosing relevant information can be seen in a number of companies observed in the author's analysis. The number of large companies has increased rapidly over time, while the number of small and medium companies has also increased at a slower rate.

The author also tested differences between industries in which observed companies operate. Based on industry analysis, the author concluded that differences exist between companies' GHG emissions and their industry. For example, the Carbon Majors Report by Griffin (2017) states that the fossil fuel industry is the highest industry when it comes to GHG emissions. The author's analysis showed that the utility industry produces, on average, the most GHG among the observed businesses, with the basic material industry being the second highest emitter and the energy industry in third place.

The utility and material industries are crucial to the EU's economy. The utility industry is responsible for producing electricity, heat, and other energy sources essential for powering the EU's economy. However, the generation of energy from fossil fuels, such as coal, oil, and natural gas, releases large amounts of carbon dioxide and other GHG emissions into the atmosphere. On the other hand, the material industry includes the production of products made from raw materials, such as metals, chemicals, and plastics. The production of materials typically requires energy inputs, but the energy use is generally less intensive than that required to generate electricity or heat. One of the main reasons is that the utility industry relies heavily on fossil fuels, particularly coal and natural gas, to generate electricity and heat. While renewable energy sources, such as wind and solar, are becoming more prevalent, fossil fuels still account for a significant proportion of energy production in the EU. In contrast, the material industry typically relies on electricity as an energy input, which can be generated from renewable sources. Furthermore, material production often requires less infrastructure and equipment, and emissions can be reduced through improvements in production processes. Finally, the utility industry faces different challenges in reducing GHG emissions than the material industry. While the material industry can reduce emissions by improving its production processes or using renewable energy sources, the utility industry must balance the need for reliable and affordable energy with the need to reduce emissions. This can be challenging, particularly in countries heavily dependent on fossil fuels for energy production. Ultimately, the utility industry emits more GHG emissions than the material industry in the EU due to its reliance on fossil fuels, the complexity of energy production, and the challenges in reducing emissions while maintaining reliable and affordable energy. While the transition to a low-carbon economy will require efforts from all sectors, the utility industry will need to play a particularly significant role in reducing GHG emissions. The EU must continue to support the development and implementation of renewable energy sources and energy efficiency measures to help reduce GHG emissions from the utility industry and move towards a more sustainable future.

The energy industry, which includes the production of electricity, heat, and other forms of energy, is responsible for a significant proportion of GHG emissions in the EU. This is largely due to the reliance on fossil fuels for energy production. When burned, these fuels emit large amounts of GHG emissions into the atmosphere. Additionally, the production and distribution of energy also contribute to GHG emissions, particularly from transportation and leaks in pipelines. Furthermore, the demand for energy in the EU has been increasing over time due to population growth, economic development, and changes in lifestyle. This has led to an increase in energy consumption, which has resulted in a corresponding increase in GHG emissions from the energy industry. To address the issue of GHG emissions from the energy industry, the EU has implemented several policies and initiatives to reduce reliance on fossil fuels and promote renewable energy sources. This involves a significant shift towards renewable energy sources, such as wind, solar, and hydropower, as well as improvements in energy efficiency measures and the promotion of low-carbon transportation options. In conclusion, the energy industry emits a lot of GHG emissions in the EU due to the reliance on fossil fuels for energy production, the transportation and distribution of energy, and the increasing demand for energy. It is crucial for the EU to continue to implement policies and initiatives that promote the use of renewable energy sources, increase energy efficiency, and reduce reliance on fossil fuels. By doing so, the EU can reduce the impact of climate change.

In recent years, there has been a growing trend among companies in the EU to report on their GHG emissions and set targets for reducing their emissions. This trend is driven by increased stakeholder pressure, regulatory requirements, and a growing awareness of the need to address climate change. Some companies have also adopted strategies to reduce their emissions, such as investing in renewable energy, improving energy efficiency, or transitioning to low-carbon transportation. In conclusion, there are significant differences in GHG emissions among companies in the EU based on their size and industry. However, there is a growing trend among companies in the EU to report on their emissions and set targets for reducing their emissions. The transition to a low-carbon economy will require sustained efforts from all companies, regardless of size or industry. The EU must continue to provide support and incentives for companies to take action.

5.1.4. Environmental Ratings

The fourth aim of the dissertation was to determine the effect of environmental innovation and resource use on environmental ratings of the EU companies. In addition, the author aimed to determine if GHG emission has greater effect on environmental ratings than environmental innovation and resource use. To the author’s knowledge, an analysis of environmental ratings and their differences between EU businesses has not been employed. Therefore, the author’s results are unique and show that environmental ratings differ between companies. It is convenient to state that, as already discussed, larger businesses disclose ESG information more often than medium and small businesses. Due to the available data, larger businesses have better environmental ratings than medium and small businesses.

The EU companies differ in their environmental ratings, as they vary in their environmental practices and impact. Environmental ratings are assessments of a company’s environmental performance, taking into account factors such as GHG emissions, energy and water consumption, waste generation and disposal, and environmental management systems. Some companies have made sustainability a core part of their business strategy and have implemented environmental management systems and policies to minimise their environmental impact. These companies may also set targets and track their progress towards reducing their environmental footprint, which can lead to higher environmental ratings. On the other hand, companies that do not prioritise sustainability or have poor environmental management practices are likely to receive lower environmental ratings. These companies may have higher levels of pollution, waste generation, and other negative environmental impacts, which can be reflected in their environmental ratings. Furthermore, some companies in the EU may be subject to stricter environmental regulations and standards than others. For example, companies in highly regulated sectors such as energy and manufacturing may be subject to more stringent emissions limits and environmental reporting requirements, which can lead to differences in environmental ratings. Environmental ratings can be useful for investors, consumers, and other stakeholders interested in a company’s environmental performance. In addition, environmental ratings can help stakeholders make informed decisions about which companies to support. By providing transparency and accountability, environmental ratings can incentivise companies to improve their environmental practices and reduce their impact on the environment.

The author tested the positive effect of resource use and environmental innovation on environmental ratings, and the analysis confirmed the positive effect. The resource use measure consists of variables such as resource reduction policy, water efficiency policy, energy efficiency policy and others. Resource use has a positive effect on the environmental ratings of companies as it is closely linked to resource efficiency. Resource efficiency refers to the efficient use of natural resources to minimise waste and environmental impact while maximising economic benefits. Resource-efficient companies can reduce their environmental impact by using fewer resources such as water, energy, and raw materials and generating less waste. This can positively affect their environmental ratings as they are perceived as having a lower impact on the environment. In addition, resource-efficient companies can also benefit financially by reducing their operational costs and improving their competitiveness. For example, by using renewable energy sources or improving energy efficiency, companies can reduce energy costs and improve profitability. Moreover, companies that use sustainable resources and promote circular economy principles can also positively affect their environmental ratings. Companies that incorporate circular economy principles into their business model can reduce their reliance on non-renewable resources and promote the use of recycled or renewable resources. This can help reduce their operations' environmental impact and promote more sustainable resource use. Furthermore, companies that source materials from sustainable sources can reduce their environmental impact and contribute to the preservation of natural resources. Resource use has a positive effect on the environmental ratings of companies in the EU when it is managed efficiently and sustainably. Resource-efficient companies can reduce environmental impact, improve competitiveness, and promote circular economy principles.

Environmental innovation positively affects environmental ratings as it is closely linked to sustainable development. It consists of multiple variables such as environmental products, eco-design products and others that require action from businesses in the past and future across different business activities. Companies that invest in environmental innovation can reduce their environmental impact by developing new technologies, processes, or products that are more sustainable and less harmful to the environment. In addition, environmental innovation can also benefit companies financially by improving their competitiveness, reducing operational costs, and creating new market opportunities. For example, by developing products made from sustainable materials or using renewable energy sources, companies can differentiate themselves from competitors and attract environmentally conscious consumers.

Moreover, companies that invest in environmental innovation can also improve their corporate image and reputation. Environmental innovation can demonstrate a company's commitment to sustainability and environmental protection, which can enhance its brand value and attract socially responsible investors. Furthermore, companies that adopt a proactive approach to environmental innovation can also benefit from regulatory compliance. Environmental regulations in the EU are becoming increasingly strict, and companies that invest in environmental innovation can stay ahead of the regulatory curve and avoid costly penalties or legal actions. Environmental innovation positively affects the environmental ratings of companies in the EU by reducing their environmental impact, improving their competitiveness, enhancing their corporate image, and ensuring regulatory compliance.

Resource use and environmental innovation have a greater positive impact on environmental ratings than GHG emissions because they address a wider range of environmental issues and show a commitment to sustainable practices and good stewardship of natural resources. GHG emissions are a significant factor in environmental sustainability, but they are not the only factor.

A list of variables that the author recommends excluding from the environmental ratings is shown in Appendix 4. The author based the decision on a number of missing values, and these variables tend to have more missing values than others during the observed time. In addition, the author recommends making the same reduction with variables of social and governance ratings. If those variables are removed from reporting, that might incentivise businesses to publish more reports since there would be fewer time-consuming actions required to disclose relevant information.

5.2. Guidelines for Changes in Environmental Governance of EU Companies

Environmental governance can be viewed as an internal system of guidelines and rules that businesses use to manage their environmental impacts and track their progress toward predetermined goals. UNEP (2017) published a report, Introduction to Environmental Governance, where the main principles of good environmental governance were presented. According to UNEP (2017), good governance includes participation, the rule of law, transparency, responsiveness, consensus-oriented, equity and inclusiveness, effectiveness and efficiency, and accountability.

Environmental governance goes beyond legal compliance to include voluntary actions to meet environmental standards higher than the minimum required by law. The governance system should undoubtedly address all domestic and international environmental laws applicable to business operations. Businesses can demonstrate their environmental responsibility by taking pre-emptive voluntary measures, which may reduce the risk of future strict legislation. Businesses can set themselves apart from rivals by being industry environmental leaders and addressing stakeholder demands for increased environmental stewardship. Businesses may play a significant part in attaining sustainability by organising and putting into practice the right strategies and operations, such as eco-friendly processes, product advancements, energy-saving measures, etc. Businesses nowadays must successfully address the issue of environmental sustainability. Numerous businesses have transformed, and many more are doing so in order to pursue more sustainable corporate objectives.

The majority of businesses are implementing environmental policies, but green product development stands out among the rest. Nevertheless, a green product development approach cannot help achieve the goal of environmental sustainability by itself. Only when it is complemented by other environmental measures can it stand on its own. All business factors, including operations, information technology, and product life cycle management, must be sufficient to protect the environment. Comprehensive environmental duties and energy consumption guidelines must be a part of a company's overall business strategy for increasing operational efficiency.

Going green enhances a company's income by attracting environmentally conscious customers and saving money. Furthermore, governments offer incentives to businesses that start environmental conservation projects. Sales tax exemptions, income tax credits, increased depreciation for some capital expenses, cash incentives, etc., are all included. Also, by encouraging environmentally friendly actions, the company's brand value increases. Overall, this helps to create a favourable perception of the business. Additionally, it draws in personnel and aids in keeping them employed by the organisation.

Many businesses have realised that employing sustainable business methods produces better outcomes and creates new opportunities. The requirement to follow environmental legislation is the first step for any business toward sustainability. Adhering to national and international environmental rules enhances the company's environmental performance. Some businesses go above and beyond the requirements of the law by implementing comprehensive programs for sustainable development.

A company's next step toward sustainability is managing environmental risk. Industries need to take aggressive action to implement techniques that will aid in resolving environmental issues. Businesses use risk management strategies to reduce environmental risks. This tactic lowers the cost to the business associated with environmental degradation. The business also saves on operational costs by reducing waste, mitigating pollution, and removing health and safety hazards. Some businesses establish environmental management systems (EMSs), environmental policies, and environmental health and safety (EHS) evaluations. Additionally, businesses adopt measures like recycling and pollution control to turn plans into successes. An important way to make sure plans are implemented is to create a situation that benefits both the environment and the bottom line. Corporate environmental policies are now a part of business plans, which also take into account customer wants and long-term economic, environmental, and social advantages.

For a business, sustainable development implies implementing plans of action that meet the organisation's, its clients', and its customers' present needs while safeguarding, preserving, and enhancing the value and quality of the company's natural and human resources for the long term. When businesses are able to protect natural resources, sustainable development is supported.

EU environmental policies help businesses to move toward a sustainable economy. Sustainable development has been the main objective of EU environmental policies. The application framework provides decision-makers with a strategy for implementing sustainable development in their day-to-day work. In order to be in accordance with the idea of sustainable development, decision-makers first and foremost need to include a set of policy-guiding principles in the decision-making processes they engage in. These principles are the product of EU law and policy, including, among other things, the "using the best available knowledge" principle, the precautionary principle, the integration of policy, and the protection of human rights. It is possible for policymakers to put these ideas into practice by conducting a sustainability impact assessment for each and every significant decision that they make.

Table 21 represents the author’s proposal of guidelines for changes in the environmental governance of EU companies. In the following text, the author describes what companies should do under each guideline.

Table 21 Guidelines for changes in environmental governance of EU companies

	Guidelines
1	Assess current environmental performance
2	Set ambitious environmental goals
3	Adopt a life-cycle approach
4	Increase transparency and reporting
5	Engage stakeholders
6	Implement environmental management systems
7	Foster innovation and green technology
8	Collaborate with supply chain partners
9	Train and empower employees
10	Align with the EU Green Deal
11	Review and revise environmental policies

Source: author’s interpretation

The first guideline is to assess current environmental performance. Companies can assess current environmental performance using several techniques. They can conduct an environmental audit that systematically reviews the company’s operations and practices to identify potential environmental impacts and compliance risks. This can be done in-house or through a third-party auditor. Companies can collect environmental data, such as energy consumption, water use, waste generation, and emissions, which can help the company understand its environmental footprint and identify areas for improvement. Companies can use EMS, such as ISO 14001, to provide a structured approach to assessing environmental performance and identifying opportunities for improvement. In addition, the company can conduct a life-cycle assessment that involves evaluating a product’s or service’s environmental impacts throughout its entire life cycle, from raw material extraction to disposal or recycling. This can help the company identify opportunities to reduce environmental impacts at each stage of the product life cycle. The first guideline aims to assess the company’s environmental performance and identify improvement areas.

The second guideline is to set ambitious environmental goals. The company need to understand the current environmental impact of its operations, products, and services. Once the current environmental impact is understood, the company can identify areas where it can improve its environmental performance. This can be done by evaluating industry best practices, researching emerging technologies, and engaging with stakeholders. The next step is to develop specific, measurable and time-bound goals, such as reducing GHG emissions by 45% by 2030. Engaging stakeholders in the goal-setting process is important to ensure that the goals are realistic and relevant to the company's stakeholders. This can include employees, customers, suppliers, investors, and local communities. Once the goals are set, the company should develop a plan outlining its actions to achieve them. The plan should include timelines, responsibilities, and performance indicators. The company should regularly monitor and report progress towards achieving its environmental goals. This can help identify areas where the company is falling short and make adjustments to the plan if necessary. Setting ambitious environmental goals is an ongoing process. Companies should continuously evaluate their environmental performance, identify opportunities for improvement, and set new goals as necessary. The second guideline aims to set clear and measurable environmental goals that align with EU environmental policies, such as reducing GHG emissions, water consumption, and waste generation. It is important to ensure that the goals are achievable and supported by management.

The third guideline is to adopt a life-cycle approach. Conducting a life cycle assessment is a comprehensive evaluation of the environmental impacts associated with a product or service throughout its life cycle. It involves assessing the impact of raw materials extraction, processing, manufacturing, distribution, use, and disposal. The company should develop a plan to manage its environmental impacts throughout the life cycle of its products or services. The plan should identify the necessary resources, responsibilities, and timelines to achieve the environmental goals. The company should implement environmental management practices, such as reducing waste and emissions, improving energy efficiency, and using environmentally friendly materials. The company should monitor and report progress towards its environmental goals to ensure it is on track to achieve them. This can include regular audits and reviews of the environmental management plan. The company should continuously improve its environmental management practices and goals based on monitoring and reporting results. The third guideline aims to adopt a life-cycle approach to the company's products and services, considering their environmental impacts from raw material extraction to disposal or recycling and identifying opportunities to reduce environmental impact at each stage of the product life cycle.

The fourth guideline is to increase transparency and reporting. The company can develop an EMS that helps companies to identify, manage, and reduce their environmental impacts. It also provides a structure for setting environmental goals, monitoring progress, and reporting on environmental performance. It can also conduct a materiality assessment to identify the most important environmental issues they face and prioritise its efforts to address them. In addition, ambitious environmental targets should be set. Companies should use standardised reporting frameworks, such as the Global Reporting Initiative or the Sustainability Accounting Standards Board, to ensure that their reporting is consistent and comparable with other companies in their industry. They should publish an annual sustainability report that provides a detailed account of its environmental performance, including its progress towards its environmental targets. The report should be easily accessible to stakeholders, including customers, investors, and NGOs. The fourth guideline aims to increase transparency and reporting on the company's environmental performance, disclosing relevant information to stakeholders, such as customers, investors, and regulators. Develop an environmental reporting strategy and establish key performance indicators to track progress.

The fifth guideline is to engage stakeholders. The company should identify its key stakeholders, such as customers, employees, investors, NGOs, and local communities, and understand their environmental concerns and priorities. It should develop a plan that outlines how it will engage with its stakeholders on environmental issues. The plan should identify each engagement activity's communication channels, timing, and objectives. The company should communicate transparently about its environmental performance, goals, and challenges. This can include publishing an annual sustainability report, holding public meetings or webinars, and providing regular updates on progress. It should involve stakeholders in decision-making processes that impact the environment. This can include consulting with local communities on site selection or involving customers in product design and development. Collaborating with stakeholders to develop solutions to environmental challenges can include partnering with NGOs to promote sustainable practices, working with suppliers to reduce environmental impacts, or engaging with customers to promote sustainable consumption. The company should monitor and report on its stakeholder engagement activities to ensure they are effective and responsive to stakeholder needs. The fifth guideline aims to understand stakeholders' environmental concerns and interests and to foster collaborative solutions. It is important to ensure that stakeholder feedback is considered in decision-making processes.

The sixth guideline is to implement environmental management systems. The company should establish a management team to oversee the development and implementation of the EMS. The team should include representatives from all relevant departments and functions, including environmental, health and safety, operations, and procurement. It should conduct a baseline assessment of its environmental impacts to identify areas for improvement. The assessment should cover all relevant company operations aspects, including raw materials, energy consumption, waste generation, and emissions. Based on the baseline assessment, the company should set environmental objectives and targets to reduce environmental impacts. The company should develop an environmental policy that outlines its commitment to environmental sustainability and sets out the goals and objectives of the EMS. The company should develop an action plan that outlines the steps needed to achieve its environmental objectives and targets. The plan should include timelines, responsibilities, and performance indicators. The company should implement the EMS by putting in place the necessary procedures, training programs, and monitoring systems. This may involve company operations changes, such as using new technologies, adopting new practices, or developing new products. The company should continuously monitor, review and improve the EMS by reviewing and updating its objectives and targets, as well as its policies and procedures, based on the results of monitoring and review. The sixth guideline aims to implement EMS to ensure continuous improvement in the company's environmental performance and compliance with environmental regulations.

The seventh guideline is to foster innovation and green technology. The company should encourage creativity and innovation by creating a culture that supports and rewards new ideas. This can include setting up innovation hubs or challenges, training on innovation techniques, and involving employees in the innovation process. It should identify opportunities to use green technology to reduce its environmental impacts. This can involve conducting research, engaging with suppliers, and collaborating with other companies or organisations. In addition, the company should invest in green technology by allocating resources to research and development, partnerships, and acquisitions of green technology companies. Besides, it should create partnerships with other organisations, such as universities, research institutions, and NGOs, to promote innovation and green technology. Furthermore, the company should foster collaboration between different departments and functions to promote the development and adoption of green technology. Likewise, it should provide incentives to employees and suppliers to encourage the development and adoption of green technology. This can include financial rewards, recognition, and support for training and development. The most important action is to promote knowledge sharing by creating platforms for employees to share information and best practices related to green technology. The seventh guideline aims to foster innovation and the development of green technologies to reduce the company's environmental impact and to create new market opportunities. Establish an innovation plan and allocate resources to research and development of environmentally friendly products and services.

The eighth guideline is to collaborate with supply chain partners. The company should assess the environmental performance of its suppliers to identify areas for improvement and opportunities for collaboration. This can include conducting audits, requesting environmental reports, and engaging in dialogue with suppliers. Following the assessment, the company should set environmental expectations for its suppliers and communicate these expectations clearly. This can include requirements for environmental performance, goals for reducing environmental impacts, and expectations for supplier collaboration. As a part of the collaboration process, the company should provide support and resources to help its suppliers improve their environmental performance. This can include training, guidance, and access to resources such as eco-design tools or green supply chain management software. The company should collaborate with its suppliers on environmental initiatives to reduce the environmental impacts of the supply chain. This can include joint projects to reduce waste, energy consumption, or emissions. In addition, the company should encourage innovation among its suppliers by creating incentives for green product design or eco-friendly processes. This can include sharing best practices or providing financial support for research and development. Monitoring and measuring the progress ensures meeting the expectations set out in the collaboration. This can include regular reporting and performance tracking. The eighth guideline aims to collaborate with supply chain partners to improve environmental performance, including selecting environmentally responsible suppliers and incentivising them to adopt sustainable practices.

The ninth guideline is to train and empower employees. The company should establish a training program to educate employees about environmental issues, the company's environmental goals and policies, and their role in achieving these goals. The program can include classroom training, online courses, or on-the-job training. In addition, it should provide employees with access to information about environmental issues and the company's environmental performance. This can include regular updates on the company's progress towards environmental goals, information on the environmental impacts of the company's operations, and best practices for reducing environmental impacts. Moreover, the company should create environmental teams responsible for implementing environmental initiatives and promoting sustainability within the company. These teams can be made up of employees from different departments and functions. The company should foster a culture of environmental responsibility by promoting sustainability, recognising and rewarding employees who contribute to environmental goals, and encouraging employees to suggest and implement environmental initiatives. It should empower employees to make a difference by providing opportunities to contribute to environmental initiatives, such as volunteering for environmental projects or participating in green teams. It is important that the company provides employees with the resources and tools they need to implement environmental initiatives. This can include access to green products and services, information on eco-friendly practices, and training on sustainable processes. The ninth guideline aims to train and empower employees to participate in environmental initiatives and to integrate environmental considerations into their daily work. The company can develop an employee training plan and establish an employee engagement program to encourage participation.

The tenth guideline is to align with the EU Green Deal. Most importantly, the company needs to understand the EU Green Deal and its goals, including achieving climate neutrality by 2050, decarbonising the economy, and promoting sustainable development. After the Green Deal is understood, the company should set ambitious environmental goals that align with the EU Green Deal. The company should implement sustainable practices that reduce its environmental impacts, such as energy-efficient operations, waste and water consumption, and renewable energy sources. Moreover, engaging in stakeholder dialogue with customers, suppliers, and other stakeholders helps to promote the EU Green Deal and encourage collaboration in achieving its goals. The company should support policy initiatives that promote sustainability and align with the EU Green Deal, such as carbon pricing, sustainable procurement policies, and circular economy initiatives. It is important that the company report on its sustainability performance using the EU taxonomy, which provides a standardised framework for measuring and reporting on environmental impacts. In addition, collaborating with other companies and organisations promotes the EU Green Deal and drives progress towards achieving its goals. The tenth guideline aims to align with the EU Green Deal, a comprehensive policy framework that aims to make the EU's economy sustainable and climate-neutral by 2050. Review the company's environmental policies and strategies to ensure they align with the EU Green Deal and incorporate relevant policies and regulations.

The eleventh guideline is to review and revise environmental policies. The company should periodically review its environmental policies to ensure they are up-to-date and effective in achieving the company's environmental goals. Changes in technology, regulations, and stakeholder expectations may require a review. In addition, the company should conduct an audit of its current environmental policies to identify areas for improvement. This can include assessing the policies' effectiveness, identifying gaps, and soliciting feedback from stakeholders. Based on the results of the policy audit, the company should develop a plan for revising its environmental policies. This plan should identify specific areas for improvement and establish a timeline for implementation. Besides, the company should engage stakeholders in the policy revision, including employees, customers, suppliers, and regulators. This can include soliciting feedback, hosting workshops or focus groups, and providing updates on the revision process. Moreover, the company should incorporate best practices in environmental policy development, such as setting measurable goals, identifying responsible parties, and establishing a system for monitoring and reporting progress. Once the revised policies have been developed, the company should obtain approval from senior management and the board of directors before implementation. Likewise, the company should communicate the changes to its environmental policies to stakeholders through a variety of channels, such as the company's website, sustainability reports, and other public disclosures. Besides, the company should establish a system for monitoring and evaluating the effectiveness of its revised environmental policies and make adjustments as necessary. The eleventh guideline aims to regularly review and revise the company's environmental policies and strategies to ensure they remain relevant, effective, and aligned with EU environmental policies and best practices.

Environmental governance is a broad term that requires businesses to restructure their decision-making process and policies according to the requirements of sustainable development. The guidelines proposed by the author help companies change environmental policies due to constant changes in environmental governance at national and supranational levels.

6. Conclusion

Over the past decade, the environment has been at the centre of discussion and research. Climate change has been definitively linked to human-caused emissions of GHGs both at home and at work. As the issue has been identified, it is crucial to discover the most effective strategy for reversing climate change and cutting back on all the activities contributing to it. Emissions from energy use not only have negative effects on the environment and human health but also contribute to global warming. Chapter 2 discussed the different measures used to fight climate change. The EU can be seen as a positive example and leader in the fight against climate change. The EU cares about sustainability, better preservation and preservation of resources for future generations through a series of regulations and proposals such as The Green Deal.

The EU was the first to develop a carbon emissions trading market, EU ETS. The EU ETS has been the focus of research from day one. As an artificial market, its efficiency was always tested. Phase I showed that the market is inefficient. Phase II showed signs of improvement but still showed weakness, and it is far from efficient. Phase III has been partially market efficient with signs of further improvement. There are a few main reasons why phase III's market efficiency has improved and reached this degree of maturity. Allowances have been auctioned off instead of distributed freely as part of phase III, and a Market Stability Reserve (MSR) has been set up to ensure that prices remain stable. The EU ETS will likely never become a fully efficient—and therefore idealised—market but rather a compromise between economic theory and political reality. The EU ETS has lived up to many of its expectations and has proven to be a successful application of economic theory to an important environmental issue following changes in companies and sustainability. The author tested market efficiency during a period of seven years in the third trading period, and the last year of the third trading period faced the COVID-19 outbreak. Despite the negative shock of the Covid-19 outbreak, the market showed it is partially efficient.

The UN SDGs and their indicators that measure GHG emissions have also been the focus of this dissertation. Analysis showed that EU Member States differ based on GHG emissions. Countries with less population emit less GHG emissions than countries with greater population. The author discussed two of the seventeen SDGs as business opportunities in the literature review. Therefore, this dissertation could help businesses to incorporate those SDGs into their business model and help countries achieve the 2030 global goal of GHG emissions reduction.

The UN SDGs serve as an indicator of the development process toward achieving emissions reduction. On the other hand, they are helping governments to track their progress and helping other countries to be more efficient. The UN SDGs were modified in 2020 and will be modified again in 2025. Five years to make changes and track progress should be enough time to adapt the goals to the current global situation. In the last few years, the world has encountered negative shocks, where the most important one from observed time is the Covid-19 pandemic. Negative shocks could impact the progress of achieving UN SDGs. Consequently, the next modification planned for 2025 would help to anticipate these shocks and adjust the goals. The SDGs may give businesses clearer guidance on improving the quality of their sustainability goals, framing them as commitments, and communicating them effectively. In addition, supply chain risk can be reduced, and quality can be increased. Greater private sector involvement and other benefits, such as reduced corruption, make results-based financing an attractive option for enhancing the effectiveness and efficiency of public services. When applied to public policy, the SDGs present an opportunity for the kind of goal-oriented action that can only boost the standard of democracy all throughout the world. By achieving SDGs, environmental performance can be enhanced, and business risks reduced, such as those caused by biodiversity loss. Participating businesses can increase productivity across supply chains and products, gain access to new markets, and connect consumers and stakeholders better.

ESG reporting has been developing over the years, and businesses can recognise its advantages. Among the observed businesses in this dissertation, the author can state that some businesses started with ESG reporting in 2011, while more joined from 2016 onwards. As discussed, ESG ratings consist of three pillars: environmental ratings, social ratings and governance ratings. The author chose to analyse the environmental ratings of EU companies. Based on the results, the author concludes that there are differences between EU companies and their GHG emissions based on size and industry. As the environmental rating consists of 156 variables, the author proposes that the rating agency decrease that number since many businesses do not report on all variables. The author did not analyse social and governance ratings; their analysis could also improve ESG reporting. Since ESG reporting is voluntary, it presents advantages and disadvantages to businesses. As an advantage, ESG reporting can promote businesses, and as a disadvantage, it can show that businesses are not reducing their emissions and other harmful activities. By incorporating ESG reporting, businesses are growing because they are actively participating in the global battle against pollution. ESG reporting can be an opportunity for partnerships between businesses. Genuine relationships can be established when businesses share their expertise on issues that are important to their stakeholders, customers, and the public. A company that makes an effort to communicate its beliefs and knowledge through ESG reports shows that it is taking the issues seriously and provides a trustworthy accountability structure. In addition, nowadays, investors are revising their holdings to incorporate environmentally and socially responsible companies and to steer clear of companies that aren't committed to sustainable operations. Investment portfolios that include companies that produce ESG reports reduce risk and boost returns. Furthermore, direct savings can be realised by ESG adoption, for example, through decreased energy consumption. Effective implementation of an ESG strategy can cut down operating costs. ESG reporting can boost the economy through staff recruitment and retention. Introducing a feeling of meaning in an employee's job might also lead to higher productivity. People are also more interested in working for environmentally friendly businesses. Better productivity and the ability to draw in top personnel can boost revenues through increased efficiency and lower retention expenses.

The applicative contribution of the dissertation is valuable to entrepreneurs, policymakers, and institutions. EU companies which are required to participate in the EU ETS will better understand the market, which is still expanding and has not reached full market efficiency. Because the EU ETS is only partially market efficient, market participants should trade cautiously in order to anticipate negative and positive shocks. The disparities across EU Member States can assist national and EU policymakers in proposing new recommendations for additional GHG emission reductions to achieve a low-carbon economy. Because of the relevance of environmental ratings in the battle against climate change, enterprises may recognise the practical contribution. Understanding the environmental ratings assists entrepreneurs in changing their businesses and reducing GHG emissions. Environmental ratings allow interested stakeholders to assess a company's progress toward sustainability and a low-carbon economy. The capacity to re-design environmental governance enables each organisation to act ethically and offer new creative GHG-reduction solutions. Similarly, monitoring environmental ratings would assist businesses in determining their strengths and prospects for future growth, as well as improving their market positions. Furthermore, analysing environmental ratings can assist competent authorities in developing rules and implementing standardisation of firms' sustainability reports. Standardisation is vital because it creates the conditions for developing uniform reporting, which will improve report quality. Furthermore, the dissertation results are valuable to scientists and researchers for future comparative studies.

The scientific contribution is the product of knowledge systematisation through comprehensive study and synthesis of scientific material. A thorough study and analysis of linked research, techniques, and findings in EU ETS market efficiency, GHG emissions, and ESG ratings aided in the advancement of scientific knowledge. Furthermore, earlier studies showed that the EU ETS was not market efficient in the first two phases. This dissertation shows that it is partially market efficient in the third phase, particularly when faced with a negative shock. Furthermore, the author discovered that EU Member States do not differ in terms of GHG emissions as measured by UN SDG indicators. This conclusion is critical in determining why EU Member States are making equal progress toward a low-carbon economy. Panel regression was utilised by the author to determine disparities between corporations and their environmental scores. The panel regression gave sufficient information to calculate determinant effect sizes and to examine environmental innovation and resource utilisation. Environmental innovation and resource consumption are major factors of environmental ratings, and research into them can assist businesses in changing their environmental governance.

Based on the obtained results, the author concludes that the EU transition toward a low-carbon economy has been challenging but with a positive outcome. The transition is observed from three levels that were part of this dissertation. The macro level regarding EU ETS market showed progress in efficiency, which can be described as a positive change toward a low-carbon economy. When the efficiency is compared to previous development phases, it has improved. The mezzo level indicated that differences in GHG emission between EU Member States could not be statistically confirmed, but the author's overall opinion is that goals of reaching GHG neutrality by 2050 in the EU can been achieved. Many countries showed that decline in GHG emissions is possible through collaboration between countries, environmental innovation, using green technologies and changing of policies. The micro level at the EU companies' level, showed that reporting on ESG ratings, which is voluntary, has been increasing. Therefore, companies are developing in transition toward a low-carbon economy. In future, if ESG reporting becomes mandatory, companies would make more effort to achieve better results in reducing GHG emissions.

6.1. Analysis of Advantages and Limitations of the Conducted Research

The dissertation contains a few advantages and disadvantages. Firstly, the author will discuss the limitations of the research, and afterwards, the advantages will be discussed.

The first limitation is data collection. Data was collected from verified and reliable sources such as Refinitiv, but it is limited to the data available on the data stream. The criteria for selecting businesses for the research was the available ESG score of the business. The data available for the bulk of the corporations related only to a limited time period, which is a constraint in terms of analysing the long-term consequences. As a result, it was impossible to draw meaningful conclusions regarding the effect of independent variables on a dependent variable over the long run. After the data was collected and the author started building the database for the research, missing values were confronted. As discussed in Chapter 3, 1457 businesses were part of a sample, but only 555 businesses had reported data for all observed years. Furthermore, the author confronted many missing values because the environmental data consisted of more than 170 variables, but businesses reported on different variables. The third limitation is the ESG score itself. Given that various organisations utilise a variety of methods to arrive at their own ESG values, the ultimate score assigned to the same company by different agencies may have been different. The fourth limitation is the statistical methods used to analyse the data. The author followed the recommendations of previous research in conducting the analysis, but there is a possibility that some methods have been improved in the meantime.

The first advantage of the dissertation is the analysis of the market efficiency of EU ETS. Most previous research has been on the first and second trading phases, while this dissertation focuses on the third trading phase. Additionally, the dissertation confirms what has already been said regarding the second trading phase but using a different approach. The second advantage is an analysis of UN SDG indicators; as discussed, most previous research analyses do not analyse indicators while they comment on why UN SDGs are not achievable. The third advantage is the analysis of environmental ratings and the variables influencing them. Previous research is based on analysing the ESG ratings as a group, this dissertation analyses only one environmental rating.

6.2. Recommendations from the Research

Based on the literature review, obtained results and limitations of the research, the author proposes the following recommendations for businesses, policymakers, and organisations that provide data. The general recommendation for future research would be to collect data on ESG ratings from other databases to compare data. In addition, if data from another data provider is analysed, the conclusion about improving ESG rating scores and what variables to exclude or include from ESG ratings could be beneficial.

There are a few recommendations for businesses, and the first one is to report on ESG whether or not the business is obligated to report. As discussed, mainly large businesses publish ESG reports, whilst medium and small businesses do not. ESG reporting could positively affect any size of business as it can improve competitiveness. Moreover, ESG reporting supports and enriches the brand. ESG reporting is a great way to compare against competitors and change business policies or models if needed.

The first recommendation for policymakers is to harmonise national policies on ESG reporting with the ones from the EU. The EU climate policies are divided into six categories energy, industry, transport, residential and commercial, agriculture and forestry, and waste as the last one. Among these six categories, there are even more subcategories. If national policies are not harmonised with the EU policies, it can confuse businesses. The second recommendation is to constitute a supervisory organisation for ESG reporting. Each Member State should have a supervisory organisation that will supervise reporting, and if a report is not fully disclosed, businesses should receive a financial fine. The author acknowledges that there may be exceptions where a report cannot be fully disclosed. The money from the fines could go into a common fund that helps businesses transform their business into the green. Therefore, businesses would profit, those paying fines would improve their reports, and the ones that need financial aid will have an opportunity to receive financial help from the common fund.

The first recommendation for organisations that provide data is to check the collected data for missing information and to contact businesses for any such missing data. In addition to this, the analysis of data would be beneficial for investors, researchers, and other stakeholders. When analysing the data, data providers could remove variables reported as missing for a consecutive period; hence, the data validity would improve. The final recommendation is for data standardisation. Making the data standardised would improve ESG reporting and measuring of ESG scores and increase businesses’ interest in submitting the report. Consequently, data providers might have additional users and increase their profits.

References

1. Aatola, P., Ollikainen, M., & Toppinen, A. (2013). Price determination in the EU ETS market: Theory and econometric analysis with market fundamentals. *Energy Economics*, *36*, 380-395.
2. Aatola, P., Ollikka, K., & Ollikainen, M. (2014). Informational efficiency of the EU ETS market–a study of price predictability and profitable trading. *Journal of Environmental Economics and Policy*, *3*(1), 92-123.
3. Abhayawansa, S., & Tyagi, S. (2021). Sustainable investing: the black box of environmental, social, and governance (ESG) ratings. *The Journal of Wealth Management*, 24(1), 49-54.
4. Abrell, J., Ndoye Faye, A., & Zachmann, G. (2011). Assessing the impact of the EU ETS using firm level data (No. 2011/08). Bruegel working paper.
5. Achim, M. V., Borlea, S. N., & Mare, C. (2016). Corporate governance and business performance: Evidence for the Romanian economy. *Journal of Business Economics and Management*, *17*(3), 458-474.
6. Adamowicz, M. (2017). Bioeconomy-concept, application and perspectives. *Problems of Agricultural Economics*, 1(350).
7. Adams, B. (2015). SDG Indicators and Data: Who collects? Who reports? Who benefits. *Global policy watch*, *9*.
8. Adams, W.A. (2005) 'Sustainability', in P. Cloke, C. Crang and M. Goodwin (Eds.) *Introducing Human Geographies*, 2nd ed., London: Hodder Arnold, pp.285–297.
9. Aggarwal, P. (2013). Impact of corporate governance on corporate financial performance. *IOSR Journal of Business and Management*, *13*(3), 01-05.
10. Alberola E., Afriat M., Rittenhouse K., Francis D., Sopher P., Deblock S. & Kouchakji K. (2015) *European Union: an emissions trading case study*. Paris, Wash- ington, DC and Brussels: CDC Climat, Environmental Defense Fund, and IETA.
11. Albrecht, W. S., Lookabill, L. L., & McKeown, J. C. (1977). The time-series properties of annual earnings. *Journal of Accounting Research*, 226-244.
12. Allan, G., Lecca, P., McGregor, P., & Swales, K. (2014). The economic and environmental impact of a carbon tax for Scotland: A computable general equilibrium analysis. *Ecological Economics*, 100, 40–50.
13. Anand, M. (2016). Innovation and sustainable development: a bioeconomic perspective. Brief for Global Sustainable Development Report. https://sustainabledevelopment.un.org/content/documents/982044_Anand_Innovation%20and%20Sustainable%20Development_A%20Bioeconomic%20Perspective.pdf
14. Anderson, B., & Di Maria, C. (2011). Abatement and Allocation in the Pilot Phase of the EU ETS. *Environmental and Resource Economics*, *48*(1), 83-103.
15. Anderson, K., & Bows, A. (2011). Beyond 'dangerous' climate change: emission scenarios for a new world. *Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences*, *369*(1934), 20-44.
16. Andries, A., Morse, S., Murphy, R. J., Lynch, J., & Woolliams, E. R. (2019). Seeing sustainability from space: Using Earth observation data to populate the UN sustainable development goal indicators. *Sustainability*, *11*(18), 5062.

17. Antwi, S. K., & Hamza, K. (2015). Qualitative and quantitative research paradigms in business research: A philosophical reflection. *European journal of business and management*, 7(3), 217-225.
18. Aragón-Correa, J. A., Hurtado-Torres, N., Sharma, S., & García-Morales, V. J. (2008). Environmental strategy and performance in small firms: A resource-based perspective. *Journal of environmental management*, *86*(1), 88-103.
19. Armitage, D., De Loë, R., & Plummer, R. (2012). Environmental governance and its implications for conservation practice. *Conservation letters*, *5*(4), 245-255.
20. Arushanyan, Y., Ekener, E., & Moberg, Å. (2017). Sustainability assessment framework for scenarios–SAFS. *Environmental impact assessment review*, *63*, 23-34.
21. Asche, F., Garlock, T. M., Anderson, J. L., Bush, S. R., Smith, M. D., Anderson, C. M., Chu, J., Garrett, k. A., Lem, A., Lorenzen, K., Oglend, A., Tveteras, S. and Vannuccini, S. (2018). Three pillars of sustainability in fisheries. *Proceedings of the National Academy of Sciences*, 115(44), 11221-11225.
22. Auer, B. R. (2018). Green, greener, greenest: Identifying ecological trends and leading entities by means of environmental ratings. *International Review of Applied Economics*, *32*(2), 139-162.
23. Bachelier, L. (1900). trans. Boness, J., 'Theory of speculation', in: Cootner, P. (ed.), *The Random Character of Stock Market Prices* (MIT Press, 1964), pp. 17–78
24. Bagele, C. (2011). Indigenous research methodologies. Sage Publications. Inc
25. Balsiger, J., & Prys, M. (2016). Regional agreements in international environmental politics. *International Environmental Agreements: Politics, Law and Economics*, *16*(2), 239-260.
26. Baltagi, B. H. (2001). *Econometric Analysis of Panel Data*. Wiley, John & Sons.
27. Barnett, M. L., & Salomon, R. M. (2012). Does it pay to be really good? Addressing the shape of the relationship between social and financial performance. *Strategic management journal*, *33*(11), 1304-1320.
28. Basiago, A. D. (1999). Economic, social, and environmental sustainability in development theory and urban planning practice. *Environmentalist*, 19(2), 145–161.
29. Bassen, A., & Kovács, A. M. (2020). *Environmental, social and governance key performance indicators from a capital market perspective* (pp. 809-820). Springer Fachmedien Wiesbaden.
30. Baumeister, C., & Kilian, L. (2016). Forty years of oil price fluctuations: Why the price of oil may still surprise us. *Journal of Economic Perspectives*, *30*(1), 139-60.
31. Bendix, B., 2014. Hans Carl von Carlowitz Sylvicultura Oeconomica. Studia i Materiały Ośrodka Kultury Leśnej, (13). https://www.studia.okl.lasy.gov.pl/documents/1004479/27614097/Bernd+Bendix.pdf/0ff746d6-9e46-4a33-bfc6-8a42d781c610
32. Bennett, N. J., & Satterfield, T. (2018). Environmental governance: A practical framework to guide design, evaluation, and analysis. *Conservation Letters*, *11*(6), e12600.
33. Beraldi-Campesi, H. (2013). Early life on land and the first terrestrial ecosystems. *Ecological Processes*, *2*(1), 1-17.
34. Bernstein, P. L. (1993). *Capital ideas: the improbable origins of modern Wall Street*. Simon and Schuster.

35. Berry, M. A., & Rondinelli, D. A. (1998). Proactive corporate environmental management: A new industrial revolution. *Academy of Management Perspectives*, *12*(2), 38-50.
36. Bhagat, S., & Bolton, B. (2019). Corporate governance and firm performance: The sequel. *Journal of Corporate Finance*, *58*, 142-168.
37. Böhringer, C., Dijkstra, B., & Rosendahl, K. E. (2014). Sectoral and regional expansion of emissions trading. *Resource and Energy Economics*, 37, 201–225.
38. Böhringer, C., Rutherford, T. F., & Tol, R. S. J. (2009). The EU 20/20/2020 targets: An overview of the EMF22 assessment. *Energy Economics*, 31, S268–S273.
39. Boyer, R. H., Peterson, N. D., Arora, P., & Caldwell, K. (2016). Five approaches to social sustainability and an integrated way forward. *Sustainability*, *8*(9), 878.
40. Britannica. (2020). *Arab oil embargo*. Encyclopaedia Britannica. https://www.britannica.com/event/Arab-oil-embargo
41. Britannica. (n.d.). *Timeline of Climate Change*. Encyclopaedia Britannica. https://www.britannica.com/story/timeline-of-climate-change
42. British Geological Survey (n.d.) *How does the greenhouse effect work.* https://www.bgs.ac.uk/discovering-geology/climate-change/how-does-the-greenhouse-effect-work/
43. Brockett, A., & Rezaee, Z. (2012). *Corporate sustainability: Integrating performance and reporting* (Vol. 630). John Wiley & Sons.
44. Brown, B. J., Hanson, M. E., Liverman, D. M., & Merideth, R. W. (1987). Global sustainability: Toward definition. *Environmental management*, *11*(6), 713-719.
45. Bryden, J., & Shucksmith, M. (2000). The concept of sustainability in relation to agriculture and rural development in the European Union. *Rural and Regional Development in Northern Periphery, Report*, 4(00).
46. Cadbury, S. A. (2000). The corporate governance agenda. *Corporate Governance: An International Review*, *8*(1), 7-15.
47. Capoor, K., & Ambrosi, P. (2006). State and trends of the carbon market 2006.
48. Capros, P., De Vita, A., Hoeglund-Isaksson, L., Winiwarter, W., Purohit, P., Bottcher, H., Frank, S., Havlik, P., Gusti, M. & Witzke, H.P. (2013). *EU energy, transport and GHG emissions trends to 2050-Reference scenario 2013*. European Commission.
49. Carbon Market Watch. (2014). What's needed to fix the EU's carbon market: Recommendations for the Market Stability Reserve and future ETS reform proposals. *Carbon Market Watch Policy Briefing*.
50. Carbon Pricing Leadership Coalition. (2016). What is the impact of carbon pricing on competitiveness. *Executive Briefing*.
51. Carroll, A. B. (1979). A three-dimensional conceptual model of corporate performance. *Academy of management review*, *4*(4), 497-505.
52. Carroll, A. B. (2012). A corporate social responsibility journey: Looking back, looking forward. *Retrieved*, *2*(28), 2015.
53. Carson, R. (2015). *Silent spring*. Houghton Mifflin Harcourt.
54. Chatterji, A. K., Durand, R., Levine, D. I., & Touboul, S. (2016). Do ratings of firms converge? Implications for managers, investors and strategy researchers. *Strategic Management Journal*, 37(8), 1597-1614.

55. Chen, H., & Wang, L. (2017). Coproducts generated from biomass conversion processes. *Technologies for biochemical conversion of biomass*, 219-264.
56. Chevallier, J. (2010). A note on cointegrating and vector autoregressive relationships between CO2 allowances spot and futures prices. *Economics Bulletin*, *30*(2), 1564-1584.
57. Climate Diplomacy. (n. d.). Food Security. Available at: https://climate-diplomacy.org/food-security
58. Climate Policy Watcher. (2022) Historical Development Of The Greenhouse Effect Concept Available at: https://www.climate-policy-watcher.org/plate-tectonics/historical-development-of-the-greenhouse-effect-concept.html
59. Cootner, P. (1964). *The Random Character of Stock Market Prices* (MIT Press, 1964).
60. Cornwall, W. (2021). Europe's deadly floods leave scientists stunned.
61. Cowles, A. III & Jones, H. E. (1937). Some a posteriori probabilities in stock market action. *Econometrica, Journal of the Econometric Society*, 280-294.
62. Creswell, J. W. (2009). *Research design: Qualitative and mixed methods approaches*. London: SAGE.
63. Crotty, M. J. (1998). The foundations of social research: Meaning and perspective in the research process. *The foundations of social research*, 1-256.
64. Cvijanovic, I., Lukovic, J., & Begg, J. D. (2020). One hundred years of Milanković cycles. *Nature Geoscience*, *13*(8), 524-525.
65. D'Amato, D., & Korhonen, J. (2021). Integrating the green economy, circular economy and bioeconomy in a strategic sustainability framework. *Ecological Economics*, 188, 107143.
66. D'Amato, D., Droste, N., Allen, B., Kettunen, M., Lähtinen, K., Korhonen, J., Leskinen, P., Matthies, B.D. & Toppinen, A. (2017). Green, circular, bio economy: A comparative analysis of sustainability avenues. *Journal of cleaner production*, 168, 716-734.
67. Daly, H. E. (1996). *Beyond Growth: The Economics of Sustainable Development.* Beacon Press.
68. Daskalakis, G. (2013). On the efficiency of the European carbon market: New evidence from Phase II. *Energy Policy*, *54*, 369-375.
69. Daskalakis, G., & Markellos, R. N. (2008). Are the European carbon markets efficient. *Review of futures markets*, *17*(2), 103-128.
70. Daskalakis, G., Psychoyios, D., & Markellos, R. N. (2009). Modeling CO2 emission allowance prices and derivatives: Evidence from the European trading scheme. *Journal of Banking & Finance*, *33*(7), 1230-1241.
71. Davies, A., & Simmons, M. (2020). Who needs Stratigraphers, Sedimentologists & Paleontologists? Evolving roles through the Energy Transition. *The Sedimentary Record*, *18*(4), 12-15.
72. Dawe, N. K., & Ryan, K. L. (2003). The faulty three-legged-stool model of sustainable development. *Conservation biology*, *17*(5), 1458-1460.
73. Declercq, B., Delarue, E., & D'haeseleer, W. (2011). Impact of the economic recession on the European power sector's CO2 emissions. *Energy Policy*, *39*(3), 1677-1686.
74. Delbeke, J. & Vis, P. (2015). *EU climate policy explained*. London: Routledge.
75. Department of Trade and Industry. (2003). Our energy future–creating a low carbon economy.

76. Desai, B.H. & Sidhu, B.K. (2015) ‘Quest for international environmental institutions: transition from the CSD to the HLPF’, in Alam, S., Atapattu, S., Gonzalez, C.G. and Razzaque, J. (eds), *International Environmental Law and the Global South*, Cambridge: Cambridge University Press, pp 152–70.

77. Dickey, D. A., & Fuller, W. A. (1979). Distribution of the estimators for autoregressive time series with a unit root. *Journal of the American statistical association*, *74*(366a), 427-431.

78. Dietz, S., & Neumayer, E. (2007). Weak and strong sustainability in the SEEA: Concepts and measurement. *Ecological economics*, 61(4), 617-626.

79. Dietz, T., Gardner, G. T., Gilligan, J., Stern, P. C., & Vandenbergh, M. P. (2009). Household actions can provide a behavioral wedge to rapidly reduce US carbon emissions. *Proceedings of the national academy of sciences*, 106(44), 18452-18456.

80. Dimson, E., & Mussavian, M. (1998). A brief history of market efficiency. *European financial management*, 4(1), 91-103.

81. Director-General of the WHO. (2018). Universal health coverage. Report. https://apps.who.int/gb/ebwha/pdf_files/EB144/B144_14-en.pdf

82. Doni, F., Gasperini, A., & Soares, J. T. (2020). Practical Tools and Mechanisms for SDG 13 Implementation. In *SDG13–Climate Action: Combating Climate Change and its Impacts*. Emerald Publishing Limited.

83. Du Pisani, J. A. (2006). Sustainable development–historical roots of the concept. *Environmental sciences*, *3*(2), 83-96.

84. Dubois, G., Sovacool, B., Aall, C., Nilsson, M., Barbier, C., Herrmann, A., Bruyère, S., Andersson, C., Skold, B., Nadaud, F.,Dorner, F.,Richardsen Moberg, K., Ceron, J. P., Fischer, H., Amelung, D.,Baltruszewicz, M., Fischer, J., Benevise, F., Louis, V. R., & Sauerborn, R. (2019). It starts at home? Climate policies targeting household consumption and behavioral decisions are key to low-carbon futures. *Energy Research & Social Science*, 52, 144-158.

85. Dupont, C. (2019). The EU’s collective securitisation of climate change. *West European Politics*, *42*(2), 369-390.

86. Eccles, N. S., & Viviers, S. (2011). The origins and meanings of names describing investment practices that integrate a consideration of ESG issues in the academic literature. *Journal of business ethics*, *104*(3), 389-402.

87. EEA (2015) *Trends and projections in Europe 2015: Tracking progress towards Europe’s climate and energy targets*, European Environment Agency, Copenhagen, Available at: https://www.eea.europa.eu/publications/trends-and-projections-in-europe-2015

88. EEA. (2022). Annual European Union greenhouse gas inventory 1990–2020 and inventory report 2022, Technical report Submission to the UNFCCC Secretariat, EEA

89. Elliot, C. & Chin, N. (2021) Why the First Global Stocktake Should Not Overlook Long-Term Climate Strategies.

90. Elsayed, K., & Paton, D. (2005). The impact of environmental performance on firm performance: static and dynamic panel data evidence. *Structural change and economic dynamics*, *16*(3), 395-412.

91. Engels, A. (2009). The European Emissions Trading Scheme: An exploratory study of

how companies learn to account for carbon. *Accounting, Organizations and Society*, 34(3-4), 488-498.

92. Engels, A., Knoll, L., & Huth, M. (2008). Preparing for the 'real'market: National patterns of institutional learning and company behaviour in the European Emissions Trading Scheme (EU ETS). *European Environment*, *18*(5), 276-297.
93. Engin, T., Amiot, M., Evans, M., Lord, R. & Burks, B. (2022). Carbon Pricing, In Various Forms, Is Likely To Spread In The Move To Net Zero. https://www.spglobal.com/esg/insights/featured/special-editorial/carbon-pricing-in-various-forms-is-likely-to-spread-in-the-move-to-net-zero
94. Engineering and Physical Sciences Research Council. (2003). Building Knowledge for a Changing Climate–The Impacts of Climate Change on the Built Environment.
95. Erbach, G. (2021a). Climate action in Poland: Latest state of play. Climate Action Research and Tracking Service, Members' Research Service, PE 698.766
96. Erbach, G. (2021b). Climate action in Slovakia: Latest state of play. Climate Action Research and Tracking Service, Members' Research Service, PE 698.767
97. Erbach, G. & Carvalho Fachada, J. (2021). Climate action in Malta: Latest state of play. Climate Action Research and Tracking Service, Members' Research Service, PE 690.683
98. Erol, I., Cakar, N., Erel, D., & Sari, R. (2009). Sustainability in the Turkish retailing industry. *Sustainable Development*, 17(1), 49-67.
99. European Commission. (2003). Directive 2003/87/EC of the European Parliament and of the Council of 13 October 2003 establishing a scheme for greenhouse gas emission allowance trading within the Community and amending Council Directive 96/61/EC. *Official Journal of the European Union*, *46*, 32-46.
100. European Commission. (2011). Energy Roadmap 2050. COM(2011) 885/2. https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52011DC0885&from=EN
101. European Commission. (2012). *Innovating for sustainable growth: a bioeconomy for Europe*, Publications Office.
102. European Commission. (2015). EU ETS Handbook. https://climate.ec.europa.eu/system/files/2017-03/ets_handbook_en.pdf
103. European Commission. (2016). The EU Emissions Trading System (EU ETS), ML-06-16-080-EN-N.
104. European Commission. (2018). A Call for Planet, COM(2018) 773 final. https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52018DC0773
105. European Commission. (2019). The European Green Deal. Brussels, 11 December, COM(2019) 640 final.
106. European Commission. (2020a). A hydrogen strategy for a climate-neutral Europe COM(2020) 301. https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52020DC0301
107. European Commission. (2020b). Regulation of the European Parliament and of the Council COM(2020) 824. https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A52020PC0824
108. European Commission. (2020c). A new Circular Economy Action Plan COM(2020) 98. https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=COM%3A2020%3A98%3AFIN

109. European Commission. (2020d). A New Industrial Strategy for Europe COM(2020)102. https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A52020DC0102
110. European Commission. (2020e). A Renovation Wave for Europe – greening our buildings, creating jobs, improving lives COM(2020) 662. https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A52020DC0662
111. European Commission. (2020f). Sustainable and Smart Mobility Strategy – putting European transport on track for future COM(2020) 789. https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A52020DC0789
112. European Commission. (2020g). European Green Deal Investment Plan COM(2020) 21. https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A52020DC0021
113. European Commission. (2021a). A Union of vitality in a world of fragility COM(2020) 690. https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A52020DC0690&qid=1612868883067
114. European Commission. (2021b). EU Action Plan: 'Towards Zero Pollution for Air, Water and Soil'COM(2021) 400. https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A52021DC0400&qid=1623311742827
115. European Commission. (n. d. a) EU Emission Trading System (EU ETS). https://climate.ec.europa.eu/eu-action/eu-emissions-trading-system-eu-ets_en#a-cap-and-trade-system
116. European Commission. (n. d. b). European Climate Law. Available at: https://climate.ec.europa.eu/eu-action/european-green-deal/european-climate-law_en
117. European Commission. (n. d.) International Partnerships. Available at: https://international-partnerships.ec.europa.eu/policies/human-development/reducing-inequalities_en
118. European Parliament. (2022). Review of the EU ETS – 'Fit for 55' package. https://www.europarl.europa.eu/RegData/etudes/BRIE/2022/698890/EPRS_BRI(2022)698890_EN.pdf
119. Eurostat. (2018). Consumption of energy. https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Archive:Consumption_of_energy
120. Eurostat. (n. d.) Small and medium-sized enterprises. https://ec.europa.eu/eurostat/web/structural-business-statistics/small-and-medium-sized-enterprises
121. Fama, E. F. (1970). Efficient capital markets: A review of theory and empirical work. *The journal of Finance*, *25*(2), 383-417.
122. Fama, E. F., & Jensen, M. C. (1983). Separation of ownership and control. *The journal of law and Economics*, *26*(2), 301-325.
123. Federal Ministry for Environment, Nature Conservation, Nuclear Safety and Consumer Protection. (n. d.). Environment Action Programmes. https://www.bmuv.de/en/topics/europe-international/europe/environment-action-programmes
124. Fekete, A., & Sandholz, S. (2021). Here comes the flood, but not failure? Lessons to learn after the heavy rain and pluvial floods in Germany 2021. *Water*, *13*(21), 3016.
125. Ferreira Gregorio, V., Pié, L., & Terceño, A. (2018). A systematic literature review of bio, green and circular economy trends in publications in the field of economics and business management. *Sustainability*, 10(11), 4232.

126. Folke, C., Biggs, R., Norström, A. V., Reyers, B., & Rockström, J. (2016). Social-ecological resilience and biosphere-based sustainability science. *Ecology and Society*, *21*(3).
127. Forster, P., Ramaswamy, V., Artaxo, P., Berntsen, T., Betts, R., Fahey, D.W., Haywood, J., Lean, J., Lowe, D.C., Myhre, G. & Nganga, J., (2007). Changes in atmospheric constituents and in radiative forcing. Chapter 2. In *Climate change 2007. The physical science basis*.Cambridge University Press, Cambridge, UK, pp 747-845.
128. Frosch, R. A., & Gallopoulos, N. E. (1989). Strategies for manufacturing. *Scientific American*, *261*(3), 144-153.
129. Galbreath, J. (2013). ESG in focus: The Australian evidence. *Journal of business ethics*, 118(3), 529-541.
130. Gareth, J., Daniela, W., Trevor, H., & Robert, T. (2013). *An introduction to statistical learning: with applications in R*. Spinger.
131. Ghazani, M., & Ali Jafari, M. A. (2021). The efficiency of CO2 market in the phase III EU ETS: analyzing in the context of a dynamic approach. *Environmental Science and Pollution Research*, *28*(43), 61080-61095.
132. Gibson, R. B. (2006). Beyond the pillars: sustainability assessment as a framework for effective integration of social, economic and ecological considerations in significant decision-making. *Journal of environmental assessment policy and management*, *8*(03), 259-280.
133. Global Climate Change (2020). Milankovitch (Orbital) Cycles and Their Role in Earth's Climate. https://climate.nasa.gov/news/2948/milankovitch-orbital-cycles-and-their-role-in-earths-climate/
134. Godet, C. (2020). An update on EU climate policy: Recent developments and expectations. *EU Environmental Governance*, 15-33.
135. Goers, S. (2014). Testing informational efficiency in the EU ETS. *Journal of Sustainable Development of Energy, Water and Environment Systems*, *2*(4), 319-330.
136. Goodland, R., & Daly, H. (1996). Environmental sustainability: universal and non-negotiable. *Ecological applications*, 6(4), 1002-1017.
137. Gough, I., Abdallah, S., Johnson, V., Ryan-Collins, J., & Smith, C. (2011). The distribution of total greenhouse gas emissions by households in the UK, and some implications for social policy. *LSE STICERD Research Paper No. CASE152*.
138. Graefe, L. (2013). Oil Shock of 1978–79. *Atlanta: Federal Reserve Bank of Atlanta*.
139. Graham, J., Amos, B., & Plumptre, T. W. (2003). *Governance principles for protected areas in the 21st century* (pp. 1-2). Ottawa, ON, Canada: Institute on Governance, Governance Principles for Protected Areas.
140. Green Business Bureau. (2022). Comparing the Carbon Footprint of Small Businesses to Large Corporations. https://greenbusinessbureau.com/topics/carbon-accounting/comparing-the-carbon-footprint-of-small-businesses-to-large-corporations/
141. Greene, W. H. (2008). *Econometric Analysis*, 6th ed. Upper Saddle River, NJ: Prentice Hall.
142. Greenwald, C. (2010). ESG and earnings performance. ASSET4: Thomson Reuters study. https://www.thomsonreuters.com/content/dam/openweb/documents/pdf/tr-com-financial/case-study/esg-and-earnings-performance.pdf
143. Griffin, P. (2017). The carbon majors database. *CDP carbon majors report 2017, 14*.

144. Haezendonck, E., & Van den Berghe, K. (2020). Patterns of circular transition: what is the circular economy maturity of Belgian ports?. *Sustainability*, 12(21), 9269.
145. Hametner, M., & Kostetckaia, M. (2020). Frontrunners and laggards: How fast are the EU member states progressing towards the sustainable development goals?. *Ecological Economics*, *177*, 106775.
146. Hamilton, J. D. (2013). Oil prices, exhaustible resources and economic growth. In *Handbook on energy and climate change* (pp. 29-63). Edward Elgar Publishing.
147. Hansmann, R., Mieg, H. A., & Frischknecht, P. (2012). Principal sustainability components: empirical analysis of synergies between the three pillars of sustainability. *International Journal of Sustainable Development and World Ecology*, *19*(5), 451-459.
148. Harris, J. M. (2003). Sustainability and sustainable development. *International Society for Ecological Economics*, 1(1), 1-12.
149. Hausman, J. A. (1978). Specification tests in econometrics. *Econometrica: Journal of the econometric society*, 1251-1271.
150. Heuer, M. (2012). Sustainability governance across time and space: Connecting environmental stewardship in the firm with the global community. *Business Strategy and the Environment*, *21*(2), 86-97.
151. Hoffman, P. F. (2019). True global warming inferred from alpine recessional moraines by scottish physicist John Leslie in 1796. *Earth Sciences History*, *38*(2), 204-214.
152. Huesemann, M. H. 2001. Can pollution problems be effectively solved by environmental science and technology? An analysis of critical limitations. *Ecological Economics. 37*(2), 271-288.
153. Hur, W. M., Kim, Y., & Park, K. (2013). Assessing the effects of perceived value and satisfaction on customer loyalty: A ‘Green’perspective. *Corporate social responsibility and environmental management*, *20*(3), 146-156.
154. Ibikunle, G., Gregoriou, A., Hoepner, A. G., & Rhodes, M. (2016). Liquidity and market efficiency in the world's largest carbon market. *The British Accounting Review*, *48*(4), 431-447.
155. IFAC. Environmental Management Accounting. New York, USA. 2005. https://www.ifac.org/system/files/publications/files/international-guidance-docu-2.pdf
156. Ilie, L. (2006). Economic considerations regarding the first oil shock, 1973-1974.
157. Intergovernmental Panel on Climate Change. (2007). *Climate Change 2007: Synthesis Report.* Contribution of Working Groups I, II and III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Geneva, Switzerland.
158. International Telecommunication Union. (2022). Connectivity in the Least Developed Countries: report 2021
159. Ioannou, I., & Serafeim, G. (2010). *What drives corporate social performance?: International evidence from social, environmental and governance sources*. Cambridge: Harvard Business School.
160. Iordachi, V. (2020). Circular economy as a new industrial paradigm.
161. IPCC. (1990). IPCC first assessment report. Geneva: WMO
162. IPCC. (2001). IPCC third assessment report. Geneva: WMO
163. IPCC. (2007a) Climate Change 2007: Synthesis Report. Contribution of Working Groups I, II and III to the Fourth Assessment Report of the Intergovernmental Panel on

Climate Change [Core Writing Team, Pachauri, R.K and Reisinger, A. (eds.)]. IPCC, Geneva, Switzerland
164. IPCC. (2007b). Climate change 2007: The physical science basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, 2007 Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M. Tignor and H.L. Miller (eds.) Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.
165. IPCC. (2014). *Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* [Core Writing Team, R.K. Pachauri and L.A. Meyer (eds.)]. IPCC, Geneva, Switzerland, 151
166. IPCC. (2022). *Climate Change 2022: Impacts, Adaptation, and Vulnerability*. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [H.-O. Pörtner, D.C. Roberts, M. Tignor, E.S. Poloczanska, K. Mintenbeck, A. Alegría, M. Craig, S. Langsdorf, S. Löschke, V. Möller, A. Okem, B. Rama (eds.)]. Cambridge University Press. In Press.
167. Jacobs, M. (1999). Sustainable development as a contested concept. *Fairness and futurity: Essays on environmental sustainability and social justice*, *1*, 21-46.
168. Jalaluddin, D., Sulaiman, M. & Ahmad, N. N. N. (2010). Environmental Management Accounting: An Empirical Investigation of Manufacturing Companies in Malaysia, *Journal of the Asian Pacific Centre for Environmental Accountability*, 16(3), 31-45.
169. Jasch, C. (2006). Environmental management accounting (EMA) as the next step in the evolution of management accounting. *Journal of Cleaner production*, 14(14), 1190-1193.
170. Jin, Y., Wang, H., & Wheeler, D. (2010). The impact of environmental performance rating and disclosure: an empirical analysis of perceptions by polluting firms' managers in China. *World Bank Policy Research Working Paper*, (5419).
171. Johnston, R., Jones, K., & Manley, D. (2018). Confounding and collinearity in regression analysis: a cautionary tale and an alternative procedure, illustrated by studies of British voting behaviour. *Quality & quantity*, *52*(4), 1957-1976.
172. Kainou, K. (2022). Collapse of the CDM Scheme under the Kyoto Protocol and Its Spillover: Consequences of" carbon panic". *RIETI highlight*, (89), 18-20.
173. Kajikawa, Y., Tacoa, F., & Yamaguchi, K. (2014). Sustainability science: the changing landscape of sustainability research. *Sustainability science*, *9*(4), 431-438.
174. Kates, R. W., Clark, W. C., Corell, R., Hall, J. M., Jaeger, C. C., Lowe, I., McCarthy, J. J., Schellnhuber, H. J., Bolin, B., Dickson, N. M. & Faucheux, S. (2001). Sustainability science. *Science*, *292*(5517), 641-642.
175. Keller, C. F. (1999). Comment: Human contribution to climate change increasingly clear. *Eos, Transactions American Geophysical Union, 80*(33), 368-372.
176. Kendall, M. G., & Hill, A. B. (1953). The analysis of economic time-series-part i: Prices. *Journal of the Royal Statistical Society. Series A (General)*, *116*(1), 11-34.
177. Kennedy, C., Steinberger, J., Gasson, B., Hansen, Y., Hillman, T., Havranek, M., Pataki, D., Phdungsilp, A., Ramaswami, A. and Mendez, G.V., (2009). Greenhouse gas emissions from global cities. *Environmental Science & Technology*, 43(19), 7297-7302
178. Kennedy, P. (2008). *A Guide to Econometrics*, 6th ed. Malden, MA: Blackwell Publishing

179. Kharuk, V. I., Ponomarev, E. I., Ivanova, G. A., Dvinskaya, M. L., Coogan, S. C., & Flannigan, M. D. (2021). Wildfires in the Siberian taiga. *Ambio, 50*(11), 1953-1974.

180. Khaw-ngern, K., Peuchthonglang, P., Klomkul, L., & Khaw-ngern, C. (2021). The 9Rs strategies for the circular economy 3.0. *Psychol. Educ. J.*, *58*, 1440-1446.

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

182. Klettner, A., Clarke, T., & Boersma, M. (2014). The governance of corporate sustainability: Empirical insights into the development, leadership and implementation of responsible business strategy. *Journal of business ethics*, *122*(1), 145-165.

183. Komiyama, H., & Takeuchi, K. (2006). Sustainability science: building a new discipline. *Sustainability science*, *1*(1), 1-6.

184. Koo, Y., Lee, Y., & Kim, Y. G. (2019). The differentiated impact of emissions trading system based on company size. *Climate Policy*, *19*(7), 923-936.

185. Korhonen, J., (2006). Editorial: sustainable development in a shrinking and sinking world. *Progress in Industrial Ecology*, 3(6), 509.

186. Korhonen, J., Honkasalo, A., & Seppälä, J. (2018). Circular economy: the concept and its limitations. *Ecological economics*, *143*, 37-46.

187. Kossoy, A. (2015). *State and trends of carbon pricing 2015*. World Bank Publications.

188. Kossoy, A., & Ambrosi, P. (2010). State and trends of the carbon market 2010.

189. Kossoy, A., & Guigon, P. (2012). State and trends of the carbon market 2012.

190. Krajnc, D. & Glavič, P. (2005). How to compare companies on relevant dimensions of sustainability. *Ecological economics*, *55*(4), 551-563.

191. Kristensen, H. S., and Mosgaard, M. A. (2020). A review of micro level indicators for a circular economy–moving away from the three dimensions of sustainability?. *Journal of Cleaner Production*, *243*, 118531.

192. Kruskal, W. H., & Wallis, W. A. (1952). Use of ranks in one-criterion variance analysis. *Journal of the American Statistical Association*, *47*(260), 583-621.

193. Küfeoğlu, S. (2021). *The Home of the Future: Digitalization and Resource Management*. Springer Nature.

194. Kuhn, T. S. [1962] (1977). The historical structure of scientific discovery. In *The essential tension: Selected studies in scientific tradition and change*, by T. S. Kuhn. Chicago: University of Chicago Press.

195. Kwiatkowski, D., Phillips, P. C., Schmidt, P., & Shin, Y. (1992). Testing the null hypothesis of stationarity against the alternative of a unit root: How sure are we that economic time series have a unit root?. *Journal of econometrics*, *54*(1-3), 159-178.

196. Labzovskii, L. D., Jeong, S., Kennedy, E. B., Belikov, D., Chang, D., & Hekman, E. (n. d.) The 2019 Siberian Wildfires as a Turning Point for Environmental Decision-Making in Russia.

197. Leal Filho, W. (2020). Accelerating the implementation of the SDGs. *International Journal of Sustainability in Higher Education*, *21*(3), 507-511.

198. Leal Filho, W., Azeiteiro, U., Alves, F., Pace, P., Mifsud, M., Brandli, L., Caeiro, S. S. & Disterheft, A. (2018). Reinvigorating the sustainable development research agenda: the role of the sustainable development goals (SDG). *International Journal of Sustainable Development and World Ecology*, *25*(2), 131-142.

199. Lecocq, F., & Ambrosi, P. (2007). The Clean Development Mechanism: history, status, and prospects. *Review of Environmental Economics and Policy*, *1*(1), 134-151.
200. Lehtonen, M. (2004). The environmental–social interface of sustainable development: capabilities, social capital, institutions. *Ecological economics*, *49*(2), 199-214.
201. Lenczowski, G. (1975). The oil-producing countries. *Daedalus*, 59-72.
202. Lieder, M., & Rashid, A. (2016). Towards circular economy implementation: a comprehensive review in context of manufacturing industry. *Journal of cleaner production*, *115*, 36-51.
203. Lincoln, Y. S. & Guba, E. G. (2000). Pragmatic controversies, contradictions, and emerging confluences. I n Deniz, N. K. and Lincoln, Y. S. (2000). *Handbook of qualitative research*. London: Sage, Chapter 6, 163 – 188
204. Lise, W., Sijm, J., & Hobbs, B. F. (2010). The impact of the EU ETS on prices, profits and emissions in the power sector: simulation results with the COMPETES EU20 model. *Environmental and Resource Economics*, *47*(1), 23-44.
205. Liselotte, J. (2021a). Climate action in the European Union: Latest state of play. Climate Action Research and Tracking Service, Members' Research Service, PE 698.844
206. Liselotte, J. (2021b). Climate action in Finland: Latest state of play. Climate Action Research and Tracking Service, Members' Research Service, PE 696.187
207. Liselotte, J. (2021c). Climate action in Ireland: Latest state of play. Climate Action Research and Tracking Service, Members' Research Service, PE 690.580
208. Liselotte, J. (2021d). Climate action in Lithuania: Latest state of play. Climate Action Research and Tracking Service, Members' Research Service, PE 690.683
209. Liselotte, J. (2021e). Climate action in Luxembourg: Latest state of play. Climate Action Research and Tracking Service, Members' Research Service, PE 690.664
210. Liselotte, J. (2021f). Climate action in Croatia: Latest state of play. Climate Action Research and Tracking Service, Members' Research Service, PE 690.662
211. Liselotte, J. (2021g). Climate action in Italy: Latest state of play. Climate Action Research and Tracking Service, Members' Research Service, PE 690.663
212. Liselotte, J. (2021h). Climate action in Czechia: Latest state of play. Climate Action Research and Tracking Service, Members' Research Service, PE 689.329
213. Liselotte, J. (2021i). Climate action in Romania: Latest state of play. Climate Action Research and Tracking Service, Members' Research Service, PE 696.185
214. Liselotte, J. & Carvalho Fachada, J. (2021). Climate action in Austria: Latest state of play. Climate Action Research and Tracking Service, Members' Research Service, PE 696.186
215. Lockwood, M. (2010). Good governance for terrestrial protected areas: A framework, principles and performance outcomes. *Journal of environmental management*, *91*(3), 754-766.
216. Lockwood, M., Davidson, J., Curtis, A., Stratford, E., & Griffith, R. (2010). Governance principles for natural resource management. *Society and natural resources*, *23*(10), 986-1001.
217. Loiseau, E., Saikku, L., Antikainen, R., Droste, N., Hansjürgens, B., Pitkänen, K., Leskinen, P., Kuikman, P. & Thomsen, M. (2016). Green economy and related concepts: An overview. Journal of cleaner production, 139, 361-371.
218. Lozano, R. (2008). Envisioning sustainability three-dimensionally. *Journal of cleaner production*, *16*(17), 1838-1846.

219. MacArthur, E. (2013). Towards the circular economy. *Journal of Industrial Ecology, 2*(1), 23-44.
220. MacFeely, S. (2019). The big (data) bang: Opportunities and challenges for compiling SDG indicators. *Global Policy*, *10*, 121-133.
221. MacFeely, S. (2020). Measuring the sustainable development goal indicators: An unprecedented statistical challenge. *Journal of official statistics*, *36*(2), 361-378.
222. MacKenzie, D. (2007), Changing the bottom line, Contribution au colloque, Exercices de metaphysique empirique (Autour des travaux de Bruno Latour).
223. Mair, S., Jones, A., Ward, J., Christie, I., Druckman, A., & Lyon, F. (2018). A critical review of the role of indicators in implementing the sustainable development goals. *Handbook of sustainability science and research*, 41-56.
224. Matthews, H. D., & Caldeira, K. (2008). Stabilizing climate requires near-zero emissions. *Geophysical research letters, 35*(4).
225. McCormick, K., & Kautto, N. (2013). The bioeconomy in Europe: An overview. *Sustainability*, *5*(6), 2589-2608.
226. McKenzie, S. (2004). Social sustainability: towards some definitions.
227. Meadows, D. H., Meadows, D. L., Randers, J., & Behrens, W. W. (2018). The limits to growth. In *Green planet blues* (pp. 25-29). Routledge.
228. Mebratu, D. (1998). Sustainability and sustainable development: historical and conceptual review. *Environmental impact assessment review, 18*(6), 493-520.
229. Meehl, G. A., Stocker, T. F., Collins, W. D., Friedlingstein, P., Gaye, A. T., Gregory, J. M., Kitoh, J. M., Knutti, A., Murphy, J. M., Noda, A., Raper, S.C. & Zhao, Z. C. (2007). Global climate projections.
230. Melnyk, S. A., Sroufe, R. P., & Calantone, R. (2003). Assessing the impact of environmental management systems on corporate and environmental performance. *Journal of* operations management, 21(3), 329-351.
231. Menard, S. (2002). *Applied logistic regression analysis* (No. 106). Sage.
232. Millennium Ecosystem Assessment. (2008). Living beyond our means: natural assets and human well-being.
233. Mohajan, H. (2011): Greenhouse gas emissions increase global warming. *International Journal of Economic and Political Integration*, 1(2), 21-34.
234. Moir, S., & Carter, K. (2012, September). Diagrammatic representations of sustainability–a review and synthesis. In *Procs 28th Annual ARCOM Conference* (pp. 3-5).
235. Moldan, B., Janoušková, S., & Hák, T. (2012). How to understand and measure environmental sustainability: Indicators and targets. *Ecological Indicators, 17,* 4-13.
236. Molina, M. J., & Rowland, F. S. (1974). Stratospheric sink for chlorofluoromethanes: chlorine atom-catalysed destruction of ozone. *Nature, 249*(5460), 810-812.
237. Montagnoli, A., & de Vries, F. P. (2010). Carbon trading thickness and market efficiency. *Energy Economics, 32*(6), 1331-1336.
238. Morgado Simões, H. (2021a). Climate action in Latvia: Latest state of play. Climate Action Research and Tracking Service, Members' Research Service, PE 696.194
239. Morgado Simões, H. (2021b). Climate action in Sweden: Latest state of play. Climate Action Research and Tracking Service, Members' Research Service, PE 690.579

240. Morgado Simões, H. (2021c). Climate action in Belgium: Latest state of play. Climate Action Research and Tracking Service, Members' Research Service, PE 690.578
241. Morgado Simões, H. (2021d). Climate action in Germany: Latest state of play. Climate Action Research and Tracking Service, Members' Research Service, PE 690.661
242. Morgado Simões, H. (2021e). Climate action in the Netherlands: Latest state of play. Climate Action Research and Tracking Service, Members' Research Service, PE 696.194
243. Morgado Simões, H. (2021f). Climate action in Cyprus: Latest state of play. Climate Action Research and Tracking Service, Members' Research Service, PE 696.195
244. Morgado Simões, H. (2021g). Climate action in Greece: Latest state of play. Climate Action Research and Tracking Service, Members' Research Service, PE 690.685
245. Morgado Simões, H. (2021h). Climate action in Slovenia: Latest state of play. Climate Action Research and Tracking Service, Members' Research Service, PE 698.061
246. Morgado Simões, H. (2021i). Climate action in Hungary: Latest state of play. Climate Action Research and Tracking Service, Members' Research Service, PE 698.060
247. Morgado Simões, H. and Fachada, J. (2021). Climate action in Portugal: Latest state of play. Climate Action Research and Tracking Service, Members' Research Service, PE 696.196
248. Morgado Simões, H. & Victoria, G. A. (2021a). Climate action in Denmark: Latest state of play. Climate Action Research and Tracking Service, Members' Research Service, PE 679.106
249. Morgado Simões, H. & Victoria, G. A. (2021b). Climate action in Spain: Latest state of play. Climate Action Research and Tracking Service, Members' Research Service, PE 690.579
250. Mori, K., & Christodoulou, A. (2012). Review of sustainability indices and indicators: Towards a new City Sustainability Index (CSI). *Environmental impact assessment review*, *32*(1), 94-106.
251. Morin, J. F., Orsini, A., & Jinnah, S. (2020). *Global Environmental Politics: Understanding the Governance of the Earth*. Oxford University Press, USA.
252. 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*(3), 369-380.
253. NASA. (n.d.). *Global warming vs climate change.* https://climate.nasa.gov/resources/global-warming-vs-climate-change/
254. Natural Resources Defense Council (n.d.) *Greenhouse effect*. https://www.nrdc.org/stories/greenhouse-effect-101
255. Nejat, P., Jomehzadeh, F., Taheri, M. M., Gohari, M., & Majid, M. Z. A. (2015). A global review of energy consumption, CO2 emissions and policy in the residential sector (with an overview of the top ten CO2 emitting countries). *Renewable and sustainable energy reviews, 43*, 843-862.
256. Nelson, G. (2017). Montreal Protocol: Successful Ozone and Climate Agreement Turns 30. http://sdg.iisd.org/news/montreal-protocol-successful-ozone-and-climate-agreement-turns-30/
257. Newbold, P., Carlson, W., & Thorne, B. (2022). *Statistics for business and economics*. Pearson UK.
258. Norgaard, R. B. (1994), *Development Betrayed: The End of Progress and a Coevolutionary Revisioning of the Future*. Routledge.

259. Novitz, T., & Pieraccini, M. (2020). "2: Agenda 2030 and the Sustainable Development Goals: 'Responsive, Inclusive, Participatory and Representative Decision-Making'?". In *Legal Perspectives on Sustainability* (pp. 39-66). Bristol University Press.

260. O'Connell, V., & Cramer, N. (2010). The relationship between firm performance and board characteristics in Ireland. *European management journal*, *28*(5), 387-399.

261. OECD. (1999). Principles of Corporate Governance. Available at: https://www.oecd.org/officialdocuments/publicdisplaydocumentpdf/?cote=C/MIN(99)6&docLanguage=En

262. Oei, P. Y., Hainsch, K., Löffler, K., von Hirschhausen, C. R., Holz, F., & Kemfert, C. (2019). A new climate for Europe: 2030 climate targets must be more ambitious. *DIW Weekly Report*, *9*(40/41), 365-372.

263. Ollikainen, M. (2014). Forestry in bioeconomy – smart green growth for the humankind, *Scandinavian Journal of Forest Research*, *29*(4), 360-366.

264. Orsini, A., & Cobut, L. (2020). Global environmental complexity and the limits of the EU's external regulatory actorness. In *Supranational Governance at Stake* (pp. 130-144). Routledge.

265. Orsini, A., & Kavvatha, E. (Eds.). (2020). *EU environmental governance: Current and future challenges*. Routledge.

266. Ostertagova, E., Ostertag, O., & Kováč, J. (2014). Methodology and application of the Kruskal-Wallis test. In *Applied mechanics and materials* (Vol. 611, pp. 115-120). Trans Tech Publications Ltd.

267. Osti, G. (2012). Green social cooperatives in Italy: a practical way to cover the three pillars of sustainability?. *Sustainability: Science, Practice and Policy, 8*(1), 82-93.

268. Ott, K. (2003). The case for strong sustainability. Greifswald's environmental ethics, 59-64.

269. Paehlke, R. (2001). Environmental politics, sustainability and social science. *Environmental Politics*, *10*(4), 1-22.

270. Pandey, D., Agrawal, M., & Pandey, J. S. (2011). Carbon footprint: current methods of estimation. *Environmental monitoring and assessment, 178*(1), 135-160.

271. Park, H. M. (2011). Practical guides to panel data modeling: a step-by-step analysis using stata. *Public Management and Policy Analysis Program, Graduate School of International Relations, International University of Japan*, *12*, 1-52.

272. Park, Y. S., Konge, L., & Artino, A. R. (2020). The positivism paradigm of research. *Academic Medicine, 95*(5), 690-694.

273. Patel, A. & Robinson, T. (2021). The EU Green Deal explained. https://www.nortonrosefulbright.com/en/knowledge/publications/c50c4cd9/the-eu-green-deal-explained

274. Patton, M. Q. (2002). Qualitative research and evaluation methods. Thousand Oaks. *Cal.: Sage Publications, 4*.

275. Pearce, D. W., & Turner, R. K. (1990). *Economics of natural resources and the environment*. Johns Hopkins University Press.

276. Penrose, E. T. (1968) The Large International Firm in Developing Countries: The International Petroleum Industry. *The Economic Journal,* 79 (314), 387–388.

277. Phillips, P. C., & Perron, P. (1988). Testing for a unit root in time series regression. *Biometrika*, *75*(2), 335-346.

278. Plattner, G. K., Knutti, R., Joos, F., Stocker, T. F., von Bloh, W., Brovkin, V., Cameron,

D., Driesschaert, E., Dutkiewicz, S., Eby, M., Edwards, N. R., Fichefet, T., Hargreaves, J. C., Jones, C D., Loutre, M. F., Matthews, H. D., Mouchet, A., Müller, S. A., Nawrath, S., Price, A., Sokolov, A., Strassmann, K. M. & Weaver, A. J. (2008). Long-term climate commitments projected with climate-carbon cycle models. *Journal of Climate, 21*(12), 2721-2751.

279. Ponnu, C. H. (2008). Corporate governance structures and the performance of Malaysian public listed companies. *International Review of Business Research Papers*, *4*(2), 217-230.
280. Pope, J., Annandale, D., & Morrison-Saunders, A. (2004). Conceptualising sustainability assessment. *Environmental impact assessment review*, *24*(6), 595-616.
281. Prado-Lorenzo, J. M., Rodríguez-Domínguez, L., Gallego-Álvarez, I., & García-Sánchez, I. M. (2009). Factors influencing the disclosure of greenhouse gas emissions in companies world-wide. *Management Decision*.
282. Purvis, B., Mao, Y., & Robinson, D. (2019). Three pillars of sustainability: in search of conceptual origins. *Sustainability science*, *14*(3), 681-695.
283. Refinitiv. (2021). Refinitiv ESG carbon data and estimate models. https://www.refinitiv.com/content/dam/marketing/en_us/documents/fact-sheets/esg-carbon-data-estimate-models-fact-sheet.pdf
284. Refinitiv. (2022). Environmental, social and governance scores from Refinitiv. https://www.refinitiv.com/content/dam/marketing/en_us/documents/methodology/refinitiv-esg-scores-methodology.pdf
285. Ricciolini, E., Rocchi, L., Cardinali, M., Paolotti, L., Ruiz, F., Cabello, J. M., & Boggia, A. (2022). Assessing progress towards SDGs implementation using multiple reference point based multicriteria methods: The case study of the European countries. *Social Indicators Research*, *162*(3), 1233-1260.
286. Robèrt, K. H., Schmidt-Bleek, B., De Larderel, J. A., Basile, G., Jansen, J. L., Kuehr, R., Thomas, P.P., Suzuki, M., Hawken, P. & Wackernagel, M. (2002). Strategic sustainable development—selection, design and synergies of applied tools. *Journal of Cleaner production*, *10*(3), 197-214.
287. Rockström, J., Steffen, W., Noone, K., Persson, Å., Chapin, F. S., Lambin, E. F., Lenton, t. M., Scheffer, M., Folke, C., Schellnhuber, H. J., Nykvist, B., de Wit, C. A., Hughes, T., van der Leeuw, S., Rodhe, H., Sörlin, S., Snyder, P. K., Costanza, R., Svedin, U., Falkenmark, M., Karlberg, L., Corell, R. W., Fabry, V. J., Hansen, J., Walker, B., Liverman, D., Richardson, K., Crutzen, P. & Foley, J. A. (2009). A safe operating space for humanity. *Nature*, *461*(7263), 472-475.
288. Rodhe, H., Charlson, R., & Crawford, E. (1997). Svante Arrhenius and the greenhouse effect. *Ambio, 23*(1), p. 2-5.
289. Rodriguez Lopez, J. M., Engels, A., & Knoll, L. (2017). Understanding carbon trading: Effects of delegating CO2 responsibility on organizations' trading behaviour. *Climate Policy, 17*(3), 346-360.
290. Rodríguez-Serrano, I., Caldés, N., De La Rúa, C., Lechón, Y., and Garrido, A. (2017). Using the Framework for Integrated Sustainability Assessment (FISA) to expand the Multiregional Input–Output analysis to account for the three pillars of sustainability. Environment, *Development and Sustainability*, *19*(5), 1981-1997.
291. Roome, N. (2011). Looking back, thinking forward: Distinguishing between weak and strong sustainability.

292. Rosen, M. A. (2012). Engineering sustainability: A technical approach to sustainability. *Sustainability, 4*(9), 2270-2292.
293. Sáez-Martínez, F. J., Díaz-García, C., & González-Moreno, Á. (2016). Factors promoting environmental responsibility in European SMEs: The effect on performance. *Sustainability*, *8*(9), 898.
294. Sampson, A. (1975) The Seven Sisters: The Great Oil Companies and the World They Made, London: Hodder and Stoughton.
295. San Ong, T., Teh, B. H., & Ang, Y. W. (2014). The impact of environmental improvements on the financial performance of leading companies listed in Bursa Malaysia. *International Journal of Trade, Economics and Finance*, *5*(5), 386.
296. Santeramo, F. G. (2022). Circular and green economy: the state-of-the-art. *Heliyon*, e09297.
297. Sattarhoff, C., and Gronwald, M. (2018). How to Measure Financial Market Efficiency? A Multifractality-Based Quantitative Approach with an Application to the European Carbon Market.
298. Saunders, M., Lewis, P., & Thornhill, A. (2009). *Research methods for business students*. Pearson education.
299. Schleich, J., & Betz, R. (2004). EU emissions trading and transaction costs for small and medium sized companies. *Intereconomics, 39*(3), 121-123.
300. Schleich, J., Lehmann, S., Cludius, J., Abrell, J., Betz, R. A., & Pinkse, J. (2020). *Active or passive? Companies' use of the EU ETS* (No. S07/2020). Working Paper Sustainability and Innovation.
301. Schoolman, E. D., Guest, J. S., Bush, K. F., & Bell, A. R. (2012). How interdisciplinary is sustainability research? Analyzing the structure of an emerging scientific field. *Sustainability Science*, *7*(1), 67-80.
302. Schwandt, T., Ofir, Z., Lucks, D., El-Saddick, K., and D'Errico, S. (2016). Evaluation: A crucial ingredient for SDG success. https://pubs.iied.org/sites/default/files/pdfs/migrate/17357IIED.pdf
303. Scientists for Future. (2019). The Concerns of the Young Protesters Are Justified: A Statement by Scientists for Future Concerning the Protests for More Climate Protection. *Gaia*, *28*(2), 79-79.
304. Scotland, J. (2012). Exploring the philosophical underpinnings of research: Relating ontology and epistemology to the methodology and methods of the scientific, interpretive, and critical research paradigms. *English language teaching*, *5*(9), 9-16.
305. SDG Tracker (n.d.) Measuring progress towards the Sustainable Development Goals https://sdg-tracker.org
306. Selin, H., & VanDeveer, S. D. (2015). *European Union and environmental governance*. Routledge.
307. Semenova, N., & Hassel, L. G. (2015). On the validity of environmental performance metrics. *Journal of Business Ethics*, *132*(2), 249-258.
308. Sharma, S., & Vredenburg, H. (1998). Proactive corporate environmental strategy and the development of competitively valuable organizational capabilities. *Strategic management journal*, *19*(8), 729-753.
309. Sierra-Escalante, K., & Lauridsen, M. L. (2018). Blended Finance: A Stepping Stone to Creating Markets.

310. Sikdar, S. K. (2003). Sustainable development and sustainability metrics. *AIChE journal, 49*(8), 1928-1932.
311. Sikora, A. (2021). European Green Deal–legal and financial challenges of the climate change. In *Era Forum* (Vol. 21, No. 4, pp. 681-697). Springer Berlin Heidelberg.
312. Smith, M.S., Cook, C., Sokona, Y., Elmqvist, T., Fukushi, K., Broadgate, W. & Jarzebski, M.P., (2018). Advancing sustainability science for the SDGs. *Sustainability Science, 13*, 1483e1487.
313. Solomon, S., Daniel, J. S., Sanford, T. J., Murphy, D. M., Plattner, G. K., Knutti, R., & Friedlingstein, P. (2010). Persistence of climate changes due to a range of greenhouse gases. *Proceedings of the National Academy of Sciences, 107*(43), 18354- 18359
314. Solomon, S., Plattner, G. K., Knutti, R., & Friedlingstein, P. (2009). Irreversible climate change due to carbon dioxide emissions. *Proceedings of the national academy of sciences, 106*(6), 1704-1709.
315. Stavins, R. N. (2003). Experience with market-based environmental policy instruments. In *Handbook of environmental economics* (Vol. 1, pp. 355-435). Elsevier.
316. Steffen, W., Sanderson, R. A., Tyson, P. D., Jäger, J., Matson, P. A., Moore III, B., Oldfield, F., Richardson, K., Schellnhuber, H. J., Turner, B. L. & Wasson, R. J. (2006). *Global change and the earth system: a planet under pressure.* Springer Science & Business Media.
317. Stern, N. (2007). *The Economics of Climate Change: The Stern Review*. Cambridge, UK: Cambridge University Press.
318. Stevens, C. (2010). Linking sustainable consumption and production: The government role. In *Natural resources forum* (Vol. 34, No. 1, pp. 16-23). Oxford, UK: Blackwell Publishing Ltd.
319. Stevens, P. (2013). History of the international oil industry. *Global resources: Conflict and cooperation*, 13-32.
320. Stigson, B. (1998). Sustainability in an era of globalisation: the business response (pp. 59-64). Paris: OECD.
321. Stirling, A. (1999). The appraisal of sustainability: some problems and possible responses. *Local Environment, 4*(2), 111-135.
322. Stocking, G. W. (1971). Middle East Oil. A Study in Political and Economic Controversy. *VRÜ Verfassung und Recht in Übersee, 4*(4), 513-514..
323. Struik, D. J. (2022). *Joseph Fourier*. *Encyclopedia Britannica*. https://www.britannica.com/biography/Joseph-Baron-Fourier
324. Székács, A. (2017). Environmental and ecological aspects in the overall assessment of bioeconomy. *Journal of Agricultural and Environmental Ethics, 30*(1), 153-170.
325. Takalo, S. K., Tooranloo, H. S., & Shahabaldini Parizi, Z. (2021). Green innovation: A systematic literature review. *Journal of Cleaner Production, 279*, 122474.
326. Tanguay, G. A., Rajaonson, J., Lefebvre, J. F., & Lanoie, P. (2010). Measuring the sustainability of cities: An analysis of the use of local indicators. *Ecological indicators, 10*(2), 407-418.
327. Tarmuji, I., Maelah, R., & Tarmuji, N. H. (2016). The impact of environmental, social and governance practices (ESG) on economic performance: Evidence from ESG score. *International Journal of Trade, Economics and Finance, 7*(3), 67.

328. Termeer, C. J., Dewulf, A., & Van Lieshout, M. (2010). Disentangling scale approaches in governance research: comparing monocentric, multilevel, and adaptive governance. *Ecology and society*, *15*(4).
329. The Australian Academy of Science (n.d.) *What is climate change*. https://www.science.org.au/learning/general-audience/science-climate-change/1-what-is-climate-change
330. The Conference Board. (2022). Report: Gap in Climate Disclosures Between Large, Small Cos Stark Gap in Climate Disclosures Exists Between Large & Small Public Companies. https://www.conference-board.org/press/climate-disclosures-gap
331. The Global Goals. (n. d.) Goal 13 – Climate action. Take Urgent Action to Combat Climate Change and its Impacts https://www.globalgoals.org/goals/13-climate-action/
332. Trauffler, G. (2019). The EU Carbon Trading System. Available at: https://fedil-echo.lu/focus/eu-carbon-trading-system/
333. Tuerk, A. & Zelljadt, E. (2016): "The global rise of emissions trading". Climate Policy Info Hub. http://climatepolicyinfohub.eu/global-rise-emissions-trading
334. Tuerk, A., Mehling, M., Klinsky, S., & Wang, X. (2013). Emerging carbon markets: Experiences, trends, and challenges. Climate Strategies.
335. Turban, D. B., & Greening, D. W. (1997). Corporate social performance and organizational attractiveness to prospective employees. *Academy of management journal*, *40*(3), 658-672.
336. UN (2012), "The future We want", Outcome document of the United Nations Conference on Sustainable Development, Rio de Janeiro, Brazil, New York, NY https://www.un.org/ga/search/view_doc.asp?symbol=A/RES/66/288andLang=E
337. UN (2017) Resolution adopted by the General Assembly on 6 July 2017, Work of the Statistical Commission pertaining to the 2030 Agenda for Sustainable Development (A/RES/71/313) https://ggim.un.org/documents/a_res_71_313.pdf
338. UN DESA. (2015). Transforming our world: The 2030 agenda for sustainable development. https://sdgs.un.org/sites/default/files/publications/21252030%20Agenda%20for%20Sustainable%20Development%20web.pdf
339. UN DESA. (2021) The Sustainable Development Goals Report: 2021
340. UN DESA. (2021). SDG indicator metadata: Goal 13. https://unstats.un.org/sdgs/metadata/files/Metadata-13-02-02.pdf
341. UN DESA. (2022). SDG indicator metadata: Goal 9. https://unstats.un.org/sdgs/metadata/files/Metadata-09-04-01.pdf
342. UN DESA. (n. d. a.), Sustainable Development Goals 11: Make cities and human settlements inclusive, safe, resilient and sustainable. https://sdgs.un.org/goals/goal11
343. UN DESA. (n. d. b) Sustainable Development Goals 13: Take urgent action to combat climate change and its impacts. https://sdgs.un.org/goals/goal13
344. UN DESA. (n. d. c). SDG Indicators. https://unstats.un.org/sdgs/indicators/indicators-list/
345. UN DESA. (n. d. d). Global indicator framework for the Sustainable Development Goals and targets of the 2030 Agenda for Sustainable Development. https://unstats.un.org/sdgs/indicators/Global%20Indicator%20Framework%20after%202022%20refinement_Eng.pdf

346. UN Global Compact (n. d.) How your company can advance each of the SDGs. https://www.unglobalcompact.org/sdgs/about
347. UN Office for Sustainable Development. (n.d.). Sustainable Development Goals. https://unosd.un.org/content/sustainable-development-goals-sdgs
348. UN Statistical Commission. 2017. Report on the forty-eighth session (7 – 10 March 2017). Economic and Social Council, Official Records 2017 – Supplement No. 4, E/2017/24-E/CN.3/2017/35. https://undocs.org/pdf? symbol=en/E/2017/24.
349. UNDP. (2016). From the MDGs to sustainable development for all: lessons from 15 years of practice. *United Nations Development Programme*, 92.
350. UNEP. (2011a). Towards a Green economy Pathways to Sustainable Development and Poverty Eradication. https://www.cbd.int/financial/doc/green_economyreport2011.pdf
351. UNEP. (2017). Introduction to Environmental Governance. https://globalpact.informea.org/sites/default/files/documents/International%20Environmental%20Governance.pdf
352. UNEP. (n. d.). *Environmental Governance.* https://www.unep.org/regions/west-asia/regional-initiatives/environmental-governance
353. UNEP. International Resource Panel, United Nations Environment Programme. Sustainable Consumption, & Production Branch. (2011b). *Decoupling natural resource use and environmental impacts from economic growth*. UNEP/Earthprint.
354. UNFCCC (n.d. a) History of the Convention. https://unfccc.int/process/the-convention/history-of-the-convention#eq-1
355. UNFCCC (n.d. b) What is the Kyoto Protocol? https://unfccc.int/kyoto_protocol
356. UNFCCC (n.d. c) Emissions Trading https://unfccc.int/process/the-kyoto-protocol/mechanisms/emissions-trading
357. UNFCCC, (1997). Kyoto Protocol, https://unfccc.int/sites/default/files/resource/docs/cop3/l07a01.pdf
358. UNFCCC, (2009). *Kyoto protocol reference manual on accounting of emissions and assigned amount*. eSocialSciences.
359. UNFCCC, (2015). Paris Agreement, https://unfccc.int/sites/default/files/english_paris_agreement.pdf
360. United Nations (n.d.) *What is climate change*. https://www.un.org/en/climatechange/what-is-climate-change
361. United Nations Development Group (2017). Guidelines to support country reporting on the Sustainable Development Goals. https://unsdg.un.org/sites/default/files/Guidelines-to-Support-Country-Reporting-on-SDGs-1.pdf
362. United Nations Economic and Social Council (2018) Progress towards the Sustainable Development Goals Report of the Secretary-General. https://digitallibrary.un.org/js/pdfjs-2.9.359/web/pdf_viewer.html?file=https%3A%2F%2Fdigitallibrary.un.org%2Frecord%2F1627573%2Ffiles%2FE_2018_64-EN.pdf%3Fregister_download%3D0andchunksize=65536#pagemode=thumbs
363. United Nations Economic Commission for Europe. (2020). Measuring and Monitoring progress towards the Sustainable Development Goals. https://unece.org/sites/default/files/2021-04/2012761_E_web.pdf
364. United Nations Environment Programme, Frankfurt School of Finance and Management, & BloombergNEF (2020). Global Trends in Renewable Energy Investment 2020. https://wedocs.unep.org/20.500.11822/32700.

365. United Nations Treaty Collection (n. d. a) Kyoto Protocol to the United Nations Framework Convention on Climate Change https://treaties.un.org/doc/Publication/MTDSG/Volume%20II/Chapter%20XXVII/XXVII-7-a.en.pdf
366. United Nations Treaty Collection (n. d. b) Paris Agreement https://treaties.un.org/doc/Publication/MTDSG/Volume%20II/Chapter%20XXVII/XXVII-7-d.en.pdf
367. United Nations. (1999). Standard Country or Area Codes for Statistics Use, 1999 (Revision 4).
368. UNSD (n.d.) SDG Indicators - Global indicator framework for the Sustainable Development Goals and targets of the 2030 Agenda for Sustainable Development https://unstats.un.org/sdgs/indicators/indicators-list/
369. US EPA, (2021), Basic Ozone Layer Science. https://www.epa.gov/ozone-layer-protection/basic-ozone-layer-science
370. Van Cauwenbergh, N., Biala, K., Bielders, C., Brouckaert, V., Franchois, L., Cidad, V. G., Hermy, M., Mathijs, E., Muys, B., Reijnders, J. and Sauvenier, X. (2007). SAFE—A hierarchical framework for assessing the sustainability of agricultural systems. *Agriculture, ecosystems & environment*, *120*(2-4), 229-242.
371. van den Breul, L., Haar, R. J., Korver, J., Kostense-Smit, E., Muller, J., Olivier, J., Sonneveld, H. & van der Valk, M. (2018). Sustainable Development Goals A business perspective. *Deloitte*.
372. Van Zon, H., & Kuipers, K. (2002). Geschiedenis & duurzame ontwikkeling: duurzame ontwikkeling in historisch perspectief: enkele verkenningen. Netwerk Duurzaam Hoger Onderwijs.
373. Varpio, L., & MacLeod, A. (2020). Philosophy of science series: harnessing the multidisciplinary edge effect by exploring paradigms, ontologies, epistemologies, axiologies, and methodologies. *Academic Medicine*, *95*(5), 686-689.
374. Vavrik, U. A. (2021). EU Perspectives on Sustainable Development: Aligning the EU Budget to the UN SDGs by 2030. *Current Global Practices of Corporate Social Responsibility: In the Era of Sustainable Development Goals*, 841-864.
375. Viederman, S. (1994). Five capitals and three pillars of sustainability. *The Newsletter of PEGS*, *4*(1), 5-12.
376. von Braun, J. (2014). Bioeconomy and sustainable development–dimensions. *Rural*, *21*(2), 6-9.
377. Waas, T., Hugé, J., Verbruggen, A., & Wright, T. (2011). Sustainable development: a bird's eye view. *Sustainability*, *3*(10), 1637-1661.
378. Wackernagel, M., Hanscom, L., Jayasinghe, P., Lin, D., Murthy, A., Neill, E., & Raven, P. (2021). The importance of resource security for poverty eradication. Nature *Sustainability*, *4*(8), 731-738.
379. Wagner, M. (2010). The role of corporate sustainability performance for economic performance: A firm-level analysis of moderation effects. *Ecological economics*, *69*(7), 1553-1560.
380. Wagner, M., & Schaltegger, S. (2004). The effect of corporate environmental strategy choice and environmental performance on competitiveness and economic performance: an empirical study of EU manufacturing. *European management journal*, *22*(5), 557-572.

381. Wahyuningrum, I. F. S., Djajadikerta, H., & Suprapti, E. (2019). The effect of company financial performance and company characteristics on Greenhouse Gas (GHG) Emission Disclosure.
382. Watt, R. (2018). A crash in value: explaining the decline of the clean development mechanism. In *Valuing Development, Environment and Conservation* (pp. 145-161). Routledge.
383. WCED. (1987). Our common future. Oxford: Oxford University Press. https://portals.iucn.org/library/efiles/documents/wcs-004.pdf
384. Weart, S. R. (2003). *The discovery of global warming*. Harvard University Press.
385. Werksman, J. 1998. The clean development mechanism: unwrapping the 'Kyoto Surprise'. *Review of European Community and International Environmental Law* 7: 147–58.
386. WHO. (2019). 1 in 3 people globally do not have access to safe drinking water – UNICEF, WHO. https://www.who.int/news/item/18-06-2019-1-in-3-people-globally-do-not-have-access-to-safe-drinking-water-unicef-who
387. Wood, D. J. (1991). Corporate social performance revisited. *Academy of management review*, *16*(4), 691-718.
388. Woodrow, L. (2014). Anova, ancova and manova. In *Writing about quantitative research in applied linguistics* (pp. 73-84). Palgrave Macmillan, London.
389. World Wildlife Fund, Zoological Society of London, Global Footprint Network & European Space Agency. (2012). Living planet report 2012: biodiversity, biocapacity and better choices. *Gland: WWF International*.
390. Wuebbles, D. J., & Jain, A. K. (2001). Concerns about climate change and the role of fossil fuel use. *Fuel processing technology, 71*(1-3), 99-119.
391. Wurzel, R. K., Connelly, J., & Liefferink, D. (Eds.). (2016). *The European Union in international climate change politics: Still taking a lead?* (Vol. 1). Taylor & Francis.
392. Yang, X., Liao, H., Feng, X., & Yao, X. (2018). Analysis and tests on weak-form efficiency of the EU carbon emission trading market. *Low Carbon Economy*, *9*(01), 1.
393. Yergin, D. (1991) *The Prize: The Epic Quest for Oil, Money and Power*. Simon and Schuster.
394. Yin, R. K. (2018) *Case Study Research: Design and Methods* (Vol 5.). Sage.
395. Yougova, D. (2021a). Climate action in Estonia: Latest state of play. Climate Action Research and Tracking Service, Members' Research Service, PE 690.684
396. Yougova, D. (2021b). Climate action in France: Latest state of play. Climate Action Research and Tracking Service, Members' Research Service, PE 690.686
397. Yougova, D. (2021c). Climate action in Bulgaria: Latest state of play. Climate Action Research and Tracking Service, Members' Research Service, PE 689.330
398. Yuan, Z., Bi, J., & Moriguichi, Y. (2006). The circular economy: A new development strategy in China. *Journal of industrial ecology*, *10*(1-2), 4-8.
399. Zijp, M. C., Heijungs, R., Van der Voet, E., Van de Meent, D., Huijbregts, M. A., Hollander, A., & Posthuma, L. (2015). An identification key for selecting methods for sustainability assessments. *Sustainability*, *7*(3), 2490-2512.
400. Zuraida, Z., Houqe, M. N., & Van Zijl, T. (2018). Value relevance of environmental, social and governance disclosure. In *Research handbook of finance and sustainability* (pp. 458-483). Edward Elgar Publishing.

List of Tables

List of Figures

Appendices

Appendix 1 Number of businesses per year and country

Country	Year				
	2020	2019	2018	2017	2016
Austria	36	34	30	18	16
Belgium	49	49	45	29	26
Cyprus	14	11	4	2	2
Czechia	3	3	3	3	3
Denmark	63	48	40	29	26
Finland	80	42	34	26	24
France	172	145	137	100	88
Germany	266	179	159	104	84
Greece	29	28	25	20	16
Hungary	6	5	5	4	4
Ireland	49	46	43	35	35
Italy	129	95	89	52	41
Luxembourg	39	31	24	17	13
Malta	9	5	5	2	2
Netherlands	72	65	60	40	38
Poland	40	39	40	31	29
Portugal	14	14	14	9	8
Romania	3	2	2	2	0
Slovenia	1	1	1	1	0
Spain	68	67	65	45	40
Sweden	315	1631	120	65	60

Appendix 2 Industry sub-categories

Industry group	Sub-categories
Energy	Fossil fuels Renewable energy Uranium
Basic materials	Chemicals Mineral resources Applied resources
Industrials	Industrial goods Industrial and commercial services Transportation
Consumer cyclicals	Automobiles and auto parts Cyclical consumer products Cyclical consumer services Retailers
Consumer non-cyclicals	Food and beverages Personal and household products and services Food and drug retailing Consumer goods conglomerates
Financials	Banking and investment services Insurance Collective investments Investment holding companies
Healthcare	Healthcare services and equipment Pharmaceuticals and medical research
Technology	Technology equipment Software and IT services Financial technology (Fintech) and infrastructure Telecommunications services
Utilities	Electric utilities and IPPS Natural gas utilities Water and related utilities Multiline utilities
Real estate	Real Estate operations Residential and commercial REITs
Institutions, associations and organizations	
Government activity	
Academic and educational services	Academic and educational services

Appendix 3 AIC for EUA Futures 2012 and EUA Futures 2020

	EUA Futures 2012			
Lag	LogL	LR	FPE	AIC
0	-2984.043	NA	0.431686	4.835696
1	3275.807	12489.29	1.72e-05	-5.295235
2	3285.479	19.26448	1.70e-05	-5.304419
3	3290.478	9.940442	1.70e-05	-5.306037
4	3293.017	5.042723	1.70e-05	-5.303672
5	3298.507	10.88146*	1.70e-05*	-5.306084*
6	3300.847	4.4630623	1.71e-05	-5.303396
7	3303.195	4.638534	1.71e-05	-5.300720
8	3305.710	4.962174	1.71e-05	-5.298317

	EUA Futures 2020			
Lag	LogL	LR	FPE	AIC
0	-3172.563	NA	0.054125	2.759290
1	4898.286	16120.65	4.88e-05	-4.4252313
2	4908.084	19.55244	4.85e-05	-4.257352
3	4916.616	17.01168	4.83e-05	-4.261291
4	4928.801	24.27509	4.80e-05	-4.268406
5	4937.068	16.45461	4.78e-05	-4.272115
6	4942.797	11.39413	4.78e-05	-4.273618
7	4950.116	14.54132*	4.76e-05*	-4.276502*
8	4951.334	2.418794	4.77e-05	-4.274084

* Indicates lag order by the criterion

- LR: sequential modified LR test statistics (each test at 5% level)
- FPE: Final prediction error
- AIC: Akaike information criterion

Appendix 4 Reported variables per year

	Year					
	2020	2019	2018	2017	2016	Excluded variable
Resource Use	3	383	512	823	902	
Resource Reduction Policy	3	385	512	823	902	
Policy Water Efficiency	505	570	656	892	1036	
Policy Energy Efficiency	235	449	564	845	941	
Policy Sustainable Packaging	756	678	767	945	1145	
Policy Environmental Supply Chain	368	496	603	859	975	
Resource Reduction Targets	3	385	512	823	902	
Targets Water Efficiency	825	703	774	954	1146	
Targets Energy Efficiency	707	635	720	915	1079	
Environment Management Team	582	577	681	896	1026	
Environment Management Training	484	546	662	879	1005	
Environmental Materials Sourcing	585	586	675	885	1023	
Toxic Chemicals Reduction	788	694	764	947	1150	
Total Energy Use Million in Revenue usd	552	694	779	962	1036	
Energy Use Total	547	692	776	960	1034	
Energy Purchased Direct	582	720	805	979	1047	
Energy Produced Direct	1176	1222	1250	1312	1340	
Indirect Energy Use	1438	1438	1442	1446	1443	Indirect Energy Use
Electricity Purchased	695	820	892	1041	1105	
Electricity Produced	1193	1241	1266	1323	1351	

Grid Loss Percentage	1450	1451	1456	1457	1457	Grid Loss Percentage
Renewable Energy Use Ratio	1081	1139	1190	1263	1301	
Renewable Energy Supply	1420	1424	1424	1428	1444	
Total Renewable Energy To Energy Use in million	930	1007	1078	1194	1389	
Total Renewable Energy	887	978	1051	1176	1370	
Renewable Energy Purchased	1034	1105	1156	1245	1281	
Renewable Energy Produced	1210	1246	1278	1330	1357	
Renewable Energy Use	385	512	630	867	974	
Cement Energy Use	1453	1453	1453	1454	1454	Cement Energy Use
Coal Produced Raw Material in Tonnes Total	1452	1452	1452	1452	1452	Coal Produced Raw Material in Tonnes Total
Green Buildings	741	657	748	926	1092	
Total Water Use Million in Revenue usd	772	848	916	1041	1094	
Water Withdrawal Total	768	847	916	1040	1094	
Fresh Water Withdrawal Total	933	997	1044	1129	1173	
Water Recycled	1385	1379	1386	1404	1409	
Environmental Supply Chain Management	423	514	611	857	974	
Environmental Supply Chain Monitoring	784	880	956	1089	1144	
Env Supply Chain Partnership Termination	718	639	728	922	1095	
Land Environmental Impact Reduction	910	748	795	963	1180	
Emissions Weight	3	383	512	823	902	
Policy Emissions	242	461	582	856	962	
Targets Emissions	527	583	696	904	1043	
Emission Reduction Target Percentage	855	1005	1115	1273	1456	

Emission Reduction Target Year	812	951	1076	1249	1457	
Biodiversity Impact Reduction	699	659	721	926	1086	
Estimated CO2 Equivalents Emission Total	0	385	512	823	902	
CO2 Estimation Method	0	385	512	823	902	
Total CO2 Emissions Million in Revenue USD	484	653	762	960	1031	
CO2 Equivalent Emissions Total	483	653	761	960	1029	
CO2 Equivalent Emissions Direct Scope 1	586	730	837	1005	1080	
CO2 Equivalent Emissions Indirect Scope 2	584	725	838	1014	1086	
CO2 Equivalent Emissions Indirect Scope 3 To Revenues USD in million	828	934	1041	1135	1187	
CO2 Equivalent Emissions Indirect Scope 3	822	933	1040	1137	1189	
Carbon Offsets Credits	1388	1399	1413	1423	1426	Carbon Offsets Credits
Emissions Trading	836	712	773	951	1136	
Cement CO2 Equivalents Emission	1452	1452	1452	1454	1454	Cement CO a Equivalents Emission
Climate Change Commercial Risks Opportunities	472	559	683	895	1029	
Flaring Gases To Revenues USD in million	1450	1452	1452	1451	1451	Flaring Gases To Revenues USD in million
Flaring Gases	1447	1450	1450	1449	1449	Flaring Gases
Ozone-Depleting Substances To Revenues USD in million	1433	1434	1433	1436	1437	Ozone-Depleting Substances To Revenues USD in million
Ozone-Depleting Substances	1406	1407	1407	1415	1418	Ozone-Depleting Substances
NOx and SOx Emissions Reduction	855	717	777	955	1150	
NOx Emissions To Revenues USD in million	1239	1252	1269	1303	1312	NOx Emissions To Revenues USD in million
NOx Emissions	1226	1242	1260	1293	1304	NOx Emissions
SOx Emissions To Revenues USD in million	1265	1273	1289	1318	1328	SOx Emissions To Revenues USD in million

SOx Emissions	1252	1263	1280	1307	1317	SOx Emissions
VOC or Particulate Matter Emissions Reduction	711	900	959	1123	1159	
VOC Emissions Reduction	882	732	789	956	1175	
Particulate Matter Emissions Reduction	901	741	798	962	1181	
VOC Emissions To Revenues USD in million	1352	1357	1367	1379	1385	VOC Emissions To Revenues USD in million
VOC Emissions	1327	1334	1348	1362	1369	VOC Emissions
Total Waste Million in Revenue usd	792	895	948	1069	1112	
Waste Recycled To Total Waste	920	995	1042	1140	1173	
Total Hazardous Waste Million in Revenue usd	923	1004	1053	1152	1180	
Waste Total	787	894	947	1069	1112	
Non-Hazardous Waste	921	1004	1054	1149	1181	
Waste Recycled Total	924	993	1043	1134	1175	
Waste Recycling Ratio	917	995	1042	1141	1175	
Hazardous Waste	920	1004	1053	1152	1181	
Waste Reduction Initiatives	241	468	587	862	969	
Waste Reduction	744	661	738	931	1127	
Total Water Pollutant Emissions Million in Revenue	1386	1389	1392	1402	1405	Total Water Pollutant Emissions Million in Revenue
Water Discharged	1242	1259	1276	1321	1331	Water Discharged
Water Pollutant Emissions	1376	1380	1384	1390	1395	Water Pollutant Emissions
ISO 14000 or EMS	0	385	512	823	902	
EMS Certified Percent	1067	1114	1151	1228	1258	EMS Certified Percent
Environmental Restoration Initiatives	765	685	766	945	1130	
Staff Transportation Impact Reduction	615	611	708	913	1080	

Accidental Spills To Revenues USD in million	1433	1436	1437	1437	1441	Accidental Spills To Revenues USD in million
Accidental Spills	1412	1418	1419	1424	1430	Accidental Spills
Environmental Expenditures Investments	305	565	654	911	971	
Environmental Expenditures	1275	1270	1273	1289	1293	
Environmental Provisions	1308	1317	1317	1318	1318	Environmental Provisions
Environmental Investments Initiatives	783	677	756	938	1127	
Self-Reported Environmental Fines To Revenues in million	1274	1300	1322	1343	1352	Self-Reported Environmental Fines To Revenues in million
Self-Reported Environmental Fines	1258	1286	1310	1333	1342	Self-Reported Environmental Fines
Environmental Partnerships	652	601	696	896	1033	
Internal Carbon Pricing	915	746	808	970	1210	
Internal Carbon Price per Tonne	1422	1434	1442	1446	1457	Internal Carbon Price per Tonne
Policy Nuclear Safety	942	759	829	1000	1234	
Emissions Target Type	1413	1455	1457	1457	1457	Emissions Target Type
GHG Emission Method	1356	1456	1457	1457	1457	GHG Emission Method
Emissions Target Annual Reduction	1453	1457	1457	1457	1457	
Fleet CO2 per Passenger Kilometer	1455	1457	1457	1457	1457	Fleet CO2 per Passenger Kilometer
Carbon Intensity per Energy Produced	1457	1457	1457	1457	1457	Carbon Intensity per Energy Produced
Carbon Intensity per Clinker Produced	1457	1457	1457	1457	1457	Carbon Intensity per Clinker Produced
Upstream scope 3 emissions Purchased goods and services	1417	1450	1456	1457	1457	Upstream scope 3 emissions Purchased goods and services
Upstream scope 3 emissions Capital goods	1441	1455	1456	1457	1457	Upstream scope 3 emissions Capital goods
Upstream scope 3 emissions Fuel- and Energy-related Activities	1427	1449	1455	1457	1457	Upstream scope 3 emissions Fuel- and Energy-related Activities

Upstream scope 3 emissions Transportation and Distribution	1432	1451	1456	1457	1457	Upstream scope 3 emissions Transportation and Distribution
Upstream scope 3 emissions Waste Generated in Operations	1425	1449	1455	1456	1457	Upstream scope 3 emissions Waste Generated in Operations
Upstream scope 3 emissions Business Travel	1408	1445	1454	1456	1457	Upstream scope 3 emissions Business Travel
Upstream scope 3 emissions Employee Commuting	1433	1450	1454	1456	1457	Upstream scope 3 emissions Employee Commuting
Upstream scope 3 emissions Leased Assets	1452	1454	1456	1457	1457	Upstream scope 3 emissions Leased Assets
Downstream scope 3 emissions Transportation and Distribution	1441	1453	1456	1457	1457	Downstream scope 3 emissions Transportation and Distribution
Downstream scope 3 emissions Processing of Sold Products	1455	1455	1455	1457	1457	Downstream scope 3 emissions Processing of Sold Products
Downstream scope 3 emissions Use of Sold Products	1436	1451	1456	1457	1457	Downstream scope 3 emissions Use of Sold Products
Downstream scope 3 emissions End-of-life Treatment of Sold Products	1446	1452	1456	1457	1457	Downstream scope 3 emissions End-of-life Treatment of Sold Products
Downstream scope 3 emissions Leased Assets	1453	1456	1456	1457	1457	Downstream scope 3 emissions Leased Assets
Downstream scope 3 emissions Franchises	1453	1455	1456	1457	1457	Downstream scope 3 emissions Franchises
Downstream scope 3 emissions Investments	1453	1456	1456	1457	1457	Downstream scope 3 emissions Investments
Upstream scope 3 emissions Other	1444	1455	1457	1457	1457	Upstream scope 3 emissions Other
Downstream scope 3 emissions Other	1453	1457	1456	1457	1457	Downstream scope 3 emissions Other
Innovation Weight	4	384	514	824	903	
Environmental Products	465	538	646	881	1006	
Eco-Design Products	788	704	777	955	1164	
Revenue from Environmental Products	1420	1437	1444	1451	1456	
Percentage of Green Products	1418	1423	1455	1457	1457	
Total Env R D Million in Revenue	1429	1432	1434	1441	1439	

Environmental RD Expenditures	1420	1423	1426	1433	1430	
Noise Reduction	888	740	802	962	1186	
Fleet Fuel Consumption	1453	1451	1452	1453	1452	Fleet Fuel Consumption
Hybrid Vehicles	902	747	802	969	1197	
Fleet CO2 Emissions	1449	1450	1451	1452	1451	Fleet CO2 Emissions
Environmental Assets Under Mgt	895	734	802	959	1182	
ESG Assets Under Management	1418	1418	1451	1454	1454	
Equator Principles	932	758	816	973	1207	
Equator Principles or Env Project Financing	1313	1324	1333	1361	1365	
Environmental Project Financing	879	728	795	958	1183	
Nuclear	917	750	806	966	1183	
Nuclear Production	1443	1444	1444	1445	1444	Nuclear Production
Labeled Wood Percentage	1428	1435	1439	1445	1445	Labeled Wood Percentage
Labeled Wood	910	741	803	970	1188	
Organic Products Initiatives	890	735	802	967	1191	
Product Impact Minimization	884	1088	1134	1253	1281	
Take-back and Recycling Initiatives	859	702	780	941	1153	
Products Recovered to Recycle	1430	1430	1455	1457	1456	Products Recovered to Recycle
Product Environmental Responsible Use	464	538	645	881	997	
GMO Products	925	753	812	971	1199	
Agrochemical Products	1436	1444	1444	1448	1448	Agrochemical Products
Agrochemical b perc Revenue	944	761	818	972	1208	
Animal Testing	879	740	801	967	1187	

Animal Testing Cosmetics	936	757	812	971	1203	
Animal Testing Reduction	917	750	808	970	1195	
Renewable Clean Energy Products	802	694	764	941	1128	
Water Technologies	908	740	803	964	1195	
Sustainable Building Products	901	739	797	966	1190	
Real Estate Sustainability Certifications	1357	1377	1390	1416	1422	Real Estate Sustainability Certifications
Fossil Fuel Divestment Policy	923	754	812	971	1211	

Appendix 5 Member States according to the recoded number used to conduct the analysis

Country name	Country code
Austria	AT
Belgium	BE
Bulgaria	BG
Croatia	HR
Cyprus	CY
Czechia	CZ
Denmark	DK
Estonia	EE
Finland	FI
France	FR
Germany	DE
Greece	GR
Hungary	HU
Ireland	IE
Italy	IT
Latvia	LV
Lithuania	LT
Luxembourg	LU
Malta	MT
Netherlands	NL
Poland	PL
Portugal	PT
Romania	RO
Slovakia	SK
Slovenia	SI
Spain	ES
Sweden	SE

Acknowledgement

The doctoral dissertation was supported by the Croatian Science Foundation under project IP-2020-02-1018.

A sincere thank you to Jelena Šerbić for her diligent proofreading of this dissertation.

List of Published Scientific Research Papers

Book chapter

1. Unukić, Ivana; Turjak, Sofija; Drvenkar, Nataša
   AGING AND RETIREMENT DIFFERENCES IN THE EU COUNTRIES. // Strategic Approach to Aging Population: Experiences and Challenges / Barković Bojanić, Ivana; Erceg, Aleksandar (ed.). Osijek: Ekonomski fakultet u Osijeku, 2021. pp. 179-197

Journal articles – Scientific and review papers

1. Hocenski, Mia; Sedlan Konig, Ljerka; Turjak, Sofija
   Entrepreneurial education - exploring teachers' creativity in 11 countries. // Ekonomski vjesnik, 32 (2019), 1; 23-35 (international peer review, article, scholarly)

2. Leko Šimić, Mirna; Turjak, Sofija
   Croatian students and alcohol consumption - implications for social marketing. // Ekonomska misao i praksa : časopis Sveučilista u Dubrovniku, 27 (2018), 1; 77-101 (international peer review, article, scholarly)

3. Sedlan-König, Ljerka; Hocenski, Mia; Turjak, Sofija
   GRADUATES ARE FROM VENUS, EMPLOYERS ARE FROM MARS: A CROATIAN STUDY ON EMPLOYABILITY. // Poslovna izvrsnost, 12 (2018), 2; 9-23 doi:10.22598/pi-be/2018.12.2.9 (international peer review, article, scholarly)

Conference proceedings papers – Scientific conference proceedings papers

1. Turjak, Sofija; Unukić, Ivana; Kristek, Ivan
EXPENDITURE ON ENVIRONMENTAL PROTECTION IN THE EU. // Economic and Social Development. 72nd International Scientific Conference on Economic and Social Development Development – "Digital Transformation and Business" / Zavrl, Irena; Vukovic, Dijana; Cerovic, Ljerka (ed.).Varaždin: Varazdin Development and Entrepreneurship Agency, Varazdin, Croatia / University North, Koprivnica, Croatia / Faculty of Management University of Warsaw, Warsaw, Poland / Faculty of Law, Economics and Social Sciences Sale - Mohammed V University in Rabat, Morocco, 2021. pp. 246-253 (lecture, peer review, full paper, scholarly)

2. Unukić, Ivana; Turjak, Sofija; Rašić, Juraj
THE CUSTOMER AND ENTREPRENEURIAL BEHAVIOR TOWARDS THE COLLABORATIVE ECONOMY IN THE EUROPEAN UNION. // Economic and Social Development. 72nd International Scientific Conference on Economic and Social Development Development - "Digital Transformation and Business". Book of Proceedings / Zavrl, Irena; Vukovic, Dijana; Cerovic, Ljerka (ed.). Varaždin: Varazdin Development and Entrepreneurship Agency, Varazdin, Croatia / University North, Koprivnica, Croatia / Faculty of Management University of Warsaw, Warsaw, Poland / Faculty of Law, Economics and Social Sciences Sale - Mohammed V University in Rabat, Morocco, 2021. pp. 173-185 (lecture, peer review, full paper, scholarly)

3. Bičvić, Dina; Turjak, Sofija; Unukić, Ivana
LOW-CARBON ECONOMY: PAST, PRESENT AND FUTURE IMPLICATIONS OF CARBON ACCOUNTING. // Economic and Social Development. 53rd International Scientific Conference on Economic and Social Development Development. Book of Proceedings / Klopotan, Igor ; Czako, Katalin ; Beker, Victor (ed.). Varaždin: Varazdin Development and Entrepreneurship Agency, 2020. pp. 38-48 (lecture, international peer review, full paper, scholarly)

4. Turjak, Sofija; Kristek, Ivan
TRANSITION TOWARDS LOW CARBON ECONOMY IN THE EUROPEAN UNION AND CEE COUNTRIES. // Proceedings of FEB Zagreb 11th International Odyssey Conference on Economics and Business / Šimurina, Jurica ; Načinović Braje, Ivana; Pavić, Ivana (ed.). Zagreb: Faculty of Economics & Business, 2020. pp. 247-257 (lecture, international peer review, full paper, scholarly)

5. Turjak, Sofija; Kristek, Ivan
THE IMPACT OF HOUSEHOLD ENERGY CONSUMPTION TOWARDS THE TRANSITION ON LOW-CARBON ECONOMY. // Economic and Social Development. 53rd International Scientific Conference on Economic and Social Development Development. Book of Proceedings / Klopotan, Igor ; Czako, Katalin ; Beker, Victor (ed.). Sveti Martin na Muri, 2020. pp. 295-303 (lecture, international peer review, full paper, scholarly)

6. Turjak , Sofija; Raič , Mario; Unukić , Ivana
THE IMPACT OF TAXES ON HEALTHY CONSUMER HABITS. // IMR2020, INTERDISCIPLINARY MANAGEMENT RESEARCH XVI, INTERDISZIPLINARE MANAGEMENTFORSCHUNG XVI / Barković, Dražen ; Dernoscheg, Karl Heinz; Erceg, Aleksandar; Glavaš, Jerko; Pap, Norbert ; Runzheimer, Bodo; Wentzel, Dirk (ed.). Osijek, 2020. pp. 1453-1466 (lecture, international peer review, full paper, scholarly)

7. Liović, Dina; Novaković, Dražen; Turjak, Sofija
Risk aversion as decision making factor in mental accounting phenomenon. // Proceedings of the 33rd International Business Information Management Association Conference, IBIMA 2019: Education Excellence and Innovation Management through Vision 2020 / Soliman, Khalid S. (ed.). Granada, Španjolska: International Business Information Management Association, IBIMA, 2019. pp. 8239-8249. (https://www.bib.irb.hr/1032588) (lecture, international peer review, full paper, scholarly)

8. Mandić, Bruno; Turjak, Sofija; Kuna, Tomislav
   EFFECTIVE ORGANIZATIONAL MANAGEMENT – A CASE STUDY. // INTERDISCIPLINARY MANAGEMENT RESEARCH XV / Barković, Dražen ; Crnković, Boris; Zekić Sušac, Marijana; Dernoscheg, Karl - Heinz; Pap, Norbert; Runzheimer, Bodo; Wentzel, Dirk (ed.). Osijek: Ekonomski fakultet u Osijeku, 2019. pp. 219-232 (lecture, international peer review, full paper, scholarly)

9. Rašić, Juraj; Turjak, Sofija; Unukić, Ivana
   The development potentials of "green" Croatia on the example of SMEs - the state and the perspectives. // MODELI RAZVOJA - iskustva drugih i naše mogućnosti Brčko, Bosna i Hercegovina, 2019. pp. 198-215 (lecture, local peer review, full paper, scholarly)

10. Turjak, Sofija; Unukić, Ivana; Liović, Dina
   SMES, RESOURCE EFFICIENCY AND GREEN MARKETS – ASPECTS OF THE TRANSITION OF SMES IN THE REPUBLIC OF CROATIA. // IMCSM BOOK OF PROCEEDINGS, An international publication for theory and practice of Management Science, Volume XIV, Issue (2) / Živković, Ž. (ed.). Bor, Serbia: University of Belgrade, Technical Faculty in Bor, Department of Engineering Management, 2018. pp. 616-625 (lecture, international peer review, full paper, scholarly)

11. Kelić, Ivan; Turjak, Sofija; Unukić, Ivana
   GLOBAL AGRICULTURAL ENVIRONMENT AND CROATIAN AGRICULTURAL CHALLENGES – CAN BRANDING HELP?. // INTERDISCIPLINARY MANAGEMENT RESEARCH XIV / Barković, Dražen; Crnković, Boris; Dernoscheg, Karl-Heinz; Papp, Norbert; Runzheimer, Bodo; Wentzel, Dirk (ed.). Opatija: Ekonomski fakultet u Osijeku, 2018. pp. 1667-1679. (https://www.bib.irb.hr/946346) (lecture, international peer review, full paper, scholarly)

12. Hocenski, Mia; Sedlan König, Ljerka; Turjak, Sofija
   Understanding of Creativity - Creative Teaching Factors. // International Conference on Economic and Social Studies (ICESoS) - PROCEEDINGS BOOK Sarajevo, 2018. pp. 4-15 (lecture, international peer review, full paper, scholarly)