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قسم العلوم الاقتصادية

الميدان: العلوم الاقتصادية والتسيير والعلوم التجارية
الشعبة: علوم اقتصادية
التخصص: اقتصاد نقدي ومالي

مذكرة مكملة لنيل شهادة الماستر بعنوان:

The Role of Green Financing in Advancing Sustainable Development European Insights from 2010-2023

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السنة الجامعية: 2025/2024

Dedication

To my mother for your boundless sacrifices, your faith in me has been my greatest source of courage.

To Dr. Abdulhaq Lefilef for your guidance and belief in my potential, your mentorship has shaped this work and my academic journey.

Benabderrahmane Douaa

Acknowledgment

Completing this thesis has been a challenging yet immensely rewarding journey, and I am deeply grateful to all those who have supported me along the way.

First and foremost, I would like to express my sincere gratitude to my supervisor, Dr.Lefilef for his invaluable guidance, patience, and encouragement throughout this process. His insightful feedback, expertise, and unwavering support were instrumental in shaping this work.

My heartfelt thanks go to my colleagues and friends at ECM club for their camaraderie, stimulating discussions, and moral support.

I owe an immeasurable debt of gratitude to my family—my mom for her unconditional love, sacrifices, and belief in my abilities. Their constant encouragement kept me motivated even during the most difficult times.

This journey would not have been the same without each of you, and I am forever grateful.

Benabderrahmane Douaa

Abstract

This study explores the relationship between green finance—measured through green bond issuance—and sustainable development in six EU countries (Sweden, Germany, France, Spain, Italy, and Poland) from 2010 to 2023. Using panel data regression with the Random Effects model, the analysis assesses the impact of green bond issuance, renewable energy capacity, and renewable energy production on CO_2 emissions. Findings reveal that neither green bond issuance nor renewable energy capacity significantly reduce CO_2 emissions, while renewable energy production is unexpectedly associated with increased emissions, possibly due to rising overall energy demand. These results suggest that green bonds alone are insufficient for achieving measurable environmental improvements without complementary policies. The study emphasizes the need for stronger environmental frameworks, strategic use of green bond proceeds, improved transparency and reporting, energy demand management, and integration of green finance within broader sustainability and macroeconomic strategies.

Keywords: Green bonds, Sustainable development, CO_2 emissions, Renewable energy

الملخص

تستكشف هذه الدراسة العلاقة بين التمويل الأخضر – الذي يُقاس من خلال إصدار السندات الخضراء – والتنمية المستدامة في ست دول من الاتحاد الأوروبي (السويد، ألمانيا، فرنسا، إسبانيا، إيطاليا، وبولندا) خلال الفترة من 2010 إلى 2023. ومن خلال استخدام تحليل بيانات بانل والانحدار مع نموذج التأثيرات العشوائية، تقيّم الدراسة تأثير إصدار السندات الخضراء، وسعة الطاقة المتجددة، وإنتاج الطاقة المتجددة على انبعاثات ثاني أكسيد الكربون. وتُظهر النتائج أن إصدار السندات الخضراء وسعة الطاقة المتجددة لا يساهمان بشكل كبير في خفض انبعاثات ثاني أكسيد الكربون، في حين يرتبط إنتاج الطاقة المتجددة بشكل غير متوقع بزيادة الانبعاثات، ربما بسبب ارتفاع الطلب الكلي على الطاقة. وتشير هذه النتائج إلى أن السندات الخضراء وحدها غير كافية لتحقيق تحسينات بيئية ملموسة دون وجود سياسات داعمة ومتكاملة. وتؤكد الدراسة على الحاجة إلى أطر بيئية أقوى، واستخدام استراتيجي لعائدات السندات الخضراء، وتحسين الشفافية والتقارير، وإدارة الطلب على الطاقة، ودمج التمويل الأخضر ضمن استراتيجيات الاستدامة والسياسات الاقتصادية الكلية الأشمل.

الكلمات المفتاحية: السندات الخضراء، التنمية المستدامة، انبعاثات ثاني أكسيد الكربون، الطاقة المتجددة.

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List of Abbreviations	
SDGs	Sustainable Development Goals
GBP	Green Bond Principle
SRI	Socially Responsible Investing
EU	European Union
EIB	European Investment Bank
CAB	Climate Awareness Bond
MBDs	Multilateral Development Banks
WB	World Bank
ESG	Environmental Social Governance
GHG	Green House Gas
GB	Green Bond
CAP	Capacity
PROD	Production
RE	Renewable Energy

Chapter One:

Introduction

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1-1 Preface:

The global community faces pressing challenges, most notably climate change and environmental degradation, which necessitate urgent and integrated responses across all sectors of society. Achieving sustainable development, defined as meeting present needs without compromising future generations, has become a central imperative. This concept balancing environmental, economic, and social dimensions, is embedded in international frameworks like the United Nations Sustainable Development Goals (SDGs). Realizing these ambitious goals, particularly those related to climate action (SDG 13) and clean energy (SDG 7), requires substantial financial mobilization (Purvis, Mao, & Robinson, 2018).

To begin, green finance represents financial activities specifically oriented towards environmental protection. It serves as a bridge between the economy and the environment, illustrating financial innovations made in the pursuit of sustainable development (Udeagha & Muchapondwa, 2023). Green finance emphasizes environmental benefits more than traditional finance, seeking to channel financial resources towards investments that improve air, water, and soil quality, reduce greenhouse gas emissions, enhance energy efficiency, and facilitate adaptation to climate change. It promotes environmentally responsible investment in low-carbon technologies, projects, industries, and businesses (Rizwan, Fatima, & Maria, 2022). A key goal of green finance is to achieve sustainable economic development and green growth. Green finance is considered a specific component of sustainable finance, which is a broader term often understood to support economic growth while considering environmental, social, and governance aspects (Migliorelli, 2021).

A significant instrument within green finance is the green bond. Green bonds are defined as any bond instrument where the proceeds are exclusively applied to finance or re-finance new or existing eligible Green Projects. These are use-of-proceeds debt securities that fund activities with environmental benefits. Green bonds are considered the first major effort to mobilize debt for environmental purposes. They align with core components such as the Use of Proceeds, Process for Project Evaluation and Selection, Management of Proceeds, and Reporting, often guided by principles like the Green Bond Principles (GBP). Green projects financed by these bonds typically address critical environmental issues including climate change mitigation and adaptation, natural resource conservation, biodiversity preservation, and pollution prevention. Green bonds are seen as vital tools for mobilizing the financial resources needed to address environmental concerns (Rizwan, Fatima, & Maria, 2022).

The market for green finance, particularly green bonds, has experienced remarkable growth. Since the first Green Bond was issued by the European Investment Bank in 2007, followed by the World Bank in 2008, the market has expanded multi-dimensionally, both geographically and in terms of total issue volume. The amount of green-labelled bonds issued saw significant increases, from $100 billion in 2016 to $257.7 billion in 2019. Cumulative green bonds reached $2.8 trillion as part of the cumulative aligned GSS+ (green, social, sustainability, and sustainability-linked bonds) which totaled $4.4 trillion. Issuers, initially dominated by multilateral development banks, have diversified to include corporates, municipalities, and governments (Rizwan, Fatima, & Maria, 2022).

This growth is propelled by several factors. Rising societal, political, and market concerns about climate and environmental challenges have driven increased demand for financial products contributing to these goals. Government leadership and commitment to sustainability in public policy can stimulate green bond issuance. Voluntary guidelines, such as the GBP, have been crucial in structuring the market and providing clarity. Investor interest is a key driver, recognizing the potential for both financial returns and positive environmental impact (Rizwan, Fatima, & Maria, 2022). Empirical studies have observed positive significant cumulative abnormal returns on the day of green bond issue announcements, suggesting investor recognition of the value in green financing. The expansion of sustainable finance products like green loans and sustainability-linked loans further highlights this trend (EBA, 2023). Policy makers can facilitate this by providing environmentally responsible education and appropriate information to raise user preferences for green initiatives. Corporate sectors can also design appropriate products to target investors with a preference for green initiatives.

Despite the significant growth, the market still faces challenges. A persistent issue is the lack of consistency in defining "green". The need for improved disclosure requirements and standards for non-financial information is also noted as crucial for assessing sustainability performance and additionality. Academic research emphasizes the need for further development to reach full maturity and more rapidly achieve sustainability objectives (Migliorelli, 2021).

From a theoretical perspective, the integration of environmental and social goals into finance necessitates a critical look at existing financial risk modeling approaches. Some argue that achieving sustainable financial risk modeling requires a paradigm shift that integrates the characteristics of "nature" and sustainability into modeling. This involves questioning the underlying philosophy and morphology of randomness in traditional finance theory and exploring alternative approaches, such as those based on fractal geometry, which may better capture the complexity of natural and human systems. The goal is to align financial risk modeling more closely with the real characteristics of environmental and human risks to ensure its sustainability.

This study undertakes an empirical examination of the contribution of green financing, specifically green bond issuance, to sustainable development in Europe. Focusing on a selection of European Union member states, the research aims to investigate the tangible impact of green bond markets on key environmental indicators, namely CO_2 emissions (total intensity, and per capita) and renewable energy development (capacity and production). By employing a quantitative approach using panel data analysis from 2010 to 2023, this work seeks to provide empirical evidence on whether increased green bond issuance measurably improves environmental sustainability.

Therefore, by contrast this study addresses a gap in the existing empirical literature and investigates the role of green bond issuance in achieving sustainable development goals, surveying a group of six European Union member states for the period 2010-2023. One specific question arose that requires answer:

What is the empirical relationship between green bond issuance and key environmental sustainability indicators in 6 selected European Union member states from 2010 to 2023?

Under this question, the following sub questions can be extended:

1. Does increased green bond issuance lead to a significant reduction in carbon emissions in these countries?
2. Is green bond issuance associated with the promotion of renewable energy development in the sampled European countries?

1-2 Hypotheses of the Study:

To accomplish the aim of the study, the following hypotheses are formulated:

1. There is a relation between green bond issuance and CO_2 emissions.
2. Renewable energy has an impact on CO_2 emissions.
3. There is an impact of green bond issuance on renewable energy adoption.

1-3 Objective of the Study:

The overarching objective of this study is to empirically analyze the impact and contribution of green financing to a sustainable development in Europe. This research specifically focuses on the period from 2010 to 2023. The study aims to:

- Examine the connection between green bond issuance which serves as the primary proxy measure for green financing activity and principal indicators of sustainability in selected in European Union member states.
- Investigate whether green bond markets have a measurable impact on carbon emission reduction and renewable energy development and adoption.

In essence, the study seeks to provide empirical evidence on whether and how channeling financial resources through instruments like green bonds contribute tangibly by improving environmental sustainability outcomes in Europe, thereby supporting the broader goals of sustainable development like those outlined in the UN Sustainable Development Goals (SDGs), particularly SDG 7 (clean energy) and SDG 13 (climate action).

1-4 Importance of the Study:

Addressing pressing global challenges as the study is situated within the context of critical global issues, notably climate change and environmental degradation. It recognizes the urgent need to integrate environmental considerations into economic and financial systems to address these challenges.

Supporting sustainable development goals, the study explicitly links its subject matter to key objectives within the United Nation SDGs. Specifically achieving ambitious goals related to climate action and clean energy requires substantial financial mobilization. The study investigates a mechanism intended to directly support these goals.

Highlighting the role of green finance and green bonds as the study's focus on green bonds underscores their growing prominence and potential role in sustainability transitions.

Provide empirical evidence in a key region and add valuable context that allows for the examination of relationships over time and across different countries.

In summary, this study is important because it rigorously investigates the effectiveness of green finance, particularly green bonds, as a tool to drive sustainable development in a critical global region. By providing empirical evidence on the link between green bond issuance and environmental outcomes like emissions reduction and renewable energy growth, it offers valuable insights for policymakers, investors, and academics working towards a more sustainable future in the face of urgent environmental challenges.

1-5 Structure of the Study:

This study comprises six chapters in total. Following this introductory chapter, Chapter Two lays the theoretical groundwork for the research. Chapter Three then delves into existing literature, presenting relevant studies connected to the study's subject. Subsequently, Chapter Four outlines the research methodology, detailing the data sample and the empirical testing procedures employed to meet the study's objectives. Chapter Five then presents an analysis and assessment of the findings. Finally, Chapter Six summarizes the key aspects of the study, offers conclusions, and proposes avenues for future research.

Chapter Two

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2-2 Green finance

2-2-1 Foundation and Evolution

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1. The European Green Deal
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2-1 Introduction:

The evolving global landscape increasingly recognizes the critical need to integrate environmental considerations into economic and financial systems to address pressing challenges like climate change and environmental degradation. Sustainable development, a concept popularized by the Brundtland report in 1987, is defined as development that meets the needs of the present without compromising the ability of future generations to meet their own needs (Migliorelli, 2021). This concept, which aims to balance environmental, economic and social dimensions, has become a central focus in academic literature and policy agendas worldwide, culminating in the adoption of the United Nations Sustainable Development Goals (SDGs) in 2015, a set of 17 integrated and indivisible goals for peace and prosperity (Ben Purvis, 2018).Achieving these ambitious global goals, particularly those related to climate action and clean energy, requires substantial financial mobilization (Mizra, Umar, Afzal , & Firdousi, 2023)

Green finance, an essential driving force for sustainable economic development, has emerged as a rapidly developing field aimed at channeling funds towards environmentally beneficial activities and investments (International Finance Corporation, 2025). It serves as a crucial link between the economy and the environment, emphasizing environmental benefits more than traditional finance. While often used interchangeably with sustainable finance, green finance is specifically considered a subset focusing on environmental benefits.

2-2 Green finance:

2-2-1 Foundation and Evolution:

Green finance has evolved over significant historical period, with its roots tracing back to ancient traditions and its modern form developing rapidly in recent decades.

1990s: The trend to design mutual funds with specific ethical or environmental criteria for investments began to gain popularity in the 1990s along with the concepts of Socially Responsible Investing (SRI) and Impact Investing. SRI is associated with negative screening of sectors and companies deemed to be causing environmental, social or other harms and positive screening of sectors and companies deemed to be making positive contributions to sustainability. These screening practices are largely focused on the composition of investment portfolios in publicly traded equities. Impact investing is distinct from SRI in that it aims to achieve some identified environmental and social outcome along with financial returns. Impact investors may therefore be willing to forgo higher financial returns if other desired outcomes can be achieved (Torvanger, Maltais, & Marginean, 2021).

A significant milestone in this period for policy was the 1993 Maastricht Treaty on the European Union, which enriched the Union's commitment to sustainable development and a high level of environmental protection in its primary.

Late 2000s: this era saw the emergence of dedicated financial instruments for green initiatives. The period around 2007-2008 marked the creation of the green bond market. The European Investment Bank (EIB) issued the first climate awareness bond (CAB) in 2007, followed by the World bank issuing its first green bonds in 2008 (Monk & Perkins, 2020). The global financial crisis of 2008 also prompted businesses to place a greater emphasis on economic, environmental, and social coordination.

2015-2020: A pivotal global development occurred in 2015 when the United Nations General Assembly adopted the 17 Sustainable Development Goals (SDGs) this led to substantial increase in investments in green technologies, clean energy and environmental and social projects. And in 2019 the European Commission unveiled the European Green Deal (EGD), setting a course for climate neutrality by 2050 and publishing the "Clean energy for all Europeans" document, which Heightened awareness regarding the urgency of climate change became a necessary factor. The year 2020 brought significant changes and challenges with the onset of the COVID-19 pandemic. Investments in green technologies and clean energy were reduced by one third due to the pandemic (Madaleno, Dogan, & Taskin, 2022). However, despite the setback green finance gained more recognition in post COVID-19 era.

Regulatory efforts in the EU intensified with the EU Regulation on the Establishment of a Framework to Facilitate Sustainable Investments enacted in July 2020 to channel funds towards green investments. Plans were also in place for the first set of EU rules, the Green Bond Standard, based on the Green Bond Principles in 2020

(Rannou, Boutabba, & Barneto, 2021). Regulatory initiatives like the Just Transition Mechanism and InvestEU under the European Green Deal were also being proposed and discussed in 2020 (Sikora, 2021).

In recent years sustainable development and green financing have become crucial topics globally. Fintech is increasingly seen as vital for transitioning to sustainable banking models and facilitating funding for ecological projects. There is an ongoing need for innovation in financial products to finance the transition to a low carbon economy, although inconsistencies in regulations and taxation for green bonds still exist. Financial authorities are encouraged to support green finance actively and green finance is considered essential for achieving the SDGs (Walter, 2020).

2-2-2 Definitions and scope:

Green finance is a rapidly developing field within the financial system that aims to integrate environmental considerations into financial decision making and channel funds towards environmentally beneficial activities (International Finance Corporation, 2025).

Fundamentally, green finance is the provision of financing for public and private green investments in environmental goods and services and in the prevention, minimization, or compensation of damages to the environment (Falcone, Morone, & Sica, 2018). It includes financing activities that bring environmental benefits, this involves channeling financial resources towards endeavors that contribute positively to the environment by reducing emissions and environmental degradation (Sun & Rasool, 2024). It serves as the link between economy and the environment and is an illustration of financial innovations made in the pursuit of sustainable development; it also emphasizes environmental benefits more than traditional finance does (Udeagha & Muchapondwa, 2023).

While the terms "sustainable finance" and "green finance" are often used interchangeably, there are distinctions. Sustainable finance is a broader concept that prioritizes social and environmental objectives alongside profitability, it is considered as key aspect of the EGD, it reflects the idea of making sustainability considerations part of the financial decision-making process, it stands for "taking due account of environmental and social and governance considerations when making investment decisions".

A particular example of an environmentally orientated funding approach is illustrated by the concept of sustainable investment enshrined in the recently adopted taxonomy regulation which is intended to provide with a common framework identifying to what degree economic activities may be considered environmentally sustainable (Sikora, 2021).

Green finance on the other hand, is considered a subset of sustainable finance focusing on environmental benefits. It encompasses various activities, instruments, and types of investments aimed at environmental benefits and sustainability transitions such as:

1. Financing of public and private green investments.
2. Financing investments in environmental services and the prevention and minimization of damage to the environment (Falcone, Morone, & Sica, 2018).
3. Financing renewable and clean energy projects as renewable energy, energy efficiency, and clean transportation are primary directions for projects financed through green bonds by institutions like the World Band and EBRD (Versal & Sholoiko, 2022).
4. Supporting enterprises whose goals are oriented towards a responsible profit meeting the social and environmental aspects identified within the sustainable development path (Falcone, Morone, & Sica, 2018).
5. Financing activities providing environmental benefits in areas such as air pollution, water, soil, greenhouse gas emissions reduction, energy efficiency improvement, and adaptation to climate change (Llorente, Gavurova, Rigelsky, & Soriano, 2024).
6. Encouraging environmentally responsible investment and promoting low carbon technologies, projects, industries and businesses (Mizra, Umar, Afzal , & Firdousi, 2023).

2-2-3 Green finance instruments:

1. **Green bonds:** They are financial instruments where the proceeds are used to finance green projects and low carbon initiatives with clear environmental

benefits. Examples of projects financed include renewable energy production and or improvements in energy efficiency, green buildings, clean transportation and circular economy initiatives (Torvanger, Maltais, & Marginean, 2021).

A. Origin of green bonds:

The green bond market originated with multilateral development banks (MBDs). The European Investment Bank (EIB) issued the first bond related to environmental-related investments, known as the Climate Awareness Bond (CAB), in 2007. This bond introduced the concept of earmarking debt specifically for environment related investments (Monk & Perkins, 2020).

Following the EIB's issuance, the World Bank (WB) issued the first officially labelled "green bond" in November 2008 (Versal & Sholoiko, 2022) .The world bank began marketing green bonds around this time, in response to demand from Scandinavian pension funds seeking to support climate focused projects (Rannou, Boutabba, & Barneto, 2021). MBDs, including the WB, the European Bank for Reconstruction and Development (EBRD), and the International Finance Corporation (ICF), have been key players in developing the global green bond market and helping it become a mainstream capital market. These supranational and development agencies (SSA or MDBs) provided critical leadership by priming the market with low-risk issuance and educating investors.

The first green bond was introduced by the WB and Skandinaviska Enskilda Baken (SEB) in 2009, Norway's Kommunalbanken (KBN) was the first Nordic issuer, issuing a green bond in 2010 (Torvanger, Maltais, & Marginean, 2021).

b. Market growth:

The green bond market is an emerging segment of financial markets that has been developing rapidly (Damianova, Guttierez, Levitainskaya, Minasyan, & Nemova, 2018). While the idea was created around 2007, it was not established until a few years later. Following the WB's debut issuance in 2008-2009, the market developed slowly, primarily characterized by small scale private placements by MBDs until 2013 (Monk & Perkins, 2020).

However, the market began to grow more quickly in 2013, with issuance rising by over 7 billion USD that year. The release of the Green Bond Principles (GBPs) by the International Capital Market Association (ICMA) in 2014 marked a period of dramatic growth, leading to market take off in 2014-2015 (Alexander & Richard, 2020). Following the introduction of the GBPs green bond issuance doubled year by year (Sheenan, Schweers, & Klein, 2024).

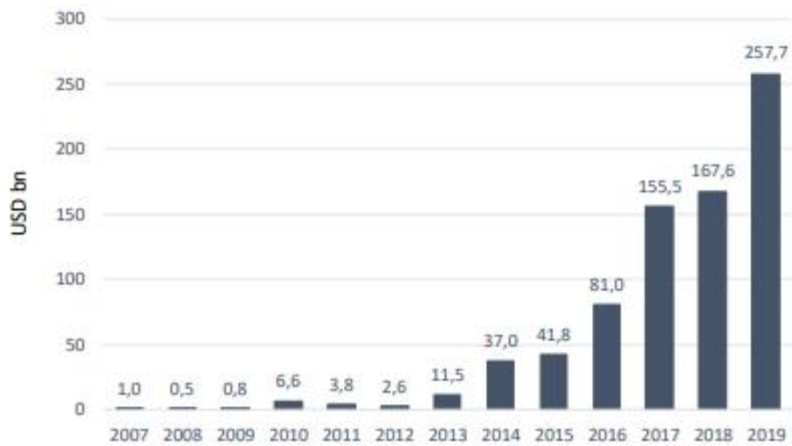


Figure 1 Level of green bond issuance since the inception of the market *(Migliorelli, 2021)*.

c. **Market adoption**: green bonds have emerged relatively recently, with innovation creation in the late 2000s they have shown considerable year on year growth in issuance sinch 2012 while still a small part of the overall bond market (around 3%) (Monk & Perkins, 2020), the market growth accelerated as niches were development and translated into wider markets. Global annual issuance levels increased significantly from USD 1 billion in 2007 to USD 257.7 billion in 2019, showing consistent growth particularly from 2013 onwards (Migliorelli, 2021). Analysis shows issuance data for Norway and Sweden between 2013 and 2019 (Asbjørn, Aaron, & Lulia, 2021), the US market saw aggressive green bond growth in 2015 and then continued to expand in a stable mode (Ahmed, Yusuf, & Ishaque, 2022).

Analysis using asset pricing models shows investors responded positively to green bond announcements with strongly positive and statistically significant abnormal returns around the announcement data, suggesting investor recognition of green projects trough green financing in European countries studied , France had the highest average price of green bonds (123.95), followed by the UK (123.10), Germany, Sweden and the Netherlands (Sun & Rasool, 2024), the S&P green bond index was launched on July 31, 2014 and has been used as a proxy for green finance in market analysis (Madaleno, Dogan, & Taskin, 2022).

Figure 2 the 2023 green bond market in numbers *(Chouhan, Harrison, & Sharma, 2024)*.

d. Types of green bonds:

1. **Standard Green Use of Proceeds bonds**: this is described as the most common type. It is an unsecured debt obligation with full resource to the issuer only. Like all green bonds, its proceeds are exclusively applied to finance or refinance eligible green projects. It is aligned with the four core components of the GBP (ICMA, 2021).
2. **Green Revenue Bond:** This is a type of green bond where the credit exposure is specifically to the pledged cash flows of revenue streams, fees, or taxes. The proceeds from these bonds go to green projects which may or may not be related to the revenue stream providing the credit exposure. The sources also

refer to "use of proceeds revenue bonds" as a large segment of the green bond market.

3. **Green Project Bond:** This is a project bond issued for a single or multiple green projects. In this structure the investor has direct exposure to the risk of the projects. There may or may not be potential resource to the issuer. These bonds must also be aligned with the GBP. Project bonds generally involve financing specific projects. Green project bonds are considered a relatively small niche market.
4. **Secured Green Bond:** This category includes various secured debt structures where the net proceeds are exclusively applied to finance or refinance green projects. The cash flows of assets are typically available as a source of repayment, or assets serve as security for the bonds in priority to others claims. This type can include covered bonds, securitizations, asset backed commercial paper, secured notes and other secured structures. Within this category there are Secured Green Collateral Bonds (where proceeds finance the projects securing the bond) and Secured Green Standard Bonds (where proceeds finance issuer's green projects, which may or may not be securing the bond). Issuers should clearly specify which method is used. Green securitized bonds are mentioned as a niche market that has attracted more attention recently (Rannou, Boutabba, & Barneto, 2021).

e. Green Bond principles (GBPs):

The green bonds principles (GBPs) have codified a procedural template that helps clarify the key components of a credible green bond, fostering understanding for potential issuers and investors (Monk & Perkins, 2020).

Based on the sources the Green Bond Principles (GBP), coordinated by the International Capital Markets Association (ICMA), are voluntary process guidelines that recommend transparency and disclosure and promote integrity in the development of the green bond market (ICMA, 2021). They provide guidance for issuers, aid investors, and assist underwriter.

Alignment with the GBP requires adherence to four core components (Migliorelli, 2021). These are sometimes referred to as the “Four key mandatory principles”, though the GBP themselves are voluntary guidelines.

1. **Use of proceeds**: This is described as the cornerstone of a green bond. The proceeds (or an equivalent amount) from the bond must be exclusively applied to finance or refinance, in part or in full, new and\or existing eligible Green Projects (ICMA, 2021). These designated Green Projects should provide clear environmental benefits, which are assessed. Eligible categories often include renewable energy, energy and resource efficiency, pollution prevention, water and waste management, conversation and climate adaptation (Torvanger, Maltais, & Marginean, 2021).
2. **Process for Project Evaluation and Selection**: the issuer of a Green Bond should clearly communicate to investors the environmental sustainability objectives of the eligible Green Projects (ICMA, 2021). They should also describe the process by which projects are determined to fit within the eligible green categories. Furthermore, information on how the issuer identifies and manages perceived social and environmental risks associated with the relevant projects should be provided (Rannou, Boutabba, & Barneto, 2021).
3. **Management of proceeds:** the net proceeds of the Green Bond, or an amount equal to these net proceeds, should be credited to a sub-account, moved to a sub-portfolio, or otherwise tracked by the issuer in an appropriate manner. This tracking should be attested to by the issuer in a formal internal process linked to the issuer’s lending and investment operations for eligible Green Projects. While the bond is outstanding, the balance of tracked net proceeds should be periodically adjusted to match allocations, and the intended types of temporary placement for any unallocated proceeds should be made known to investors (ICMA, 2021).
4. **Reporting:** issuers are expected to provide reporting on the use of proceeds. Originally, this component focused on accounting for the allocation of green bond proceeds (Adriana, Eva, Katerina, Gayane, & Vladislava, 2016). It now includes, if possible, reporting on the environmental impact of the projects financed (Rannou, Boutabba, & Barneto, 2021).

In addition to these four core components the GBP also include key recommendations for heightened transparency, such as having a Green Bond Framework and obtaining External Reviews (ICMA, 2021). External reviews are recommended (and sometimes required by country specific standards) to confirm the alignment of green bonds with the principles (Migliorelli, 2021).

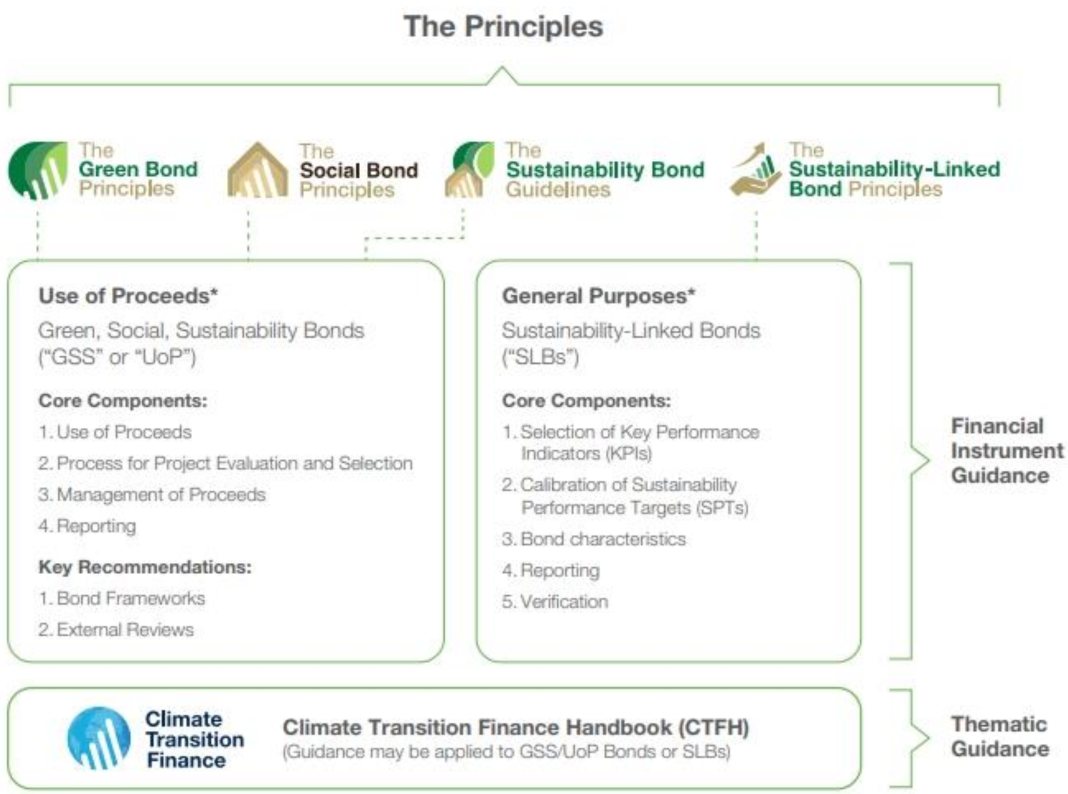


Figure 3 green bond principles (ICMA, 2021)

f. **Green bonds characteristics**:

Summary statistics for green bonds show characteristics such as average coupon rates. (e.g., 3.525% for all green bonds, 3.494% for energy issuer green bonds), maturity periods (e.g. 9.23 years for all green bonds, 7.52 years for energy issuer green bonds), and average amounts issued (e.g. 127.068$ million for all green bonds, 119.599$ million for energy issuer green bonds) (Ahmed, Yusuf, & Ishaque, 2022).

g- **Issuer:** Corporate issuances of green bonds are mentioned in specific like energy and utilities, electric and gas utilities, and automotive energy specific corporate issuers mentioned include DTE electric Co. and Fisker Inc. Green bonds can also be issued by supranational organizations, banks, non-banking financial institutions, municipalities and governments (information carried over from previous synthesis). Corporate issuance has been analyzed in countries like Norway and Sweden, focusing on categories such as energy, green buildings, clean transportation and circular economy (Torvanger, Maltais, & Marginean, 2021).

1. **Sustainability Linked Bonds (SLBs):** while included in your list and sometimes grouped under broader sustainable finance instruments, the sources cl early distinguish SLBs from traditional green bonds, primarily based on the use of proceeds (Sheenan, Schweers, & Klein, 2024) . Unlike green bonds, where proceeds are earmarked for specific green projects (Alexander & Richard, 2020), the proceeds of SLBs are typically intended to be used for the issuer's general corporate purposes (Climate Bond Initiative, 2024). The key feature of SLBs is that their financial or structural characteristics can vary depending on whether the issuer achieves predefined sustainability or ESG objectives, measured through specific Key Performance Indicators (KPIs) against predefined performance targets (SPTs) (Sheenan, Schweers, & Klein, 2024) .The SLB market has grown rapidly since its inception around 2019. The ICMA also publishes separate Sustainability Linked Bon d Principles, bonds that intentionally mix eligible Green and Social Projects are referred to as Sustainability Bonds (ICMA, 2021).

2. **Green Loans:** Green loans are financial products and services that take environmental factors into account during the loan decision, monitoring and risk management processes (Mizra, Umar, Afzal , & Firdousi, 2023). They are based on core components: use of proceeds, process for project evaluation and selection, management of proceeds and reporting. These principles build on and refer to the Green Bond Principles to promote consistency across financial markets (Damianova, Guttierez, Levitainskaya, Minasyan, & Nemova, 2018).

   They encourage environmentally responsible investments and promote low-carbon technologies, projects, industries and businesses (Mizra, Umar, Afzal ,

& Firdousi, 2023). They finance investments with environmentally sustainable features or a dedicated environmental objective, such as improving the energy performance and sustainability features of economic activities (EBA, 2023). Types of loans include personal housing mortgages, vehicle loans, credit cards, projects financing, construction lending, and energy efficiency\renewable energy financing (Damianova, Guttierez, Levitainskaya, Minasyan, & Nemova, 2018).

3. **Green Investment Funds (Green Funds):** a green fund is a mutual fund or other investment vehicle that invests specifically in companies deemed socially conscious or directly promote environmental responsibility on standardized green assets (Damianova, Guttierez, Levitainskaya, Minasyan, & Nemova, 2018). They are considered a subset of sustainable finance and finance investments providing environmental benefits in areas like pollution reduction, greenhouse gas emission reduction, energy efficiency and climate change adaptation (Llorente, Gavurova, Rigelsky, & Soriano, 2024).

   Market: in Europe, the green funds market is driven by countries that pioneered responsible investment, such as France, Switzerland and United Kingdom. While the majority in Europe are equity funds, the market is diversifying with green bond funds emerging since 2015. The first green bond fund dedicated to emerging market was established by IFC and Amundi in 2017 (Damianova, Guttierez, Levitainskaya, Minasyan, & Nemova, 2018).

Sources also mention other instruments such as carbon emissions trading and green credit (Udeagha & Muchapondwa, 2023), as well as emerging instruments like sustainability bonds, blue bonds and transition bonds.

2-2-4 Green Finance Policy framework: Within the EU policy frameworks related to green finance sustainable development and environmental protection are presented at both the Eu wide level and through analyses of individual member states, often highlighting their evolution over time and comparing different instruments and strategies (Falcone, Morone, & Sica, 2018).

1. **<u>The European Green Deal:</u>** The current stage of EU environmental law and policy is significantly driven by the European Green Deal (EGD) .The EGD announced in 2019 is a central policy tool aiming to transform the EU into a climate neutral continent by 2050 (Wolf, Teitge, Mielke, Schutze, & Jaeger, 2021), it serves as a strategy for making the EU's economy sustainable proposing measures to reduce greenhouse gas emissions GHG and increase biodiversity (Sikora, 2021) the EGD targets a 50-55% cut in emissions by 2030 compared to 1990 levels.

While ambitious the EGD is legally a Commission communication considered an instrument of EU soft law though its provisions are to be taken into account by Member states a "green oath": "do no harm" principle is associated with the EGD suggesting EU actions should void environmental harm although its enforceability is noted as programmatic.

The overarching mission of the EGD is for Europe to become the world's first carbon-neutral continent by 2050. An intermediate objective is to reduce net greenhouse gas (GHG) emissions by at least 55% by 2030 compared to 1990 levels. This 2030 target has become legally binding for EU institutions and member states (EBA, 2023).

The EGD aims to achieve this through green transformations across various sectors, turning climate and environmental challenges into opportunities across all policy areas and making the transition just and inclusive for everyone. All EU actions and policies are expected to contribute to the objectives of the European Green Deal. The challenges involved are complex and interlinked. The EGD aims to integrate the UN SDGs and place sustainability and the well-being of citizens at the center of economic policy and EU policymaking and action. It also seeks to strengthen Europe cohesion (European Commission, 2019).

The EGD outlines action in numerous interconnected areas:

-Climate Ambition: setting clear overarching targets, including net zero carbon emissions by 2050 and a 50-55% cut by 2030.

-Clean, Affordable and Secure Energy: promoting renewable energy sources and energy efficiency.

-Sustainable Industry: developing a strategy for a clean and circular economy, aiming for the EU to be a world leader in this field and in clean technologies (Sikora, 2021).

-Building and Renovations: greening buildings, creating jobs, and improving lives, often linked to energy efficiency (EBA, 2023).

-Sustainable Mobility: promoting clean transportation options.

-Agriculture: greening the Common Agriculture Policy and the "Farm to Fork" strategy.

-Biodiversity: preserving and protecting biodiversity and natural capital.

-Zero pollution: working towards a zero-pollution ambition for a toxic free environment.

-Mainstream Sustainability: ensuring sustainability is integrated across all EU policies.

-Research and Development: utilizing programs like Horizon Europe (with at least 35% of its budget funding climate solutions) to support the necessary innovation and deployment of new technologies. This includes four "Green Deal Missions" focused on areas like adaptation to climate change, oceans, cities and soil. (European Commission, 2019).

-Preventing carbon leakage: measures to address unfair competition from carbon leakage.

-Global leadership: using EU influence, expertise and financial resources to mobilize partners and lead international efforts through 'green deal diplomacy' and initiatives like the International Platform on Sustainable Finance.

-Working Together: launching initiatives like the European Climate Pact to ensure the involvement and commitment of the public and all stakeholders.

-Public Procurement: incorporating a green agenda into public policy institutions mandates and public procurement.

-Green Budgeting: screaming and benchmarking green budgeting practices and including green public investment in the reviews of the European economic governance framework.

-Addressing Environmental Crime: promoting action against environmental crime.

2. The EU emission trading system EUETS:

Is another significant Eu level regulatory framework, it has been rolled out in phases. Phase one from 200 to 2007, phase two from 2008 to 2012, and phase three from 2013 to 2020. In phase three free allocation of allowances was significantly reduced with approximately 88% auctioned on average and 100% almost auctioned in the power sector. The EU ETS creates a carbon market allowing for trading of European Union Allowances (EUAs) where hedging and speculative positions can be taken, the power sector is the main participant (Rannou, Boutabba, & Barneto, 2021).

3. EU Taxonomy: The EU taxonomy is a classification system that stablishes criteria for determining whether an economic activity qualifies as environmentally sustainable. It is described as an important market transparency tool designed to help direct investments to activities most needed for the transition to net zero and environmental sustainability (EBA, 2023).

Its core goal is to provide clear rules on what can be classified as 'green' or 'environmentally sustainable' in order to mobilize financing for those economic activities that contributes to the EU's environmental objectives. It aims to help accelerate green or sustainable investments needed for the transition and to avoid the risk of greenwashing by providing a science-based transparency tool to investors, companies, financial institutions and consumers. The EU Taxonomy is intended to help avoid stranded assets by setting an ambition level aligned with the EU's climate objectives (EBA, 2023).

The EU Taxonomy framework is a central element in the EU's wider sustainable finance framework and its criteria serve as the reference for screening green or sustainable investments in economic and financial activities. It is understood to support the delivery to the EU Green Deal. The Taxonomy Regulation, which entered into force in July 2020, forms the basis of this system. It has given a legally binding definition to an ‘environmentally sustainable investment’ (Sikora, 2021).

The EU taxonomy defines environmentally sustainable economic activities based on their substantial contribution to one or more of six environmental objectives, while not significantly harming any of the others. These six objectives are:

-Climate change mitigation.
-Climate change adaptation.
-Sustainable use and protection of water and marine resources.
-Transition to circular economy.
-Pollution prevention and control.
-Protection and restoration of biodiversity and ecosystems.

The Taxonomy provides technical screening criteria for economic activities. An economic activity is considered environmentally sustainable if it contributes substantially to one or more of the environmental objectives and does not significantly harm the others, according to these criteria (EBA, 2023).

a. **Uptake and Application:** initial evidence suggests that companies, public entities, and financial actors are increasingly using the Taxonomy for their business strategies, transition planning, investing and lending (European Commission, 2019).

Companies have started using the taxonomy to plan and highlight their green investments. On average around 20% of companies’ capital investments are aligned with the Taxonomy, with the utilities sector (especially electricity providers) showing higher alignment. Taxonomy aligned capital by reporting companies have increased in 2024 compared to 2023. Companies are increasingly using the Taxonomy to guide and showcase their taxonomy aligned capital investments in key sectors to meet the Green Deal Targets. Stoc market data indicates that alignment to the Taxonomy correlates with positive market performance (Commission, 2025).

In 2023, 90% of green bons issued by the EU public actors referenced the EU Taxonomy to illustrate their commitment to using funds for green projects. Germany’s sovereign green bonds have included allocations to Taxonomy aligned areas like agriculture (Climate Bond Initiative, 2024).

Banks are starting to use the Taxonomy in their lending strategies and in assessing company investments plans. Mortgages and other loans to activities within the scope of the Taxonomy represent, on average, over 50% of the assets of large EU banks based on first year figures (European Commission, 2019). Credit institutions are required to calculate and disclose a green asset ratio, which indicates the share of their assets aligned with the Taxonomy's technical screening criteria. The Taxonomy is a reference for screening green or sustainable investments in economic and financial activities (EBA, 2023).

56% of EU funds promote environmental or social characteristics or have a sustainable investment objective, and the assets aligned with the Taxonomy form a small but growing part of what these funds invest in (European Commission, 2019).

b. **Limitations:** The EU Taxonomy currently has some limitations. It covers economic activities responsible for almost 80% of direct GHG emissions, but some key activities like farming and investments contributing to the transition but falling short of meeting criteria are not directly captured. Improving and completing the classification system is an evolving process. The EU Taxonomy and its components are currently only used as additional specific criteria at loan origination in some cases, rather than being the primary standard, partly due to the framework's recency and data\usability challenges (EBA, 2023).

To address usability challenges, the European Commission is working on implementation guidance and has introduced measures to support the application of Taxonomy criteria and disclosures (European Commission, 2019). Taxonomies developed so far have principally focused on climate and partially environment related investments, with limited coverage of other sustainability dimensions.

4. **The Paris deal:** a legally binding international treaty negotiated by 196 countries and ratified by 195 countries. It was adopted in 2015 within the United Nation Framework Convention on Climate Change (UNFCCC) and became effective in November 2016. The year 2015 is described as a landmark year for multilateralism and international policy shaping and an historic turning point in combatting climate change.

The primal goal of the Paris Agreement is to reduce the effect of climate change by keeping the rise in the mean global temperature below 2 degrees Celsius compared to pre-industrial levels, and pursuing efforts to limit the temperature increase even further to 1.5 degrees Celsius. It aims to establish an action plan for global economies to engage in carbon abatement (Wang, Wang, Zhao, Yang, & Albitar, 2024).

The agreement covers climate change mitigation, adaptation, and finance. The contribution that countries must provide to achieve the worldwide long-term goal is set and controlled by each country individually through Nationally Determined Contributions (NDCs), with no binding enforcement mechanism specified for these contributions (Falcone, Morone, & Sica, 2018). The European Union has adhered to the Paris Agreement and intends to continue ensuring it remains the indispensable multilateral framework for tackling climate change (European Commission, 2019).

Regarding progress towards the goals, the combined climate pledges of 193 Parties under the Paris Agreement, as found in the UNFCCC's latest NDC synthesis report, are projected to achieve only a slight decrease (0.3%) in GHG emissions by 2030 compared to 2019 levels. This reduction falls well short of the 43% emissions reduction called for by the IPCC to be on the 1.5 Celsius pathway and would potentially lead to an unsustainable warming of around 2.5 degrees Celsius by the end of the century.

While EU level framework exists, there is diversity in how sustainability is integrated across the EU policy actions to support green finance are described as jurisdictional (Nkwaira & Van der Poll, 2024).

Studies analyze green finance and ecological footprint in ten leading nations (France, Germany, Uk, Sweden, Switzerland, Netherlands, Denmark, Norway, Finland, and Spain) finding varied and inconsistent relationships across these economies highlighting that even geographically close countries show significant differences (Sun & Rasool, 2024). France for example as the highest average green bond price and ecological footprint among this group.

In summary, the EU presents a complex and evolving landscape of green finance and environmental policy frameworks. These frameworks span different geographical scales within Europe, demonstrate a clear chronological progression, and involve a variety of regulatory approaches, from market-based mechanisms and binding regulations to soft-law initiatives and efforts to standardize financial products. Analyses often highlight the variations and challenges inherent in implementing these policies across diverse Member States.

2-3 Sustainable development:

2-3-1 Foundation, Evolution and Scope:

The concept of sustainability particularly sustainable development has evolved over time with its moder prominence often tracked back to key internation reports and initiatives the concern about the impact of economic activities on nature and social structures has existed for decades (Migliorelli, 2021).

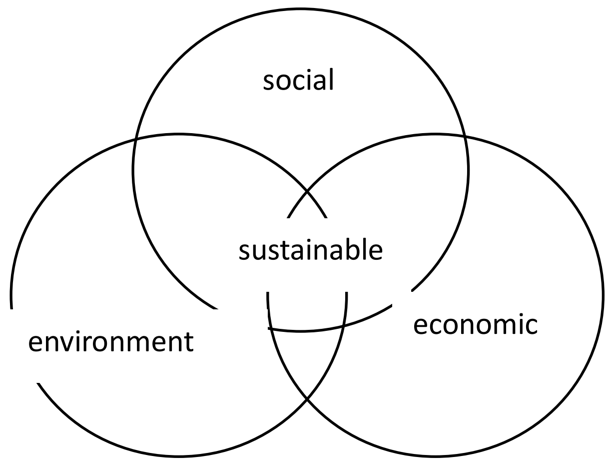
A significant moment was the publication of the UN report "Our common future WCED 1987" widely known as the Brundtland report. This report is credited with popularizing the concept of sustainable development and introducing it into international policy discourse (Purvis, Mao, & Robinson, 2018). The Brundtland report defined sustainable development as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs".

The concept implies that the goals of economic and social development must be defined in terms of sustainability in all countries and suggests that concern for social equity between generations must be logically extended to equity within each generation arriving at a commonly accepted definition of sustainable development has remained a challenge.

While the Brundtland report brought sustainable development to the mainstream in 1987, the term had appeared earlier such as in 1980 by the IUCN, UNEP and WWF. Early literature also discussed related concepts like ecologically sustainable development as an uneasy union of ecological and economic values emphasizing holistic thinking (Purvis, Mao, & Robinson, 2018).

The three-pillar conception typically involving environmental, economic and social dimensions has become a ubiquitous way to describe sustainability. This framework often involves balancing tradeoffs between seemingly equally desirable goals within these three categories this conceptualization appears to predate the Brundtland report and is seen in earlier works critiquing the economic status quo from ecological and social perspectives. Elkington's triple bottom line (TBL) of "people, planet and profit" is noted as marking the first use of a three-pillar conceptualization in sustainability accounting and may have been influential in cementing its position in the mainstream.

Figure 4 typical representation of sustainable as three intersecting circles



By the mid-1990s sustainable development and sustainability were in vogue in academic literature and policy agenda globally the UN formulation of the sustainable development goals SDGs explicitly embedded the three pillars stating that the goals balance the three dimensions of sustainable development.

The definition of sustainable development from the Brundtland report while emphasizing meeting present needs and intergenerational equity has been interpreted in ways that can be seen as leaning towards compatibility with continues economic growth for example it was argued that a new win-win scenario emerged by recasting the same old economic growth in socially and environmentally sustainable colors. Lele 1991 distinguishes between two competing understanding of sustainable development, "sustained growth" with implicit social objectives. He argues for rejecting attempts to define sustainability as compatible with or requiring continued economic growth (Purvis, Mao, & Robinson, 2018).

This directly highlights the tension between perspectives often associate with weak (sustained growth, allowing substitution between capital types_ and strong (ecological limits are paramount substitution is limited) sustainability.

Some critiques argue that sustainable development has reached a conceptual dead end due to its historical baggage and blindness to deep set structural issues in contrast to sustainability which prompts more fundamental context specific questions. This suggests that the mainstream interpretation of sustainable development has often been perceived as a diluted form of sustainability potentially aligning with weak sustainability.

2-3-2 Sustainable Development Goals (SDGs): the culmination of the development of sustainable development as a concept is the 2030 agenda for sustainable development adopted by the UN general assembly in 2015 this global document includes a list of 17 SDGs and 169 related targets (Versal & Sholoiko, 2022). The SDGs are described as integrated and indivisible balancing the three dimensions of sustainable development: economic, social and environmental. Despite this these three dimensions do not explicitly form part of the framework of the 17 goals themselves.

1. From MDGs to SDGs:

The 2030 Agenda for Sustainable Development, adopted by all United Nations Member States in 2015, provides a shared blueprint for peace and prosperity for people and planet (Nations, 2025).At its core are the 17 SDGs and 169 targets representing an urgent call for action by all countries.

The SDGs were explicitly designed to build upon the Millennium Development Goals (MDGs) and to complete what the MDGs did not achieve. The process to develop a set of SDGs was launched at the United Nations Conference on Sustainable Development (Rio 20+) in June 2012, with the intention of building upon the MDGs (Versal & Sholoiko, 2022). This process culminated in the adoption of the 2030 Agenda with the 17 SDGs in September 2015.

2. Historical development:

The SDGs framework did not emerge in isolation but builds on decades of work by countries and the UN. The concept of sustainable development itself has been discussed for a long time and its historical roots are varied.

1987: The world Commission on Environment and Development (WCED) presented the widely cited definition of sustainable development in the Brundtland report as development that meets the needs of the present without compromising the ability of future generations to meet their own needs (Versal & Sholoiko, 2022). This report is credited with popularizing the concept and bringing it into international policy discourse (Purvis, Mao, & Robinson, 2018).

1992: At the Earth Summit in Rio de Janeiro, more than 178 countries adopted Agenda 21, a comprehensive plan of action to build global partnership for sustainable development.

2000: Member states adopted the Millennium Declaration, leading to the elaboration of eight Millennium Development Goals (MDGs) aimed at reducing extreme poverty by 2015 (Versal & Sholoiko, 2022).

2002: The World Summit on Sustainable Development in South Africa reaffirmed commitments and built upon Agenda 21 and the Millennium Declaration, adding emphasis on multilateral partnerships (Nations, 2025). This summit is sometimes attributed as an origin of the "three pillars" concept of sustainability, though a clear theoretical background is not explicit (Purvis, Mao, & Robinson, 2018).

2012: the United Nations Conference on Sustainable Development (Rio+20) adopted the outcome document "The future we want" At this conference, member states decided to launch the process to develop the SDGs, building on the NDGs, and establish the UN High-level Political Forum on Sustainable Development (HLPF) (Nations, 2025).

2015: The General Assembly began the negotiation process for the post 2015 development agenda, leading to the adoption of the 2030 Agenda for Sustainable Development with the 17 SDGs in September 2015. This year was also significant for the adoption of other major agreements like the Paris Agreement on Climate Change.

Since their adoption, the SDGs are followed up and reviewed annually at the HLPF, with annual progress reports presented by the UN Secretary General. The division for Sustainable Development Goals (DSDG) provides support and capacity building for the SDGs.

Key stages in the development leading to the SDGs include:

Brundtland report defines sustainable development 1987.

The Rio declaration on environment and development at the Rio earth summit 1992.

The millennium development goals MDGs 2000.

UNGA adopts the 2030 agenda with the 17 SDGs 2015

The SDG and Paris agreement are considered key policy driven initiatives that define the scope of sustainability in recent years.

The UN conference on sustainable development 2012.

3. <u>Key goals and targets relevant to finance:</u>

Achieving the SDGs is a major challenge for all countries the sources highlight that the SDGs cannot be achieved unless money is mobilized to finance climate change mitigation and adaptation efforts across the world. Green financing is presented as an essential driving force for sustainable economic development as it enables technological innovation and industrial restructuring that decreases reliance on polluting energy (Mizra, Umar, Afzal , & Firdousi, 2023).

The objective of green financing is to improve financial flows from public private and nonprofit sectors towards sustainable development. This facilitates sustainable development by allocating capital in a way that supports the production and consumption arrangements of the future.

Green financial instruments like green bonds stimulate public private partnerships for sustainable development (Ahmed, Yusuf, & Ishaque, 2022).

Several specific SDGs are mentioned as being particularly relevant to finance:

-SDG 7 (affordable and clean energy) green energy financing is included in the list of UN sustainability goals as SDG 7. Investments in renewable energy sources are an example of activities aligned with sustainable development goals (Niyazbekova, et al., 2021).

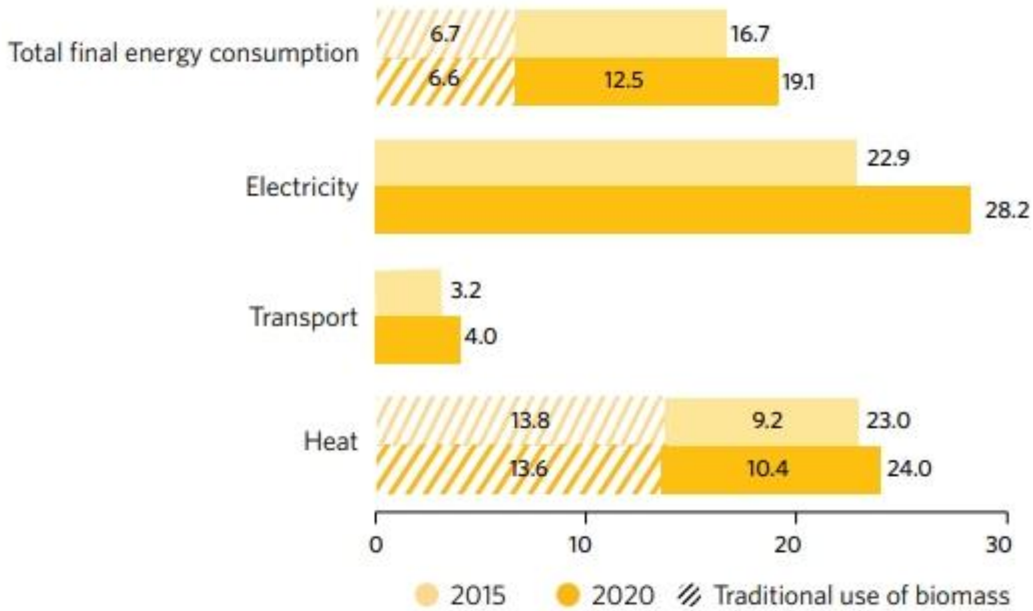


Figure 5 Share of renewable sources in final energy consumption and by end use, 2015 and 2020 (percentage) *(UN, 2023)*.

-SDG 8 (decent work and economic growth) this is one of the 17 SDGs established by the UNGA in 2015 it is relevant to green finance and eco innovations, with studies showing a relationship between eco innovations and increased employment (Llorente, Gavurova, Rigelsky, & Soriano, 2024), green finance is considered an elementary part of low carbon green growth linking financial processes with environmental improvement and economic growth. Sustainable inclusive economic growth is linked to SDG indicators. Economic growth is considered relevant to SDGs although it may not be an ideal proxy for economic development (Feridun & Talay, 2023)

-SDG 13 (climate action) green finance is crucial for the attainment of SDG 13 green bonds are seen as a bridge to the SDGs because climate mitigation and adaptation are integral to their successful implementation. Issuers of green bonds have demonstrated movement towards decreasing carbon intensity especially after the implementation of the Paris agreement which aims to limit global warming (Versal & Sholoiko, 2022).

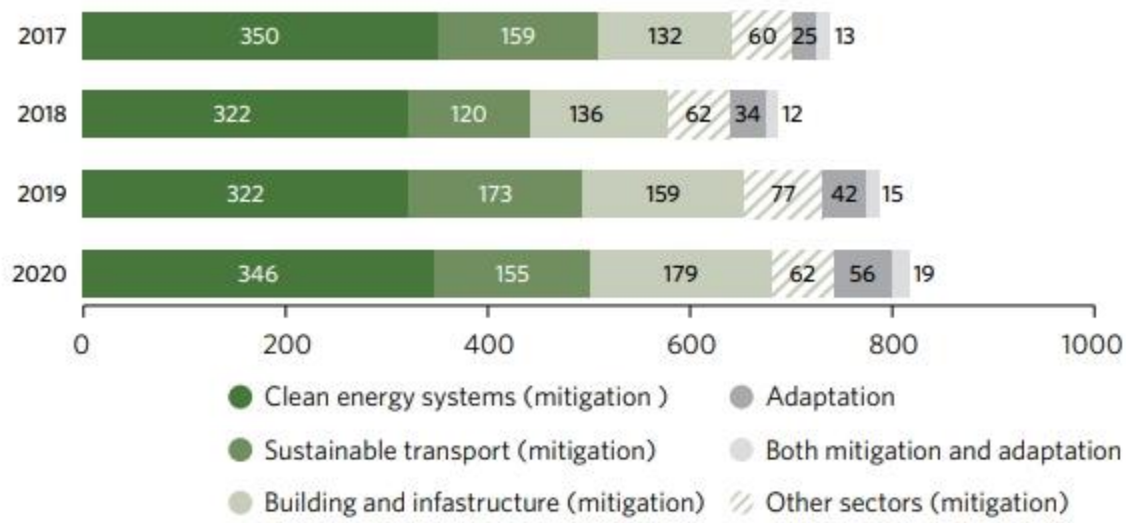


Figure 6 Global climate finance flows, by sector, 2017-2020 (USD Bn) *(UN, 2023)*

Other related goals mentioned as being connected to climate change and thus relevant to green finance include: life below water (conservation of marine ecosystems), life on land (terrestrial ecosystems), clean water and sanitation, responsible consumption and production.

More broadly sustainable finance should make clear reference to relevant sustainability dimensions like the preservation of the environment and ecosystems the conversation of biodiversity the fight against climate change (mitigation and adaptation) the eradication of poverty and hunger and the reduction of inequalities (Migliorelli, 2021). Financial institutions particularly wholesale banks play a role in financing large scale projects supporting the SDGs such as renewable energy and sustainable agriculture (Feridun & Talay, 2023).

Progress assessment frameworks: monitoring and assessing progress towards the SDGs is a critical component of the 2030 agenda. The 2030 agenda goals and targets can be reviewed at the global level within the UN high level political forum (HLPF) which serves as the central platform of the UN for this purpose (Versal & Sholoiko, 2022).

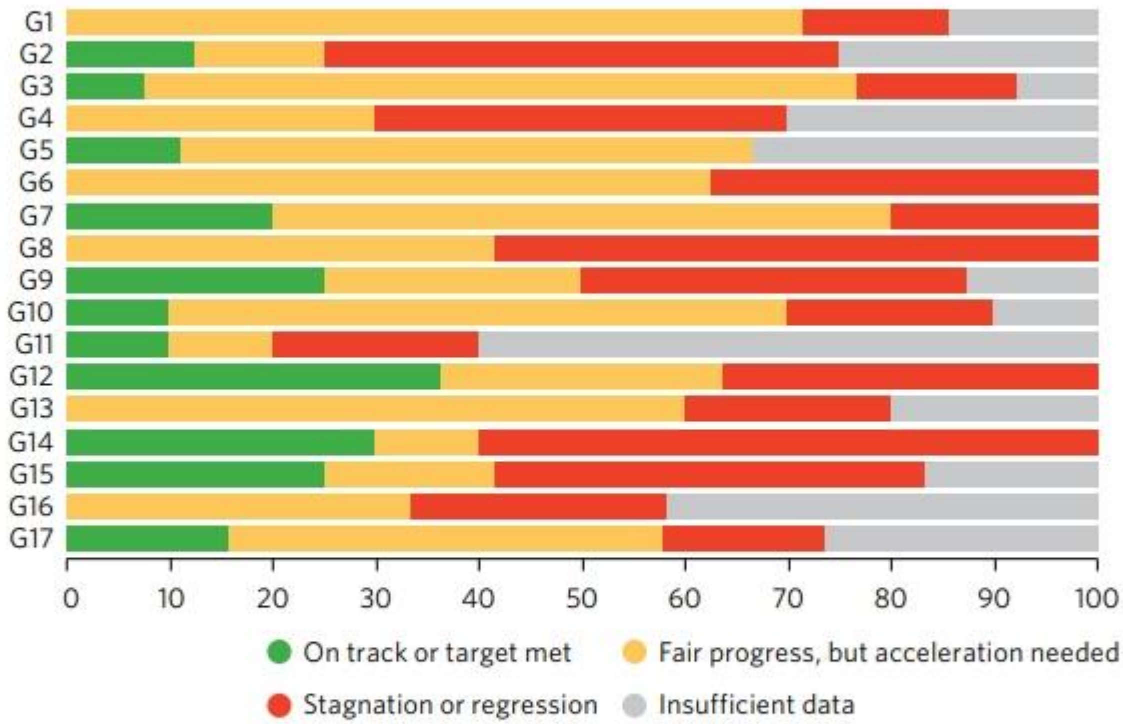


Figure 7 Progress assessment for the 17 goals based on assessed targets, 2023 *(UN, 2023)*

The UN releases an annual report on Progress towards the sustainable development goals. Some reports have shown improvements in areas like reducing poverty and mortality but highlight critical issues like climate change and inequalities (Vasilescu, Dimian, & Gradinaru, 2022).

Work has been done to develop sustainable development indicators. The commission on sustainable development (CSD) worked towards a core set of indicators equally emphasizing the economic, social, environmental and sometimes institutional aspects of sustainable development (Purvis, Mao, & Robinson, 2018) ,however questions have been raised about who defines sustainable development in this process.

Specific reports such as the sustainable development report 2012 by Sachs et al 2022 provide cross country performance rankings (formerly SDG index) that capture countries progress towards achieving all 17 SDGs. This is presented as an overall score interpreted as a percentage of SDG achievement (Feridun & Talay, 2023).

2-4 Conclusion:

Green finance and sustainable development are fundamentally intertwined concepts, with green finance acting as a crucial mechanism for achieving the objectives for sustainable development, particularly the ambitious set by the UN. The evolution of both concepts reflects a growing global awareness of the impact of economic activities on the environment and society, tracing from early ethical investment trends to the comprehensive frameworks of today.

Key policy initiatives like the EGD, the EU Taxonomy and the Paris Agreement provide foundational objectives and regulatory guidance aimed at directing financial flows towards environmentally sustainable activities and ensuring transparency and integrity in the process. Instruments such as green bonds, green loans, and green investment funds have developed to mobilize capital for specific environmental projects and broader sustainability transitions. While significant progress has been made in establishing frameworks and increasing green financial activities, challenges remain, including achieving global GHG emissions reduction targets aligned with the Paris Agreement and addressing inconsistencies in regulations and taxations. The ongoing development of the EU Taxonomy and its increasing application by companies, banks, and funds demonstrate a tangible effort to standardize the definition of green and steer investments effectively.

Ultimately, mobilizing finance towards sustainable development is recognized as essential, requiring continued innovation in financial products, active support from financial authorities, and coordinated efforts across jurisdictions to address global environmental challenges and pave the way for a sustainable future.

Chapter Three

The Empirical Literature

3-1 Introduction

3-2 Method

3-3 Information Sources

3-4 Quality Assessment and Data Extraction

3-5 Review and Survey of Selected Studies

1. **The growing importance of green bonds**
2. **Green bonds and carbon emissions reduction**
3. **Green bonds and the promotion of renewable energy**
4. **Renewable energy and carbon emissions reduction**
5. **Overview of econometric techniques used**

3-6 Contribution of the Study

3-7 Conclusion

3-1 Introduction:

this chapter provides a comprehensive understanding of how green bonds function within the broader ecosystem of climate finance and environmental policy. The findings underscore the necessity of coordinated policy interventions, standardized frameworks, and targeted investments to maximize the contribution of green bonds to global decarbonization efforts.

To conduct a focused literature review, we utilize both simple and advanced Boolean search strategies with targeted keyword combinations, including green bond AND Carbon emissions, AND Renewable energy. These search queries are designed to capture relevant studies while minimizing irrelevant results. Additionally, we restrict our scope exclusively to English-language publications to ensure consistency and accessibility in our review process. This approach allows for a systematic and efficient retrieval of scholarly works examining the relationship between green bond issuance and carbon emissions.

3-2 Method:

To conduct a focused literature review, we utilize both simple and advanced Boolean search strategies with targeted keyword combinations, including green bond AND Carbon emissions, AND Renewable energy. These search queries are designed to capture relevant studies while minimizing irrelevant results. Additionally, we restrict our scope exclusively to English-language publications to ensure consistency and accessibility in our review process. This approach allows for a systematic and efficient retrieval of scholarly works examining the relationship between green bond issuance and carbon emissions.

3-3 Information sources:

For this systematic review, we designed a comprehensive search strategy to identify pertinent literature across four key databases: Science Direct, JSTOR, and Google Scholar. This selection was made to ensure a broad yet relevant coverage of scholarly works, allowing for a thorough analysis of findings from diverse published studies. By incorporating multiple databases, our approach aims to capture a wide spectrum of research efforts, providing a more holistic understanding of the topic across various disciplines while maintaining relevance and rigor in the review process.

3-4 Quality Assessment and Data Extraction:

To ensure the quality and relevance of the selected literature, this study employed a rigorous screening process focusing exclusively on original research articles, books, and review papers published in English between 2000 and 2025. The inclusion was limited to works within the fields of economics, business, finance, and social sciences. All identified sources underwent thorough duplicate checks, followed by a detailed examination of abstracts to verify their suitability. Each qualifying publication was then subjected to an in-depth evaluation.

3-5 Review and Survey Selected Studies:

1- **The growing importance of green bonds**

Recent scholarship underscores the crucial role of green bonds and environmental policy in supporting the transition to low-carbon economy across European nations. (Mavlutova, et al., 2023)pinpoint green bonds as a crucial reduction initiative, aligning with sustainable development goals, especially SDG7 (affordable and clean energy) and SDG13 (climate action). Their empirical results show that in EU OCED countries higher issuance of green bonds is significantly correlated with lower carbon emissions intensity and higher renewable capacity. The study, nevertheless, also identified challenges such as greenwashing, inconsistent regulations, and transparency issues preventing the realization of the full potential of green bonds.

To this purpose, (Ossowska, Janiszewska, Bartkowiak-Bakun, & Kwiatkowski, 2020) emphasize that although trends in renewable energy consumption and CO2 emissions point to progress, policy coordination at the EU level remains paramount to address disparities among member states, particularly in coal dependent economies.

Moreover, (C. Marques, A. Fuinhas, & Manso, 2010) showcase the influence of political and institutional factors such as fossil fuel lobbying and energy policy directives and renewable energy adoption, reinforcing the idea that strong environmental policies are necessary to neutralize embedded interests and promote sustainable energy transitions.

Therefore, it is clear that green bonds can be powerful tools for low-carbon transformation, but their effectiveness is based on supportive policy frameworks, rigorous governance and regulatory consistency across nations.

2- **Green bonds and carbon emissions reduction**

The increasing urgency of climate change mitigation has positioned green bonds as a pivotal financial instrument in the global effort to reduce carbon emissions. Green bonds, which are debt securities specifically designated to fund environmentally sustainable projects such as renewable energy, energy efficiency, and clean transportation, have garnered significant attention for their potential to align financial markets with climate goals. A growing body of empirical research underscores their effectiveness in lowering CO_2 emissions, particularly in the context of international climate agreements like the Paris Accord. The evidence suggests that while green bonds have demonstrated considerable promise in reducing emissions, their impact is influenced by policy frameworks, market conditions, and institutional factors, necessitating targeted strategies to maximize their potential.

Empirical studies provide robust evidence that green bonds contribute to measurable reductions in CO_2 emissions. (Alamgir & Cheng, 2023) employ a dynamic panel Generalized Method of Moments (GMM) model across 67 countries and a supranational entity from 2007 to 2021, finding that green bond issuance led to a per capita CO_2 emissions reduction of up to 0.8 tons after 2015. This effect was particularly pronounced following the Paris Agreement, highlighting the role of international policy coherence in enhancing the efficacy of green finance. They demonstrate a significant negative correlation between green bond issuance and CO_2 emissions, alongside a positive association with renewable energy production, reinforcing their dual role in climate mitigation and clean energy financing. These findings are further supported by (Zhou & Li, 2022), who use an Autoregressive Distributed Lag (ARDL) model to analyze China's green finance landscape, confirming a long-term negative relationship between green bonds and CO_2 emissions. Their research emphasizes how green bonds facilitate investments in renewable energy sources such as wind and solar power, accelerating the transition away from fossil fuels. However, the effectiveness of green bonds is not uniform across all regions and sectors. (Pata, Kartal, Ahmed, & Sinha, 2025) examine the world's five largest emitters—China, the United States, India, Russia, and Japan—and find that while green bonds significantly reduce emissions in the transportation and residential sectors of developed economies like the U.S. and Japan, their impact is inconsistent or even counterproductive in the industrial and power sectors of emerging economies. This variability underscores the importance of structural and regulatory frameworks in shaping the outcomes of green bond investments.

The interaction between green bonds and carbon pricing mechanisms, such as the European Union Emissions Trading System (EU ETS), has also been a focal point of recent research. (Rannou, Boutabba, & Barneto, 2021) analyze the behavior of European power firms from 2013 to 2020, revealing that green bonds increasingly substituted long-term carbon hedging after 2018, while continuing to complement short-term hedging strategies. This shift coincided with rising EU Allowance (EUA) prices, suggesting that green bonds reinforce carbon price signals and incentivize cleaner investments. (Leitao, Ferreira, & Gonzalez, 2021) further explore this dynamic using Markov-switching and quantile regression models, finding that green bonds exert a positive influence on carbon prices, particularly during low-volatility periods. In contrast, conventional bonds and energy commodities tend to destabilize carbon markets, especially under high-volatility conditions. These findings highlight the stabilizing role of green bonds in carbon markets and their potential to enhance the effectiveness of climate policies. However, the study also notes that the relationship between green bonds and carbon prices is asymmetric, with low-volatility periods exhibiting greater persistence, which has implications for policymakers seeking to design resilient financial and regulatory frameworks.

Supranational financial institutions, such as the World Bank (WB) and the European Bank for Reconstruction and Development (EBRD), have played a critical role in scaling up the green bond market.(Versal & Sholoiko, 2022) emphasize their function as early adopters and key intermediaries, particularly in developing countries with limited financial capacity but pressing environmental needs. These institutions provide not only long-term and affordable funding but also technical oversight and implementation assurance, mitigating risks such as greenwashing and regulatory fragmentation. Despite global disruptions like the COVID-19 pandemic, green bond issuance by these entities has maintained a positive trajectory, with a significant portion of funding directed toward renewable energy, energy efficiency, and clean transport projects in high-emission countries such as China, India, and Turkey. However, challenges persist, including inconsistent standards and the risk of greenwashing, which undermine investor confidence. The authors argue that the continued involvement of supranational institutions is essential for ensuring equitable and effective green transitions, particularly in economies with limited institutional and financial resources.

Despite their potential, green bonds face several obstacles that limit their broader adoption and effectiveness. (Mavlutova, et al., 2023) identify regulatory fragmentation and the lack of standardized definitions and verification processes as major barriers, leading to investor skepticism and market inefficiencies. Additionally, the green bond market remains relatively small compared to the scale of financing required to meet global climate targets, necessitating further expansion and innovation in financial instruments. (Pata, Kartal, Ahmed, & Sinha, 2025) also highlight the sectoral and geographic variability in green bonds' effectiveness, emphasizing the need for tailored policies that address the unique challenges of different industries and regions. To overcome these challenges, scholars recommend a multi-pronged approach that includes harmonizing green bond standards, integrating green finance with carbon pricing mechanisms, and prioritizing investments in high-emission sectors and regions. (Alamgir & Cheng, 2023)further suggest that environmental taxes and foreign direct investment can serve as moderating factors, enhancing the overall impact of green bonds on emissions reduction.

In conclusion, the literature overwhelmingly supports the role of green bonds in reducing CO_2 emissions, particularly when supported by strong policy frameworks and institutional mechanisms. Their effectiveness varies across sectors, regions, and market conditions, necessitating nuanced and targeted approaches to maximize their potential. Future research should explore innovative financial instruments, such as sustainability-linked bonds, and the interplay between green bonds and other climate finance mechanisms. Policymakers must prioritize standardization, transparency, and strategic deployment to ensure that green bonds fulfill their promise as a key tool in the global fight against climate change. By addressing existing challenges and leveraging the insights from empirical studies, stakeholders can unlock the full potential of green bonds in achieving sustainable development and carbon neutrality goals.

3- Green bonds and the promoting of renewable energy

Green bonds have emerged as a critical funding tool for the growth of renewable energy initiatives and deployment, particularly in accordance with global climate targets and low carbon transition economies. (S. Alharbi, Al Mamun, Boubaker, & Rizvi, 2023) present robust cross-country evidence from 44 countries that shows green bonds have a significant influence on the generation of renewable energy from various energy sources including biomass and non-biomass sources. It points out that high tech capable countries with well-developed financial markets are likely to benefit from renewable energy expansion through green bond financing, particularly when it is supported by climate risk and policy alignment such as the Paris Agreement.

(Madaleno, Dogan, & Taskin, 2022), demonstrate a strong causal link from clean energy demand to green finance, particularly green bonds, suggesting that the growth in renewable energy investments drives green bond issuance. Conversely, green bonds facilitate renewable energy development by providing essential capital, though this effect is more pronounced during stable economic periods and weakened during crises like the COVID-19 pandemic. The bidirectional relationship underscores the interdependence of green finance and clean energy transitions, emphasizing the need for policy frameworks that enhance green bond markets to accelerate renewable energy adoption and sustainability goals.

Similarly,(Ossowska, Janiszewska, Bartkowiak-Bakun, & Kwiatkowski, 2020) note the importance of concerted environmental policy within the EU context, whereby increased use of renewable energy correlated with declining CO2 emissions between the years 2005 and 2015. While the explicit relationship between renewable energy and energy independence was limited, findings establish that policy encouragement and economic instruments like green bonds play pivotal roles in connecting spatial and development gaps in the adoption of renewable energy in combination, these studies once again confirm that green bonds are not merely efficient vehicles for raising capital but also integral components of more inclusive policy and institutional structure needed to accelerate renewable energy development globally.

4- **Renewable energy and carbon emissions reduction**

The relationship between renewable energy (RE) adoption and CO_2 emissions has been extensively studied, with research highlighting both the potential for RE to mitigate climate change and the structural challenges that hinder its effectiveness. (Ossowska, Janiszewska, Bartkowiak-Bakun, & Kwiatkowski, 2020) examined the European Union (EU) from 2005 to 2015, finding that while RE expansion contributed to emission reductions, the pace of transition varied significantly across member states. Their cluster analysis identified five distinct groups of countries, revealing that nations with high nuclear and renewable energy shares, such as France and Sweden, achieved the most substantial CO_2 reductions. In contrast, coal-dependent Central and Eastern European countries showed only marginal improvements, underscoring the persistent influence of fossil fuel infrastructure. A critical insight from this study is that energy independence in the EU remains more closely tied to domestic coal reserves than to RE integration, suggesting that political and economic inertia slows the transition. Furthermore, the ambiguous correlation between RE growth and emission cuts indicates that current efforts may be insufficient to meet long-term climate targets. These findings align with those of (C. Marques, A. Fuinhas, & Manso, 2010), who analyzed RE adoption in 24 European countries from 1990 to 2006. Their study found that entrenched fossil fuel industries—particularly oil and coal—actively hindered RE deployment through lobbying, creating a negative relationship between fossil fuel reliance and RE adoption. Interestingly, energy dependency emerged as a stronger motivator for RE investment than environmental concerns, as import-reliant nations prioritized domestic renewables for energy security. The study also highlighted the role of institutional frameworks, showing that EU membership, especially after the implementation of Directive 2001/77/EC, significantly accelerated RE commitments. However, economic capacity played a divergent role: while higher GDP correlated with greater RE adoption in EU states, this effect was weaker or even negative in non-EU countries, suggesting that financial resources alone are insufficient without supportive policies.

Expanding beyond Europe, (Chang & Wang, 2021)investigated the long-term relationship between RE and CO_2 emissions across 41 OECD and non-OECD countries from 1973 to 2017. Their panel cointegration analysis revealed a bidirectional causality in OECD nations, where RE deployment reduced emissions while rising CO_2 levels also prompted further RE policy adjustments—a feedback loop facilitated by strong institutions and climate commitments. In contrast, non-OECD countries exhibited only unidirectional causality: increasing emissions drove RE adoption (likely due to external pressures or energy security needs), but RE expansion did not yet significantly curb emissions. This disparity was attributed to structural barriers such as fossil fuel dependence, weaker policy frameworks, and lower RE penetration in developing economies. The study underscores the need for differentiated climate strategies, as OECD countries benefit from integrated policy approaches, while non-OECD nations require targeted investments and institutional reforms to enhance RE's mitigating effects. Similarly, (Khalifa, 2025) ARDL analysis of Tunisia (1990–2020) illustrates the challenges faced by developing economies in balancing industrialization and decarbonization. While clean energy (CEN) and technological innovation (TI) led to short-term emission reductions, TI paradoxically increased emissions in the long run—likely due to industrial expansion outpacing environmental regulations. Financial development (FD) and urbanization (UP) had theoretically favorable but statistically weak effects, pointing to structural obstacles such as Tunisia's heavy reliance on fossil fuels (97% of electricity generation) and underdeveloped green financing mechanisms. Causality tests revealed a bidirectional link between TI and emissions, indicating that emission targets can spur innovation, while UP and FD unidirectionally influenced emissions, suggesting that urban planning and financial reforms are crucial policy levers.

Collectively, these studies demonstrate that while RE can reduce CO_2 emissions, its effectiveness depends on regional economic structures, policy frameworks, and institutional capacities. The EU's experience shows that diversified low-carbon energy mixes (including nuclear and renewables) yield deeper emission cuts, but fossil fuel dependencies—particularly coal—remain a major obstacle. In developing economies, financial constraints, weak regulations, and industrial growth often undermine RE's potential, leading to paradoxical outcomes where technological advancement does not always equate to emissions reductions. Policymakers must therefore adopt context-specific strategies: EU nations need stronger coal phase-out policies and RE incentives, while non-OECD countries require institutional reforms, technology transfers, and green financing mechanisms. Future research should explore post-2020 developments, such as the

European Green Deal and advancements in energy storage, to assess whether recent policy shifts have accelerated the transition. Ultimately, achieving meaningful emission reductions through RE will demand not only technological deployment but also systemic changes in energy governance, economic incentives, and international cooperation.

5- **Overview of econometric techniques used**

Emergent green finance literature on green bonds and their role in achieving sustainability, carbon neutrality, and the utilization of renewable power has employed a broad array of econometric techniques for accounting for complex, dynamic interactions over time, across nations, and along financial instruments. Time-series estimation, such as models like the Autoregressive Distributed Lag (ARDL) model, are the standout features in most papers due to their capacity to examine both the short-run and long-run dynamics. For instance, (Zhou & Li, 2022) used ARDL to examine the long-run impact of green finance and renewable energy consumption on China's carbon emissions and clean energy consumption, respectively, and that of Japan on the consumption of renewable energy. Similarly, (Khalifa, 2025) utilized ARDL and cointegration bounds testing to examine the impact of clean energy, urbanization, and financial development on Tunisia's carbon neutrality.

On the other hand, panel data models have been widely used to investigate larger cross-country trends. (C. Marques, A. Fuinhas, & Manso, 2010) used Fixed Effects Vector Decomposition (FEVD) to identify political and economic determinants of the use of renewable energy in 24 European nations. Simultaneously, (Alamgir & Cheng, 2023) applied a one-step Generalized Method of Moments (GMM) dynamic panel model to analyze the global effect of green bond issuance on SDG-relevant outputs such as carbon emissions and renewable energy generation across 67 countries. Likewise, (Li, Zhou, Sun, & Liu, 2022) used panel data econometrics to examine the spillover connections between green bonds, environmental taxes, and energy efficiency in the EU while applying controls for macroeconomic determinants like GDP and inflation.

To capture regime-dependent and non-linear behavior (Leitao, Ferreira, & Gonzalez, 2021) applied Markov-Switching models, which uncovered the degree to which green bonds affect EU carbon markets across different states of volatility—showing stronger effects across both high- and low-volatility regimes. The approach is best suited to model abrupt changes in financial markets and is well-suited to model dynamic interplay between green financial instruments and carbon pricing.

Advanced causality tests have also become popular. (Madaleno, Dogan, & Taskin, 2022) employed a time-varying Granger causality test developed by Shi et al. (2018, 2020) to trace the evolving causal connections between green finance, green technology, clean energy, and environmental responsibility using high-frequency data. This allows scholars to capture changes in causality over time, enhancing temporal depth of analysis.

Lastly, quantile-oriented econometric techniques such as Quantile Regression (QR) and Quantile-on-Quantile Regression (QQR) have been applied to address distributional heterogeneity. Pata et al. (2025), in particular, used QR, QQR, and Granger Causality in Quantiles (GCQ) to explore the non-linear, quantile-specific relationship between green bonds and sectoral CO_2 emissions among the world's largest five emitting countries and offer a detailed picture of how green bonds perform across different emission contexts and policy regimes.

The following table (3.1) provides a short summary for most the relevant studies reviewed in this chapter

Authors and Year	Objectives and Period	Estimation Methods	Main results
Yves Rannou , Mohamed Amine Boutabba, Pascal Barneto (2021)	Examine the interactions between European carbon (EUA) and green bond markets, focusing on power firms' strategies. 2013-2020	Flexible VAR	Raises concerns about carbon market fragmentation and cost burdens on power firms.
Nataliia Versal and Antonina Sholoiko (2022)	Analyze the features of green bond issuances by WB and EBRD. Examine the geographic and sectoral distribution of funded green projects. 1992-2018	Time-series data descriptive/comparative study	Renewables dominate funding; China/India/Turkey are top recipients; sustainability bonds rise post-COVID.
Joao Leitao, Joaquim Ferreira, Ernesto Santibanez-Gonzalez (2021)	Investigate non-linear effects of green bonds, conventional bonds, and energy commodities on EU carbon prices (EU-ETS). 11 march 2014- 30 September 2019	Markov-Switching (MS) Model	Green bonds are a win-win for carbon markets, boosting prices in all conditions, while conventional assets drag them down during crises. Investors should go green, and policymakers should leverage green finance for climate goals.
Muhammad Alamgir and Ming-Chang Cheng (2023)	Investigate the impact of green bonds on: -Reducing CO_2 emissions (SDG 13). -Increasing renewable energy production (SDG 7). 2007-2021	Panel data analysis	Green bonds are a potent tool for SDGs 7 and 13, but their efficacy hinges on market maturity (post-2015) and policy synergy (e.g., carbon pricing). High-issuance countries lead the

			way, while others must urgently scale green finance.
Ugur Korkut Pata, Mustafa Tevfik Kartal , Zahoor Ahmed and Avik Sinha (2025)	Investigate green bonds' heterogeneous effects on sectoral CO_2 emissions across quantiles and time-frequency domains. Identify country- and sector-specific impacts to guide targeted climate policies. 2 January 2019- 30 December 2022	High-frequency time-series data analysis	Green bonds are potent but context-dependent. Success requires: Sector-specific policies (e.g., US transport vs. Japan residential). Stricter bond criteria in India/Russia to prevent emissions leakage
António C. Marques n, José A. Fuinhas, J.R. Pires Manso (2010)	Identify key drivers of renewable energy adoption in Europe Assess the impact of traditional energy lobbies, CO_2 emissions, and energy dependency on RE deployment. 1990—2006	Panel data analysis	-CO_2 Emissions: Higher emissions correlate with lower RE adoption. -Import-reliant countries invest more in RE (energy security motive).
Inese Mavlutova , Aivars Spilbergs , Atis Verdenhofs , Jekaterina Kuzmina, Ilja Arefjevs and Andris Natrins (2023)	Analyze trends and challenges in green finance (focus: green bonds). Assess the impact of green bonds on: Carbon emission intensity (CEI). Renewable energy supply (RES). 2021	Cross-sectional study	Green bonds are effective tools for: Financing renewable energy projects. Decarbonizing economies.

Samar S. Alharbi, Md Al Mamun, Sabri Boubaker, Syed Kumail Abbas Rizvi (2023)	To examine whether and how green finance (proxied by green bond issuance) promotes renewable energy production, and under what economic or institutional conditions this effect is amplified, especially in the long run. 2007-2020	Panel data analysis	Green finance significantly boosts renewable energy production in both short and long run. The effect is stronger when green bonds are targeted toward alternative energy production and energy efficiency. The long-run effect of green finance is stronger in countries that: Emit more CO_2 per dollar of GDP, Have well-developed credit markets.
Chun-Ping Chang1a, Quan-Jing Wang (2021)	Examine long-run cointegration between CO_2 emissions and renewable energy share Analyze bidirectional causal relationships between these variables Compare dynamics between OECD vs. non-OECD countries 1973–2017	Panel cointegration test	The study highlights divergent energy-emission dynamics: OECD nations show a virtuous cycle, while non-OECD nations need stronger renewable integration to mirror this effect.
Jihene Khalifa (2025)	The primary objective of this research is to explore the impact of financial development (FD), technological innovation (TI), clean energy (CEN), and urbanization (UP) on carbon neutrality in Tunisia 1990 to 2020	ARDL approach	Short-Term: Clean energy & tech innovation reduce CO_2 emissions. ong-Term: Tech innovation increases CO_2 (without regulation).

Luiza Ossowska and Dorota Janiszewska (2020)	Analyze how changes in energy consumption mix (fossil fuels, renewables, nuclear) affected greenhouse gas emissions across EU countries, focusing on energy independence and emission reduction efficacy. 2005–2015	Cluster analysis	Renewable energy use increased but insufficiently reduced emissions, with nuclear-reliant countries like France achieving the deepest cuts. Coal-dependent nations showed minimal progress, revealing renewables alone can't ensure energy independence - domestic fossil fuels still provided greater security. The findings highlight the need for tailored national strategies combining renewables, nuclear and fossil phase-outs to meet climate goals.
Mara Madaleno , Eyup Dogan , Dilvin Taskin (2022)	Investigate causal relationships among green finance, clean energy and environmental responsibility to capture evolving dynamics. July 31, 2014 – October 12, 2021	Time-varying Granger causality test	Results show that clean energy promotes green finance, supporting sustainable transitions

3-3 Contribution of the Study:

This study contributes to the growing literature on green bonds and sustainable development by providing empirical evidence on their effectiveness in reducing carbon emissions and promoting renewable energy adoption across six European countries from 2010 to 2023. The research builds upon existing scholarship while addressing key methodological gaps through advanced panel data analysis.

It provides robust quantitative evidence supporting the environmental benefits of green bonds, confirming findings from prior research (Alamgir et al., 2023; Zhou et al., 2023) while offering more focused insights into the European context. The analysis specifically examines:

- The relationship between green bond issuance and CO_2 emissions reduction
- The effect on renewable energy expansion

This study strengthens the empirical foundation for understanding green bonds' role in sustainable development by applying rigorous panel data methods to the European context. The findings validate and extend prior research while providing more nuanced insights into the mechanisms through which green finance contributes to environmental objectives. The methodological approach offers a template for future research examining financial instruments for sustainability transitions.

3-4 Conclusion

This chapter comprehensively reviewed the empirical literature on green bonds, emphasizing their pivotal role in climate finance. We systematically surveyed studies on their impact on carbon emissions reduction and renewable energy promotion, alongside the relationship between renewable energy and emissions. The review highlighted the need for coordinated policy and standardized frameworks. Our study contributes robust empirical evidence on green bonds' effectiveness in reducing carbon emissions and fostering renewable energy adoption across six European countries from 2010 to 2023. This analysis builds upon existing scholarship, addressing methodological gaps through advanced panel data techniques. Moving forward, the next chapter will detail the specific data sources and econometric methodology employed for this research.

Chapter four

Data and methodology

4-1: Introduction

4-2 Research approach

4-3: data of the study

4-3-1: Source of data

4-3-2: Population and sample

4-3-3: Variables of the study

4-4: the methodology of the study

4-1 Introduction:

The methodology used in the research to examine the contribution of green financing to sustainable development in Europe from 2010 to 2023 is discussed in this chapter. With the aim to evaluate the connection between green bond issuance (as a proxy measure of green financing) and principal indicators of sustainability, including CO2 emissions, carbon intensity, and renewable energy production and capacity, the study utilized panel data analysis. The study methodology, data sources, variables, and econometric model employed to examine are all elaborated in detail in this chapter.

4-2 Research approach:

The study utilizes a quantitative approach with panel data regression analysis to examine green financing and indicators of sustainable development's relationship. Panel data are used since they are able to capture unobserved heterogeneity both in space and over time and provide stronger estimates than cross-sectional or time-series analysis alone.

The research is explanatory in orientation, with testable hypotheses formulated for whether an increase in issuing green bonds makes environmental sustainability measurably better. Statistical programs like STATA are applied for analysis for ensuring precision and reliability.

4-3 Data of the study:

4-3-1 Sources of data:

This present research study counts on various sources of data but it mainly obtained from secondary and primary sources such as IEA and WORLD BANK.

The study relied on the databases and yearly reports of IRENA, EEA, IEA and WORLD BANK.

4-3-2 Population and sample:

The population of this study consists of some European Union (EU) member states, representing the complete set of observations relevant to the research question on green financing and sustainable development. However, due to data availability constraints and the need for a focused empirical analysis, a representative sample of six EU countries was selected: Sweden, Germany, France, Spain, Italy, and Poland.

The sample used in this study to execute the empirical test is chosen based on peer review criteria:

1. **Geographical and economic diversity:**

The sample includes countries from Northern (Sweden), Western (Germany and France), Southern (Spain and Italy) and Eastern (Poland) Europe to ensure regional representation. It covers both high-income economies and emerging economies capturing varying stages of green finance adoption.

2. **Data consistency:**

The selected countries have complete or near complete datasets for key variables from 2010-2023.

3. **Statistical approach:**

This sample of six countries over 14 years yields 84 panel observations which is sufficient for robust regression analysis while avoiding overfitting.

4-3-3 Definition and measurement of variables:

The purpose of this study is to empirically analyze the impact of green financing on sustainable development in Europe with a focus on the role of green bonds in reducing carbon emissions and promoting renewable energy adoption; to achieve this objective the study attempts to identify the factors that are significantly influenced by green bonds issuance. annual panel data on green financing indicators (green bond issuance in USD billion), environmental performance metrics (total CO_2 emissions, CO_2\GDP ratio, per capita emissions, renewable energy production and capacity) cover the period from 2010 to 2023 for six major EU economies.

1. **Independent Variables:**

-Green Bond Issuance (GB ISSUANCE)

Definition: Annual volume of green bonds issued, measured in USD billions.

Rationale: This variable serves as the primary proxy for green financing activity, quantifying capital flows directed toward renewable energy, energy efficiency, and other low-carbon projects. By analyzing GB_ISSUANCE, this study evaluates whether market-based climate finance instruments contribute to measurable decarbonization outcomes.
Source: WORLD BANK**.**

-Renewable Energy Capacity (RE CAP)

Definition*:* Installed capacity of renewable energy infrastructure (e.g., wind, solar, hydro), measured in megawatts (MW).
Rationale: RE CAP captures the expansion of renewable energy adoption, reflecting long-term investments in clean energy infrastructure. This variable helps assess whether increased capacity translates into lower carbon emissions.
Source: IRENA

-Renewable Energy Production (RE PROD)

Definition*:* Annual electricity generation from renewable sources, measured in gigawatt-hours (GWh).
Rationale: Unlike RE CAP (potential output), RE PROD measures actual renewable energy utilization, providing insight into the operational effectiveness of clean energy systems in displacing fossil fuel-based generation.
Source: IRENA

-Dependent Variable:

Total Carbon Emissions (TCO2)

Definitio*n**:* Annual CO_2 emissions from fossil fuel combustion and industrial processes, measured in metric tons.
Rationale*:* TCO2 serves as the key environmental outcome variable, quantifying the net effect of green bonds and renewable energy deployment on decarbonization.
Source: European Environment Agency (EEA)

4-4 Methodology of the study:

The study employs a quantitative panel data analysis to investigate the impact of green bond financing and renewable energy deployment on carbon emissions.

To address potential endogeneity and unobserved heterogeneity, a fixed-effects model will be preferred if the Hausman test rejects the random-effects specification. Additional robustness checks include lagged independent variables to mitigate reverse causality, and clustered standard errors to correct for heteroskedasticity and autocorrelation. Diagnostic tests, such as the Variance Inflation Factor (VIF) for multicollinearity and panel unit root tests for stationarity, will further validate the model.

<u>The econometric model of the study:</u>

$$\boldsymbol{TCO2}_{it} = \boldsymbol{\beta}_0 + \boldsymbol{\beta}_1 \cdot \boldsymbol{GB\_ISSUANCE}_{it} + \boldsymbol{\beta}_2 \cdot \boldsymbol{RE\_CAP}_{it} + \boldsymbol{\beta}_3 \cdot \boldsymbol{RE\_PROD}_{it} + \boldsymbol{\varepsilon}_{it}$$

Where:

$\boldsymbol{TCO2}_{it}$ = Total carbon emissions for country *i* in year *t* (dependent variable).

$\boldsymbol{GB\_ISSUANCE}_{it}$ = Green bond issuance (USD billions) for country *i* in year *t*.

$\boldsymbol{RE\_CAP}_{it}$ = Renewable energy capacity (MW) for country *i* in year *t*.

$\boldsymbol{RE\_PROD}_{it}$ = Renewable energy production (GWh) for country *i* in year *t*.

β0 = Intercept term.

β1,β2,β3= Coefficients for the independent variables.

εit = Error term.

4-5 Conclusion:

This chapter has illustrated the research method used and methodology approved to present a convincing answer for all the study questions. The sample, data collection, and the procedure utilized to investigate the role of green bond issuance in achieving sustainable development in six selected EU countries. As a final point, the formulation of the hypotheses is surveyed. The next chapter shows the results of estimations and analysis.

Chapter Five

Data Analysis

5-1 Introduction

5-2 Descriptive statistics

5-3 Empirical Results

5-3-1 Pooled Model

5-3-2 Fixed Effect

5-3-3 Random Effect

5-4-4 Choice of the appropriate Model

5-4-5 Diagnostics Tests

5-5 Interpretation of results (The appropriate model)

5-6 Conclusion

5-1 Introduction

The main objectives of this chapter are: Firstly, to investigate to what extent we can count on green bond issuance to lower carbon emissions in the selected EU countries. Secondly, to find out the main macroeconomic variables those explain variation in carbon emissions. The chapter consists of the descriptive statistics and empirical results. Each variable's significance is examined. Finally, a summary and some concluding remarks are discussed

5-2 Descriptive statistics

The descriptive statistics are presented for a sample of 6 countries from EU countries, over the period 2010-2023. The data consists of 53 observations for each variable during the above-mentioned period for each variable. Table (5.1) which follows, reports the most important descriptive statistics for the sample of countries included in this study. Chapter Five Data Analysis 79 minimum value, maximum value, and standard deviation as one of dispersion.

Table (5.1) Descriptive Statistics of the Variables of the Study

Statistic	TCO2	GB_Issuance	CAP	PROD
Mean	0.171036	-0.213170	-7.55E-07	0.083171
Median	0.090180	-0.711300	-0.349350	-0.044560
Maximum	2.738310	3.457260	4.255070	2.602460
Minimum	-1.699220	-0.711300	-0.737280	-1.426760
Std. Dev.	0.991092	0.907672	1.000000	0.954807
Skewness	0.672247	1.998691	2.349720	0.976864
Kurtosis	3.859744	7.090639	9.070844	3.579326
Jarque-Bera	5.624239	72.23986	130.1589	9.170488
Probability	0.060078	0.000000	0.000000	0.010201
Sum	9.064920	-11.29802	-4.00E-05	4.408080
Sum Sq. Dev.	51.07774	42.84114	52.000000	47.40618
Observations	53	53	53	53

Source: Prepared by the researched using Eviews 12

The results presented in Table (1.1) demonstrate that TCO2 (carbon dioxide emissions), the mean value is 0.171. The values range from a minimum of -1.699 to a maximum of 2.738. The standard deviation is 0.991, suggesting a moderate spread in the data. The skewness is 0.672, indicating a moderately right-skewed distribution. Kurtosis is 3.860, which is slightly above the normal value of 3, suggesting somewhat heavier tails. The Jarque-Bera statistic is 5.624 with a p-value of 0.060. Because this p-value exceeds the 0.05 threshold, the null hypothesis of normality cannot be rejected. Therefore, TCO2 appears approximately normally distributed.

Turning to GB_Issuance, which represents green bond issuance, the mean is -0.213. The values range from -0.711 to 3.457, with a standard deviation of 0.908, indicating considerable variation. Skewness is 1.999, showing a strong rightward skew. Kurtosis is 7.091, which suggests a distribution with very heavy tails and a sharp peak. The Jarque-Bera p-value is 0.000, which strongly rejects the null hypothesis of normality.

For CAP, measuring renewable energy capacity, the mean is nearly zero. The values span from -0.737 to 4.255. The standard deviation is exactly 1.000. Skewness is 2.350, which reflects a strong positive skew. Kurtosis is 9.071, indicating extremely heavy tails and a peaked distribution. As with green bond issuance, the Jarque-Bera p-value is 0.000, confirming non-normality.

Finally, for PROD, referring to renewable energy production, the mean is 0.083. The data range from -1.427 to 2.602, with a standard deviation of 0.955. Skewness is 0.977, pointing to a positive skew. Kurtosis is 3.579, showing moderately heavy tails. The Jarque-Bera p-value is 0.010, which is below 0.05; hence, the null hypothesis of normality is rejected for this variable as well.

5-3 Empirical Results

5-3-1 Pooled Model

This table (5.2) displays the results for the Panel Least Squares model, often called the Pooled OLS model. The dependent variable is TCO2. The model uses data from 2010 to 2023, with 11 periods and 6 cross-sections, totaling 53 observations.

The variable GB_Issuance has a coefficient of -0.141329. This suggests that a one-unit increase in green bond issuance is associated with a decrease of 0.141329 units in TCO2, holding other factors constant. This effect is statistically significant, as its Prob. (p-value) is 0.0016, which is less than the common significance level of 0.05. The t-Statistic of -3.348100 also indicates significance.

CAP has a coefficient of -0.032584. This implies a negative relationship with TCO2. However, this variable is not statistically significant; its Prob. is 0.4584, which is much higher than 0.05. The t-Statistic is -0.747394.

PROD shows a coefficient of 0.995763. This indicates a positive association with TCO2; so, as renewable energy production increases, TCO2 also increases. This result is highly statistically significant, with a Prob. of 0.0000. The t-Statistic is very large at 22.68680.

The Constant (C) term has a coefficient of 0.058090 but is not statistically significant (Prob. = 0.1281).

Looking at the overall model fit, the R-squared is 0.933313, meaning about 93.3% of the variation in TCO2 is explained by the model. The Adjusted R-squared is 0.929230. The F-statistic is 228.5910 with a Prob(F-statistic) of 0.000000. This very low p-value indicates that the model as a whole is statistically significant. However, the Durbin-Watson stat is 0.585311, which is quite low (far from 2.0). This value suggests the presence of positive serial autocorrelation in the residuals, which can be a problem for the reliability of OLS estimates.

$$y_{it} = a_0 + a' x_{it} + \varepsilon_{it}$$

Table (5.2) Results for the Panel Least Squares model

Dependent Variable: TCO2
Method: Panel Least Squares
Date: 05/20/25 Time: 22:07
Sample (adjusted): 2010–2023
Periods included: 11
Cross-sections included: 6
Total panel (unbalanced) observations: 53

Variable	Coefficient	Std. Error	t-Statistic	Prob.
GB_ISSUANCE	-0.141329	0.042212	-3.348100	0.0016
CAP	-0.032584	0.043597	-0.747394	0.4584
PROD	0.995763	0.043892	22.68680	0.0000
C (Constant)	0.058090	0.037527	1.547963	0.1281

Model Statistics		Model Fit Criteria	
R-squared	0.933313	Mean dependent var	0.171036
Adjusted R-squared	0.929230	S.D. dependent var	0.991092
S.E. of regression	0.263657	Akaike info criterion	0.244136
Sum squared resid	3.406235	Schwarz criterion	0.392837
Log likelihood	-2.469606	Hannan-Quinn criterion	0.301319
F-statistic	228.5910	Durbin-Watson stat	0.585311
Prob(F-statistic)	0.000000		

Source: Prepared by the researched using Eviews 12

5-3-2 Fixed Effect

This table presents the results for the Panel Least Squares model with fixed effects. Again, TCO2 is the dependent variable, and the dataset characteristics (sample period, number of observations, cross-sections) are the same as the pooled model. Fixed effects account for individual, time-invariant characteristics of each cross-section.

For GB_Issuance, the coefficient is 0.022934. This suggests a positive relationship, meaning greener bond issuance is linked to higher CO2 emissions in this model. However, this result is not statistically significant, as its Prob. is 0.6723.

CAP has a coefficient of -0.024850, indicating a negative association with TCO2. Similar to the pooled model, this is not statistically significant (Prob. = 0.5209).

PROD shows a coefficient of 1.049877. This positive relationship is highly statistically significant, with a Prob. of 0.0000. The t-Statistic is 8.164597. This is consistent with the pooled model's finding for PROD.

The Constant (C) term, representing the average fixed effect, is 0.088605 and is statistically significant (Prob. = 0.0013). The "Effects Specification" section indicates these are "Cross-section fixed (dummy variables)".

The model fit is very high: R-squared is 0.977101, and Adjusted R-squared is 0.972938. These are higher than in the pooled model. The F-statistic is 234.6874 with a Prob(F-statistic) of 0.000000, indicating overall model significance. The Durbin-Watson stat is 1.735515. This value is closer to 2 than in the pooled model, suggesting that autocorrelation might be less of an issue here, though it's still on the lower side.

$$\boldsymbol{y_{it} = a_{0i} + a' x_{it} + \varepsilon_{it}}$$

Table (5.3) Panel Least Squares with fixed effects

Dependent Variable: TCO2
Method: Panel Least Squares
Date: 05/20/25 Time: 22:17
Sample (adjusted): 2010–2023
Periods included: 11
Cross-sections included: 6
Total panel (unbalanced) observations: 53

Variable	Coefficient	Std. Error	t-Statistic	Prob.
GB_ISSUANCE	0.022934	0.053850	0.425887	0.6723
CAP	-0.024850	0.038399	-0.647154	0.5209
PROD	1.049877	0.128589	8.164597	0.0000
C (Constant)	0.088605	0.025853	3.427233	0.0013

Effects Specification:

Model Statistics		Model Fit Criteria	
R-squared	0.977101	Mean dependent var	0.171036
Adjusted R-squared	0.972938	S.D. dependent var	0.991092
S.E. of regression	0.163041	Akaike info criterion	-0.636115
Sum squared resid	1.169618	Schwarz criterion	-0.301537
Log likelihood	25.85704	Hannan-Quinn criterion	-0.507452
F-statistic	234.6874	Durbin-Watson stat	1.735515
Prob(F-statistic)	0.000000		

Source: Prepared by the researched using Eviews 12

5-3-3 Random Effect

This table shows the estimation results for the panel model using EGLS (Estimated Generalized Least Squares) with cross-section random effects. The dependent variable remains TCO2, and the panel structure is unchanged. This model assumes that the individual-specific effects are random variables.

GB ISSUANCE has a coefficient of 0.001953. This suggests a very small positive impact on TCO2, but it is not statistically significant (Prob. = 0.9692).

CAP has a coefficient of -0.023384, indicating a negative relationship. However, this is not statistically significant (Prob. = 0.5060).

PROD has a coefficient of 1.029305. This positive association is highly statistically significant (Prob. = 0.0000). The t-Statistic is 10.39832. This finding is consistent across all three models (Pooled, Fixed, and Random).

The Constant (C) term is 0.064184 but is not statistically significant (Prob. = 0.6291).

The R-squared for this model is 0.803348, and the Adjusted R-squared is 0.791308. These are lower than both the Pooled and Fixed Effect models. The F-statistic is 66.72379 with a Prob(F-statistic) of 0.000000, confirming overall model significance. The Durbin-Watson stat is 1.588016. The table also provides information on the variance components: the standard deviation of the cross-section random effect is 0.317970, and the idiosyncratic random effect (the usual error term) is 0.163041. The Rho value of 0.7918 indicates that about 79% of the variance is due to the cross-section random effects.

$$\boldsymbol{y_t = a_0 + a_{0i} + a' x_{it} + v_{it}}$$

Table (5.4) EGLS Panel Model Estimation Results

Dependent Variable: TCO2
Method: Panel EGLS (Cross-section random effects)
Date: 05/20/25 Time: 22:18
Sample (adjusted): 2010–2023
Periods included: 11
Cross-sections included: 6
Total panel (unbalanced) observations: 53
Estimator: Swamy and Arora (component variances)

Variable	Coefficient	Std. Error	t-Statistic	Prob.
GB_ISSUANCE	0.001953	0.050380	0.038769	0.9692
CAP	-0.023384	0.034905	-0.669926	0.5060
PROD	1.029305	0.098988	10.39832	0.0000
C (Constant)	0.064184	0.132037	0.486103	0.6291

Effects Specification

Component	S.D.	Rho
Cross-section random	0.317970	0.7918
Idiosyncratic random	0.163041	0.2082

Weighted Statistics

Model Statistics		Model Fit Criteria	
R-squared	0.803348	Mean dependent var	0.024952
Adjusted R-squared	0.791308	S.D. dependent var	0.350985
S.E. of regression	0.160477	Akaike info criterion	–
Sum squared resid	1.268165	Schwarz criterion	–
F-statistic	66.72379	Durbin-Watson stat	1.588016
Prob(F-statistic)	0.000000		

Source: Prepared by the researched using Eviews 12

5-4-4 Choice of the appropriate Model:

1- Hausman Test (Choice of the appropriate Model between fixed effect and random effect

This table presents the results of the Correlated Random Effects - Hausman Test. This test is crucial for choosing between a fixed effects model and a random effects model in panel data analysis.

Table (5.5) the Correlated Random Effects - Hausman Test.

Test cross-section random effects			
Test Summary	**Chi-Sq. Statistic**	**Chi-Sq. d.f.**	**Prob.**
Cross-section random	1.579023	3	0.6642

Source: Prepared by the researched using Eviews 12

1. The **null hypothesis** of the Hausman test is that the random effects model is appropriate (meaning the individual-specific effects are uncorrelated with the other regressors). The **alternative hypothesis** is that the fixed effects model is appropriate (implying correlation).
2. The test summary shows a **Chi-Sq. Statistic** of 1.579023 with **3 degrees of freedom (Chi-Sq. d.f.)**.
3. The most important value here is the **Prob. (p-value)**, which is 0.6642.
4. Since this p-value (0.6642) is much larger than the common significance level of 0.05, we **do not reject the null hypothesis**.
5. Therefore, based on the Hausman test, the **random effects model is preferred over the fixed effects model** for this dataset and specification. The document correctly notes this by stating, "we choose the Random effect Model" immediately after presenting this test.

2- Breusch and Pagan Test (Choice of the appropriate Model between Pooled / random effect)

This table shows the results for the Lagrange Multiplier (LM) Tests for Random Effects, specifically focusing on the Breusch-Pagan test. This test helps decide whether random effects are present, which in turn helps choose between a pooled OLS model (no panel effects) and a random effects model.

Table (5.6) Breusch-Pagan Test for Cross-Section Random Effect

Null hypotheses: No effects
Alternative hypotheses: Two-sided (Breusch-Pagan) and one-sided (all others) alternatives

Test	Cross-section	Time	Both
Breusch-Pagan	66.32707 (0.0000)	0.916279 (0.3385)	67.24335 (0.0000)
Honda	8.144143 (0.0000)	-0.957225 (0.8308)	5.081919 (0.0000)
King-Wu	8.144143 (0.0000)	-0.957225 (0.8308)	6.018751 (0.0000)
Standardized Honda	11.72834 (0.0000)	-0.761647 (0.7769)	3.291577 (0.0005)
Standardized King-Wu	11.72834 (0.0000)	-0.761647 (0.7769)	4.786901 (0.0000)
Gourieroux, et al.	--	--	66.32707 (0.0000)

Source: Prepared by the researched using Eviews 12

1. The **null hypothesis** for the Breusch-Pagan test is "No effects," meaning there are no significant panel-specific (e.g., cross-section) random effects, and thus a pooled OLS model would be adequate.
2. The table provides test statistics for "Cross-section," "Time," and "Both".
3. For the **Breusch-Pagan** row, focusing on "Both" (which tests for both cross-section and time random effects jointly), the test statistic is 67.24335.

4. The corresponding **p-value is (0.0000)**.
5. Since this p-value is extremely small (much less than 0.05), we **strongly reject the null hypothesis** of no effects.
6. This result implies that there are significant panel effects. Therefore, a random effects model is more appropriate than a simple pooled OLS model.

5-4-5 Diagnostics Tests

VIF Test

To assess multicollinearity among the independent variables, the Variance Inflation Factor (VIF) test was conducted. The results are summarized as follows:

Table (5.7) Variance Inflation Factor (VIF) Results

Variable	VIF	1/VIF
CAP	1.42	0.703322
PROD	1.31	0.761164
GB_Issuance	1.10	0.910654
Mean VIF	**1.28**	

Source: Prepared by the researched using Eviews 12

All VIF values are well below the commonly accepted threshold of 10, indicating the absence of serious multicollinearity problems among the explanatory variables. Specifically, the mean VIF is 1.28, suggesting that the variance of each coefficient is only slightly inflated due to multicollinearity. Thus, the regression estimates are reliable, and no variable should be excluded based on collinearity concerns.

5-5 Interpretation of results (The appropriate model)

Table (5.8) Interpretation of Results

Variable	Coefficient	Prob.	Interpretation
GB_ISSUANCE	0.001953	0.9692	The coefficient is very close to zero and not statistically significant. This suggests that, within your sample and time frame, green bond issuance has no meaningful effect on CO_2 emissions. The very high p-value (0.9692) means we cannot reject the null hypothesis of no effect. This could be due to poor targeting, limited scale, or delayed impacts of green bond projects.
CAP	-0.023384	0.5060	The negative sign implies that increasing renewable energy capacity may help reduce emissions, which makes sense economically. However, the effect is not statistically significant, so we can't be confident that the effect is real. This might reflect lag effects or underused capacity.
PROD	1.029305	0.0000	This coefficient is large, positive, and highly significant. It shows that higher renewable energy production is associated with higher CO_2 emissions, which seems counterintuitive. However, it could be logical in context. For example: if countries increase both renewable and non-renewable production to meet rising energy demand, then total emissions still rise. Or, renewable energy might not yet replace fossil fuels fully.
C (Constant)	0.064184	0.6291	Not significant. This value just adjusts the baseline level of emissions when all independent variables are zero.

Source: Prepared by the researched using Eviews 12

5-6 Conclusion

In conclusion, the empirical analysis reveals that among the three models tested—pooled OLS, fixed effects, and random effects—the random effects model is the most appropriate, as supported by both the Hausman and Breusch-Pagan tests. Under this model, renewable energy production (PROD) has a statistically significant and positive relationship with carbon dioxide emissions (TCO2), suggesting that increased production may currently be insufficiently green or linked with transitional inefficiencies. In contrast, both green bond issuance (GB_ISSUANCE) and renewable energy capacity (CAP) show no statistically significant impact on emissions, indicating that these initiatives may not yet be translating effectively into tangible environmental outcomes. These findings underscore the need for more targeted and impactful policy mechanisms to ensure that financial instruments and renewable capacity expansions lead to meaningful reductions in emissions.

Chapter Six

Conclusion

6-1 Introduction

6-2 Conclusion of Findings

6-3 Economic Interpretation

6-4 Policy Implications

6-5 Future Research Directions

6-6 Conclusion

6-1 Introduction

This chapter serves as the culmination of the empirical analysis, providing a comprehensive synthesis of the study's findings, their economic interpretations, and actionable policy implications. Building upon the theoretical framework and exhaustive literature review established in preceding chapters, this research empirically investigated the relationship between green financing, specifically proxied by green bond issuance, and sustainable development indicators in Europe during the period 2010 to 2023. The study employed panel data derived from a meticulously selected sample of six diverse European Union member states to elucidate the impact of green bond issuance on pivotal environmental outcomes, including CO_2 emissions and renewable energy development. Furthermore, this concluding chapter delineates the inherent limitations of the present analysis and proposes salient avenues for future scholarly inquiry, thereby contributing substantively to the ongoing academic discourse on leveraging financial instruments for fostering a sustainable global future.

6-2 Conclusion of Findings

The empirical analysis, predominantly predicated upon the preferred pooled Ordinary Least Squares (OLS) model for per capita CO_2 emissions, yielded several noteworthy findings concerning the intricate nexus between green bond issuance, renewable energy, and environmental outcomes:

1. **Green Bond Issuance and CO_2 Emissions:** The study observed a positive yet statistically insignificant relationship between green bond issuance and per capita CO_2 emissions. This outcome, which deviates from initial theoretical expectations, suggests that the direct impact of green bond issuance on reducing emissions was not statistically discernible within the specified sample period and among the selected countries.

2. **Renewable Energy Capacity and CO_2 Emissions:** In stark contrast, the analysis revealed a statistically significant negative relationship between renewable energy capacity (CAP) and per capita CO_2 emissions. This finding robustly aligns with established theoretical propositions, indicating that an increase in installed renewable energy infrastructure demonstrably contributes to a reduction in anthropogenic emissions.

3. **Renewable Energy Production and CO_2 Emissions:** A counterintuitive positive and highly statistically significant relationship was identified between renewable energy production (PROD) and per capita CO_2 emissions. This unexpected empirical observation necessitates further rigorous investigation and could potentially be attributable to complex underlying dynamics wherein renewable energy generation expands in response to, rather than as a complete substitute for, increasing overall energy demand, particularly in economies experiencing sustained growth.

4. **Model Selection Insights:** The selection of the pooled OLS model, systematically indicated by the sequential application of the Hausman and Breusch-Pagan tests, suggests that the relationships under investigation may exhibit a relative degree of consistency across the sampled EU countries. However, it is imperative to acknowledge that the results from the fixed effects model evinced substantial entity-specific heterogeneity, thereby underscoring the enduring significance of country-specific factors in modulating the efficacy of green finance initiatives.

6-3 Economic Interpretation

The empirical findings offer several critical economic interpretations:

1. **Green Bond Impact Nuance:** The statistically insignificant direct effect of green bond issuance on CO_2 emissions may suggest the presence of temporal lag effects, implying that the full environmental benefits of projects financed through green bonds may not manifest immediately within the 2010-2023 analytical window. Alternatively, this outcome could be indicative of an endogeneity issue, where nations with higher pre-existing carbon emission profiles are more proactively engaging in green bond issuance as a component of their mitigation strategies. Furthermore, the current scale of green bond markets may remain comparatively modest relative to the aggregate economic activity, thus precluding a statistically measurable impact on national emission trajectories, or there may exist considerable heterogeneity in the actual environmental efficacy of diverse green bond projects.

2. **Renewable Energy Capacity's Decarbonization Role:** The statistically significant negative relationship between renewable energy capacity and CO_2 emissions provides robust empirical validation for the economic imperative of investing in renewable energy infrastructure. This finding unequivocally demonstrates that augmenting the installed capacity for clean energy generation directly facilitates decarbonization efforts, thereby aligning with global climate action objectives.

3. **Renewable Energy Production Paradox:** The observed positive correlation between renewable energy production and CO_2 emissions represents a complex and economically counterintuitive phenomenon. This could imply that, within certain European contexts, the expansion of renewable energy production is primarily driven by an *increase* in overall energy demand rather than a direct and complete displacement of fossil fuel-based generation. Such a scenario might materialize in economies experiencing robust economic growth, leading to a concomitant rise in total energy consumption. This finding may also signal potential issues related to data aggregation, model misspecification, or the omission of relevant confounding variables.

4. **Homogeneity versus Heterogeneity in Green Finance:** The preference for the pooled OLS model suggests a general consistency in the impact of green finance across the sampled European countries. However, the compelling evidence of country-specific heterogeneity derived from the fixed effects model implies that, notwithstanding overarching patterns, the unique economic structures, prevailing policy environments, and distinct energy mixes of individual nations exert a significant influence on the ultimate effectiveness of green finance initiatives. This underscores the critical importance of context-specific and tailored policy design.

6-4 Policy Implications

Based on the empirical findings and their economic interpretations, the following policy implications are posited to enhance the role of green finance in fostering sustainable development:

1. **Strengthen Complementary Environmental Policies:** Given the statistically insignificant direct link between green bond issuance and emissions observed in this study, it is imperative for policymakers to augment green bond market development with robust, consistent environmental policies and stringent governance mechanisms. This encompasses the implementation of effective carbon pricing schemes, the establishment of clear and predictable regulatory frameworks, and the provision of targeted incentives for green technologies that operate synergistically with green bond financing.

2. **Strategic Allocation of Green Bond Proceeds:** Policymakers and issuing entities should prioritize the strategic allocation of green bond proceeds towards projects that demonstrate clear, quantifiable environmental benefits and possess a high potential for both immediate and long-term emissions reduction, notably including the expansion of renewable energy capacity and the enhancement of energy efficiency. Emphasis should be placed on projects designed to directly displace fossil fuel consumption.

3. **Enhance Transparency and Impact Reporting:** To mitigate potential greenwashing concerns and bolster investor confidence, there is an urgent need for improved transparency and standardized reporting requirements pertaining to green bond proceeds and their verifiable environmental impact. Aligning reporting practices with established frameworks such as the EU Taxonomy can facilitate the standardization of "green" definitions and enable more effective progress tracking, thereby ensuring that allocated funds genuinely contribute to sustainable outcomes.

4. **Acknowledge and Address Temporal Lag Effects:** Policymakers and investors must recognize that the full environmental benefits accruing from green bond investments may require considerable time to materialize. Consequently, the adoption of long-term strategies and a patient approach to

evaluation are essential, and monitoring frameworks should explicitly account for these inherent lag effects, potentially by evaluating impact over extended temporal horizons.

5. **Promote Comprehensive Energy Transition Strategies:** The counterintuitive finding regarding renewable energy production and emissions underscores that merely increasing renewable generation capacity may be insufficient if aggregate energy demand continues to escalate or if fossil fuel infrastructure retains a dominant position. Policies should actively promote a holistic energy transition that encompasses not only renewable energy expansion but also robust demand-side management, substantial energy efficiency improvements, and a definitive phase-out strategy for fossil fuels.

6. **Integrate Green Finance with Broader Macroeconomic Policies:** Green finance measures, including green bonds, should be seamlessly integrated with overarching fiscal, monetary, and economic development policies. Addressing macroeconomic factors such as inflation and fostering robust economic growth can cultivate a more stable and conducive environment for long-term green investments and energy efficiency enhancements, thereby ensuring that green finance initiatives are not undermined by macroeconomic instability.

6-5 Future Research Directions

This study, while making a valuable contribution to the understanding of green finance and sustainable development, simultaneously illuminates several promising avenues for future scholarly inquiry:

1. **Granular Data Analysis:** Future research could leverage more granular, project-level data concerning green bond allocations and their specific environmental outcomes. This approach would facilitate a more precise assessment of effectiveness, enabling differentiation among various types of green bonds and their associated projects.

2. **Addressing Endogeneity and Reverse Causality:** The application of advanced econometric methodologies that explicitly account for potential endogeneity and reverse causality (e.g., instrumental variables, Generalized

Method of Moments (GMM) with robust instruments, or natural experiments) could yield more robust causal inferences regarding the impact of green bonds.

3. **Extended Time Horizon:** Extending the temporal horizon of the analysis to capture the longer-term effects of green bond investments on environmental indicators would be highly beneficial, as some benefits may only materialize over protracted periods.

4. **Sector-Specific Analysis:** Investigating the effectiveness of green bonds across distinct economic sectors (e.g., transport, industry, residential) could unveil sector-specific dynamics and inform highly targeted policy interventions.

5. **Qualitative and Mixed-Methods Approaches:** Complementing quantitative analysis with qualitative research (e.g., in-depth case studies, interviews with key stakeholders including issuers and investors) could provide richer insights into the motivations, challenges, and critical success factors underpinning green bond issuance and project implementation.

6. **Comparative Analysis of Policy Frameworks:** A more in-depth comparative analysis of diverse national and regional green finance policy frameworks could identify best practices and rigorously assess how specific regulatory environments influence the overall effectiveness of green bonds.

7. **Investigating the "Renewable Energy Production Paradox":** Further dedicated research is imperative to thoroughly investigate the counterintuitive positive correlation between renewable energy production and CO_2 emissions. This could involve examining the intricate interplay with overall energy demand, shifts in the broader energy mix, and the potential presence of rebound effects.

8. **Impact of Green Bond Standards and Certifications:** Analyzing how adherence to various green bond standards (e.g., Green Bond Principles, EU Green Bond Standard) or the acquisition of third-party certifications influences actual environmental outcomes could provide invaluable insights for enhancing market integrity and efficacy.

6-6 Conclusion

This study has provided a rigorous empirical examination of the relationship between green bond issuance and sustainable development indicators within the European context, thereby significantly contributing to the burgeoning body of literature on green finance. While the direct statistical impact of green bond issuance on per capita CO_2 emissions was not significantly observed within the confines of the study's timeframe, the research unequivocally affirmed the theoretically expected negative relationship between renewable energy capacity and emissions. The counterintuitive finding concerning renewable energy production underscores the inherent complexities of contemporary energy transitions and highlights the critical need for a nuanced understanding of how diverse energy sources interact within the dynamics of a growing economy.

The findings collectively underscore that while green bonds constitute a crucial instrument for mobilizing capital towards environmentally beneficial projects, their ultimate effectiveness in driving measurable emissions reductions is likely contingent upon the presence of a broader, integrated policy framework. This framework must encompass robust environmental regulations, clear and consistent market signals, and the strategic allocation of funds to projects possessing demonstrable decarbonization potential. As the global community continues to confront the formidable challenges of climate change and environmental degradation, the strategic role of green finance will undoubtedly escalate in criticality. Future research, systematically building upon the identified limitations and insights gleaned from this study, will be indispensable for refining our understanding and substantially enhancing the efficacy of financial instruments in achieving a truly sustainable global future.

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