About the Influence of CO_2 and Sustainability Data on Financial Markets

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To my family, without you this would never have been possible. I will always be connected to you. Wherever you are now.

To my supervisor Christian and my second supervisor Bernhard, to the whole team of the Sustainable Finance Department, to Tobias, Thomas C., Thomas P. and Frank for their research cooperation and Juris for his support and proofreading.

To all of you and many more people I would like to say only one thing

THANK YOU

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List of abbreviations

AGCY	Agency
APT	Arbitrage Pricing Theory
CAPM	Capital Asset Pricing Model
CBI	Climate Bond Initiative
CFP	Corporate Financial Performance
CORP	Corporate
CO_2	Carbon dioxide
CSR	Corporate Social Responsibility
CSRD	Corporate Sustainability Reporting Directive
DACH	Germany, Austria and Swiss
DEO	Debt-energy-others
DGB	Debt-green-bonds
E	Environmental
EBF	Equity-building-infrastructure funds
EC	European Commission
EEF	Equity-energy-infrastructure funds
EEU	European electric utilities
EEP	Equity-energy-participation rights
ESG	Environment, social and governance
EU	European Union
EUR	Euro
EU ETS	European Emission Trading System
FIN	Financial Institution
FNG	Forum Nachhaltige Geldanlagen
G	Governance
GHG	Greenhouse gas
HLEG	High-Level Expert Group on Sustainable Finance
LCIIP	Low Carbon Infrastructure Investment Product
MBC	Mezzanine-capital-building-crowdfunding
MEC	Mezzanine-capital-energy-crowdfunding

NFRD	Non-Financial Reporting Directive
OECD	Organization for Economic Co-operation and Development
OLS	Ordinary least squares
IPCC	Intergovernmental Panel on Climate Change
PA	Paris Agreement
PST	Pastor, Stambaugh and Taylor
S	Social
SE	Standard error of the estimate
SFDR	Sustainable Finance Disclosure Regulation
SOV	Sovereign
SPO	Second party opinion
SRI	Socially Responsible Investment
SSE	Explained sum of squares
SSF	Swiss Sustainable Finance
SSOV	Sub-Sovereign
SSR	Residual sum of squares
SST	Total sum of squares
SUPR	Supranational
TEG	Technical Expert Group on Sustainable Finance
TCFD	Task Force on Climate-related Financial Disclosures
TWh	Terawatt hours
UK	United Kingdom
UN	United Nations
UNFCCC	United Nations Framework Convention on Climate Change
UNPRI	United Nation Principals of Responsible Investment
US	United States
USD	US-Dollar

1. Introduction

1.1 Purpose of the work

In April 1896, Svante Arrhenius (1896) published his study "On the Influence of Carbonic Acid in the Air upon the Temperature of the Ground" in the Philosophical Magazine and Journal of Science, in which he was the first to quantify the influence of greenhouse gas emissions on the global climate. The starting point of his study is the question whether heat-absorbing gases in the atmosphere have an influence on the climate and the belief that the atmosphere would behave like the glass of a "hot-house". He first investigates whether water vapor or carbon dioxide (CO_2) is responsible for the greenhouse gas effect and concludes that the concentration of CO_2 in the air is linearly related to the increase (decrease) in temperature. Based on his results, Arrhenius (1896) discusses the research work of Högbom in his paper, which deals with the geological consequences of decreasing (increasing) CO_2 concentrations in the atmosphere. Here Arrhenius (1896) is particularly interested in the question whether it is possible within a short period of time[1] that enormous fluctuations in the CO_2 concentration occur in order to estimate how likely a new ice age threatening human civilization[2] is. Arrhenius (1896) calculates that the concentration would have to decrease to 0.55 to 0.62 times the concentration of 1896 for the global temperature to fall to the level of the last ice age. Furthermore, he assumes that an increase of the CO_2 concentration to 2.5 to 3 times would lead to an increase of 8° to 9° degrees Celsius at the Arctic poles, while the temperature in the regions near the equator would increase less. In addition to this, Arrhenius (1896) follows Högbom's estimate and assumes that the amount of CO_2 sequestered in the Earth exceeds the amount in the atmosphere by a factor of 25,000. Therefore, Arrhenius (1896) summarizes his results to the conclusion that the transparency of the atmosphere exerts a decisive influence on the global climate. However, he

[1] Arrhenius speaks from a geological perspective of a short period of time.
[2] Arrhenius means with civilization the civilizations which would be most developed in his opinion. For Arrhenius these are North America, (Northern) Europe and Russia.

considers the emissions of CO_2 by modern industry to be insufficient to influence the global climate.

The biggest difference between Arrhenius (1896) and today's research is that Arrhenius (1896) does not consider CO_2 emissions from modern industry to be sufficient to change the global climate and thus views his research from a perspective of a possible new impending ice age based on geological processes rather than a possible human-caused hot age (Fleming 1998). Today, 125 years later, there is a scientific consensus that mankind is not living in a cold age but in a man-made hot age. (IPCC 2021).

Based on the before mentioned fact, the nations of this world met 2015 in Paris under the auspices of the United Nations (UN) and signed a joint agreement (UNFCCC 2015). The central objective of this convention is stated in Article 2 paragraph 1 (a) and states:

> „Holding the increase in the global average temperature to well below 2 °C above pre-industrial levels and pursuing efforts to limit the temperature increase to 1,5 °C above pre-industrial levels, recognizing that this would significantly reduce the risks and impacts of climate change."

Whereas the last words of this section of Article 2 make it clear that much of the world community perceives climate change as a global threat. Moreover, it is already clear from the first overarching words of Article 2:

> „This Agreement, in enhancing the implementation of the Convention, including its objective, aims to strengthen the global response to the threat of climate change, in the context of sustainable development and efforts to eradicate poverty."

That combating climate change must be part of the sustainable development of the world. That humanity must arm itself against the threat of climate change is clear from Article 2 paragraph 1 (b), as it reads:

> „Increasing the ability to adapt to the adverse impacts of climate change and foster climate resilience and low greenhouse gas emissions development, in a manner that does not threaten food production."

Furthermore, this paragraph is noteworthy because it names the cause of climate change, namely greenhouse gas emissions, and calls for their reduction. Thus, this paragraph is directly related to the previously mentioned study by Arrhenius (1896), since Arrhenius (1896) also speaks of a "hot-house" and thus describes exactly the mechanism named by the world community. In other words, this means that the world community agrees that considerations of some researchers from more than 125 years ago are correct. The research and considerations of Arrhenius (1896) and others (see Fleming 1998) thus form the basic understanding of the prevailing mechanism of a global threat.

In addition to the objective and the requirement to adapt to the already prevailing and upcoming climatic changes, article 2 paragraph 1 (c) obliges all signatory nations to adapt their financial flows. Specifically, it states:

> „Making finance flows consistent with a pathway towards low greenhouse gas emissions and climate-resilient development."

This sentence means that all financial flows must be examined and, if necessary, adjusted to ensure that they are in line with the goals of the Paris Agreement (PA) (UNFCCC 2015). Based on this, it is important for each signatory nation to ensure that in the future, greenhouse gas emissions are taken into account in every decision regarding financial flows. Based on the recognition that financial flows are a central component of real economic as well as financial economic activities, this point is to be understood as a commitment to transform the entire economic and financial system. This fundamental change in the economic and financial system may also mean that previous scientific knowledge about these very systems now no longer applies. In order to continue to have a scientifically sound understanding of the financial markets and to research the effects of the necessary change to the financial markets and financial flows from a scientific perspective. Therefore, it is important to investigate the influence of CO_2 and sustainability data on the financial markets.

1.2 A brief introduction into sustainable finance

In response to the PA on climate change, the European Commission (EC) established the High-Level Expert Group on Sustainable Finance (HLEG) in 2016 and mandated it to develop a comprehensive blueprint for reforming the entire investment chain and thus financial flows (HLEG 2018). As a result, the HLEG (2018) proposed a transformation of the entire financial system into the most sustainable financial system in the world and describes sustainable finance as part of a core strategy to systematically integrate sustainability into the European Union's (EU) economic system. The HLEG (2018) formulates two imperatives as a basis to express its understanding of sustainable finance. The first imperative is that finance in general should contribute to sustainability and growth in general, as well as help to address the consequences of climate change. The second imperative is that the entire financial system should be strengthened and that non-financial indicators from the areas of environment, social and governance (ESG) should be taken into account in financial decisions in the future. However, the authors do not explain in their report why they only use imperatives but no definition of sustainable finance as a basis. In addition, the HLEG (2018) points out that the term sustainable finance already existed before, from which it could be concluded that a definition of sustainable finance already exists in the literature. In the related academic literature, however, some authors such as Wallis and Klein (2015) point out that while there are a number of terms in the literature, such as climate finance or Socially Responsible Investment (SRI), which can all be grouped under the heading of sustainable finance or a subset thereof, there is no single definition of sustainable finance and/or its subsets. In its United Nations Principals of Responsible Investment (UNPRI), the UN defines responsible investment as follows (UNPRI 2021):

> “The PRI defines responsible investment as a strategy and practice to incorporate environmental, social and governance (ESG) factors in investment decisions and active ownership.”

Another definition of sustainable investments is provided by Busch et al. (2016):

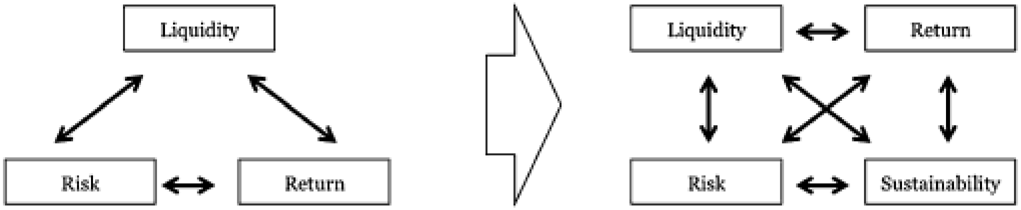
> “[…] we regard sustainable investments as a generic term for investments that seek to contribute toward sustainable development by integrating long-term ESG criteria into investment decisions.”

Here, the two definitions differ in two main respects. First, (i) the investment horizons differ in the two definitions, as Busch et al. (2016) explicitly state that only long-term investments are covered by the term sustainable investments, whereas the UNPRI (2021) definition leaves the investment horizon open. Second, (ii) according to Busch et al. (2016), a sustainable investment must contribute to sustainable development and needs not merely consist of considering ESG data in investment decisions. The scope of this difference becomes clear when looking at the evolution of understanding of what is meant by sustainable finance over different periods.

According to Busch et al. (2021), the origins of sustainable finance can be traced back over 3500 years into the past without the term itself being that old. Furthermore, the authors divide the term sustainable finance into three different phases.

The first phase is called Sustainable Finance 1.0 (Busch et al. 2021). The characteristic feature of this phase is that business practices are rejected due to mostly ethic-religious beliefs and thus followers of these ethic-religious beliefs do not want to participate in such business practices. As an example, the authors cite, among others, the Quakers, who did not want to earn money from the slave trade or related businesses. However, the authors (Busch et al. 2021) make clear that the consideration of one's own values within this phase did not have the goal of achieving a real change in the given circumstances, although changes in circumstances may have been a possible byproduct. For Busch et al. (2021), the second phase- Sustainable Finance 2.0- begins with the consideration of ESG data in investment decisions. Here, the three classic financial categories of risk, return and liquidity are expanded to include the category of sustainability (for this, see Figure 1)

Figure 1.1: Extension of the classic financial categories to include the category of sustainability



See Wallis and Klein (2015)

This phase is characterized by the conviction that the use of ESG data would bring an advantage for investors not only from an ethical but also from a financial perspective. Here, the financial benefit was due to the hypothesis that environmental and social risks increasingly had an impact on financial performance and that taking ESG data into account would help to manage these risks (Busch et al. 2021). On the one hand, Busch et al. (2021) point out that during this phase, it is often argued that there is no financial advantage because sustainable investments yield a worse return than non-sustainable ones and therefore the lower risk is justified. On the other hand, Busch et al. (2021) cite several studies like Friede et al. (2015) and Wallis and Klein (2015) which find no empirical evidence that there is a link between sustainable investments and low returns. Thus, Busch et al. (2021) conclude that considering ESG data to mitigate risk leads to consistent returns and thus represents an actual financial benefit. It should be mentioned here that some studies show that the ESG data from different leading providers diverge among themselves in terms of the ESG rating of the rated companies. Here, the differences are found at the level of the overall rating as well as at the level of the individual Environmental (E), Social (S), Governance (G) pillars. Therefore, it is of crucial importance for investors to be aware of this fact (e.g. Dorfleitner et al. 2015; Chatterji et al. 2016). However, according to Busch et al. (2021), even in the Sustainable Finance 2.0. phase, changing the given circumstances would not have been the goal. The third and final phase described by Busch et al. (2021) is Sustainable Finance 3.0, in which the authors define all investments that generate an impact as Sustainable Finance 3.0. For this purpose, they present the following definition:

> „We define impact investments as investments that focus on real-world changes in terms of solving social challenges and/or mitigating ecological degradation."

With this definition, Busch et al. (2021) clearly distinguish themselves from the other two phases described. While phase Sustainable Finance 1.0 was dominated by the fact that an additional non-financial benefit for the investor results from (not) holding investments, phase Sustainable Finance 2.0 is dominated by the fact that a financial benefit for the investor is added to this non-financial benefit. According to Busch et al. (2021), Sustainable Finance 3.0 is a phase in which society must also derive a positive benefit from the investor's investment for it to be considered Sustainable Finance. Busch et al. (2021) introduce a new term for the third phase and call it impact investing. Critically, however, Busch et al. (2021) reduce the term sustainable finance to impact investments and do not refer to the entire financial system such as payment processing, as is the case with the HLEG (2018). The definition of the Swiss Sustainable Finance (SSF) network reads:

> „Sustainable finance refers to any form of financial service integrating ESG criteria into the business or investment decisions for the lasting benefit of both clients and society at large."[3]

[3] https://www.sustainablefinance.ch/en/resources/what-is-sustainable-finance-_content---1--1055.html; Accessed March 07, 2023

The SSF thus includes the entire financial system and not only the investments.

However, in the course of the last few years, the sum of all sustainably managed investments in Germany has grown annually. The Forum Nachhaltige Geldanlagen (FNG) compiles an annual report on this subject. In its 2022 market report, the FNG (2022) arrives at a total of €501 billion in sustainable investments for Germany, of which €409 billion is accounted for by mutual funds, mandates and special funds, and the rest is made up of own investments and customer deposits. The enormous growth of such investments can be seen from the fact that the FNG (2022) identified just €6 billion in sustainable investments in mutual funds, mandates and special funds in 2006. In addition, the growth from 2020 to 2021 alone amounted to 65% for the three categories in Germany. These numbers show that sustainable investments have moved from a niche to a mainstream financial product.

As described by Wallis and Klein (2015), the category of sustainability must be integrated into the decision-making processes of financial investments in order for them to be considered sustainable investments. There are a number of strategies for this, which are described in more detail in Table 1.1.

Busch et al. (2021) categorize different sustainable investment strategies according to their three phases of sustainable finance. However, they only describe seven different strategies in their paper, as they combine engagement and voting as active ownership.

Table 1.1: Definition of sustainable investment strategies

Best-in-Class	Investment strategy according to which - based on ESG criteria - the best companies within an industry, category or class are selected.
Engagement	Long-term dialog with companies to improve their behavior with regard to ESG criteria.
ESG-Integration	Explicit inclusion of ESG criteria or risks in traditional financial analysis.
Impact Investing	Investing in companies, organizations or funds with the aim of influencing social and environmental factors in addition to financial returns.
Negativ Screening	excluding certain investments or investment classes such as companies, industries or countries from the investment universe if they violate specific criteria.
Norm-based or positive Screening	Review of investments for compliance with certain international standards and norms, e.g. the UN Global Compact, the OECD Guidelines for Multinational Enterprises or the ILO core labor standards.
Thematic Investments	Investing in issues or assets related to the promotion of sustainability that have an ESG connection.
Voting	Exercising shareholder rights at general meetings to influence company policies regarding ESG criteria. Exercising voting rights is part of ESG engagement.

See FNG (2022)

The first category is ESG-screend investments. According to Busch et al. (2021), only the exclusion criteria fall under this category and this category represents the minimum possible E, S or G consideration. The aim of this strategy is primarily to avoid investments in unethical business practices or ESG-related risk. Negative Screening can therefore be assigned to phase 1.0. The second category is ESG-managed investments. In addition to exclusion criteria, at least one other approach is taken into account in the investment process. The aim is to exploit ESG-related risks and opportunities for the company's own investments. According to Busch et al. (2021), the following strategies fall into this category: norm-based screening, best-in-class, ESG integration or sustainable theme funds. The category can thus be assigned to phase 2.0. The third category is impact-related investments, which include investments that bring about an actual change in the given circumstances. However, the category of impact-related investments is divided by the authors into two subcategories. The first subcategory is impact-aligned investments. This is contrasted with impact-generating investments. The authors illustrate the difference between the two using the example of CO_2 emissions. Accordingly, investments belong to the impact-aligned investments category if they have lower CO_2 emissions than comparable investments. Therefore, it is not only necessary to implement a sustainability strategy into the investment process in advance, but also to show afterwards that due to this strategy the own investments have a better sustainability performance than the benchmark. In the case of impact-generating investments, investors must act actively and, secondly, the link between action and actual change must be clearly demonstrable. For the example, this means that the investors are actively engaged in ensuring that their investment object emits less CO_2, and this low emission must be traceable to the investors' engagement. Due to the fact that investors have to be active, Busch et al. (2021) assign the strategy active ownership more precisely engagement and voting to impact-generating investment.

In this dissertation, sustainable finance can neither be assigned to the definition of SSF nor to a specific phase of Busch et al. (2021) for several reasons. The reasons are (i) that in this thesis all chapters directly target different aspects in investing. Thus, a general view of the whole financial system as by HLEG (2018) and in the definition of SSF is not necessary. Second, (ii) the paper by Busch et al. (2021) is titled "Impact investments: a call for (re)orientation", from which it is clear that this paper is intended to encourage other researchers to adopt the authors' understanding in the future, which in turn means that the understanding of Busch et al. (2021) does not reflect a generally accepted basic understanding of all researchers. Third, (iii) the understanding of Busch et al. (2021) was not adopted because parts of the paper and especially the research ideas behind it predate the work of Busch et al. (2021) and therefore cannot logically be based on the understanding of Busch et al. (2021). Fourth, (iv) the delineation between phases in the academic literature does not follow the phases described, so different parts of the same research work can be attributed to different phases. Regardless of this problem, the work of Busch et al. (2021) nevertheless provides a good overview of different developmental stages within the topic area of sustainable finance and reflects the current state of the debate on what sustainable finance should actually be and do.

1.3 Structure and positioning of the thesis

The aim of this thesis is to provide a scientific contribution to the influence of CO_2 and sustainability data on financial markets. For this purpose, each chapter deals with a different question within the research question. The individual chapters thus represent self-contained units in which the individual questions are answered but are always to be understood in the context of climate change and the resulting necessary change in the financial system and the entire economy (HLEG 2018). As already described, the individual questions do not deal with finance as a whole but focus on the sub-areas of investments and investment processes. On the one hand, different investor groups, namely retail investors (chapter 3) and institutional investors (chapter 4), i.e. standardized private customers and professional investors, will be discussed. On the other hand, the influence of the consideration of CO_2 and sustainability data on equity (chapter 5) and debt capital (chapter 6) will be examined. In particular, the consideration of sustainability ratings can be seen as a detachment from the focus on CO_2 data, but this is not the case. Some authors emphasize in their papers that green bonds have climate-related benefits (e.g. Ehlers und Packer 2017; Dorfleitner et al. 2022) and have a supporting role in transforming the economy to a low-carbon economy (Sartzetakis 2021). This is underlined by the fact that some papers (e.g. Bachelet et al. 2019; Hyun et al. 2020) mainly examine green bonds issued by the Climate Bond Initiative (CBI). Therefore, the consideration of sustainability ratings in Green Bonds represents an indirect consideration of CO_2 data.

Since the final report of the HLEG (2018) is a central starting point of this thesis, this thesis focuses on the other hand on the impact of CO_2 sustainability data in German-speaking countries (chapter 3 and 4) and on Europe (chapter 5). Only in chapter 6 this focus is abandoned in favor of a global view, as the data situation in the area of sustainability ratings of green bonds is too limited for an analysis focusing on Europe.

Specifically, the following chapters examine the following. chapter 2 presents the methodological foundations of this thesis. Through this, the reader should get a better understanding of the respective individual chapters and the corresponding methodologies. More precisely, qualitative and quantitative research are distinguished from each other and qualitative research is discussed, the aspects of surveys relevant for this work are shown and the basics of regression models are described.

Chapter 3 examines the question of whether retail investors can invest in low-carbon infrastructure investment products (LCIIP) and what investment barriers prevent them from doing so. Finally, the financial performance of the identified investment products is compared with standard investment products for retail investors. For this purpose, desk research is used to search for possible investment products, and these are clustered into the categories mezzanine, equity and debt capital, as well as investments in buildings and energy. The aim of chapter 3 is to clarify whether the financial participation of private households in the transformation of the economy to a low-carbon economy, as called for by the HLEG (2018), is possible. In terms of the sustainable finance phases according to Busch et al. (2021), this chapter can be classified in phase 3.0 and here in impact-aligned investments. The reason for this is that the chapter examines investments for retail investors that lead to lower CO_2 emissions than a comparable benchmark.

Chapter 4 examines how institutional investors take CO_2 data into account in their investment decisions, which investment strategies they use to do so, and what impact they expect from taking it into account for different time horizons. Furthermore, it will be investigated how investors feel about a uniform regulation of the financial markets. For this purpose, a survey of professional investors is used as a research method. The goal of the chapter is to gain a better understanding of how institutional investors integrate CO_2 data into financial markets and to determine what increase in global temperature these investors expect. This chapter cannot be classified in any of the phases. The background to this is that the sustainable investment strategies, for example, ask about the use of strategies from all three phases.

Chapter 5 explores the question of how the returns of high and low carbon European electric utilities (EEU) differ in the production of electric energy. For this purpose, a list of all publicly traded EEUs in Europe, the United Kingdom (UK) and Switzerland was compiled, and the respective CO_2 intensity was calculated. Then the EEUs were divided into taxonomy compliant and non-compliant companies. Based on this, the returns of the two groups were then compared. The goal of the chapter is to find out if taxonomy compliance in energy production has a negative (positive) impact on returns. This chapter can be assigned to Phase 2.0 because it explores the question of whether considering sustainability has an impact on returns. Busch et al. (2021) describe such studies as classic for Phase 2.0.

Chapter 6 examines the question of whether investors are willing to forego returns when investing in green bonds and whether the willingness to forego returns increases if the green bonds have a better sustainability rating. For this purpose, a list of green bonds was compiled on the basis of the ISS ESG Sustainable Bond Rating and two conventional bonds were assigned to each of them. The conventional bonds were then combined into a synthetic conventional bond using interpolation (extrapolation) and the return on this bond was compared with the return on the green bond, taking into account the sustainability rating of the green bonds. The aim of the chapter is to clarify whether investors are willing to forego (more) return. The corresponding phase here is Sustainable Finance 3.0, since investors are financing a real-world change.

Overall, the stand-alone scientific part of this thesis (chapters 3 to 6) contributes to the following questions: Can investments with lower CO_2 emissions be made and what prevents investors from doing so? How is CO_2 data incorporated into the decision-making process? What does this integration mean for the financial performance of the investments and are sustainable investors willing to sacrifice returns?

Finally, chapter 7 summarizes the results of chapters 3 through 6 and draws an overall conclusion across all chapters. In addition, ideas for future research needs are briefly highlighted.

2. Methods

2.1 Introduction

> The choice of methods depends on the question to which the research should produce an answer. Reichertz (2022)

Reichertz (2022) describes in his article "Empirical Social Research and Sociological Theory" that with the enlightenment the cultural and natural sciences had replaced religion as the proclaimer of truth. Furthermore, Reichertz (2022) summarizes the methods still used today to a total of four essential methods for the validation of scientific knowledge. The first three of these four methods have a religious origin. More exactly it is:

- The safeguarding with the help of recognized authorities, which has its origin in God as highest authority.
- The protection with the help of the use of the understanding, whereby the origin of the understanding is the gift of God to all humans.
- The protection with the help of personal clairvoyance, which has its origin in the gift of God to individuals.
- The fourth safeguard does without any help from God, since it bases its scientific knowledge and theories on observations, i.e. empiricism.

Thus, empirical research is always based, according to Reichertz (2022), on the core statement that its results are correct, since these would build on observations of the reality. Empirical research is thus nothing other than generalized observations.

Here, a basic distinction can be made between two different research strategies or research approaches, namely the quantitative and the qualitative research approach. Quantitative research approaches assume that human beings, their behavior, actions, and interactions can be studied using the same research methods as those used in the natural sciences, and thus that the standardized measurement methods and procedures developed there can be applied to scientific studies of human beings. This implies, among other things, that there is a clear cause-and-effect relationship and that researchers need only discover it in order to formulate universally valid laws. Qualitative research approaches deny the transferability of scientific approaches to the study of human beings and their actions. Qualitative researchers assume that humans do not act according to a simple stimulus-response pattern but are independent beings who process the stimuli acting on them and then act on the basis of previously made experiences. However, since people always have different experiences than all other people, the reactions to a stimulus could turn out very differently, so that a generally valid cause-effect relationship does not exist.

The origins of these two research strategies can be traced back to antiquity, although according to Wichmann (2019), qualitative research has been overshadowed by quantitative research since at least the enlightenment. However, this circumstance would not have prevented that until today there are researchers who have no understanding for the use of the respective other strategy, so that until today advocates of the respective strategy struggle about which is today the "right" strategy. From the end of the 1990s, according to Reichertz (2022), the tendency can be observed that researchers no longer want to give a general answer to the choice of research strategy but make it dependent on which question is to be answered. In other words, the research question determines the strategy and thus both strategies are on an equal footing (Reichertz 2022). Furthermore, some researchers would already use both strategies at the same time, i.e. so-called mixed-methods.

This thesis aims to contribute to the impact of CO_2 and sustainability data on financial markets. To this end, chapters 3 to 6 each address a different question in this area. Following the quote at the beginning of this chapter, the best possible research method to answer the respective research question is chosen in each chapter, so that this thesis does not exclusively use qualitative or quantitative research. What all chapters have in common, however, is that the results of each chapter are always based on observations and their evaluation, so that the entirety of this thesis is an empirical investigation. Overall, a combination of qualitative and quantitative research strategies is chosen in chapter 3, while quantitative research strategies are used in chapters 4 through 6. Again, chapter 4 differs from chapters 5 and 6 as that in chapter 4, data is collected independently using standardized interviews, while in chapters 5 and 6, it is obtained from external sources. In addition, in chapters 5 and 6, the data are analyzed using regressions, which is not done in chapter 4. Furthermore, chapters 3 to 6 represent self-contained works, so that the respective methods used are described there. However, a certain degree of basic methodological understanding is always assumed in all chapters. In the respective chapters, the methodological approach that goes beyond this is explained on the basis of this basic understanding of the methods. Therefore, this chapter will lay just this basic understanding, only going into the basics of methods and research strategies necessary for the understanding of this thesis. It follows that the foundations of qualitative research are laid first, and then the basics of standardized surveys and regressions are addressed.

2.2 Qualitative research

The philosophy of science foundation of qualitative research is not based on an independent principle detached from quantitative research but derives much more from the criticism of some scientists on the implicit assumptions of quantitative research. In this context, different currents of philosophy of science present different points of criticism, but all currents have in common that they have a unified main point of criticism of quantitative research (Wichmann 2019). The assumption is rejected that the human being and the social world created by humans as well as his behavior can be investigated with the same principles and methods as they are used in the natural sciences. Therefore, all these currents, despite their sometimes different theoretical assumptions and differing methods, are summarized under the term interpretivism. The conception of man of interpretivism is thereby characterized by the fact that man actively shapes his world and does not simply react to stimuli from outside. It follows that qualitative researchers reject a stimulus-response scheme as an implicit assumption for their research (Wichmann 2019). Rather, people interpret the stimuli that affect them and then decide whether and how to react to them against the background of previous experience. Thus, external stimuli only exert an influence on people if these stimuli have a meaning for the respective individuals. It follows that external stimuli lead to no reaction or very different reactions based on different previous experiences. From this, some researchers deduce that the standardized quantitative approaches used in the natural sciences to study a phenomenon are not transferable to humans. Furthermore, they question the establishment of laws and regularities, since it is always concrete people who act and not all people always act the same way. From this it follows that, in order to understand people and their ways of acting, it is necessary for researchers to take the point of view of the people being researched and thus to research the phenomenon in question from their point of view, i.e. from the point of view of the people being researched. It is therefore a matter of researchers taking an internal perspective.

According to Wichmann (2019), describing the phenomena relevant to the research question is the basis for both qualitative and quantitative research strategies. Here it is to be noted that scientific describing can consist of the reproduction of characteristics and conditions and furthermore the defining, classifying and classifying of the described characteristics and conditions contains. However, the relevance of describing is different for the two research strategies, as it is an upstream step to analysis for quantitative research, description has a central role for qualitative research. This role results from the fact that the description is the basis for the following interpretation and thus the source of knowledge in the analysis. Furthermore, many research projects claim not only to describe a phenomenon, but also to explain and understand it. Wichmann (2019) falls back on the explanations of Max Weber, in order to describe the two terms explaining and understanding nearer. According to this, explaining is about identifying cause-effect relationships and deriving regularities from them. The researchers would take an external perspective. In understanding, it would be a matter of grasping a phenomenon and working out which reasons are responsible for the actions of the persons. The researchers would take an internal perspective. According to Reichertz (2022), this classification is undifferentiated, since the goal of any scientific work is to make generally valid statements and to recognize and explain patterns in action. Thus, there would be no renunciation of explaining in understanding and qualitative research. However, Reichertz (2022) admits that the generally valid statements of qualitative researchers do not apply without restrictions but are always subject to probabilities.

Which method is used in qualitative research to analyze the described phenomenon in more detail is, just as with the question of qualitative or quantitative research in section 2, a question of which research question should be investigated and what data are available. Basically, Reichertz (2022) identifies four lines of questioning. The first (i) line of questioning is the question about the subjective meaning of actions. The second (ii) line of questioning is the descriptive of social action and social milieus. The third (iii) question is the reconstruction of structures that generate meaning and action, and the fourth (iv) question is the (re)construction of historically and socially pre-typed interpretive work.

The method in chapter 3 is based on a qualitative part and a quantitative part. The quantitative part results from the use of standardized data, which are quantitative. On the other hand, the content analysis of the data is partly qualitative since the research approach is based on Reichertz' (2022) third line of questioning. However, we modify the question direction in that we ask which structures determine the non-action of subjects, as we work out what prevents retail investors from acting, i.e. not investing in LCIIP. Further qualitative aspects are that we only deal with those retail investors who are attracted by the fight against climate change and therefore want to take action. This is particularly evident in the fact that we take a desk research approach. This approach ensures that firstly (i) we only research the investment barriers of retail investors who want to combat climate change, i.e. on whom climate change exerts an appeal, and secondly (ii) we take the inside view of these retail investors. Moreover, we describe the object of study in Wichmann's (2019) sense, as we cluster it beyond mere description and use comparative values to better classify it. Finally, our results are not general for all retail investors in the sense that they never invest in LCIIP but lower the probability of investing in them.

2.3 Survey

2.3.1 Introduction into surveys

Surveys are a widespread and classic research instrument for generating data in empirical research. Here, the survey can be understood as a reaction of the respondent to a communication process, whereby surveys can be differentiated according to the type of communication and the degree of standardization of the survey (Reinecke 2022). While in qualitative research mostly a direct communication between researcher and interviewee takes place with a tendency to rather low standardization, in quantitative research a degree of standardization as high as possible is aimed at. The background to this is that standardized surveys aim to investigate as large a population as possible, and it must therefore be ensured that the different responses can also be attributed to the respondents and are not based on different survey conditions (Reinecke 2022).

In chapter 4, a standardized quantitative survey will be used to collect data. The following chapter therefore lays the necessary foundations for this. To this end, the necessary prerequisites for a standardized survey will first be discussed. This is followed by a brief look at the special features of an online-based survey, since this is the form of communication selected in chapter 4. This is followed by some basic considerations about quality criteria of data, as these have to be taken into account especially regarding data collection. However, these considerations are also relevant to a certain extent for chapters 5 and 6, as these are based on regression models as a methodological approach. In the section regression models in this chapter these quality criteria regression models are again briefly discussed. After the quality criteria, the principles of question formulation in surveys according to Porst (2022) are presented, since these are of particular relevance for the development of a questionnaire. After that, the answer scales in standardized surveys are discussed, since they are of central importance in the measurement of the individual data. Other aspects such as interviewer effects, the particularities of using multimedia content such as videos and sound recordings are not discussed in detail. This is done partly because these aspects are either a problem in qualitative interviews or simply do not occur within the framework of the questionnaire used in chapter 4. Thus, as already mentioned, only the relevant content of standardized surveys necessary for a better understanding of chapter 4 will be discussed. Basically, all explanations about surveys follow different contributions of the anthology “Handbuch Methoden der empirischen Sozialforschung” and their structure by Baur und Blasius (2022)

The goal of a standardized survey is to enable a comparison between different subjects (Scholl 2018). For this to be successful, some conditions must be met. Diekmann (2021) describes four conditions. The existence of (i) a common language, whereby it is common that both interviewee and researcher must not only speak the same language, so that a basic understanding exists, but these must also have the same conceptual understanding of relevant technical terms. The second condition (ii) is the cooperation of the respondent, whereby people with a positive attitude towards surveys are more likely to complete a questionnaire and less likely to leave questions unfilled in questionnaires. The third condition (iii) is the recognition that one's opinion considered as important. The last condition (iv) is the existence of a norm of sincerity. By this it is meant that respondents also declare their actual opinion and do not give a socially desirable answer. Since socially desirable response behavior can systematically bias research results without the researchers being aware of it, there are a number of studies investigating what influences this condition (Reinecke 2022). One possibility to exclude social desirability is an online survey (Wagner-Schelewsky and Hering 2022).

Online surveys differ from other forms of standardized surveys in that online surveys choose a special form of communication with the Internet, which has only been possible for about 30 years (Wagner-Schelewsky and Hering 2022). At the same time, the spread of online surveys has risen sharply. While at the beginning of the millennium only a small proportion of standardized surveys were conducted as online surveys, by 2020 more than half of all standardized surveys were conducted online (Wagner-Schelewsky and Hering 2022). However, when conducting online surveys, it is important to remember that this form of survey also has various advantages and disadvantages (Wagner-Schelewsky and Hering 2022). Online surveys have the advantage that they are independent of time and space. This means that respondents can be surveyed over long distances and within a predefined period of time, so that methodological distortions due to different survey times are eliminated. Furthermore, graphically sophisticated instruments and multimedia content can be integrated in the context of online surveys, so that on the one hand misunderstandings among the participants can be avoided and additional previously unexplored aspects can be observed. In addition, as mentioned above, social desirability effects are eliminated. Another advantage of this form of communication is that there are no errors due to the manual collection of data and thus the resulting bias of the data is eliminated. The last advantage is the low financial expenditure, which results from the fact that neither personnel costs for interviewers nor for personnel for the manual input must be invested in. The advantages are offset by one disadvantage in particular. The increasing spread of online surveys means that many potential participants simply ignore emails asking them to take part in a survey, as these are very often sent or suspect commercial purposes behind these emails and therefore they do not take part (Wagner-Schelewsky and Hering 2022).

2.3.2 Quality criteria of quantitative social research

According to Diekmann (2021), the research process of a standardized survey can be divided into five phases. These are (i) formulation and specification of the research problem, (ii) planning and preparation of the survey, (iii) data collection, (iv) data processing and data analysis, and (v) reporting.

A number of decisions need to be made during preparation. Here, it is necessary to determine which research design, which type of questionnaire, which measurement instruments, whether the questionnaire will be asked once or multiple times, and which population will be surveyed. In particular, the theoretical work must be completed before the questionnaire is created to ensure that all questions and scales used meet the classic quality criteria of a standardized survey. The aim here is to achieve the highest possible degree of objectivity so that the conditions for reliability and validity are created (Diekmann 2021).

Objectivity can be divided into three points, namely implementation objectivity, evaluation objectivity and interpretation objectivity. Interpretational objectivity means that the collected data are interpreted objectively, i.e. without the influence of the researcher's own values. Since researchers are always influenced by their own values, interpretive objectivity is very limited in quantitative social research. Implementation objectivity means that all respondents must be exposed to the same stimuli in the same order so that the results are not influenced by different stimuli. In the context of online surveys, this is done by standardizing all questions and not having an interviewer effect. Evaluation objectivity means that the data have been evaluated in a way that is comprehensible to other researchers. Careful documentation of the data preparation must be ensured, and in particular the data must be checked for errors and completeness. In addition, it must be comprehensible how the data were processed for statistical purposes and, if necessary, summarized (Krebs and Menold 2022).

Reliability is defined by Krebs and Menold (2022) as the extent to which repeated measurements of an attitude object lead to the same values. Reliability thus describes whether the measured values are obtained again with repeated measurement. Based on the latent attitudes of participants in standardized surveys, it must be assumed that there is always a certain amount of variation across different measurements, which is why statistical methods can be used to control for this variation and thus demonstrate the quality of the model.

Validity describes how accurately a behavior or attitude is measured. Like objectivity, validity can be divided into three sub-parts. The first sub-item is content validity. This indicates how well a question measures what it is intended to measure. The second subitem is criterion validity, which indicates the relationship between the attitude measured in the questions and other attitudes not measured in the questions. Construct validity refers to the entire questionnaire or a part related to its content. The construct validity indicates how strongly the individual questions within the questionnaire, or the content-related part are related to each other. This can be determined mathematically and statistically (Krebs and Menold 2022).

The three quality criteria are not detached from each other but are in a hierarchical relationship. The objectivity must be given, so that the reliability can be given. Reliability, in turn, must be given so that validity can be given (Reinecke 2022).

2.3.3 Principles of question formulation

The questionnaire represents one of the most important measuring instruments of social science. Here, the underlying research question must be mapped exactly, and the quality criteria must be taken into account. Since a questionnaire assesses a construct by the means of its questions, special attention must be paid to the questions or the question wording (Porst 2022).

Porst (2022) describes the development of question wording in questionnaires over time. In doing so, the author comes to the conclusion that the cooperation of researchers from various disciplines would have led to a new quality in the development of questionnaires. The starting point would have been to focus on the quality of the questions. In particular, the model of Strack and Martin (1987) was used as a basis for this. The model assumes that respondents would always have to solve four tasks. These are, (i) understanding the question asked, (ii) retrieving relevant information to answer the question from memory and form a judgment about it, (iii) fitting this judgment into an answer format, and (iv) editing the judgment before passing it on to the questionnaire. In order to cope with these tasks in the best possible way, the quality of the questions and, in particular, of the question wording must be as high as possible. Porst (2022) illustrates this with the example of the first task. From the respondents' point of view, understanding the question has two dimensions, namely semantic understanding and pragmatic understanding. Semantic understanding is about the respondents understanding what the question is supposed to mean. Pragmatic understanding is about the respondents understanding what the researcher wants to know. According to Porst (2022), a good question is one that takes both semantics and pragmatics into account. Failure to do so would be fraught with a number of problems, which is why Porst (2022) describes ten commandments of question formulation to avoid these very problems.

The first commandment is: “You shalt use simple, unambiguous terms that are understood in the same way by all respondents.” By this, the author means that questions must be understood in the same way by all respondents so that the answers are comparable. The chances of this would increase if the questions were formulated simply and unambiguously. Whether a question is understood as simple and unambiguous by the respondents depends on who is being interviewed. An expert in a certain field may judge a question on this very field as simple and unambiguous, while other people would perceive this differently. Therefore, it is imperative that the questions are formulated from the point of view of the respondents and that their understanding of the question forms the basis of the question formulation.

The second commandment is: “You shalt avoid long and complex questions.” With long and complex questions comes the risk that the questions become incomprehensible and/or contain multiple stimuli that lead to different reactions in individual respondents. As a result, it would not be clear which stimulus the respondent reacted to in a question, and thus it would not be clear which reaction to which stimulus was measured.

The third commandment is: “You shalt avoid hypothetical questions.” Hypothetical questions require the respondent to put themselves in a situation in which they are not. Whether this is successful depends on the extent to which the person being interviewed has dealt with the situation before and how far the situation is from the person. Since both points are not present to the same extent in all persons, but are very individual and difficult to control, there is a risk of distorted results.

The fourth commandment is: “You shalt avoid double stimuli and negations.” Both double stimuli and double negations can result in respondents not being able to fit their answer into the schema provided. An example would be the question, do you think A and B are good? Here, respondents might find A good and B not good, so no universal answer can be given. The solution to this problem would be to ask two separate questions. With double negation there is the danger that respondents do not understand the actual meaning, that it is not clear to them what exactly is meant and that they understand the question exactly the wrong way around. This can lead to distorted results, as some participants answer exactly the opposite.

The fifth commandment is: “You shalt avoid insinuations and suggestive questions.” Insinuations in questions can lead to respondents having to express themselves from a position or opinion that you yourself do not share, so this can also lead to distorted results. Also, suggestive questions lead to distorted results, because you have to influence the respondents in one direction and therefore, they are not free from external influences in their answer.

The sixth commandment is: “You shalt avoid questions that target information that many respondents presumably do not have.” This means that if, for example, you ask how measure A will affect the population in a distant region B, then most respondents, with the exception of experts, will not be able to answer this and will tend to guess. It then follows, that the question does not measure what the question is supposed to measure but is simply a reflection of what the respondents have guessed.

The seventh commandment is: “You shalt use questions with a clear temporal reference.” By this, it is meant that the questions do not contain vague or interpretable time periods. An example would be a question about the long term without defining it in more detail. Different people have different understandings of what long term means and would thus answer based on their individual understanding.

The eighth commandment is: “You shalt use answer categories that are exhaustive and disjunctive (non-overlapping).” This means that the answers must cover every possible case. An example would be if you were asked how much assets under management an investment company manages, and the largest category was closed at €25 billion. Here, respondents from companies with a higher asset under management value could not give a correct answer. It would be better if the category greater than €25 billion were introduced so that all with more than €25 billion could give a correct answer here. Disjunctive answer alternatives would exist if the same limit applied to two categories. An example would be if related to the same question one answer would be “up to €25 billion” and another “€25 billion or more”. Here, someone managing exactly €25 billion is not able to give an accurate answer because the person would fall into both groups.

The ninth commandment is: “You shalt ensure that the context of a question does not (uncontrollably) affect its answer.” This means that previous questions influence the questions that follow, so this effect should be kept as small as possible.

The tenth commandment is: “You shalt define unclear terms.” This means that terms are unclear if they are not understood or are understood differently by different groups. This problem is very similar to the problems in commandments 1 and 6, but here the solution is to define the unclear term and thus make it understandable to the respondents.

According to Porst (2022), the commandments are to be understood as signposts and not as fixed laws that must always be followed. On the one hand, the commandments are not applicable in some cases, up to cases in which the exact opposite is necessary, and on the other hand, the commandments must always be critically questioned.

2.3.4 Answer scales of the standardized survey

At a certain point, researchers have to ask themselves which questions they want to ask in their questionnaire and which answer options they want to use to measure the answers. Franzen (2022) describes all relevant points in his work, but in this thesis only the points necessary for chapter 4 will be dealt with.

Basically, closed response specifications can be divided into unordered and ordered response categories. Unordered response categories are those such as hair color or the question about which of the a set of strategies is used. The response scales here are usually nominal scales. In addition, the design of the response categories is highly dependent on the question, so very few rules exist. Franzen (2022) counts exhaustive, disjunctive and not too extensive among these.

The situation is different with ordered answer specifications. Here, for example, the agreement or disagreement to a statement is asked. Therefore, researchers have to decide on a certain number of rating scales. Research has investigated how many response options would be the best. Among other things, it was tested whether more levels lead to better results because the respondents have more choices. The result of this is that the increased number of answer options demands an increased thinking ability from the respondents. Therefore, five to nine answer choices are the ideal number. In addition, scales with fewer than five response options can be discouraged because they tend to have reliability problems. Response scales with more than nine response options do not provide any further advantages (Franzen 2022).

Another aspect is the question of whether the number of response options should be even or odd. The argument in favor of an even number of answer options is that respondents are forced to choose a side. However, this is contradicted by the fact that respondents tend to answer a question in the affirmative. Odd answer alternatives have a center and therefore do not force anyone to choose a side. However, respondents tend to choose the center when in doubt, so the data is distorted. Nevertheless, an odd number of answer choices is preferable to an even number of answer choices because the problem of the tendency toward the center is solved with an additional off-scale answer option. To do this, the option "don't know" must be inserted so that respondents without an opinion can select this answer option.

Furthermore, when designing the answer options, it must be considered whether all or only some of the answer options should be verbalized. With questions with more than nine answer options it can become difficult to distinguish the individual answer options from each other linguistically. In addition, according to Franzen (2022), some studies show that reliability increases when all answer options are verbalized. It is important to ensure that the different levels are formulated at the same intervals during verbalization.

Finally, according to Franzen (2022), it must be considered whether the most positive or most negative answer option is given first. According to his explanations, there is a hypothesis according to which the respondents first read through all answer options and then answer the one that applies to them. However, various studies have shown that this is not the case and that many respondents tend to select the answer option they read first. Therefore, Franzen (2022) advocates starting alternately with the most positive and then the most negative.

2.4 Regression models

2.4.1 Basics of regression models

Regression analysis can be traced back to Sir Francis Galton (1822-1911) (Backhaus et al. 2021). Galton developed this method in connection with his studies of heredity, and his work on regression analysis is considered by some researchers to be one of the great triumphs of science (Backhaus et al. 2021). Regression analysis is used to test whether one variable has an effect on another variable and how strong that effect is (Backhaus et al. 2021). To do this, it is determined in advance of the analysis which variable is the explanatory or independent variable and which is the to be explained or dependent variable. The aim of the regression analysis is firstly (i) to describe reality, i.e. to show how different variables are related. Second, (ii) to test how well the model used can represent reality, and third, (iii) to make predictions (Auer and Rottmann 2020). In economics, the use of regression models is ubiquitous (Schröder 2012). Especially in financial market analysis, some of the most important and widely used methods, such as the Capital Asset Pricing Model (CAPM) (Sharpe 1964) and the Arbitrage Pricing Theory (APT) model (Ross 1976) are based on regression analysis. Chapter 5 is based on the three-factor Fama-French model (Fama and French 1993), which is a further development of the CAPM. Moreover, the difference between the CAPM and the Fama and French model is that the former is a simple regression model, while the Fama and French model is a multiple regression model. Therefore, it is essential for chapter 5 to know the basics of regression models and to be able to distinguish between simple and multiple regression models. Furthermore, the quality of the overall model as well as the individual parameters are discussed, thus creating a basic understanding for the evaluation of the individual analyses. Chapter 6 is also based on regression analyses, but goes one step further than chapter 5, since chapter 6 performs a second regression analysis based on the results of a first regression analysis. Since the second regression analysis continues with the residuals of the first regression analysis, the explanations on the residuals are of central importance for understanding. The aim of this section is to provide a basic understanding of regression analyses, their assessment and their assumptions, so that the explanations in chapters 5 and 6 can be followed. For this purpose, this section follows in particular the two works of Backhaus et al. (2021) and Auer and Rottmann (2020) structurally as well as in the explanations.

In general, it has to be kept in mind that a regression analysis alone cannot establish causality (Auer and Rottmann 2020). Rather, the cause-effect relationship must be derived in advance, i.e., before the model formulation, by means of one's own considerations and theories, which is then examined by the regression analysis (Auer and Rottmann 2020). This is based in particular on the form of regression analysis, since the independent variable is used to explain the dependent variable. So already with the model formulation an assumption is implied, which variable has an influence on the dependent variable. Regression analysis is then only used to investigate whether this influence can be statistically represented and, if necessary, to quantify this influence more precisely.

With the model formulation first assumptions about reality are made. It should be noted that the model is a simplified representation of the world, which on the one hand is kept as simple or sparse as possible (principle of parsimony) and on the other hand, care is taken to ensure that all relevant variables are included (principle of completeness). Thus, the model formulation represents already a balancing act between the two principles (Backhaus et al. 2021).

The simplest economic estimation procedure is the ordinary least squares (OLS) model. The simplest form of the OLS-model with an independent variable X and a dependent variable Y is:

$$Y_i = \beta_0 + \beta_1 X_i \qquad (2.1)$$

Here, β_0 and β_1 are regression parameters or regression coefficients. β_0 stands for the regression constant and indicates the intersection of the line with the Y-axis when X takes the value zero. β_1 indicates the slope of the line and thus tells us by how many units Y increases when X

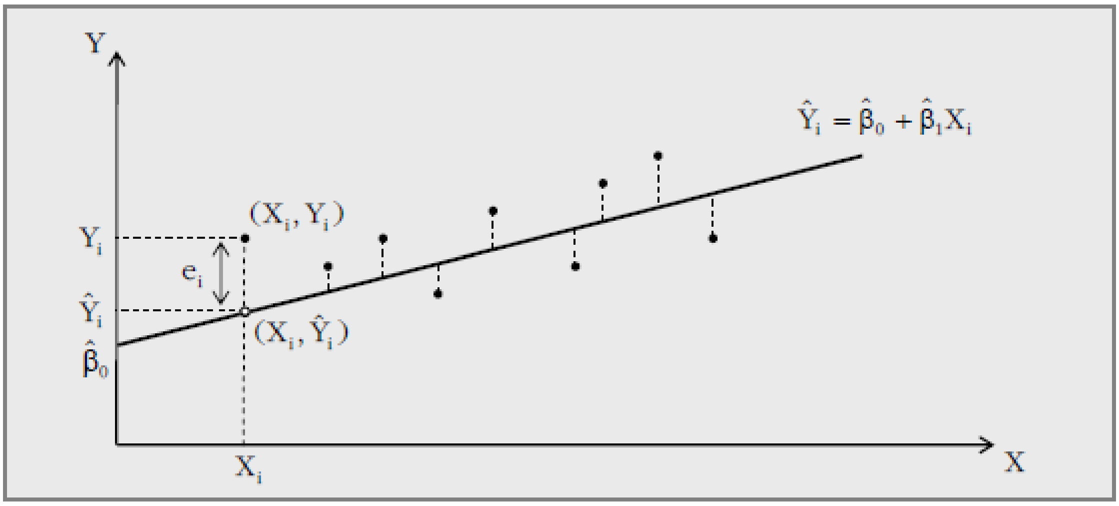
increases by one unit. Based on the fact that we can observe the values X and Y in the world, the question arises how the values β_0 and β_1 can be determined (Auer and Rottmann 2020).

In a perfectly linear statistical world with exactly two observations of X and Y, these two observations could simply be entered into a coordinate system and then the values for β_0 and β_1 could be read from it or determined by drawing a straight line. Since in the real world, on the one hand, there are more than two observations for one fact and, on the other hand, economics is a social science, it must be assumed that there will always be observations which are influenced to a certain extent by chance or unobservable influences. This is especially due to the fact that social science mainly examines people or aspects influenced by people and that they do not always act identically according to a certain pattern. Based on this, we could assume that we had estimated the two values $\hat{\beta}_0$ and $\hat{\beta}_1$ for some observations. Then, using $\hat{\beta}_0$, $\hat{\beta}_1$ and X, we could determine the estimated or fitted value $\hat{Y}_i$. Therefore, the new formular is:

$$\hat{Y}_i = \hat{\beta}_0 + \hat{\beta}_1 X_i \quad (2.2)$$

Since the collected observations are to some degree subject to random chance, this fact must be accounted for in the regression equation. The figure 2.1 of Auer and Rottmann (2020) illustrates such a case.

Figure 2.1: OLS-model



See Auer und Rottmann (2020)

The actual observed values of Y do not lie exactly on the regression line. The dashed vertical line between the individual observations and the regression line indicates the deviation of the observations from the estimated regression line. These deviations are denoted by the variable ϵ_i. Here ϵ stands for error or the error term. Because the regression line is an estimation, it is not possible to calculate the true value ϵ for each observation, but only the deviation of the observations from the estimated line. These values are therefore called residuals. If ϵ is now taken into account in the regression equation, the following regression equation results:

$$\hat{Y}_i = \hat{\beta}_0 + \hat{\beta}_1 X_i + \epsilon_i \tag{2.3}$$

In order to keep the influence of chance on the regression equation as small as possible, an OLS estimation aims at determining $\hat{\beta}_0$, and $\hat{\beta}_1$ in such a way that the deviations from Y to $\hat{Y}_i$, i.e. ϵ_i, are as small as possible. Here it must be considered that the residuals can have a positive as well as a negative sign, which is why the sum of squares of the residuals is minimized as far as possible. The background is that by squaring the residuals all signs become positive and positive and negative signs can no longer cancel each other out. Mathematically, the goal of an OLS-regression can be formulated as follows:

$$OLS\ min \sum_{i=1}^{n} \epsilon_i^2 \tag{2.4}$$

The equation in formula 2.3 represents the simplest form of a regression model and is called simple regression.

Starting from the simplest form of a linear regression model, much more complex models can also be estimated by means of OLS-regressions. For this purpose, on the one hand, other mathematically more complex forms can be chosen for X and, on the other hand, more than one X can be used as explanatory variable. Furthermore, combinations of mathematically more complex independent variables as well as the use of several independent variables in one model are also possible.

Mathematically more complex X can always be used in an OLS-model, if individual variables are not linear, although parameter linearity is present. This means that a variable e.g. with the form X^2 does not have variable linearity, because the variable loses its linear form by squaring. Nevertheless, it is possible to consider such a variable in a model, since the variable X^2 can be transformed back into a linear form by introducing a new variable Z. Mathematically, this changes the regression equation as follows:

$$\hat{Y}_i = \hat{\beta}_0 + \hat{\beta}_1 Z_i + \epsilon_i \quad with \quad Z_i = X_i^2 \tag{2.5}$$

It follows that the individual variables need not be linear as long as they can be transformed back into a linear form, which is called parameter linearity. Thus, parameter linearity exists when individual non-linear variables can be replaced by a linear parameter. Such a change of the respective equation is possible for various forms. Auer and Rottman (2020) list the following forms among others but point out that the list is not complete.

$$linear\ form: Y_i = \beta_0 + \beta_1 X_i + \epsilon \tag{2.6}$$

$$quadratic\ form: Y_i = \beta_0 + \beta_1 X_i^2 + \epsilon \tag{2.7}$$

$$logarithmic\ form: ln\,Y_i = \beta_0 + \beta_1 lnX_i + \epsilon \tag{2.8}$$

$$inverse\ form: Y_i = \beta_0 + \beta_1 \frac{1}{X_1} \tag{2.9}$$

Furthermore, models with several explanatory variables can be estimated. In this case, the basic form of the model changes in that way that instead of X, now X_{1i} to X_{Ni} are used to explain Y. The model then changes as follows:

$$Y_i = \beta_0 + \beta_1 X_{1i} + \cdots + \beta_N X_{Ni} + \epsilon_i \tag{2.10}$$

A regression model with multiple independent variables is called a multiple regression model and is predominantly used. However, the mathematical principles are the same. Therefore, even in a multiple regression model, the goal is to estimate all β such that the residual sum of squares (SSR) $\sum_{i=1}^{n} \epsilon_i^2$ is minimized. However, in a multiple regression model, the interpretation of each X_{1i} changes from the interpretation in the simple regression model. The new interpretation is that β_1 indicates by how many units Y changes when X_{1i} changes by one unit, holding all other variables constant (Auer and Rottmann 2020).

2.4.2 Testing the quality of the overall model

After a model has been formulated and all βs have been estimated, questions arise as to how well the model can represent reality. For this purpose, the quality or goodness of a regression model must be assessed (Backhaus et al. 2021). For this purpose, there are different metrics in regression analysis. In the following, the standard error, the coefficient of determination, the corrected coefficient of determination and the F-test will be considered in more detail, as they are relevant for the present work.

The standard error of the estimate (SE) indicates how much the observed Y deviates vertically from the regression line (see Figure 2.1) and thus measures the precision of the model. Here, the smaller the value of SE, the better the estimated model. SE is defined as the standard deviation of the residuals and is calculated as follows:

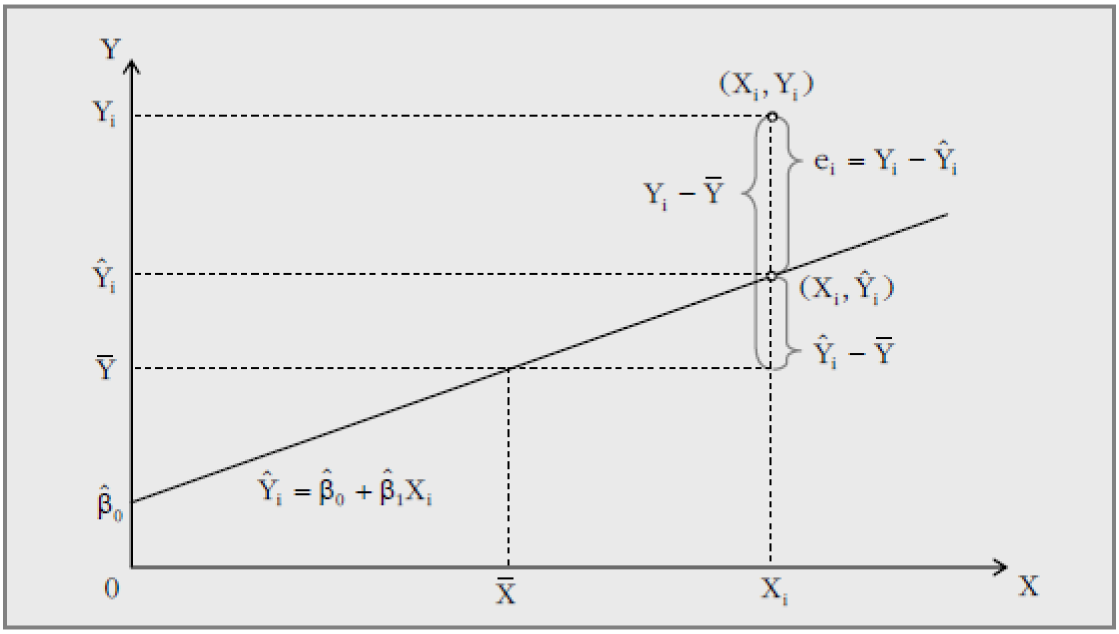
$$SE = \sqrt{\frac{SSR}{N - J - 1}} \tag{2.11}$$

Where N is the number of observations J is the number of variables in the regression model. J takes the value 1 in a simple regression model and increases with each additional parameter in multiple regression models.

Another measure for determining the quality of the overall model is the coefficient of determination. The coefficient of determination indicates how much of the scatter of Y can be explained by the estimated model and is denoted by R^2. The dispersion of Y is defined as the sum of all squares of Y minus the average Y or $\bar{Y}$. This total scatter is called total sum of squares

(SST). To determine R^2, the total sum of squares of Y is decomposed into an explained and an unexplained part (see Figure 2.2).

Figure 2.2: Decomposition of the variance of Y



See Auer and Rottmann (2020)

The unexplained part is the sum of the squares of all estimated $\hat{Y}_i$ minus the average Y. This corresponds exactly to the residual squared sum. The explained part is called explained sum of squares (SSE) and can be calculated after estimating the model. For this purpose, the sum of all squares of $\hat{Y}_i$ minus $\bar{Y}$ is calculated. All three parts SST, SSR and SSE behave as follows:

$$SST = SSR + SSE \tag{2.12}$$

Based on equation 2.9, the explainable part of the scatter can then be given as a ratio to the total scatter.

$$\frac{Explained\ scatter}{Total\ scatter} = \frac{SSE}{SST} = R^2 \tag{2.13}$$

This approach has two advantages. First, (i) maximizing R^2 is accompanied by minimizing SSR. Second, (ii) this method works for simple as well as multiple regressions. In addition, the interpretation of R^2 is very straightforward, as it indicates, in some sense, the percentage of how much of the scatter can be explained by the estimated model. Consequently, R^2 is:

$$0 \leq R^2 \leq 1 \tag{2.14}$$

Despite the widespread use of the coefficient of determination to determine the quality of a model, the adjusted coefficient of determination or $adjusted\ R^2$ is also frequently specified. The reason for this is that the coefficient of determination does not take two aspects into account. First, the number of observations is not taken into account. A model with 1000 observations represents reality with a higher probability than a model with 10 observations. This fact becomes even more obvious if we look at an extreme case with only two observations. In a model with only two observations, the regression line can be laid exactly through both points. From this it would follow that R^2 would take the value one, because there would be no scatter and therefore no unexplainable scatter. Second, the coefficient of determination does not take into account how many independent variables are used in the model. More variables may increase the R^2 value, but they do not necessarily make the model better, since they could randomly increase the R^2 value. Especially against the background of the problem of multicollinearity between the variables, adding variables can lead to the model being biased. On the other hand, if too few variables are included in a model, then this can also bias the model.

Therefore, it makes sense to consider the adjusted R^2. The adjusted R^2 takes into account the number of independent variables. If additional variables are included in the model and these provide only a very small or no further explanatory content, then the adjusted R^2 becomes smaller. It follows that the adjusted R^2 only becomes larger if the additional independent variables provide a larger explanatory content. Thus, the change in the adjusted R^2 when additional variables are added indicates whether they add value to the model or whether their explanatory power is small and thus negligible. This prevents the models from becoming unnecessarily complex and thus helps to adhere to the principle of parsimony, while at the same time controlling for completeness. The adjusted R^2 is calculated as follows:

$$R^2_{adj.} = 1 - \frac{SSR/(N-J-1)}{SST/(N-1)} \tag{2.15}$$

As with the standard error, N represents the number of observations and J the number of variables estimated in the model.

Another measure to determine the quality of a model is the F-test. Here, the following is tested:

$$H_0: \beta_1 = \beta_2 = \cdots = \beta_N = 0 \tag{2.16}$$

The counter hypothesis is:

$$H_1: at\ least\ one\ \beta\ is \neq 0 \tag{2.17}$$

To prove H_1 we must reject the null hypothesis. F is calculated by the following formula:

$$F = \frac{R^2/J}{(1-R^2)/(N-J-1)} \tag{2.18}$$

The value alone has little meaning but must then be evaluated taking into account the F-distribution. The F-distribution can be looked up in relevant works, whereby it must always be noted that the F-distribution is different depending on the number of degrees of freedom. The degrees of freedom are determined by N and J. If the values of F and the degrees of freedom are available, the p value can be read from the table for the F-distribution. The decision criterion is we reject H_0 if $p \leq \alpha$. Classic alpha values are 1%, 5% or 10%, reflecting the probability of error. Probability of error denotes the probability that we reject the H_0 hypothesis even though it is correct. In other words, the probability of error means that with an alpha of 5%, we incorrectly accept H_1 in 5% of the cases, although it is not true. If H_0 is rejected, then one speaks of statistical significance, and it means that at least a β of zero is different. From this it can be deduced that the estimated model can explain the dependent variable and that the relationship between the independent and the dependent variable is not based on pure chance (Backhaus et al. 2021).

2.4.3 Testing the quality of the individual parameters

In addition to the overall model, the individual regression parameters should also be checked for their goodness. Here, the two concepts of the standard error and the F-test are applied to the individual regression parameters.

The standard error of the individual parameters is based on the previously mentioned insight that β indicates the true value with which on average each X influences Y. The standard error of the individual parameters is based on the previously mentioned insight that β indicates the true value with which each X influences Y. Since the observed values of Y always depend to a certain extent on chance, this is taken into account in the regression equation with the error term ϵ. The standard error of the individual parameters is therefore the same. It follows that the true value of β can only be estimated. This estimated value is given as $\hat{\beta}$. The standard error of the individual parameters is the deviation of the observation from the regression line. However, for the individual parameter not the sum over all residuals is calculated, but the value for each parameter is given separately. The calculation of the standard error can be determined for the simple regression model with the following formula:

$$SE(\hat{\beta}) = \frac{SE}{s(x) * \sqrt{N-1}} \tag{2.19}$$

Where SE is the standard error of the overall model, $s(x)$ is the standard deviation of the independent variables, and N is the number of observations. For a multiple regression model, the following must be calculated:

$$SE(\widehat{\beta_i}) = \frac{SE}{s(x) * \sqrt{N-1} * \sqrt{1-R_j^2}} \tag{2.20}$$

Unlike the standard error of the overall model, the standard error of the regression coefficients does not get smaller with a better model. In order to increase the precision of the individual regression coefficients, it can be deduced from the formula that either the number of observations must increase, or the standard deviation must increase. This is logical, because with increasing observations more information is available and therefore the true value can be estimated better. In addition, as the number of observations increases, the range of random unexplained variation also increases, and so does the standard deviation. With more variation in the standard deviation, it is then easier to determine what is chance and what is part of the true value.

Furthermore, the question must be asked whether every X has any influence on the corresponding Y at all. To do this, we analyze whether the individual regression coefficients β are significantly different from zero.

The tested hypothesis is:

$$H_0: \beta_i = 0 \tag{2.21}$$

The counter hypothesis is:

$$H_1: \beta_i \neq 0 \tag{2.22}$$

Unlike the test of the overall model, the t-test and not the F-test is used for this. The difference can be seen by comparing the tested hypotheses. The F-test checks whether, starting from all β, one β is not equal to zero. The t-test checks for each β individually whether the respective X has a significant influence on Y in the amount β. The t-test is calculated using the following formula:

$$t = \frac{\hat{\beta}_i}{SE(\hat{\beta}_i)} \tag{2.23}$$

The value determined from this must then again be compared with the value from the t-distribution, taking into account the degrees of freedom. If the determined value for t lies outside the previously determined error probability, e.g. $\alpha = 5\%$, then H_0 can be rejected and the respective β has a significant influence on Y. As with the F-test, frequently chosen error probabilities are $\alpha = 1\%$ or $\alpha = 5\%$.

After answering the question of whether a $\hat{\beta}$ differs from zero and X has a statistically significant influence on the dependent variable Y at all, the question must be asked as to how strong the influence of X is. Here, we can build on the considerations made earlier, since the t-test can be used to clarify this question. $\hat{\beta}$ is to some extent based on chance and will take on a different value in a different sample, which will also fluctuate around the true value β. Moreover, the previous remarks above have made it clear that the reason we estimate $\hat{\beta}$ is because we cannot determine the exact value of β. Nevertheless, it is possible to estimate an interval in which the true value β must lie. This interval is called the confidence interval of the regression coefficient. However, it must be noted that the true value of β does not lie in this range with complete certainty, but only with a certain probability. The probability results from the selected alpha. It can therefore be stated that with $(1 - \alpha)\%$ the true value of β lies in the range of the confidence interval. Mathematically, the confidence interval can be calculated as follows:

$$\hat{\beta}_i - t_{\frac{\alpha}{2}} * SE(\hat{\beta}_i) \leq ß_i \leq \hat{\beta}_i + t_{\frac{\alpha}{2}} * SE(\hat{\beta}_i) \tag{2.24}$$

Here, $\hat{\beta}$ stands for the estimated value of β, β for the true value, $t_{\frac{\alpha}{2}}$ for the t-value taking into account the chosen alpha and the freedom line of the regression, and SE for the standard error of the respective β. The value thus obtained can then be interpreted as follows. The true value of β lies with $(1 - \alpha)\%$ probability between the two determined limits.

2.4.4 Testing the assumptions of regression models

Regression analysis represents a simple and powerful tool for exploring the observable world. However, the application of this tool can lead to biased or erroneous results. Therefore, it is advisable not only to check the quality of a model, but also to determine whether any of the underlying assumptions of the regression model have been violated. Based on a multiple regression model (see formula 2.10), the regression model has a total of seven assumptions following Backhaus et al. (2021). The seven assumptions are:

- Assumptions 1: Linearity in the parameters.
- Assumptions 2: No relevant independent parameters are missing.
- Assumptions 3: The independent parameters are measured without error.
- Assumptions 4: The disturbance variables have a constant variance.
- Assumptions 5: The disturbance variables are uncorrelated.
- Assumptions 6: The disturbance variables are normally distributed.
- Assumptions 7: No perfect multicollinearity.

The first assumption that all parameters must be linear has already been discussed above. However, it was only pointed out that it would be problematic if the parameter linearity would not be present. More precisely, such a presence leads to the fact that the results are systematically distorted and thus the regression equation has no significance. Therefore, it is important to identify whether linearity is present or not. Backhaus et al. (2021) suggest as a solution to visualize the data in a scatterplot, because non-linear structures can be shown this way. Especially in the case of multiple regression models, the Y with each individual X must be transferred into an independent scatterplot, since otherwise the visualization would lead to a confusing result that is difficult to analyze. In addition, non-linearity can also be present if the sum of the effect of, for example, X_1 and X_2 is smaller or larger than the sum of the individual effects. These so-called interaction-term can be based on the fact that there is an effect or correlation between the two X and thus they influence each other. The solution to the problem is to use an interaction term. For this, the product of X_1 and X_2 is included in the regression equation so that this product exerts a corrective influence on the overall equation. The regression equation then changes as follows:

$$Y_i = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_1 X_2 + \epsilon_i \tag{2.25}$$

The second assumption is based on the realization that, especially in economics, the dependent variables under study usually depend on a large number of independent variables. Therefore, it is not possible to take all of these variables into account. Therefore, the second assumption simply states that no relevant variable may be missing. From this follows the question of what is and what is not a relevant variable. A relevant variable is one in which the absence causes the error term to correlate with the explanatory variables. This definition makes sense because, on the one hand, many independent variables are correlated to some degree. On the other hand, in a model with missing relevant variables, the explanatory part of the missing relevant variables would be covered by the error term. Since the independent variables correlate with each other, an incomplete model would then correlate the error term with the explanatory variables. This would have the effect of biasing the estimators, since the regression model would then either overestimate or underestimate the explanatory content of the variable considered. Thus, the assumptions ensures that the error term does not contain any systematic explanatory content but is based on chance only. A possible violation of the assumption can again be determined by means of a graphical representation (Auer and Rottmann 2020).

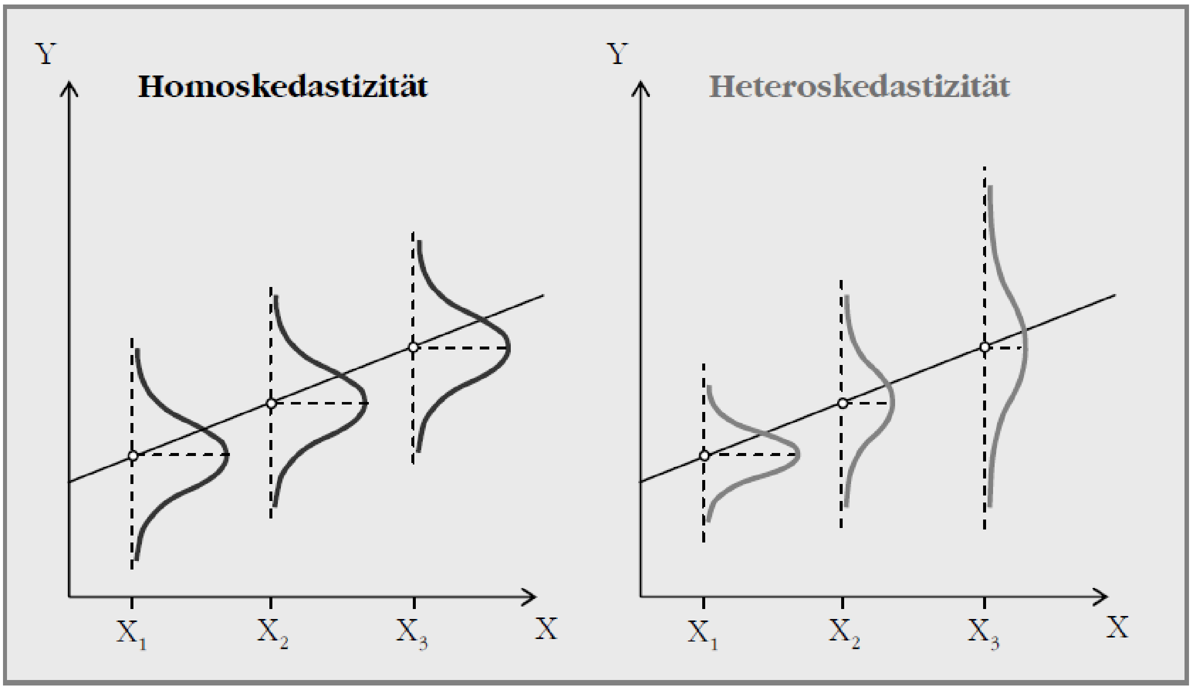
The third assumption states that the independent variables are measured without error. Basically, the regression model assumes that the observed Y depend to some extent on chance and are therefore subject to error. To account for this, the error term was included in the regression equation to absorb this effect. Since in the social sciences the measurement of observations is subject to error, or is rather error-prone, it must be assumed that many variables are never measured with complete reliability. This can be expressed mathematically as follows:

$$\hat{\beta} = \beta * Reliability \tag{2.26}$$

Here β takes the value 1 and $\hat{\beta}$ deviates from β the more, the smaller the value of the reliability is. It follows that the estimated values of $\hat{\beta}$ deviate more from the true value β when the reliability is small, or the random error is large. Backhaus et al. (2021) state that there would be no simple solution to this problem since it is not known whether and if how many errors are present in the independent variables. Nevertheless, it is necessary to know about this problem and to be aware that a bias in the data may be due to precisely erroneous measurements.

The fourth assumption states that homoscedasticity exists. The word homoskedasticity is composed of the words homos, which means equal in Greek, and skedastos, which means scatter. This means that the dispersion or variance of the residuals is the same for all X. The opposite would be heteroskedasticity.

Figure 2.3: Homo- and Heteroskedasticity



See Auer and Rottmann (2020)

Figure 2.3 illustrates homo- and heteroscedasticity. If the residuals vary differently for all X, leading to different variances, then the precision of each X will be different (see section standard error). It follows that the quality of the individual X is to be evaluated differently and that not all X stand on an equal footing. This in turn would mean that the values for X_1, for example, would be closer to the true value than those for X_2. The assumption therefore assumes the equivalence of all X and thus allows for the equal treatment of all X (Auer and Rottmann 2020). The presence of heteroskedasticity indicates nonlinearity or neglect of relevant variables. Heteroscedasticity can be detected using various statistical tests (Backhaus et al. 2021).

The fifth assumption states that the confounding variables or error terms of the individual independent variables are not correlated with each other. If the error terms are correlated with each other, then this is called autocorrelation. Autocorrelation is always present, if the deviations from the regression line are not based on independent coincidences, but in regression observations are analyzed, in which some observations depend on other observations. It follows that the residuals of the connected observations are related to each other. This occurs in particular with time series, since a characteristic is observed over several points in time and thus later observations might stand in a relationship to earlier observations. It then follows that the quality of the regression model decreases, since the precision of the individual independent variables decreases. In addition, the occurrence of autocorrelation may indicate the violation of the linearity assumption of the regression equation or indicate that the estimated model does not take into account relevant variables. Autocorrelation can be controlled for mathematically using the Durbin-Watson test or can be determined by visualizing the residuals against the estimated Y values. However, it must be noted that autocorrelation was decreasing precision, but does not lead to biased estimators and thus can be accepted to a certain extent (Backhaus et al. 2021).

The sixth assumption states that the error terms are normally distributed. The assumption must be made for the significance tests to be valid, since these are always based on the assumption that the underlying values are normally distributed. Since the residuals are considered in these tests, they must be normally distributed for the tests to be valid. The sixth assumption is not critical to the validity or precision of the actual model. Backhaus et al. (2021) suggest visualizing the residuals in the form of a histogram to identify the problem. A violation of the assumption is usually based on the violation of one of the previously mentioned assumptions (Backhaus et al. 2021).

The last assumption states that there may not be perfect multicollinearity in the data. As described earlier, there is always multicollinearity among the individual independent variables to some extent. Therefore, the assumption is that there must not be perfect multicollinearity. Perfect multicollinearity exists when a variable, e.g., X_2, is a multiple of X_1. Another possible form could be that X_1 and X_3 together explain X_2. In both cases, X_2 would not provide any further explanatory content and would thus not be relevant for the model (Auer and Rottmann 2020). The consequence of (perfect) multicollinearity is a decrease in the precision of a model. Multicollinearity in general can be controlled for using the Variance Inflation Factor (VIF). Since multicollinearity exists to a certain extent, a value of five or more for the VIF is considered problematic, so that the model should be checked and adjusted when this value is exceeded (Backhaus et al. 2021).

In addition to the seven assumptions of a regression model, Backhaus et al. (2021) and Auer and Rottmann (2020) also discuss outliers under this bullet point in their respective works. Since the previous structure of this section is based on the structure of these two works and outliers are of central importance for a regression model, we will follow the two works here and will also discuss outliers. Basically, outliers represent observations which deviate very strongly from the majority of the other observations. In individual regression models, there can always be single outliers or a whole series of outliers. Backhaus et al. (2021) list four possible causes for this. First, (i) outliers may simply be due to chance. Second, outliers may be measurement errors or due to incorrect data collection or data entries. Third (i), an unusual event outside one's research may cause outliers. Fourth (iv), an unusual event within one's research can lead to outliers. Regardless of the reason why an outlier occurred, regressions should be controlled for outliers because they can (strongly) affect regression results. Whereby the impact of an outlier on the regression results depends on two aspects. First, outliers have a stronger influence on the regression results, the further they deviate from the regression line. In other words, the larger the individual residual of a single outlier, the stronger the influence on the regression. From this, it can be seen that the influence of an outlier depends on its position on the Y-axis, since the residuals are defined as a vertical line and thus run parallel to the Y-axis. In addition to the position on the Y-axis, the position on the X-axis has an influence on how strongly an outlier affects the regression equation. Here, the influence of an outlier increases the further away the outlier is from $\bar{X}$. The reason for this is that the slope of the regression line is calculated from the X-values of the observation. Thus, the influence of outliers on the regression line depends on its position on the X- and Y-axis and increases the further away the outlier is from the other values. To detect outliers, Backhaus et al. (2021) suggest the calculation of standardized and other forms of residuals. However, they point out the difficulty of detecting outliers by means of these residuals. Therefore, the authors also suggest that graphical solutions can help to detect individual outliers, although this method is also confusing and thus not very practical, especially with a very large number of observations. Therefore, Backhaus et al. (2021) mention the calculation of Cook's distance as a possible option to detect outliers. However, the problem with this method is that no clear cutoff value can be found in the literature as to when an observation counts as an outlier. Furthermore, if an outlier is suspected, it can be deleted and then the model with outlier and the model without outlier can be compared. However, the problem with this approach is that it is usually not clear whether the observation is actually an outlier or simply an exceptional observation. Therefore, in the spirit of good scientific practice, the removal of outliers from a sample should always be described and justified in the text to avoid accusations of data manipulation (Backhaus et al. 2021).

3. Low-carbon infrastructure investment products and retail investors[4]

3.1 Introduction

Since December 2015, more than 191 countries signed the Paris Agreement (UNFCCC 2015) and have committed themselves to limit global warming to well below two degrees Celsius compared to pre-industrial levels.[5] To achieve this goal, the Organization for Economic Co-operation and Development (OECD 2017) sees it as inevitable to modernize infrastructure, because more than 60% of the global greenhouse gas (GHG) emissions are connected to the use of energy, buildings, transport, and water consumption. Furthermore, Granoff et al. (2016) describe that once infrastructure is built, lock-in effects occur. This effect means GHG emissions cannot be easily reduced under a specific level for infrastructure based on, e.g., fossil fuels and the long-term GHG emissions reduction goals cannot be achieved. Therefore, Granoff et al. (2016) conclude that the infrastructure which is currently being built will have a major impact on whether global warming can be kept below 2°C. To make infrastructure PA compatible, global financial requirements are estimated to be 6.9 trillion USD per year until 2030, whereas current spending is between 3.4 to 4.4 trillion USD per year (OECD 2017). Hence, the OECD (2017) demands to align global financial flows to build low-carbon infrastructure. The HLEG (2018) quantifies the additional yearly financial needs until 2030 to be 180 billion EUR for the (EU) to make the building, energy, transport and other sectors PA compatible (HLEG 2018). To raise the money, the HLEG (2018) introduced key elements of a retail strategy for sustainable finance, because more than 40% of the savings in the EU belong to private households of which two-thirds state that environmental and social aspects are

[4] The present chapter was written as part of a BMBF-funded project in a joint effort by JProf. Dr Tobias Bauckloh, Prof. Dr Christian Klein, Mr Leonard Remme and Dr habil Bernhard Zwergel. Mr. Leonard Remme was responsible for the data collection, data analysis, method development, literature research and the results. He was also responsible for the literature research and the discussion of the results. JProf. Dr. Bauckloh and Dr. habil Zwergel read the text critically and helped to shape it with their comments. Prof. Dr. Klein has also commented critically on the text.

[5] https://www.un.org/en/climatechange/paris-agreement; Accessed September 03, 2021

important for their investment decisions. Given the financial power and willingness of retail investors to participate in the shift of the economy to a more sustainable one and the importance of the establishment of a low-carbon infrastructure for mitigating climate change, it is important to evaluate whether retail investors have the possibility to finance low-carbon infrastructure and if there are any barriers that prevent them from doing so. Gutsche und Zwergel (2020) investigate investment barriers to socially responsible investments (SRI) for German investors and conclude that retail investors have the opportunity to invest in SRI products but are often not aware of this opportunity. They further find that if retail investors are aware of this opportunity, a lack of transparency in SRI products regarding the financial and sustainability performance leads to high search and information costs and prevents them from investing. When it comes to investing a conventional retail investor usually focuses on the elements of the magic triangle of investing (return, risk, liquidity) (Wallis and Klein 2015). A sustainable investor adds sustainability as a fourth measure e.g., in the context of low-carbon infrastructure investment products a metric for GHG emissions savings could be suitable (Wallis and Klein 2015). To the best of our knowledge, whether transparency problem for retail investors to invest in LCIIPs has not been answered yet. Therefore, we try to offer an initial insight into this topic by empirically analyzing the transparency of the German LCIIP market with respect to the above mentioned four most important investment characteristics (Bassen et al. 2019). The results suggest a lack of LCIIPs that are suitable for German retail investors. Moreover, most LCIIP providers do not report transparently the necessary information of the financial and GHG emission data so that retail investors can hardly assess the underlying LCIIPs in order to make a decision based on the data. Furthermore, even if retail investors used a commercial database on the sustainability performance of some LCIIPs (i.e., green bonds), retail investors could not be sure that their investments contribute to lower GHG emissions. Consequently, the transparency problem of LCIIPs is an actually existing investment barrier for retail investors to participate in the financing of low-carbon infrastructure. Therefore, given the willingness of retail investors to finance the transition to a low-carbon economy, we propose the development of financial products that enable retail investors to finance low-carbon infrastructure projects and to build a public database with free access to information on the financial and sustainability performance of LCIIPs.

The rest of the paper is structured as follows: first, we give an overview of the relevant academic literature then we introduce the data and methods that we use. Section four presents our results and section five provides a summary.

3.2 Literature review

Since we are unaware of any studies examining the relationship between retail investors and LCIIPs, we build off the results of different studies investigating the relationship between retail investors and SRI products regarding potential investment barriers. We consider LCIIPs to be a subcategory of SRI products, because investing in the reduction of GHG emissions can be a goal of an SRI. Many studies investigated the question why retail investors do not invest (more) in SRI products. Heinemann et al. (2018) investigate the supply-demand gap of SRI products in Germany. The key findings are that financial advisors do not offer SRI products to retail investors, because they believe retail investors would ask if they were interested. However, retail investors are interested in SRI products but do not communicate it to their advisors. Some authors (e.g. Zuber 2005) point out that many retail investors do not understand complex financial products. This lack of understanding applies in particular to SRI products, because there are general information deficits amongst retail investors regarding these products (Nilsson et al. 2010). These information deficits paired with high information costs and a lack of advice by investment advisors are substantial investment barriers.

Independently of the before mentioned studies, various researchers have studied retail investors' beliefs and attitudes toward SRI products. Nilsson (2009) investigates the beliefs and attitudes of Swedish retail investors in two studies. In the first study, he found that retail investors believe their investments in SRI products can help solve sustainability issues and that demographic variables like gender and education have an effect on the percentage of the portfolio invested in SRI products (Nilsson 2008). In the second study (Nilsson 2009), he points out that some retail investors do not consider financial aspects in the first place when making an investment decision. A study which focuses on German retail investors is by Gutsche et al. (2017). The authors split the respondents of their representative survey into three groups based on investment behavior: investors currently holding SRI products, investors interested in SRI and conventional investors who have no interest in SRI. According to Gutsche et al. (2017), the currently holding SRI and interested investors more often feel responsible for a sustainable development and want to support this process in part through their investment decisions. Furthermore, the authors show that investors are willing to accept lower returns if the product is considered to be sustainable. They find that more than 50% of all respondents think that SRI have lower returns than their conventional counterparts. This belief is not in line with studies that analyze SRI performance Friede et al. (2015) examine the relation between sustainability, especially environmental, social and governance (ESG) factors and corporate financial performance (CFP) in a second-order meta-analysis based on more than 2000 studies. The authors state that 90% of the analyzed studies show a nonnegative ESG-CFP relation and that they find no evidence for the conviction that the consideration of ESG-factors goes along with lower (risk-adjusted) returns.

Although the literature cited so far makes it clear that sustainable retail investors do not base their investment decisions solely on financial aspects, financial aspects do still play a significant role in the investment decisions of retail investors. Therefore, it is important for sustainable retail investors to understand whether an investment opportunity is a suitable investment for them. A common approach to determine whether an investment is worth considering is to compare the underlying investment with a suitable benchmark. Blanc-Brude (2014) discusses the need for and proposes a financial benchmark for long-term infrastructure investments in general, without focusing on sustainable or low-carbon infrastructure. He emphasizes the lack of a database and describes the collection of financial data like risk, return and cash flow as a great challenge for infrastructure projects, even for institutional investors. In addition, he notes that even if such a database existed the explanatory power would be low, because infrastructure investments are long-term investments and past completed infrastructure projects are very different from the infrastructure projects that need to be financed today. So, the risk-return profile of finished projects would be very different to the risk-return profile of present projects and cannot be easily compared. Consequently, it would be important to have information in such a database about ongoing LCIIPs which would allow a comparison of somewhat more similar projects.

3.3 Data and methods

Granoff et al. (2016) focus their analysis of low-carbon infrastructure on the sectors of renewable energy, energy-efficient buildings and transport systems. The reason for this is the lock-in effects mentioned above and the fact that these sectors influence the decarbonization of other sectors, e.g., given the enormous energy requirements of a data center, the GHG emissions of that data center largely depend on whether the energy used is generated by fossil fuels or renewable energy and whether resulting thermal discharge is used as e.g., district heating. In its report, the IPCC (2014) shows that the three sectors account for around 50% of total global GHG emissions. Consequently, we follow the approach of Granoff et al. (2016) and focus in a first step on the three sectors renewable energies, energy-efficient buildings and transport systems.

In a second step, we assume that emissions from the transport sector are changing from direct (e.g., exhaust gases) to indirect emissions because of an increasing electrical energy consumption due to the current political, economic, and technological developments. Thereby most likely increasing the demand for low carbon energy. Hence, we expect that the GHG emissions of the transport sector are part of the energy sector in the long run. In conclusion, we classify low-carbon infrastructure as energy and building infrastructure, which produces fewer GHG emissions than the current infrastructure and therefore leads to a decarbonization in the two previously mentioned sectors.

Based on the findings from Heinemann et al. (2018), we know that financial advisors do not offer SRI-products to their clients. Therefore, we can assume that retail investors interested in LCIIPs must search for such products on their own. Consequently, we started with desk research via different search-engines to find existing LCIIPs. This approach allows us to understand the specific problems retail investors face when investing in LCIIPs and provides the opportunity to gain insight into the market for LCIIPs. We searched for any possible type of LCIIPs for retail investors including, e.g., equity funds, participation rights and crowd investing. We generated a sample focusing on products which released their investment information mostly in German and were or are investable for a German retail investor. More precisely, we have started to look for terms like ‘low carbon investments’, ‘renewable energy’, 'energy efficiency’, ‘renewable buildings’ and other related terms which are connected to our definition of low-carbon infrastructure and investments into this infrastructure. In addition, we then expanded our search terms to include the words and terms of the names of the LCIIPs which we found such as ‘carbon infrastructure funds’. Furthermore, we collected only until the moment we reached saturation[6] for a respective cluster of products. The used method is a qualitative approach rather than a quantitative approach; therefore, we make no claim of completeness.

[66] i.e. by saturation we mean that we have not found any new product characteristics for a corresponding cluster of LCIIPs

Accordingly, the collected data does not represent a market overview. Instead, it shows what retail investors could have found when looking for LCIIPs on the internet in 2020.

We identified different LCIIPs and created a list of LCIIPs and their characteristics. Financial data for these products was collected by hand in January 2021 to ensure comparability and equal time periods of the LCIIPs' historical financial data.

This manual data collection gathered information for the LCIIPs in form of primary data from investment product suppliers and secondary data via internet research. We gathered information on the following: return, volatility, minimum investment requirements, specific characteristics of the investment products, and their contribution to climate change mitigation through their GHG emission savings. After the data collection, we evaluate, cluster, and compare the LCIIPs with descriptive methods. Furthermore, we compared the risk-return profile of LCIIPs with conventional investments where possible. However, this was not possible for all products due to the lack of data in some clusters.

Most LCIIPs that we found are in the form of green bonds. Since it was beyond the scope of the study to assess all traded green bonds, we used the ISS ESG sustainability bond database which we have access to. We use the ISS ESG database to investigate the transparency of green bonds with regard to their stated GHG emission savings. Furthermore, the database can give an idea whether financial advisors who could also afford access to it could use this database to aid their retail clients in finding low-carbon infrastructure green bonds that meet their preferences.

3.4 Results

3.4.1 Transparency

We cluster the LCIIPs in our sample by infrastructure and investment type to understand the underlying transparency in light of heterogeneous thematic infrastructure investments (i.e., energy and buildings) on the one hand and investment type (i.e., equity, mezzanine and debt capital) on the other hand. Therefore, we build the following clusters: Equity-energy-infrastructure funds (EEF), equity-energy-participation rights (EEP), equity-building-infrastructure funds (EBF), mezzanine-capital-energy-crowdfunding (MEC), mezzanine-capital-building-crowdfunding (MBC), debt-green-bonds (DGB) and debt-energy-others (DEO), i.e. a debenture and a time deposit. The DEO cluster will not be considered in the rest of the paper due to the small number of detectable LCIIPs in the DEO cluster.

Table 3.1: Reported data for each cluster

Cluster	Number	Return	Volatility	GHG Emission Saving Data
EEF	8			2
1 Year		8	8	
5 Years		6	6	
10 Years		2	2	
EBF	8			1
1 Year		8	8	
5 Years		5	5	
10 Years		n.a.	n.a.	
EEP	6			3
predicted p.a.		6	n.a.	
MEC	13			5
predicted p.a.		13	n.a.	
MBC	4			2
predicted p.a.		4	n.a.	

The table shows the following clusters: Energy-equity-infrastructure funds on stocks (EEF), buildings-equity-infrastructure fonds on stocks (EBF), energy-equity-participation rights (EEP), mezzanine-capital-energy-crowdfunding (MEC), mezzanine-capital-buildings-crowdfunding (MBC). Futhermore, the number of detected LCIIPs in each cluster and the numbers of LCIIPs which report return, volatility and GHG emission saving data for each cluster are given.

To analyze the transparency of the detected LCIIP clusters, we report the number of detected LCIIPs in each cluster and the number of LCIIPs which report historical return and volatility data for each cluster. We also provide the clustered returns and volatilities for different time periods. If historical returns were not available, we collected the predicted yearly returns published by the issuer. Moreover, we report whether the issuer provides any information about the GHG emission[7] savings attributable to an investment in the respective LCIIP (Table 3.1.).

In the EEF cluster all eight LCIIPs report their one-year return and volatility. In the five and ten-year time period the number of reporting LCIIPs decreases, because many LCIIPs in the cluster do not have a long history. A severer information problem emerges when looking at the GHG emission information of the issuers. Only 25% of the detected LCIIPs report any information about their GHG emission savings. Therefore, the statement can be made that the LCIIPs in the EEF cluster are more transparent with regard to their financial data than their GHG emission data. The LCIIPs in the second cluster, EBF, have similar results to the first cluster. Hence, the financial data is transparently reported meaning the LCIIPs report their historical return and volatility since inception. Furthermore, GHG emission savings are not transparently reported for most LCIIPs in this group, similar to the EEF cluster. Contrary to the EEF and EBF cluster, the LCIIPs in the EEP cluster only report their predicted return and do not include the volatility. Moreover, most LCIIPs in the EEP cluster are citizens' cooperatives which did not place their products on the financial market and only report actual financial data to members of their cooperative. However, 50% of the LCIIPs in the EEP cluster publish their GHG emission savings. The MEC cluster are mezzanine energy LCIIPs which only report predicted returns and no historical return and volatility information. The main reason for this lack of reporting is that these LCIIPs only report to their investors after the financing phase was successful. The financial transparency of the MBC cluster is like the financial transparency of the MEC cluster and the transparency of the GHG emission savings are similar, too. The reason for this similarity obviously is that both products have the same basic structure and therefore the same problem that financial data is only reported after launching to their actual investors.

[7] The stated GHG emission savings may be planned or actual GHG emission savings. The reason for the lack of distinction is that the LCIIPs in our sample do not make uniform claims and it therefore varies from LCIIP to LCIIP.

In general, LCIIPs which are traded on the financial markets, e.g., products in the EEF and EBF clusters more transparently report their financial data whereas the non-traded LCIIPs (EEP, MEC, MBC) more transparently report carbon information.

As mentioned above, we have been able to identify a large number of green bonds so it is plausible to assume that retail investors can do that too. However, a large number of green bonds means that retail investors would be forced to analyze each of these green bonds and ask themselves whether they finance projects that save GHG emissions and whether the risk-return profile is appropriate. Based on the assumption that not the first green bond found is already suitable for the respective retail investor and that retail investors in general want to compare different green bonds, a very large number of available green bonds means that high search costs would be incurred, resulting in a very time-consuming endeavor in order to identify suitable green bonds.

Therefore, we use the ISS ESG sustainable bond database, as a financial advisor could, to get a systematic overview of the transparency of green bonds. The commercial ISS ESG sustainable bond database provides ESG assessments of sustainable, social and green bonds. To do so, ISS rates the issuers of the bonds and the bonds themselves. In case of the bonds, ISS analyzes the projects for which the proceeds are used and rates the environmental and social aspects of every project that is financed with the collected money. Most importantly, even though the database rates more than 400 bonds on a very detailed level even this database does not provide the actual GHG emission savings of each bond. Therefore, the question must be asked, why the ISS ESG cannot report the GHG emission savings and in addition it must be noted that the lack of transparency regarding GHG emission savings for sustainable bonds even cannot be overcome with the help of an advisor who uses this commercial database.

3.4.2 Financial performance

We consider the return and risk of the LCIIPs in addition to the examination of transparency of LCIIPs. We do so because as previously mentioned retail investors are willing to accept lower returns if they invest in sustainable products as long as they receive a green return in addition to a financial return.

Table 3.2: Financial Data for each cluster

	Number	Return		Volatility (annualized)	
Cluster		Average	Median	Average	Median
EEF					
1 Year	8	17.53	7.1	24.4	27.17
5 Years	6	90.54	79.7	16.54	16.84
10 Years	2	146.34	146.34	17.73	17.73
EBF					
1 Year	8	-10.63	-9.24	31.59	31.34
5 Years	5	0.78	1.81	23.73	22.15
10 Years	0	n.a.		n.a.	
EEP					
predicted p.a.	6	5.43	6	n.a.	
MEC					
predicted p.a.	13	6.17	6	n.a.	
MBC					
predicted p.a.	4	5.95	6	n.a.	

The table shows the number of detected LCIIPs and the return, risk for each cluster. The return and risk data are stated in percent. The table shows the following clusters: Energy-equity-infrastructure funds on stocks (EEF), buildings-equity-infrastructure fonds on stocks (EBF), energy-equity-participation rights (EEP), mezzanine-capital-energy-crowdfunding (MEC), mezzanine-capital-buildings-crowdfunding (MBC).

The EEF cluster has high average returns for the one to ten-year periods, whereby especially the one-year return is driven by a single fund with a return of 77.81%.[8] The difference between the mean and the median underlines this finding. We then compared these results to a standard non-LCIIP, a MSCI World ETF,[9] from the beginning of February 2011 to the end of January

[8] Not reported in table 2.2

[9] iShares Core MSCI World UCITS ETF, ISIN: IE00B4L5Y983. Since not all LCIIPs in the EEF cluster match the regional distribution of the MSCI ETF the performance analysis only gives a rough idea how the returns of LCIIPs in the EEF cluster compare with the MSCI World. The same is analogously true for the EBF cluster.

2021. We find that the average EEF cluster 10-year return (146%) is lower than that of the MSCI World ETF[10] (176%) and the annualized volatility (18%) is higher than that of the MSCI World ETF (15%). Therefore, the MSCI World ETF has a better return-risk-profile in our timeframe than the average LCIIP in the EEF cluster over ten years.

The second cluster can be analyzed like the first one. Similar to the EEF cluster the EBF cluster is based on infrastructure fonds on stocks, but in this case the fonds invests in buildings. Accordingly, the EBF cluster can be compared with the DAX ETF.[11] The problem is that the necessary data for the comparison are not given, because only return and volatility are reported for a five-year time horizon, whereby the recommended investment period is larger than five years.[12] Therefore, a data-based statement of EBF in comparison to the DAX ETF needs to be interpreted carefully. However, if one considers the given data, the reported data points to the statement that the standard investment product has the better financial performance, because the DAX ETF has a higher 5-year return (37%) than the average LCIIP (0.78%) and a lower annualized volatility (20%) than the average LCIIPs (23%) in the cluster.

In contrast to the EEF and EBF cluster, the LCIIPs in the EEP cluster do not report actual returns or volatility. The reason is that the LCIIPs in the EEP cluster only report information to their investors and not to the public, therefore an outsider can only use the publicly available information which are the predicted returns and the risk in written form from the prospectuses. The actual return can be lower or higher than the predicted return due to the inherent structure of the participation rights which link the product's return to the projects financial performance instead of just paying a fixed interest rate as a bond would do. Therefore, a public database to which all LCIIPs have to report their annual financial data to would increase transparency and allow retail investors to compare the return of EEP investments with other LCIIPs. Furthermore,

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[10] Own calculation, based on the iShares Core MSCI World UCITS ETF.
[11] iShares Core DAX UCITS ETF (DE), ISIN: DE0005933931.
[12] E.g. KCD-Catella Nachhaltigkeit IMMOBILIEN Deutschland Wesentliche Anlegerinformationen.

the risks of these products are only stated in written form in the investment prospectuses and are therefore not numerically analyzable. In principle, the risk description in the product information is separated into different kinds of risk and possible outcomes, but most of the risk sections in the prospectuses simply refer to the possibility of a total loss without giving the likelihood of such a total loss.[13] Because of this fact on the one hand and the fact that there is no database to calculate the probability of losing (parts of) the investment amount on the other, retail investors are not able to estimate the true risk-return-profile of such an investment. Therefore, retail investors would need a deep understanding of regulation, technology, and further aspects to truly understand the actual risk, which go along with participation rights. This however is beyond the capabilities of an average retail investor.

The MEC and MBC clusters have some similar aspects compared to the EEP cluster. However, different to the EEP cluster the MEC and MBC products are so called subordinated loans. The investors of subordinated loans will not be paid before all other investors of unsubordinated loans are paid (Siller 2017). Moreover, when it comes to defaults, a total loss is the most common case and different to participation rights the investors do not have the right to participate in the shareholders' meeting. Hence, retail investors must be trusting the management because they do not have the opportunity to intervene in the management's decisions (Siller 2017).

Overall, this section has shown, that the LCIIPs presented in this paper, except maybe for the green bonds, are quite unsuitable for the average German retail investor who is very risk averse. Furthermore, the information costs regarding sustainability criteria like the GHG emission savings are quite high due to the low transparency of the surveyed LCIIPs.

[13] E.g. Produktinformationen HEP Solar Portfolio 1; p. 24.

3.5 Conclusion

Originating from the estimation of the HLEG that yearly additional 180€ billion are necessary to reach the goals of the PA and that private households must be part of the financiers, we examine possible LCIIPs for retail investors. Thereby we concentrate on renewable energy and energy-efficient buildings as low-carbon infrastructure.

Our results suggest a lack of transparency of LCIIPs that are suitable for German retail investors. Moreover, most LCIIP providers do not report transparently the necessary information of the financial and GHG emission data to the public so that retail investors can hardly assess the underlying LCIIPs in order to make a sound investment decision. Additionally, in case of the green bonds retail investors even cannot expect to overcome the non-transparency of the green bond market with regard to the bonds' GHG emission savings with the help of a financial advisor since even commercial databases like the ISS ESG sustainability bond database do not report the GHG emission savings of green bonds adequately. Consequently, the transparency problem of LCIIPs is an investment barrier for retail investors to participate in the urgently needed financing of a low-carbon infrastructure. Therefore, given the willingness of retail investors to finance the transition to a low-carbon economy, we first propose the development of financial instruments that enable retail investors to finance low-carbon infrastructure projects in alignment with their risk preferences and second to build a public database with free access to information on the financial and sustainability performance of LCIIPs. Such a public database could help to overcome the described investment barriers because the high search and information costs would be reduced. If the public database would register information like, return, volatility, probability of default and GHG emission savings, retail investors or their advisors could more easily compare return-risk-profiles of LCIIPs. Then retail investors would not have to understand the specific regulation and technology risk of a LCIIP in detail, since they could deduce e.g., the possibility of a default from the default of similar products in the database. A database would also help to overcome the limitation of this paper that general statements for all clusters are more qualitative than quantitative, because of the limited number of detected LCIIPs.

4. Institutional investors‘ perception of climate-related financial disclosures[14]

4.1 Introduction

The European Union’s green transition strategy critically hinges on markets pricing negative externalities, such as carbon emissions, adequately and thus steer investments on to more sustainable path. One central approach aims at increasing transparency about the sustainability of corporate activities. Therefore, past regulations and proposals include the updated Non-Financial Reporting Directive (NFRD) – the Corporate Sustainability Reporting Directive (CSRD) or the EU Taxonomy for sustainable activities that classifies business activities as sustainable based on their carbon intensity. The goal of these reporting regulations is to give capital market participants the necessary information to understand, which companies are (not) compatible with national and European climate and sustainability targets, and to assess companies’ physical and transitional climate-related risks. As financial markets play a key role to tackle the climate crisis, it is important to understand the current perception of climate and sustainability transition risks among financial market actors.

Currently, there are some concerns about the transparency regarding companies’ climate-related issues based on the current reporting standards. For example, using a natural language processing algorithm, Bingler et al. (2022) find that companies reporting according to the standards set by the Task Force on Climate-related Financial Disclosures (TCFD) mostly focus on immaterial issues and cherry-pick topics in areas where they perform well. Companies themselves also fail to understand the risks connected to climate change and the importance of both adapting in real terms and reporting their strategies to investors (Goldstein et al. 2019). Although the EU is at the forefront in terms of sustainability disclosure regulations, the fact that

[14] The present chapter was written as part of a BMBF-funded project in a joint effort by Mr. Thomas Pioch, Mr. Leonard Remme, Prof. Dr. Frank Schiemann and Dr. habil Bernhard Zwergel. The design of the questionnaire, the literature research and the data collection were done in collaborative work. Mr. Leonard Remme was responsible for data evaluation and analysis.

nuclear power plants and gas-fired power plants are considered sustainable activities under the EU Taxonomy again potentially distorts the perception of investors who are meant to steer their investments towards sustainability. Slawinski et al. (2017) show that such institutional factors contribute to climate inaction as they reinforce short-termism and uncertainty avoidance behavior. This is especially relevant, because the time factor is of central importance in the climate crisis. The latest IPCC report estimates our remaining carbon budget to last only until 2030 if warming is to be limited to 1.5°C (Arias et al. 2021). Thus, it is important to understand investors' current view on short-and long-term investment decisions. In order to avoid catastrophic climate change, a great transition also towards sustainable finance is necessary. That means, also traditional investors have to move in the direction of sustainable investments. Therefore, it is essential to understand the information needs of investors interested in considering climate-related issues in their investment decisions. (Krueger et al. 2020) have investigated information needs of investors in a survey consisting of traditional investors in European countries and the US with the majority of their investments not integrating ESG aspects (60%).

Our focus is on experienced investors in the area of sustainable finance. We believe their assessment of the current information environment and necessary developments provides valuable insights into the necessary steps, which can facilitate policy environments that enable the shift towards sustainable finance. Our exploratory survey addresses professionals working in financial markets such as fund managers or investment analysts from the DACH region (Germany, Austria and Switzerland) (91% of our sample) with a focus on sustainability. Thereby, the regulatory and political environment in the EU is already impacted by discussion about the EU Sustainable Finance Action Plan.

4.2 Results

We conducted our survey in the DACH region between February and June 2020 with German-speaking financial professionals that are focusing on sustainability in their work environment. In total, 126 respondents answered our survey, however, not all respondents answered all questions, limiting our sample size to 53 participants. Table 4.1 shows the composition of our respondent group in terms of position in the company, type of company and headquarter location, as well as their timeframe for considering investments, the percentage of sustainable investments in their company, the portfolio structure and the total assets under management. The survey was answered mainly by ESG Investment Analysts (28%), Heads of Sustainability (26%) and Board Members or Other Executives (31%). They work in Asset Management companies (26%), Banks and Financial Institutions (23%) or Pension Funds (24%), the majority of which are located in Germany (74%). Their investment timeframe is rather evenly distributed between short-term (33%), mid-term (20%) and long-term (48%) investments. Companies are either focused on sustainable investments with 58% showing a share of more than 75% investments in that category, or mainly focused on traditional investments (24%). Only a few companies are in a hybrid position, where they have some sustainable and some traditional investments (17%). 24% of companies report assets under management of up to €1bn, 58% report between €1bn and €25bn and 18% report more than €25bn assets under management.

Table 4.1: Respondents, organisation and portfolio statistics

Position of the respondent (N=38)	Percentage
Fund Manager	3%
Investment Analyst	5%
ESG Investment Expert	28%
Head of Sustainability	26%
CIO	5%
Board Member and Other Executive	31%

Type of Organisation (N=47)	Percentage
Asset Manager	26%
Investment Company	9%
Banks and Financial Institute	23%
Church Institute and Charity	9%
Insurance	6%
Pension Fund	24%
Others	2%

Headquarter (N=47)	Percentage
Germany	74%
Austria	6%
Swiss	11%
Other Country in Europe	9%

Portfolio Structure	Average
% of actively managed (N=44)	88%
% of passively managed (N=29)	15%

Investment Period (N=40)	Percentage
Less than 6 Months	0%
Between 6 Months and 2 Year	33%
Between 2 Years and 5 Years	20%
Between 5 Years and 10 Years	28%
More than 10 Years	20%

Sustainable Investments (N=41)	Percentage
Less than 25%	24%
Between 25% and 50%	7%
Between 50% and 75%	10%
Between 75% and 95%	12%
Between 95% and 99%	12%
More than 99%	34%

Assets under Management (N=45)	Percentage
Less than €0.5bn	11%
Between €0.5bn and €1bn	13%
Between €1bn and €5bn	24%
Between €5bn and €10bn	18%
Between €10bn and €25bn	16%
Between €25bn and €100bn	9%
More than €100bn	9%

This table provides information about the respondents, their organization and characteristics of the portfolios they hold. Not all respondents answered all questions. In this table, only the answers of the 47 respondents who answered the questions by the end of the questionnaire are given. The aim is to describe the primary sample in a meaningful way. In later tables, the number of answers given can be greater than 47 if the additional answers do not distort the result. The exact number of observations for each question can be found in the table.

Table 4.2 shows the expectations of respondents concerning the financial performance impact of GHG reductions in different industries within the next two years and within the next five to ten years. Respondents were asked to indicate their expectations about the impact of GHG reductions on financial performance on a five-point Likert scale in the range of 1 (very negative), 2 (negative), 3 (no effect), 4 (positive) and 5 (very positive). For the near term within the next two years, we observe that investors expect GHG reductions to have on average no negative or positive effect with a mean of 2.96 and a median value of 3. The exceptions here are the means in the *Industrial* (2.58) sector, *Raw Materials* (2.34) sector and *Oil and Gas* (1.92) sector where investors expect a slightly negative effect of GHG reductions on financial performance. In the long-term within the next five to ten years, expectations change. The negative outlook only remains for the *Raw Materials* and *Oil and Gas* sectors with a median of 2 and a mean of 2.38 and 1.83 respectively. In the other sectors, the outlook improves to a median of 4 (*IT, Utilities, Real Estate, Food Industry, Consumer Goods*) and an overall average of 3.22. The differences are significant for Utilities, Finance, Real Estate, Food Industry and Industry sectors.

Table 4.2: Effect of GHG reduction on the financial performance of individual industries

	In the next 2 Years				Between 5 and 10 Years				
Industrials	N	Mean	SD	Median	N	Mean	SD	Median	Differences in the means
53	3.51	0.96	3	49	3.8	0.96	4	0.29	
50	3.43	1.05	3	51	3.65	1.05	4	0.22	
Communication	53	3.32	0.87	3	52	3.6	0.87	3	0.28
Healthcare	50	3.24	0.84	3	50	3.54	0.84	3	0.3
52	3.17	0.96	3	49	3.47	0.96	3	0.3	
Real Estate	52	3.06	0.9	3	51	3.47	0.9	4	0.41
Food Industry	50	3.04	1.03	3	51	3.45	1.03	4	0.41
Consumer Goods	49	2.96	0.93	3	51	3.31	0.93	4	0.35
53	2.58	1.19	2	53	2.96	1.19	3	0.38	
Raw Materials	50	2.34	1.09	2	50	2.38	1.09	2	0.04
Oil and Gas	53	1.92	1.14	2	53	1.83	1.14	2	-0.09
	2.96				3.22			0.26	

The table provides the respondents' assessments of the effect of a reduction in GHG emissions on financial performance for different industries at different points in time. The response is measured using a 5-point Likert scale. Where the scale is constructed as 1 '*very negative*', 2 '*negative*', 3 '*no effect*', 4 '*positive*' and 5 '*very positive*'. The time spans are ‘in the next to 2 years’ and ‘between 5 to 10 years’. Based on the responses, the mean, standard deviation and median were calculated. Furthermore, the difference between the means of the two time spans was calculated and tested for significant differences using two-side t-test. **, * indicate a significance level of 5% and 10%.

We also asked respondents to assess the influence of various risks on their investment decisions in the short term (within the next two years) and in the long term (within the next five to ten years). The answers were collected on a five-point Likert scale from 1 (very low importance) to 5 (very high importance). On average, participants evaluate all risks as being of *"high importance"* for their decision-making in the short term, with their answers centered around a median of 4 and an average of 3.79. The exception is *Financial Risk*, which is of "very high importance" with a median of 5 and an average of 4.39. *Governance Risk* and *Regulatory Climate Risk* also rank as rather important at average scores of 3.9 and 3.98, respectively. In the long-term risk perception does not change significantly, although the average increases by 0.22 and it increases the most in the more tangible outcomes of the climate crisis, (i.e., *Social Risk*, *Ecological Risk w/o Climate Risk*, *Technological Climate Risk* and *Physical Climate Risk*). In these categories, the average increases by 0.29 to 0.49.

Table 4.3: Assessment of the influence of various risks on investment decisions

	In the next 2 Years				Between 5 and 10 Years					
Types of Risk	N	Mean	SD	Median	N	Mean	SD	Median	Differences in the means	Significant differences in the mean
Financial Risk	47	4.32	0.96	5	46	4.43	0.89	5	0.11	-
Regulatory Climate Risks	48	3.98	1.04	4	46	4.04	0.89	4	0.06	-
Governance Risk	48	3.9	1.06	4	46	3.91	0.96	4	0.01	-
Ecological Risk w/o Climate Risk	48	3.75	1.12	4	46	4.07	1.04	4	0.32	-
Social Risk	48	3.65	1.19	4	46	3.98	1.02	4	0.33	-
Technological Climate Risk	47	3.64	1.19	4	45	3.93	1.05	4	0.29	-
Operational Risk	47	3.53	0.93	4	45	3.67	0.98	4	0.14	-
Physical Climate Risk	47	3.53	0.93	4	46	4.02	1.02	4	0.49	-
Average		3.79				4.01			0.22	

The table provides the respondents' assessments of the influence of various risks on investment decisions for different risks at different points in time. The response is measured using a 5-point likert scale. Where the scale is constructed as 1 '*very low importance*', 2 '*low importance*', 3 '*moderate importance*', 4 '*high importance*' and 5 '*very high importance*'. The time spans are ‘in the next to 2 years’ and ‘between 5 to 10 years’. Based on the responses, the mean, standard deviation and median were calculated. Furthermore, the difference between the means of the two-time spans was calculated and tested for significant differences using two-side t-test. **, * indicate a significance level of 5% and 10%.

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Next, we asked participants about the different strategies that are used to integrate GHG information in the investment process. Given a particular investment strategy, which integrates GHG information, participants were asked about their expectation of the impact on financial performance. Respondents indicated their answer on a three-point Likert scale of 1 (worsen), 2 (unchanged) and 3 (improving). The average response lies between 2.19 (*Negative Screening*) and 2.65 (*Impact Investing*) and the median is 3 except for *Active Ownership*, *Negative Screening* and *Positive Screening* strategies. The differences between the two screening strategies and the other strategies are significant at $p < 10\%$.

Table 4.4: Investment strategy

Investment Strategy	N	Mean	SD	Median	Significant differences in mean response vs. rows
Impact Investing	34	2.65	0.54	3	7.-8.
ESG Integration	38	2.63	0.54	3	7.-8.
Best-In-Class-Screening	38	2.61	0.50	3	7.-8.
Thematic Investment	33	2.58	0.56	3	7.-8.
Engagement	41	2.56	0.50	3	7.-8.
Active Ownership	36	2.47	0.51	2	8
Positive Screening	30	2.27	0.52	2	1.-5,
Negative Screening	42	2.19	0.77	2	1.-6.

The table provides the respondents' assessment of the impact of the above investment strategies on the financial performance of their investments if this strategy is used to incorporate GHG information into the investment process. The response is measured using a 3-point Likert scale. Where the scale is constructed as 1 '*worsen*', 2 '*consistent*' and 3 '*improve*'. Based on the responses, the mean, standard deviation and median were calculated. The last column indicates the investment strategies that differ significantly from the given investment strategy. The significance was determined using a two-sided t-test based on the mean values. All significances are significant at least at the 10% level.

Furthermore, we asked participants for their assessment of the importance of considering GHG emissions in future investment decisions. On a five-point Likert scale, respondents could indicate their perception of the importance between 1 (very low importance) and 5 (very high importance) for the short-term (within the next two years), mid-term (within the next two to five years) and long-term (within the next five to ten years). Results show that participants' sentiment changes when considering different timespans. In the short-term the average importance is at 3.66, which increases to 4.43 in the mid-term and to 4.62 in the long-term. The difference between the short-term, mid and long-term is significant at $p < 1\%$.

Table 4.5: Importance of considering GHG information in future investment decisions

Time Period	N	Mean	SD	Median	Significant differences in mean response vs. rows
In the next 2 years	47	3.66	0.73	4	2.-3.
Between 2 and 5 years	47	4.43	0.58	4	-
Between 5 and 10 years	47	4.62	0.57	5	-

The table provides the respondents' assessment of the importance of considering GHG information in future investment decisions. The response is measured using a 5-point likert scale. Where the scale is constructed as 1 'very low importance', 2 'low importance', 3 'moderate importance', 4 'high importance' and 5 'very high importance'. The different time periods are given in the table. Based on the responses, the mean, standard deviation and median were calculated. The last column indicates the investment strategies that differ significantly from the given investment strategy. The significance was determined using a two-sided t-test based on the mean values. All significances are significant at least at the 1% level.

We have also asked participants on their preference regarding mandatory or voluntary disclosure of GHG information for companies as well as for financial products. A majority of respondents was in favor of a mandatory disclosure regulation for both, companies (75%) and financial products (67%).

In their expectations of actual global warming, respondents in our sample gave similar estimates as the respondents in Krueger et al. (2020), with 52% expecting 2-3°C warming. However, only 26% of our respondents are certain or very certain about their answer, compared to around 50% in Krueger et al. (2020).

Table 4.6: Assessment of the global temperature increase

Degree celsius	N=42	Percentage	Certainty	N=42	Percentage
0 to 1	0	0%	very uncertain	8	19%
1 to 2	8	19%	uncertain	12	29%
2 to 3	22	52%	partly	11	26%
3 to 4	11	26%	certain	9	21%
more than 4	1	2%	very certain	2	5%

The table provides the respondents' assessment of how much the global average temperature will rise by the end of the century compared to the pre-industrial era. The respondents could choose between 5 levels from "*0 to 1"* degree to "*more than 4"* degrees. All degrees were given in degrees Celsius. Respondents were also asked to indicate how certain they were in their prior assessment.

4.3 Discussion

A clearer understanding of how actors in the finance sector evaluate GHG emissions and climate risks is necessary, since the whole finance industry is under pressure to address climate change. For example, the EU considers their sustainable finance strategy as a pillar of their European Green Deal strategy (Claringbould et al. 2019). Therefore, we investigate financial professionals' current considerations on sustainable finance aspects, such as climate risks.

Our results show that the majority of our respondents and their organizations focus more on long-term investments. 68% of respondents indicated an investment horizon of at least 2 years (48% indicated an investment horizon of at least 5 years). Yet when comparing short-term and long-term consequences, the expected impacts of GHG reductions on financial performance, do not differ substantially. An explanation could be that respondents expect many firms to still have low-hanging fruit solutions to reduce GHG emissions. In the long-term, increasing carbon emission allowance prices in the European Union Emission Trading System (EU ETS) will render costlier GHG reduction solutions favorable compared to stable emission levels. It is also possible that investors suffer from blind spots regarding the cost of physical climate change. Where most estimates predict trillions of dollars of negative impacts on managed assets, the aggregate financial risks reported through corporate disclosures amounts to tens of billions

(Goldstein et al. 2019). Future research into the relationship of company reported climate change risk and analysts' expectations could help shed light on this apparent discrepancy.

Our respondents' answers about the influence of various risks on their investment decisions adds further evidence towards this distortion in perception. The biggest changes in the importance of different risks when considering short-term and long-term investments occur in the actual physical climate risks and their regulation and direct consequences. Participants identified *Physical Climate Risk* as the challenge that is gaining the most in importance, followed by *Social Risk*, *Ecological Risk w/o Climate Change* and *Technological Climate Risk*. Investors are aware of the substantial risks and the speed with which they are increasing, but their perception of how GHG reductions will impact financial performance of companies does not change substantially for short- and long-term perspectives. This is important to note for policy makers. For climate goals to be reached, the reduction of GHG emissions has to become substantially more financially beneficial than continuing on the current path. The European Union already has the tool to address this necessity with the EU ETS. Indeed, research has for some time communicated, that a significantly higher carbon price is required, and recent years witness more substantial increases in the carbon price (Reuters 2021).

For the integration of GHG information in investment processes, *Negative* and *Positive Screening* strategies have the smallest positive impact according to our respondents' assessment. All other strategies in our survey were seen as to potentially improve financial performance to similar degrees. Where Krueger et al. (2020) ask about the adoption of such strategies in the past, we ask about future expectations, which can provide important information for investors about financial performance, given that legislation like the Sustainable Finance Disclosure Regulation (SFDR) plays an important role in the EU sustainability strategy. Combined with our finding that most investors would prefer mandatory reporting regimes for the finance sector as well as the real economy, this is a call on policy makers to improve the consistency and reliability of GHG information provided to the markets by companies and to investors by the finance industry.

Overall, our study provides new insights into the expectations and risk perception of financial professionals who already work on integrating sustainability aspects, such as GHG emissions and climate risks, into their investment decisions today. Their strategies can provide a window to the future, of what will become necessary for the whole industry and in turn inform policy makers of what is needed in new regulations to facilitate the shift.

4.4 Conclusion

Overall, our results provide novel insights on a number of issues regarding investors' expectations of climate risks, their financial impact and their influence on investment decisions. From these insights we formulate several policy recommendations that will help integrate climate risk in financial decision making.

One important insight is, that a majority of investors believe reporting on GHG emissions should be mandatory for both companies and financial products. We can thus recommend to further develop policies in this direction, which should also help to improve the reliability and comparability of information. Similarly, we recommend that mandatory disclosures also include aspects of scenario-based assessments regarding assets under physical climate risk like droughts, floods or storms. Although investors recognize the importance of physical climate risks in their investment decisions, the extent of the potential damage appears to be underestimated—even by our sample of sustainability-affine investors. Lastly, investors expect GHG emission reductions to impact financial results positively in the future in most sectors. This expectation is likely influenced by numerous studies, which investigate when and how it pays to be green and which generally report a non-negative or positive effect of improved ESG performance (Friede et al. 2015). A better assessment of the financial impact of (decreases in) carbon emissions, would be possible, if companies mandatorily report information about the current cost per ton GHG emission reduction, and whether such reductions could be achieved through actual reductions or through carbon offset mechanisms.

5.Portfolio benefits of taxonomy orientated and renewable European electric utilities[15]

5.1 Introduction

"*If you do not change direction, you may end up where you are heading*."[16]

Over the course of the last 17 years, the role finance plays in changing the direction of global warming has been solidified by the EC. The EC demonstrated a willingness to transition to a climate compatible economy with the introduction of the *European Emissions Trading System* (EU ETS) in 2005 (Directive 2003/87/EC). This goal was confirmed by the EU on the world stage with the signing of the PA aiming to limit global warming to well below 2°C compared to pre-industrial levels (UNFCCC 2015). The EC recently released a roadmap to achieve this goal: the *Strategy for Financing the Transition to a Sustainable Economy (European Commission 2021b)*. This transition's success is partly dependent on the EU-Taxonomy (European Commission 2021a) (hereafter referred to as the taxonomy), which creates a uniform definition of certain sustainable activities. This taxonomy should allow investors to better assess a company's capital expenditures in, e.g., renewable energy projects. Changing how electricity is produced in Europe represents an integral part in achieving the European climate goals since the supply of energy accounts for more of Europe's GHG emissions than any other single activity (European Commission 2020a). Consequently, European regulators are setting signals to reduce the carbon intensity of energy production and green the fuel mix of this production (e.g., the taxonomy sets limits for which activities can be considered sustainable based on both the carbon intensity of electricity production and the source of energy used in the production). The EC's *climate and energy package (Directive 2009/28/EC; Directive 2009/29/EC)* set goals to reduce GHG emissions by 20 percent[17] while increasing the share of renewables in the energy

[15] The present chapter was written jointly by Thomas Cauthorn, Prof. Dr. Christian Klein, Leonard Remme and Dr. habil Bernhard Zwergel as part of a BMBF-funded project.
[16] Attributed to Lao Tzu.
[17] The goals from the EC are all compared to levels in 1990.

mix to 20 percent by 2020. Furthermore, the EC set a 40 percent GHG emission reduction goal in 2014 (European Commission 2014) to be achieved by 2030 which was then later raised in September 2020 to a 55 percent reduction with at least 65 percent of Europe's energy coming from renewable sources (European Commission 2020b). Finally, the GHG emission reduction goal was expanded to at least 80 percent by 2050 in the *energy roadmap (European Commission 2011)*. The recent regulatory developments lead us to pose the question whether investors could have perceived an increased (decreased) risk in holding high-carbon (low-carbon) emitting or conventional (renewable) electric utilities. We identify two important reasons for examining whether investors have adjusted their risk perceptions concerning electric utilities. First, companies could benefit from better understanding how investors' view risks associated with the transition to a carbon neutral economy. For example, if investors have adjusted their risk perceptions due to regulatory pressure, companies' cost of capital should have been adjusted. Second, the papers findings could be used by regulators in developing future regulations targeting climate change and the transition to a carbon neutral economy. Despite the urgent need for research on renewable infrastructure due to the important role it plays in achieving carbon neutrality, Gupta and Sharma (2022) demonstrate in a systematic literature review on infrastructure that such research is scant. This paper contributes to the literature on a subgroup of infrastructure, electric utilities, by examining the financial performance of green and brown electric utilities in a time of regulatory evolution. We provide evidence on the performance of green and brown electric utilities which could help companies and regulators master the transition to a carbon neutral economy.

In order to investigate our research question, we build on the efficient market and market equilibrium theories. According to the *efficient market hypothesis* from Fama (1970), markets should quickly incorporate any relevant information into a security's price. Therefore, if investors deem the recent regulations to raise (lower) the risk premium for high-carbon and conventional (low-carbon and renewable) electric utilities, we would expect this information to lead to higher (lower) costs of capital for such firms. Investors' non-pecuniary tastes à la Fama und French (2007) could also explain why investors might be willing to pay more for sustainable companies thereby lowering their expected return while raising the realized return (Pástor et al. (2021); Stotz (2021) Moreover, Pástor et al. (2021) argue that brown i.e. environmental sinners, stocks could be devalued compared to green, i.e. environmentally friendly, stocks if the government fines brown stocks due to an unforeseen worsening of the climate. Based on the previous literature, we expect markets to adjust their risk perception for low-carbon and renewable utilities which should lead to a short-term outperformance over high-carbon and conventional utilities. Additionally, we expect to see a gradual decrease in the cost of capital for low-carbon and renewable European companies over the last decade as the goals set by regulators were strengthened. This expectation means that renewable energy and low-carbon utilities can be expected to have outperformed conventional energy and high-carbon utilities in the last decade. We argue that the case can be made that this outperformance is due to investors lowering the expected return from renewable and low-carbon utilities causing higher realized returns in our timeseries. Our findings suggest that the European electric utilities market is not yet in a state of green/brown equilibrium à la Pástor et al. (2021).

This research uses a unique hand-collected dataset to examine the performance of portfolios comprising listed EEU to determine if there is evidence of either carbon risk or energy mix risk[18] premia for this group. We create portfolios based on taxonomy orientation and levels of renewables in the energy mix. We show that portfolios of taxonomy orientated and renewable EEU outperform portfolios of non-taxonomy orientated and conventional EEU. Furthermore, we find evidence of carbon risk and energy mix premia for EEU in the period we examine. These findings are robust to various adjustments in the calculation of the risk factors employed in our model. To the best of our knowledge, we are the first to examine the performance of

[18] The risk associated with having a large share of non-renewable fuels used in producing electricity, since non-renewable fuel sources should be phased out in order to achieve climate neutrality.

portfolios comprising EEU based on taxonomy orientation while including the possibility of carbon and energy risk premia for such portfolios.

The rest of this paper is structured as follows. First, a brief introduction to factor and carbon risk literature is given and our hypotheses are presented. Second, the data and model used in analyzing the data are explained. Third, the results of this analysis are presented and discussed. Lastly, concluding remarks are made.

5.2 Literature and hypotheses

Since Fama und French (1993) extended the *Capital Asset Pricing Model (Sharpe 1964)* with two further factors representing size and value, researchers have expanded the list of factors attempting to explain abnormal returns, e.g., Carhart (1997) added a momentum factor, Amihud (2002) found evidence of an illiquidity premium and Novy-Marx (2013) observed a gross profitability premium. Hübel und Scholz (2020) extended the 5-factor model from Fama and French (2015) with Carhart's momentum factor and 3 factors based on environmental, social and governance scores. They find the 3 ESG-factors significantly add to the explanatory power of the extended Fama and French model. Stotz (2021) investigated the realized and expected returns of a portfolio long high-ESG companies and short low-ESG companies. He found a higher (lower) realized (expected) return in his US sample from 2008 to 2018. Other literature has focused on the existence of additional green or carbon premia. Koch und Bassen (2013) uncovered a carbon premium leading to increased capital costs for EEU with a very carbon intensive energy mix from 2005 to 2010. Oestreich und Tsiakas (2015) investigated German companies affected by the EU emissions trading system and uncovered a carbon premium for firms with high emissions. Monasterolo und Angelis (2020) investigate the systematic risk associated with carbon intensive and low-carbon indices and find that investors started overweighting low-carbon investments after the Paris Agreement. Choi et al. (2020) find that carbon intensive companies underperform in areas with higher than normal temperatures. They contribute their findings to investor awareness of global warming and suggest creating policies that lower the information gap between the public and researchers. Alessi et al. (2021) find evidence of a negative green premium for European stocks. Kempa et al. (2021) find evidence that renewable energy companies (they did not investigate electric utilities) had higher costs of debt than conventional energy companies before 2007. However, after 2007 the opposite was true. They propose regulatory pressure and lower risk premia as explanations for this change. Bernardini et al. (2021) investigated the equity returns of an unbalanced panel of EEU, ranging from four firms in 2006 to 12 firms in 2016. They extended traditional factor models with a low-carbon minus high-carbon factor and found a risk premium for low-carbon EEU. Dorfleitner et al. (2022) found evidence of a green bond premium that rises given external evaluation of the greenness of the use of proceeds. In et al. (2019) found evidence that carbon-efficient US equities outperformed their carbon-inefficient counterparts from 2005 to 2015. Whereas, Bolton und Kacperczyk (2021) discovered a carbon premium in the cross-section of US stock returns from 2005 to 2017 suggesting that investors expect to be compensated for carbon risk as measured by carbon emissions. They contribute the results from In et al. (2019) to “the market inefficiency hypothesis” while arguing that the carbon premium is a newer phenomenon and is therefore only recently observable. Görgen et al. (2020) investigate a cross section of global equities and find evidence of a brown minus green factor. However, they do not find evidence of a carbon risk premium attributing this result to mispricing by investors. Basse-Mama and Mandaroux (2022) investigate firms regulated by the EU emissions trading system and find a valuation discount related to carbon emissions. Given the mixed results found in previous literature, we investigate the possibility of a carbon risk premium in the returns of European electric utilities. We expect investors to account for carbon risk in our sample of EEU due to the previously mentioned sizeable contribution to global warming (climate change is assumably more important in calculating the risk involved in owning utilities than, e.g., a software company or the whole market). Furthermore, the EU has strengthened its commitment to achieving a carbon neutral economy over the last 17 years since the introduction of the EU ETS and has emphasized the need for low-carbon and renewable electricity. Therefore, the authors believe investors have lowered their risk perception for renewable and low-carbon EEU (compared to conventional and high-carbon EEU) over time due to regulatory change and greater climate awareness.

We test the following four hypotheses. First, this paper furthers the carbon premium research by substantially extending the sample size and model employed by Bernardini et al. (2021) while investigating a different time period and portfolios. Furthermore, based on the carbon emissions premium found by Bolton and Kacperczyk (2021) we hypothesize that a carbon intensity premium exists for EEU (**H1**). Second, this paper investigates the possibility of an energy mix premium, building off the results of Koch and Bassen (2013). We expect investors to assign EEU with a higher proportion of conventional energy sources a higher level of risk. We, therefore, hypothesize that there is an energy mix premium for EEU (**H2**). Third, due to the regulatory pressure to decarbonize electricity production, we hypothesize that portfolios of taxonomy orientated and renewable energy[19] EEU outperform their counterparts, non-orientated and conventional energy respectively (**H3**). This third hypothesis, at first, seems to contradict some of the previous literature including the theory presented by Pástor et al. (2021) which finds that climate risk leads to lower costs of capital for green stocks and therefore an underperformance compared to brown stocks in a state of market equilibrium. While our outperformance hypothesis might seem counterintuitive, since lower costs of capital should lead to lower portfolio returns in the long-term, the short-term effect[20] of lowering capital costs results in rising stock prices. In other words, if green stocks are viewed as becoming less risky due to a tightening of climate policies, investors will expect a lower return to hold such stocks

[19] This paper defines renewable energy according to Article 2 paragraph 1 of Directive (EU) 2018/2001 (2018) "wind, solar (solar thermal and solar photovoltaic) and geothermal energy, ambient energy, tide, wave and other ocean energy, hydropower, biomass, landfill gas, sewage treatment plant gas, and biogas."

[20] We believe that there were multiple short term adjustments during our analysis due to the increasing regulatory pressure to decarbonize and green electricity production during the last decade.

which results in rising prices until the price reflects the lower level of risk. Hence, the short-term outperformance of green stocks compared to brown stocks.[21] We do, however, theoretically expect green stocks to underperform brown stocks in a market equilibrium as outlined by Pástor et al. (2021). Fourth, Matsumura et al. (2014) found that a penalty was imposed on the firm value of firms in the S&P500 that did not report carbon emissions data. This penalty can be seen as an adjustment to the expected returns of non-reporting companies, i.e., a risk premium for not reporting relevant information to investors. Dhaliwal et al. (2011) find that the initiation of a CSR report leads to a lower cost of capital in the following year. Therefore, we also hypothesize: taxonomy orientated and non-orientated portfolios outperform a non-reporting portfolio (**H4**).

5.3 Data and model

5.3.1 Data

We created a list of all listed companies from the 27 countries currently in the EU, the United Kingdom and Switzerland with the Standard Industrial Classification codes 4911 and 4924. This list comprised 79 companies. We then read annual reports from the companies to determine if they primarily produce electricity. After removing companies from the list that do not primarily produce electricity, we had 47 electric utility companies. According to *eurostat*, the *Department for Business, Energy & Industrial Strategy* and the *Swiss Federal Office of Energy* the 27 EU countries, the United Kingdom and Switzerland generated 3,046 TWh[22] of electricity in 2020. The 47 EEU on our list produced 2,845 TWh of electricity in 2020. We are, therefore, confident that our 47 EEU are representative of the European electric utilities market. The carbon emission and electricity production data necessary for our analysis was not available

[21] For a more detailed explanation of expected and realized returns in a sustainability context, please refer to (Cornell 2021).
[22] Statistical Office of the European Union 2022; Department for Business, Energy & Industrial Strategy 2021; Swiss Federal Office of Energy 2021.

for every company in each year due to a lack of reporting. Therefore, we have an unbalanced panel of 47 EEU with 114 monthly returns from July 2011 to December 2020 for a total of 5,046 observations. A list of the 47 EEU can be found in *Table 5.5* in the appendix.

5.3.2 Dependent variables

The quality and quantity of available carbon emission and electricity production data from various data providers was insufficient to test our hypotheses. First, the main sustainability data providers did not have the source of energy used in electricity production for the EEU in our time series. Second, the carbon intensity of said electricity production was only available for a portion of the time series and is often estimated by data providers. Third, Busch et al. (2020) find carbon data reported in corporate reports to be more consistent than estimated data, for which estimation methods are fairly untransparent. Consequently, we hand-collected the data required for our analysis from annual and sustainability reports from 2010 to 2019 which provided us with the unique dataset necessary for the evaluation of our hypotheses. We gathered the carbon intensity (gCO_2e/kWh) of total electricity produced at the company level and the percentage of company level electricity production from each source of energy for the 47 EEU. The taxonomy specifies that all types of electricity production should adhere to a threshold based on lifetime emissions at the activity level of 100 gCO_2e/kWh of electricity produced (European Commission, 2021a). However, previous non-financial reporting did not provide this information, therefore, this paper could only apply the carbon intensity threshold to a company's aggregated carbon intensity from electricity production and not the lifetime intensity of individual power plants. We were unable to determine actual taxonomy conformity since past reporting does not provide the necessary information. We therefore chose to use proxies for taxonomy conformity, i.e., aggregate firm-level CO_2 intensity instead of lifetime plant-level CO_2 intensity. Hence, the portfolios are constructed based on taxonomy orientation and not taxonomy conformity. Furthermore, the EC had not made a definitive decision about the inclusion/exclusion of nuclear energy as a clean source of energy during our sample period. The EC ruled against the recommendations of the Technical expert group on sustainable finance (TEG) by including nuclear power as a potentially taxonomy conform and green source of electricity (TEG 2020). However, this unexpected decision came after the sample period for this research ended. Therefore, we believe investors assumed the EC would follow the recommendation of the TEG by excluding nuclear power from taxonomy conform electricity. Furthermore, European countries have been split about whether nuclear power can be considered sustainable and future orientated for over a decade. This division could have created uncertainty for investors which could have influenced their investment decisions. We ultimately chose to exclude nuclear from the taxonomy orientated portfolio since this decision came after the period under consideration. Therefore, we excluded any company involved in the production of electricity from nuclear sources from the taxonomy orientated portfolio. These definition and aforementioned data problems are not unique to our portfolio construction but rather would have also been problematic for portfolio managers. Therefore, we believe the use of a proxy for taxonomy conformity to be justified.

Value-weighted discrete monthly returns are used to create dynamic portfolios[23] with a 6-month lag from the time the carbon intensity and energy mix data was published to ensure that the information would have been available during portfolio construction. Five portfolios were constructed based on quintile breaks in the percentage of renewable energy in the energy mix of the 47 EEU. Three additional portfolios were created based on the taxonomy orientation of the 47 EEU. *Table 5.1* provides an explanation of the eight portfolios.

[23] Portfolios were reconstructed on a yearly basis at the end of June i.e., a company assigned to one portfolio in a given year *t* could be assigned to a different portfolio in *t+1*.

5.3.3 Independent variables

The *smb* and *hml* factors from Fama und French (1993) are calculated from the monthly returns of the EEU. Their three-factor model is extended with proxies for *oil*, *gas* and *coal* returns since Henriques und Sadorsky (2008) found the oil price to have a significant impact on the stock price of alternative energy companies. Furthermore, gas and coal constitute a significant portion of the energy mix for EEU and fluctuating prices for these commodities might influence their performance. Two further factors based on the carbon intensity of the EEU and the level of renewable energy in their energy mix extend the model.

Table 5.1: Overview of variables

Variables		Description
Dependent	**n**	
T	*11*	A portfolio of taxonomy orientated EEU, i.e., companies emitting ≤100 gCO_2e/kWh from aggregated electricity production and no nuclear energy production.
NT	*27*	A portfolio of non-taxonomy orientated EEU, i.e., emitting >100 gCO_2e/kWh from aggregated electricity production or nuclear energy production.
NR	*9*	A portfolio of non-reporting EEU, i.e., companies that do not provide enough information to determine the carbon intensity of electricity production and potential nuclear involvement.
RE_{80}	*9*	A portfolio of EEU with a percentage of energy from renewable sources in the top quintile.
RE_{60}	*8*	A portfolio of EEU with a percentage of energy from renewable sources in the fourth quintile.
RE_{40}	*8*	A portfolio of EEU with a percentage of energy from renewable sources in the third quintile.
RE_{20}	*8*	A portfolio of EEU with a percentage of energy from renewable sources in the second quintile.
RE_{0}	*9*	A portfolio of EEU with a percentage of energy from renewable sources in the bottom quintile, i.e. conventional energy.
Independent		
mkt	*47*	The market return: the return of a value weighted portfolio of all EEU.
rf		The risk-free rate: the monthly return on the 3-month EURIBOR.
smb	*47*	The size factor: the small minus big factor was calculated using the methodology from Fama & French (1993) and the EEU.
hml	*28*	The value factor: the high minus low factor was calculated using the methodology from Fama & French (1993) and the EEU.
lmh	*22*	The carbon intensity factor: the low-carbon intensity minus high-carbon intensity factor was calculated using the methodology from Fama & French (1993) for their hml factor and the EEU.
rmc	*26*	The energy mix factor: the renewable minus conventional energy factor was calculated using the methodology from Fama & French (1993) for their hml factor and the EEU.
coal		A proxy for the return of coal in euros: the ICE Rotterdam continuous coal future.
gas		A proxy for the return of gas in euros: the ICE Endex Dutch TTF gas future
oil		A proxy for the return of oil in euros: the Europe Brent Spot FOB future.

This table includes the description of the variables used in the regressions and the number (*n*) of companies in each portfolio/factor for 2020. Financial data was downloaded from Refinitiv's Datastream. Equity returns are based on local currencies Megginson et al. (2000) and are adjusted for splits and dividends. The *smb*, *hml*, *lmh* and *rmc* factors used information from December of t-1 for portfolio construction at the end of June in year t. The market capitalization for the portfolio weights is the closing market capitalization in euros at the end of June in each year of portfolio construction. Portfolios were reconstructed and rebalanced yearly at the end of June. Returns are monthly and continuous. Since the portfolios used to construct the *hml*, *lmh* and *rmc* factors are based on 2x3 portfolios which excluded the middle portfolios, 28 is the maximum possible number of companies in these factors.

intensity (gCO_2e/kWh). The two middle (40 percentile-break) portfolios were excluded from the factor calculation. Discrete value weighted monthly returns were calculated for each of the following four portfolios: small/low-carbon intensity, big/low-carbon intensity, small/high-carbon intensity and big/high-carbon intensity. The following formula was then used to calculate a low minus high-carbon intensity factor

$$lmh = 0.5(SL + BL) - 0.5(SH + BH)$$

where SL is the discrete monthly return of the small/low-carbon intensity portfolio, BL is the discrete monthly return of the big/low-carbon intensity portfolio, SH is the discrete monthly return of the small/high-carbon intensity portfolio, BH is the discrete monthly return of the big/high-carbon intensity portfolio and lmh is the low-carbon intensity minus high-carbon intensity factor. The log returns of the lmh factor were used for the regression analysis. Our second factor is the renewable minus conventional energy (*rmc*) factor. The methodology used to create the *lmh* factor was also used to create the *rmc* factor. The only difference is that the *rmc* factor is based on the percentage of renewable energy a company produces instead of carbon intensity, i.e., breaks in the percentage of renewable energy produced at 30/40/30 percentiles. The *lmh* and *rmc* factors are used to investigate the possibility of carbon risk and energy mix risk premia, respectively, among EEU. All factors are presented in *Table 5.1*.

5.3.4 Models

This paper uses an ordinary least squares methodology in regressing the following three models to test our hypotheses. Model 1 is the three-factor model from Fama und French (1993)

$$r_{i,t} - rf_t = \alpha_i + \beta_{i,mkt}(mkt_t - rf_t) + \beta_{i,smb}\, smb_t + \beta_{i,hml}\, hml_t + \epsilon_{i,t} \qquad (5.1)$$

where the dependent variable is the return of each of the previously mentioned portfolios in excess of the risk-free rate (rf), mkt is the return of the entire EEU sample, smb is the size factor, hml is the value factor and ϵ is the error term. Model 2 extends the first model with proxies for the returns on oil, gas and $coal$

$$r_{i,t} - rf_t = \alpha_i + \beta_{i,mkt}(mkt_t - rf_t) + \beta_{i,smb}\, smb_t + \beta_{i,hml}\, hml_t + \beta_{i,oil}\, oil_t + \beta_{i,gas}\, gas_t + \beta_{i,coal}\, coal_t + \epsilon_{i,t} \qquad (5.2)$$

Model 3 extends the second model with rmc (the energy mix factor) and lmh (the carbon intensity factor)

$$r_{i,t} - rf_t = \alpha_i + \beta_{i,mkt}(mkt_t - rf_t) + \beta_{i,smb}\, smb_t + \beta_{i,hml}\, hml_t + \beta_{i,oil}\, oil_t + \beta_{i,gas}\, gas_t + \beta_{i,coal}\, coal_t + \beta_{i,rmc}\, rmc_t + \beta_{i,lmh}\, lmh_t + \epsilon_{i,t} \quad (5.3)$$

5.4 Empirical findings

5.4.1 Descriptive statistics

Table 5.2 provides the mean, median and standard deviation (Std. dev.) for the eight portfolios and the eight factors presented in *Table 5.1*. Further descriptive statistics for each of the dependent portfolios for the year 2020 are given in *Table 5.6* in the appendix. The portfolio of companies with the largest percentage of renewable energy in the mix has the highest mean return followed by the portfolio of taxonomy orientated companies. We interpret this finding as the first indication that **H3** is correct. The mean portfolio return for each of the five portfolios based on the energy mix decreases as the amount of renewable energy produced decreases (the order of the fourth and fifth quintile portfolios are exchanged). The mean return of the non-orientated and non-reporting portfolios are both lower than that of the taxonomy orientated portfolio pointing to a possible confirmation of **H4**. The *mkt-rf* factor notably has the highest mean among the factors. Furthermore, the *hml* and *lmh* factors and commodity proxies are all negative in the mean.

Table 5.2: Descriptive statistics

Dependent Variables	RE_{80}	T	RE_{60}	RE_{40}	NT	NR	RE_0	RE_{20}
Mean	0.0135	0.0128	0.0112	0.0087	0.0048	0.0031	0.0015	0.0010
Median	0.0170	0.0163	0.0115	0.0104	0.0083	0.0002	0.0065	0.0034
Std. dev.	0.0537	0.0562	0.0527	0.0542	0.0486	0.0603	0.0619	0.0467
Independent Variables	**mkt-rf**	**rmc**	**smb**	**hml**	**lmh**	**coal**	**gas**	**oil**
Mean	0.0087	0.0060	0.0025	-0.0010	-0.0016	-0.0036	-0.0053	-0.0054
Median	0.0110	0.0101	0.0024	0.0074	-0.0044	-0.0029	-0.0035	-0.0035
Std. dev.	0.0515	0.0545	0.0317	0.0402	0.0496	0.0746	0.0392	0.1587

All returns are monthly, continuous and sorted by the mean. Dependent variable returns are net the *rf* rate. A one-sided (greater than) Wilcoxon test was used to test the significance of the differences between the portfolio means. Significance is denoted by: * p<0.1, ** p<0.05 and *** p<0.01 and given in parenthesis. Only portfolios with significant differences are listed. RE_{80}•RE_{20} (***), RE_{80}•RE_0 (**), RE_{80}•NT (**); RE_{60}•RE_{20} (***), RE_{60}•RE_0(***), RE_{60}•NT (*), RE_{60}•NR (*); RE_{40}•RE_{20} (***), RE_{40}•RE_0 (*), RE_{40}•NT (**); T•RE_{20} (***), T•RE_0 (**) and T•NT (**).

5.4.2 Regression results

First, each of the eight portfolios' monthly returns was regressed against a six-factor model to determine if the three-factor model from Fama und French (1993) and the commodity proxies adequately explain these returns. *Panel A of Table 5.3* presents these results. While the alphas from NT, RE_{80} and RE_{20} are significant (possibly hinting that some excess return is not accounted for), the other five dependent variables have insignificant alphas. The adjusted R-squared for all regressions is fairly low, except for the NT regression, further pointing to the possibility that the model could be improved. We then extended the six-factor model with the *rmc* and *hml* factors and regressed each of the eight portfolios against this model. The results of these regressions can be seen in *Panel B of Table 5.3*. The adjusted R-squared for each of the regressions increased compared to those in *Panel A of Table 5.3*. Furthermore, the *rmc* factor has the expected sign and is significant in all the regressions except for the RE_{40} and RE_{20} portfolios. The *lmh* factor is significant in half of the regressions: T, RE_{80}, RE_{40} and RE_0. These results point to the existence of both carbon (confirming **H1**) and energy mix premia (confirming **H2**) for the majority of the EEU portfolios.

The next step in this analysis addresses **H3** and **H4**. Difference portfolios are computed to investigate if taxonomy orientated EEU outperform both non-orientated EEU (T-NT) and non-reporting EEU (T-NR). We also examine whether non-orientated EEU outperform non-reporting EEU (NT-NR) and if renewable EEU outperform conventional EEU (RE_{80}-RE_{0}). *Panel A of Table 4* presents the results of the difference portfolio regressions based on the three-factor model. The size beta is significant for all four difference portfolios and plays the largest role. Both taxonomy orientated and renewable energy EEU tend to be smaller than their non-taxonomy orientated and conventional counterparts. Non-reporting EEU are smaller than taxonomy orientated EEU which is in line with Drempetic et al. (2020). Most other factors do not significantly explain the difference portfolios. However, the alphas for three of the four portfolios are significant, demonstrating an outperformance of the taxonomy orientated portfolio over both the non-orientated and non-reporting portfolio. Furthermore, the renewable energy portfolio outperforms the conventional energy portfolio.

Table 5.3: Full sample regressions

Panel A: Six-Factor Model

	T	**NT**	**NR**	**RE_{80}**	**RE_{60}**	**RE_{40}**	**RE_{20}**	**RE_0**
α	0.0063	-0.0027 *	-0.0053	0.0069 *	0.0029	-0.0007	-0.0051 *	-0.0052
	(0.0038)	(0.0014)	(0.0046)	(0.0039)	(0.0031)	(0.0029)	(0.0027)	(0.0033)
mkt-rf	0.8202 ***	0.8455 ***	0.6671 ***	0.7868 ***	0.8374 ***	1.0152 ***	0.6697 ***	0.7936 ***
	(0.083)	(0.0326)	(0.099)	(0.0957)	(0.0734)	(0.0701)	(0.0481)	(0.0862)
smb	0.3259 **	-0.1174 **	0.8017 ***	0.4541 **	0.1998	0.2422 **	-0.1619 **	-0.2489 **
	(0.1559)	(0.0502)	(0.1137)	(0.1821)	(0.1212)	(0.1059)	(0.079)	(0.1011)
hml	0.1037	-0.0195	0.2844	0.0671	0.1534	-0.0025	0.0026	-0.011
	(0.1079)	(0.036)	(0.1901)	(0.1)	(0.0946)	(0.065)	(0.0679)	(0.0718)
oil	0.0186	0.0265 *	0.0542 *	0.0023	-0.0013	-0.0323 **	0.0395 **	0.1077 ***
	(0.0269)	(0.015)	(0.0284)	(0.0195)	(0.0173)	(0.0142)	(0.0188)	(0.0376)
gas	0.0006	0.0134	-0.0237	-0.0306	-0.0227	-0.0813	0.0755	0.0837
	(0.1023)	(0.0409)	(0.1125)	(0.101)	(0.079)	(0.0746)	(0.0665)	(0.1114)
coal	-0.067	-0.0293	0.1338 *	-0.0359	-0.0812 *	0.007	-0.0189	-0.0763 *
	(0.0603)	(0.0186)	(0.077)	(0.0561)	(0.0418)	(0.0442)	(0.0307)	(0.0433)
Adj. R^2	0.514	0.922	0.421	0.465	0.613	0.762	0.727	0.721

Panel B: Eight-Factor Model

	T	**NT**	**NR**	**RE_{80}**	**RE_{60}**	**RE_{40}**	**RE_{20}**	**RE_0**
α	0.0043	-0.0022 *	-0.0025	0.0049	0.0006	-0.0002	-0.0046 *	-0.004
	(0.0033)	(0.0013)	(0.004)	(0.0031)	(0.0028)	(0.0029)	(0.0027)	(0.0033)
mkt-rf	0.8998 ***	0.8292 ***	0.6058 ***	0.8693 ***	0.8787 ***	0.9952 ***	0.6566 ***	0.7849 ***
	(0.0792)	(0.029)	(0.0954)	(0.0781)	(0.074)	(0.0706)	(0.047)	(0.0892)
smb	0.3877 ***	-0.1261 ***	0.8036 ***	0.5257 ***	0.1821 *	0.2236 **	-0.1644 **	-0.2162 **
	(0.1048)	(0.0417)	(0.1055)	(0.1269)	(0.1063)	(0.0999)	(0.0762)	(0.0924)
hml	0.1814 **	-0.0354	0.2258	0.1479 **	0.1925 **	-0.0221	-0.01	-0.0184
	(0.0749)	(0.0354)	(0.1602)	(0.0666)	(0.0897)	(0.0722)	(0.0651)	(0.0751)
rmc	0.2145 ***	-0.0617 **	-0.3867 ***	0.1886 ***	0.3345 ***	-0.0407	-0.07	-0.1996 ***
	(0.0794)	(0.0256)	(0.0946)	(0.069)	(0.0769)	(0.0626)	(0.046)	(0.0668)
lmh	0.3452 ***	-0.0504	-0.0118	0.3966 ***	-0.0766	-0.1023 *	-0.017	0.1647 *
	(0.0838)	(0.0306)	(0.0964)	(0.0802)	(0.0699)	(0.0615)	(0.0617)	(0.0858)
oil	0.0011	0.0301 **	0.0671 ***	-0.016	-0.0099	-0.0278 *	0.0423 **	0.1091 ***
	(0.0218)	(0.0151)	(0.0229)	(0.0171)	(0.0141)	(0.0143)	(0.0191)	(0.0352)
gas	-0.0713	0.0224	-0.0395	-0.1159	0.0116	-0.0589	0.0762	0.0349
	(0.0907)	(0.0396)	(0.0931)	(0.0847)	(0.0764)	(0.0638)	(0.0678)	(0.11)
coal	-0.0132	-0.0389 **	0.1103 *	0.0226	-0.0714 *	-0.0076	-0.0249	-0.0678
	(0.0425)	(0.0169)	(0.0564)	(0.0435)	(0.0373)	(0.0406)	(0.0323)	(0.043)
Adj. R^2	0.702	0.932	0.536	0.691	0.706	0.771	0.73	0.74

Heteroskedasticity and autocorrelation corrected standard errors are in parentheses. R^2 has been adjusted for degrees of freedom. All regressions are highly significant. Significance is denoted by: * $p<0.1$, ** $p<0.05$ and *** $p<0.01$

In *Panel B of Table 5.4*, the taxonomy orientated and renewable energy portfolios still outperform the non-orientated and conventional energy portfolios respectively. Furthermore, the taxonomy orientated and non-orientated portfolios have less exposure to the coal beta than the non-reporting portfolio, which could indicate that non-reporting companies might have a higher level of coal in the energy mix. The renewable energy portfolio has less exposure to the oil beta than the conventional energy portfolio. *Panel C of Table 5.4* presents the results of the regressions with the complete model.

Table 5.4: Difference portfolio regressions

Panel A: Three-Factor Model

	T-NT	T-NR	NT-NR	$RE_{80}-RE_{0}$
α	0.0087 *	0.0101 *	0.0011	0.0119 *
	(0.0044)	(0.006)	(0.0044)	(0.0062)
mkt-rf	-0.0289	0.1016	0.1295	-0.1296
	(0.0532)	(0.1069)	(0.1072)	(0.1568)
smb	0.4673 ***	-0.3925 *	-0.8881 ***	0.6391 ***
	(0.1642)	(0.2119)	(0.086)	(0.1982)
hml	0.1088	-0.2287	-0.3345 *	0.0985
	(0.1272)	(0.2435)	(0.1863)	(0.1557)
Adj. R^2	0.098	0.039	0.319	0.151

Panel B: Six-Factor Model

	T-NT	T-NR	NT-NR	$RE_{80}-RE_{0}$
α	0.0085 *	0.0093	0.0006	0.0099 *
	(0.0043)	(0.0062)	(0.0042)	(0.0053)
mkt-rf	-0.0218	0.1364	0.1553	0.0101
	(0.0904)	(0.1161)	(0.0954)	(0.1331)
smb	0.4561 **	-0.4447 **	-0.9308 ***	0.7220 ***
	(0.1822)	(0.2142)	(0.0958)	(0.2001)
hml	0.122	-0.1666	-0.2845	0.061
	(0.1263)	(0.2422)	(0.1737)	(0.1283)
oil	-0.0059	-0.0409	-0.0321	-0.0828 **
	(0.0235)	(0.0463)	(0.0358)	(0.0317)
gas	-0.0149	0.0371	0.0381	-0.1465
	(0.1097)	(0.1674)	(0.1191)	(0.1652)
coal	-0.0398	-0.2118 *	-0.1708 **	0.0392
	(0.0681)	(0.1141)	(0.0805)	(0.0735)
Adj. R^2	0.079	0.076	0.356	0.197

Panel C: Eight-Factor Model

	T-NT	T-NR	NT-NR	$RE_{80}-RE_{0}$
α	0.0059 *	0.0044	-0.0018	0.0067
	(0.003)	(0.0044)	(0.004)	(0.0044)
mkt-rf	0.0756	0.2775 **	0.1992 **	0.103
	(0.0749)	(0.1093)	(0.1003)	(0.1214)
smb	0.5283 ***	-0.3846 ***	-0.9437 ***	0.7651 ***
	(0.1056)	(0.1457)	(0.1038)	(0.1459)
hml	0.2171 **	-0.03	-0.2429	0.151
	(0.086)	(0.1406)	(0.1529)	(0.103)
rmc	0.2782 ***	0.6024 ***	0.3284 ***	0.3809 ***
	(0.0829)	(0.1264)	(0.1061)	(0.0938)
lmh	0.4047 ***	0.3578 ***	-0.0507	0.2533 **
	(0.0864)	(0.1099)	(0.1011)	(0.123)
oil	-0.0274 *	-0.0714 *	-0.0413	-0.1030 ***
	(0.0146)	(0.0388)	(0.0344)	(0.03)
gas	-0.0978	-0.019	0.0659	-0.1884
	(0.0803)	(0.12)	(0.1053)	(0.1327)
coal	0.0248	-0.1344 *	-0.1582 **	0.0913
	(0.0483)	(0.0712)	(0.0631)	(0.0648)
Adj. R^2	0.525	0.512	0.434	0.448

Heteroskedasticity and autocorrelation corrected standard errors are in parentheses. R^2 has been adjusted for degrees of freedom. All regressions are significant. Significance is denoted by: * $p<0.1$, ** $p<0.05$ and *** $p<0.01$

The outperformance of taxonomy orientated companies compared to non-orientated companies is confirmed but the alphas of the two other difference portfolios are insignificant. The *rmc* beta is significant and positive for all four difference portfolios and the *lmh* beta is significant and positive for three of the difference portfolios. The taxonomy orientated portfolio also has less exposure to the oil beta than the non-orientated and non-reporting portfolios. The adjusted R-squared for each difference portfolio is also much higher than in *Panel A* or *B*, which lends strength to the explanatory power of the carbon intensity and energy mix factors. In summary, we find evidence confirming **H3:** a taxonomy orientated portfolio outperforms a non-orientated portfolio (statistically significant in all 3 models) and a renewable energy portfolio outperforms a conventional energy portfolio (statistically significant in models 1 and 2). However, we can only partially confirm **H4** based on the results of the regression with model 1 where the taxonomy-orientated portfolio significantly outperforms the non-reporting portfolio. The other models do not confirm **H4** and the outperformance of the non-orientated over the non-reporting portfolio cannot be confirmed. This evidence reinforces the findings in the descriptive statistics that taxonomy orientated and renewable EEU outperform their counterparts, non-orientated and conventional energy respectively. This outperformance is at least partially due to carbon and energy mix premia. In short, the market seems to reward greener EEU with lower costs of capital as evidenced by the higher prices commanded by the green EEU in our time series.

5.4.3 Robustness checks

Since the self-constructed Fama and French factors used to test our hypothesis were formed from a relatively small sample, they could be fairly dependent on the returns of a few firms which could lead to a self-fulfillment bias. We, therefore, ran regressions with the European *mkt, rf*, *smb* and *hml* factors from Kenneth R. French's website[24] to check the robustness of our

[24] https://mba.tuck.dartmouth.edu/pages/faculty/ken.french/data_library.html

results. Furthermore, we used different breaks in the percentage of renewable energy a company produces and its carbon intensity when creating the portfolios for the *rmc* and *lmh* factors to ensure that the factors are robust to different breaks. The results are largely consistent with the findings presented in *Panel B of Table 5.3 and Panel C of Table 5.4.* Finally, we regressed the *rmc* and *lmh* factors against the other 6 factors and found these other factors do not significantly explain our two factors. Table 5.7 in the appendix presents the correlations between the 8 factors. The results of the robustness checks lead us to believe that our results are not dependent on: self-fulfilling regressions due to sample size; the chosen breaks when constructing the factors; and that *rmc* and *lmh* cannot be explained by the other factors used in our analysis.

5.5 Conclusion

This paper investigates whether taxonomy orientated and renewable energy EEU portfolios outperform their counterparts while exploring the possibility of carbon and energy mix premia. We investigated a different timeseries than Bernardini et al. (2021) while considerably expanding their sample. We find a positive low-carbon premium (confirming **H1**) for portfolios of taxonomy orientated and renewable energy EEU. Furthermore, we find evidence of an energy mix premium for a more representative sample and updated timeseries thereby confirming the robustness of the earlier results from Koch and Bassen (2013). We can confirm **H2**, i.e., the level of renewables in the energy mix positively affects the returns of the taxonomy orientated and renewable energy portfolios while negatively affecting the non-orientated, non-reporting and conventional energy portfolios. The taxonomy orientated and renewable energy portfolios outperformed their counterparts confirming **H3**. This outperformance can be partially explained by the carbon and energy mix premia. This outperformance agrees with the findings from In et al. (2019) pertaining to carbon efficient and inefficient US equities while not directly contradicting Bolton and Kacperczyk (2021), who do not find evidence of a high-carbon intensity premium but rather a carbon emissions premium for their cross-section of US stocks.

Furthermore, they investigated the effect of carbon emissions on the stock returns of US companies from 71 GIC 6 industries whereas we investigated the performance of portfolios of European electric utility companies. Next, we find that a taxonomy orientated portfolio outperforms a non-reporting portfolio in agreement with the results from Matsumura et al. (2014) pertaining to the S&P500. However, the non-orientated portfolio does not significantly outperform the non-reporting portfolio. Hence, we can only partially confirm **H4**. This finding could be interpreted as evidence that investors value non-financial reporting from companies with a higher sustainability performance. Our results provide evidence that investors could have anticipated regulations, similar to the taxonomy, pertaining to carbon intensity and that they could have acknowledged certain risks associated with global warming and the transition to a carbon neutral system of energy production.

Our results are important for investors, EEU and regulators. Investors could potentially profit from creating portfolios based on taxonomy orientation and the percentage of renewables used in the energy mix depending on how close we are to a market equilibrium a la Pástor et al. (2021). European electric utilities could potentially profit from lower costs of capital if they either raise the level of renewables in their energy mix or align their energy production to the taxonomy. If these companies then report their climate friendly electricity production, they could be rewarded with lower costs of capital. Finally, Regulators can see that the markets are pricing in carbon and energy mix risks which could be a result of their signaling/regulations. Further research should test this paper’s findings in a few years once data granularity allows for the creation of portfolios based on taxonomy conform energy production at the activity level. We were only able to determine a company’s aggregate level of CO_2 intensity, due to insufficient reporting, and not the CO_2 intensity of the company’s individual power plants. Furthermore, it would be interesting to test the effects of the unexpected inclusion of nuclear energy in the taxonomy by repeating our study with portfolios sorted along the newest taxonomy definitions. An event study could also examine the effects of including nuclear and gas in the taxonomy on the returns of nuclear and gas EEU. Lastly, the identified carbon and energy mix risk premia should be both tested on a longer time series of EEU and calculated for both other regions and industries that are significantly affected by climate change regulation to ensure that the results of this paper are not attributable to a short-term market anomaly.

6. Green bonds premium revisited[25]

6.1 Introduction

Since the European Investment Bank issued the first green bond in 2007, the total spending has risen to $500 billion only in 2021 and is expected to exceed $1 trillion in 2022.[26] Despite this enormous growth from a niche product into the financial mainstream, not all questions about this new bond form have been answered. Therefore, in this paper we address the question: can the level of the green bond premium be determined by the sustainability ratings of third-party opinions of green bonds? The answer to the question leads to a better understanding of what determines the price of green bonds on the secondary market and is interesting for investors, scholars and regulators. Investors are gaining a deeper understanding of what affects green bond asset prices and can better estimate the expected return. Scholars gain a better understanding of how the financial markets work, allowing them to develop more accurate research models in the future. Regulators can learn to what extent a sustainable bond rating has an impact on whether bonds with such a rating generate a financial advantage and thus whether a binding sustainable rating can help finance the transformation of the economy.

According to modern portfolio theory, the price of an asset is only influenced by the risk of the respective asset in relation to the risk of the overall market. In contrast, Fama and French (2007) have shown that the investors taste, e.g. taste of socially responsible investing, can also have an impact on asset pricing. More precise, Pástor et al. (2021) have introduced a sustainable investing equilibrium model in which green assets have lower returns than conventional assets, because the taste of investors for sustainability moves the asset prices of sustainable

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[25] The present chapter was jointly written by JProf. Dr Tobias Bauckloh, Prof. Dr Christian Klein, Mr Leonard Remme and Dr habil Bernhard Zwergel as part of a BMBF-funded project. Mr. JProf. Dr. Tobias Bauckloh was responsible for major part of the R-code. Mr. Leonard Remme was responsible for data analysis, literature search, discussion of results. In addition, the realization that the method of Zerbib is problematic is based on the further development of the concept and all related steps on the work of Mr. Leonard Remme. Moreover, he was the main author of the text. Dr. habil Bernhard Zwergel and JProf Dr. Tobias Bauckloh was responsible for proofreading.

[26] https://www.climatebonds.net/2022/01/500bn-green-issuance-2021-social-and-sustainable-acceleration-annual-green-1tn-sight-market Accessed August 23, 2022.

investments. The existence of such a lower return on sustainable investments has been shown by some empirical studies on secondary-market investments in green bonds (Baker et al. 2018; Gianfrate and Peri 2019; Nanayakkara and Colombage 2019). However, these studies compare either self-labeled green bonds or green bonds with a second-party opinion with conventional bonds without addressing the greenness of the respective bonds. Therefore, Dorfleitner et al. (2022) examine a four-level scale of the shades of green for several green bonds using four different types of external review reports. The findings are that the greenness of a bond influences the extent to which investors are willing to sacrifice returns (so-called green bond premium). More specifically, investors are willing to sacrifice more returns if the bond has a higher greenness (dark green) than if it has a medium greenness (medium green) or low greenness (brown). Nevertheless, there are some methodological limitations in the study by Dorfleitner et al. (2022). First, the green bonds are grouped into a separate sustainability rating, for which it is not clear why investors should use this in the same way. Second, some of the variables examined are dummy variables, and only a small number of dummy variables are examined, so that no conclusions can be drawn about the influence of the sustainability of a bond on its return. Finally, Dorfleitner et al. (2022) use CBI data, which contradicts parts of the academic literature, as CBI data are mandated certifications. Finch (2014) examines the different forms (solicited, unsolicited and cooperative) of financial and sustainability ratings and concludes that only the cooperative rating is an acceptable rating. The main reasons for this are that only a cooperative rating provides the financial independence of the rating agency and at the same time sufficient data are available to provide a substantiated picture of the rating object. Consequently, the question of whether the sustainability of a bond has an influence on the asset pricing of the bond should be answered by using a cooperative rating and not a mandated/solicited rating.

In this paper, we examine whether the previous empirical evidence also holds true when a cooperative rating is used to measure the sustainability of green bonds. In particular, we investigate whether the sustainability of a green bond can explain the difference in yields between a green bond and its synthetic conventional bond. To do so, we follow the methodological approach of previous studies (Zerbib 2019; Bachelet et al. 2019) and combine a matching method with a two-step-regression procedure. Therefore, we use the green bonds from the ISS ESG Sustainability Bond Rating database and match two conventional bonds to each green bond. The synthetic conventional bond is then formed from the two conventional bonds using interpolation and extrapolation. The main finding is that the sustainability of a green bond has no effect on the return of green bonds and therefore investors are not willing to accept lower returns for (more) sustainable bonds.

Our contribution to the literature is the following. First, we provide a contribution to the question of whether investors are willing to forgo return if the investment is sustainable compared to an unsustainable investment. Furthermore, we investigate the question of whether the return sacrifice increases with increasing sustainability. Finally, we show whether sustainability ratings have an impact on the valuation of (green) bonds.

The remainder of the paper is organized as follows. First, we review the related academic literature, starting with the theoretical considerations of sustainable investments and yield sacrifice. We then highlight the empirical findings to date in the area of sustainable bonds. We then present our methodology and data set, and how we arrived at our data set, before presenting the results of our study in the fourth section. In the last section we conclude.

6.2 Literature review and hypotheses

The Capital Asset Pricing Modell (William F. Sharpe 1964) assumes that the expected return of an investment depends only on the risk-free interest rate and the risk of the respective investment in relation to the risk of the overall market. Since the risk-free interest rate is given externally, the expected return of an investment depends mainly on the ratio between the risk of the investment and the risk of the overall market. For this to hold, the CAPM makes some assumptions, of which one is that investors are only interested in the payoffs of their portfolio which means investments are not consumer goods. Fama and French (2007) reject this assumption as unrealistic and show that the taste of assets, e.g. taste of responsible investing, as consumption good has an impact on asset prices and therefore on the returns of an investment. Accordingly, Pastor, Stambaugh, and Taylor (2021) (hereafter PST) develop a two-factor equilibrium model that takes into account investors' taste for sustainable investments. The main implications of this model are that investors derive a utility from holding sustainable investments and are therefore willing to pay more for sustainable investments. According to the PST model, it implies that with increasing sustainability, the benefit from holding sustainable investments increases, so that investors are willing to pay more for more sustainable investments. As a result, sustainable investors reduce the firms' costs of capital depending on sustainability, which leads to sustainable investments having a lower expected return than conventional (brown) investments. Based on the higher realized returns of sustainable investments in the past, Pástor et al. (2022) use their own PST model in a further research paper to explain the difference between theoretical considerations of lower returns and actual observation of higher returns of sustainable investments. Following Pástor et al. (2022), this can be explained by climate shocks, which in turn cause investors to unexpectedly increase the demand for sustainable investments, resulting in higher asset prices for sustainable investments. From this, the authors conclude that the higher realized returns of sustainable investments are only temporary but not long-term, namely until climate shocks have no (more) impact on the financial markets. The implications of the PST model are studied by other researchers (e.g. Ardia et al. 2022) and they can confirm that unexpected climate shocks have an impact on company equity.

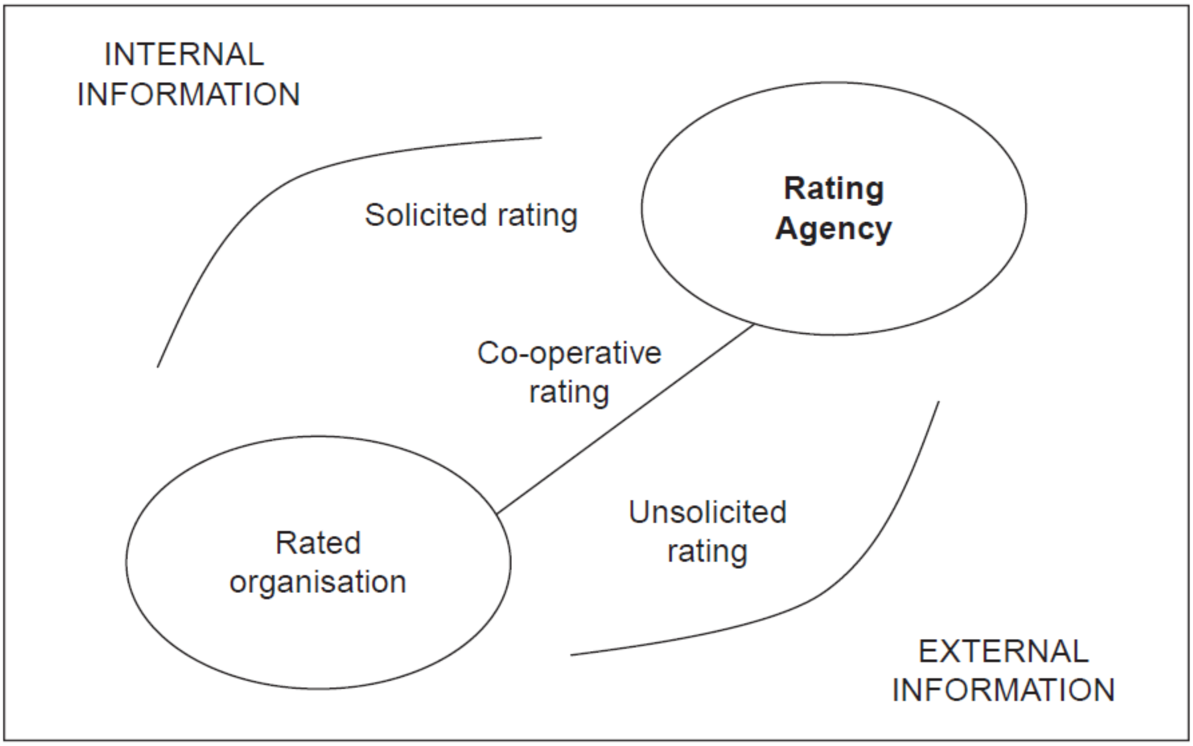
However, several empirical studies investigate the existence of lower returns on (green) bonds. Larcker and Watts (2020) and Flammer (2021) analyze yield differentials of green and non-green municipal bonds at the primary market level to investigate whether investors are willing to accept lower yields (pay a 'green bond premium' or 'greenium') on green bonds. Larcker and Watts (2020) observe lower yields for the average green bond. In a further analysis, the authors show that this result is driven by a small subset of the sample. The differences in yields are only found for approximately 15% of the matched bonds in the sample, while for the other matching pairs there is exactly no difference between the yields of the green bond and the yield of the matched conventional bond. Therefore, the authors conclude that there is no greenium, because if there was, it would have to be observable for a much higher percentage of the matched bond pairs than for the 15 percent. Flammer (2021) comes to similar results and shows that there is no significant difference between the yields of green and non-green bonds. Both conclude that investors are not willing to sacrifice returns to finance sustainable projects. They argue that the reasons for issuing green bonds are to broaden the investor base (Larcker and Watts 2020) or to send a signal to (potential) investors that the issuer is committed to the environment (Flammer 2021).

In contrast to the relatively clear picture for primary market research, the results for secondary market research are much more divergent. Some authors find evidence for a negative green bond premium, i.e. green bonds have lower yields than conventional bonds (e.g. Baker et al. 2018; Gianfrate and Peri 2019; Zerbib 2019; Nanayakkara and Colombage 2019), others that there is no green bond premium (e.g. Hachenberg and Schiereck 2018; Hyun et al. 2020) and a few find that green bonds have a positive premium (e.g. Karpf and Mandel 2018; Bachelet et al. 2019). However, a positive premium can only be observed for private but not institutional green bonds (Bachelet et al. 2019), or it changes from an initial negative to a positive one over the observed period (Karpf and Mandel 2018). The different results can be explained by different methods used, the exclusive use of municipals, the use of self-labeled green bonds without external validation and very small sample sizes (Ehlers and Packer 2017). Regardless, none of the aforementioned studies take into account the shades of green of the respective green bonds, but merely divide the bonds into green or brown using a dummy variable, and thus do not consider whether different shades of green have an effect on the difference in yields. Two studies consider the different shades of green in their analysis. Immel et al. (2021) describe that the greenium increases with a rising sustainability rating, which leads them to conclude that investors are willing to sacrifice returns for particularly green projects. In contrast, Kapraun and Scheins (2019) find no generally valid relationship between sustainability rating and greenium. They do, however, find lower yields with rising sustainability ratings for green bonds issued in EUR or issued by governance or supranational organizations. However, both studies use corporate (ESG) ratings as a proxy to measure sustainability and therefore cannot compare green and conventional bonds of the same issuer but analyze green bonds across companies. While this approach allows differences in yields between sustainable and non-sustainable organizations to be analyzed, the approach does not allow conclusions to be drawn as to whether the differences in yields are based on the project being financed or the sustainability of the issuer in general.

To the best of our knowledge, there is only the paper of Dorfleitner et al. (2022) that directly measures and analyzes the shades of green for green bonds. In their paper, Dorfleitner et al. (2022) describe that there are four different forms (second-party opinion, verification, certification and ratings) of external reporting on the sustainability of green bonds and analyze which of these four forms has an impact on the yields of green bonds and thus exerts an influence on the financial markets. In addition, they investigate for second-party opinions whether the shades of green have an impact on yields. To do so, the authors examine a total of 250 green bond triples. The results are that green bonds with second party opinion (SPO) and verification have lower yields than their conventional counterparts. Therefore, they conclude that investors are already willing to sacrifice more return if a green bond has one of these two sustainability reporting forms. In addition, Dorfleitner et al. (2022) conclude in their analysis of the shades of green that investors are willing to sacrifice more returns if the bond has a higher greenness (dark green) than if it has a medium greenness (medium green) or no shade of greenness. Regardless of the results, there are some methodological limitations in the study. First, Dorfleitner et al. (2022) only consider the respective shades of green for the second-party opinions and only on a self-developed 4-level scale (dark green, medium green, brown, no shades). As a basis for their own scale, Dorfleitner et al. (2022) use the concluding statements of various providers of SPOs (CICERO, Vigeo, ISS-Oekom, Sustainalytics) and sort these into one of their four levels, whereby no green bond is sorted into the third level 'brown'. All green bonds for which an SPO is available, but for which no concluding statement was made by the respective SPO provider, are assigned to the fourth level, 'no shades'. These green bonds are thus all treated equally in the analysis, although the reports of the providers can go in very different directions with regard to the sustainability of the respective green bond. This is particularly problematic as 95 of the 196 green bonds analyzed with SPO are classified as 'no shades', but it is not clear why investors should also use this approach. It is therefore questionable whether the results of the study are based on actual observations or on the methodological approach. Second, the three other reporting forms (verification, certification and ratings) are only examined as dummy variables, which means that no shades of green are considered and thus the approach is identical to the approach of previously cited studies (e.g. Nanayakkara and Colombage 2019; Zerbib 2019; Flammer 2021). Third, Dorfleitner et al. (2022) only use ten sustainability reports from rating agencies in their analysis. Due to the small sample size, it can be assumed that the results are not representative. Finally, it must be noted that, Dorfleitner et al. (2022) also use CBI certification for their analysis. A bond receives CBI certification when an approved external third-party verifier analyzes a bond to determine that it meets CBI's standards. In return, the bond issuer pays a fee to CBI and the external third-party verifier for the certification. This is therefore mandated certification. However, the use of mandated ratings is inconsistent with some of the academic literature.

Finch (2014) examines three different forms of rating methodology, namely solicited, unsolicited and cooperative rating, and compares them in terms of independence and acceptability. To do so, the author focuses firstly on the (financial) relationship between the rating agency and the rating object, whereby the focus here is on the independence of the rating agency from the rating object, and secondly on the data basis used by the rating agency to make its assessment of the rating object. According to Finch (2014), the rating agencies are financially independent in the case of unsolicited and cooperative rating, since in these two rating forms the agencies earn revenue by selling their rating to third parties afterwards. In solicited rating, the rating object would commission the rating agency to rate the rating object. In turn, the rating object pays a fee to the rating agency. Finch (2014) does not see any principal conflict of interest in this procedure, as independence can exist despite the fee, but points out that the rating agency must ensure that there is no conflict of interest. His analysis of the data basis comes to the conclusion that unsolicited ratings are not suitable because they only use freely available information for their analysis. Cooperative ratings, in contrast, use not only publicly available information but also supplementary internal information from the rating object, which is obtained by means of surveys, interviews or other forms of data collection. In the case of solicited ratings, the rating agencies generally have access to all the necessary internal information in order to provide the most meaningful statement possible on the rating object.

Figure 6.1: Information source for rating agencies



See Finch (2014)

Overall, Finch (2014) comes to the conclusion that only the cooperative rating is an acceptable rating because, on the one hand, only this type of rating ensures the financial independence of the rating agency and, on the other hand, the database is large enough to provide a reliable statement on the rating object. Consequently, the question of whether the sustainability of a bond has an influence on the asset pricing of the bond should be answered by using a cooperative rating.

Due to the inconsistent empirical results and the methodological concerns in the previous analyses, we base our hypotheses on the aforementioned theoretical considerations. In particular, we follow the explanations of the PST model and assume that sustainable investors derive a utility from simply holding sustainable investments. Conversely, this means that sustainable investors are willing to sacrifice returns in order to hold sustainable investments. Therefore, our first hypothesis:

H1: Green bonds have lower yields than their synthetic conventional counterparts.

We are aware that, based on the results of Pástor et al. (2021), climate shocks may be responsible for our results being contrary to our hypothesis, but we also consistently follow the theory that this is only temporary. Based on this, we again follow the theory for our second hypothesis and adopt the considerations that with increasing sustainability of an investment, sustainable investors are willing to sacrifice more return. Therefore, our second hypothesis is:

H2: The better the sustainability rating of a green bond, the lower the returns.

6.3 Methodology and data

Our methodological approach is the same approach as the one used by Zerbib (2019). Here, just like Zerbib (2019), we vary the boundaries in the matching procedure to show that our results are robust. We use this approach because it is the best possible approach under the given circumstances. The overall best approach would be if the same issuer issued two bonds with almost identical characteristics at the same time and with the same maturity. The only difference between these two bonds would be that one would be a green bond and the other a conventional bond. An example of such bond pairs would be the "twin" bonds issued by the German government in 2020 (Larcker and Watts 2020). However, since we do not know of any sustainability rating for green bonds in which a sufficient number of rated green bonds with a matching conventional twin exists, we follow Zerbib (2019) and use the model-free or direct approach. In this approach, the effect of the sustainability of a bond on the yields of the respective bond is measured by matching each green bond with a synthetic conventional bond and then examining the differences in yield spreads between the green and the synthetic conventional bond. This approach has been used in the past to study liquidity differences between bonds (Helwege et al. 2014). Therefore, in a first step, we explain the differences in yield spreads between green and matched conventional bonds by the different liquidity of the respective bonds. Based on this, we define, like Zerbib (2019), the green bond premium $\hat{p}$ as the unobserved specific effect in the regression explaining the differences in the liquidity of the bonds. In a second step we analyze the effect of our sustainability bond rating on this unobserved specific effect.

We start by examining the entire sample of 453 green bonds from the ISS ESG Sustainability Rating database. The ISS ESG Sustainability Bond Rating measures and provides a detailed overview of the ESG performance of green, social and sustainable bonds. To do this, the Sustainability Bond Rating assesses the overall sustainability of the respective bonds on a 12-level scale from d- to a+. The rating is based on an assessment of the projects financed in terms of their environmental and social effects, whether the framework conditions are aligned with the green bond principals, the ESG performance of the issuer, and whether there are any controversies related to the respective bonds. However, the rating only assesses the sustainability performance of the respective bond without addressing or providing financial metrics for the user. Due to the lack of financial market data for the green bonds, we also use Thomson Reuters Refinitiv data to obtain all financial market data for the green and conventional bonds. For 274 of the 453 green bonds in the ISS database, not all necessary financial market data for the matching process are available from Refinitiv, so that these bonds are omitted from our sample. For the remaining 179 green bonds, we have created a list of matching conventional bonds from the same issuer, where the green bonds and the conventional bonds have exactly the same characteristics in terms of currency, financial rating, bond structure, seniority, collateral and coupon type. For 18 green bonds, we could not find two matching conventional bonds with the exact same characteristics, so these green bonds are also dropped from our sample. As mentioned above, we cannot use twin bonds, which is why the conventional bonds, and the green bonds differ in liquidity and maturity. Both differences have an effect on our analysis. In order to minimize the effect of maturity in the matching process, we only use conventional bonds with a maturity neither more than two years before nor two years after the maturity of the green bond. The differences in liquidity, in turn, can be explained in part by the issue size or the issue date (Helwege et al. 2014). Therefore, we only select conventional bonds that are issued within a certain distance of the respective green bond in order to keep the differences in liquidity as small as possible. More specifically, we only use conventional bonds that (i) have an issue size of at least one quarter or at most four times that of the matching green bond and (ii) have an issue date that is at most six years earlier or at most six years later than that of the matching green bond.

Table 6.1: Sample selection for the first matching

	Number of green bonds
Total ISS ESG Sustainability Bonds universe	453
- Green bonds with missing matching data	274
Green bonds available for matching	179
- Green bonds discarded in exact matching	18
Green bonds after exact matching	161
- Green bonds discarded in distance matching	100
Green bonds after matching	61
- Green bonds without yields or prices	5
Final green bond sample	56

The table shows the process for selecting the green bonds sample.

Since we exclude all green bonds from our sample for which we do not find two matching conventional bonds according to the above matching parameters, 100 bonds are excluded. Finally, we check whether the ask yields for all green bonds and their conventional counterparts are available and only take into account observations where the ask yields are available for all three bonds. All green bond triples with missing values are excluded. In total, 56 green bond triples remain (see Table 6.1).

Since we want to explain the differences in yields between the green bond and its synthetic conventional counterpart in the first regression, we first need to identify the dependent variable $\Delta\bar{y}_{i,t}$ which is the yield difference between the green bond and its synthetic match. To do this, we interpolate (extrapolate) the yields of the conventional bonds (CB) linearly to the maturity of the matching green bond to obtain the yield of the synthetic bond $\bar{y}_{i,t^{CB}}$. $\bar{y}_{i,t^{CB}}$ and the yield of the green bond (GB) $y_{i,t^{GB}}$ then differ only in terms of liquidity while all other characteristics are the same. Therefore, $\Delta\bar{y}_{i,t}$ can be calculated as follows:

$$\Delta\bar{y}_{i,t} = y_{i,t}^{GB} - \bar{y}_{i,t}^{CB} \tag{1}$$

As the matching process limited but did not completely eliminated differences in liquidity based on the selection criteria, we use proxies to control for differences in liquidity. To do so, we create the variable ΔLiq by calculating the difference between the liquidity of the green bond and the synthetic conventional bond. Therefore, we have to measure the liquidity of the green bond, which we calculate from the bid-ask spread of the respective green bond as follows:

$$Liq_{i,t}^{GB} = y_{i,t}^{gb,bid} - y_{i,t}^{gb,ask} \tag{2}$$

Where $Liq_{i,t}^{GB}$ represents the liquidity of the green bond, while $y_{i,t}^{gb,bid}$ represents the bid-yield of the respective green bond and $y_{i,t}^{gb,ask}$ represents the ask-yield of the respective green bond. The liquidity of the synthetic conventional bond $Liq_{i,t}^{syn}$ is calculated on the basis of the two underlying conventional bonds. As with the green bond, the liquidity of the two underlying conventional bonds is first calculated for each of the two conventional bonds. In a second step, the liquidity of the synthetic conventional bond is computed by interpolating the two previously calculated liquidity values of the two conventional bonds. The formula used for this is:

$$Liq_{i,t}^{syn} = Liq_{cb_{i,t}} \frac{Liq_{cb_{j,t}} - Liq_{cb_{i,t}}}{Mat_{cb_{j,t}} - Mat_{cb_{i,t}}} \times \left(Mat_{gb_t} - Mat_{cb_{i,t}}\right) \tag{3}$$

Where $Liq_{cb_{j,t}}$ and $Liq_{cb_{i,t}}$ represent the liquidity of the respective individual conventional bonds and $Mat_{cb_{j,t}}$ and $Mat_{cb_{i,t}}$ represent the maturity of the conventional bonds. Based on this, the liquidity proxy $\Delta Liq_{i,t}$ is then determined as follows:

$$\Delta Liq_{i,t} = Liq_{i,t}^{gb} - Liq_{i,t}^{syn} \tag{4}$$

As mentioned above, we define the green bond premium as the unobserved specific effect in a regression to explain the yield differentials between the green bond and the synthetic conventional bond by the liquidity $\Delta Liq_{i,t}$. Therefore, we estimate the following regression:

$$\Delta \bar{y}_{i,t} = p + \beta \Delta Liq_{i,t} + \in \tag{5}$$

Where $\Delta \bar{y}_{i,t}$ is the yield difference of the green and synthetic conventional bond, p is the unobserved specific effect, which we define as the green bond premium, $\Delta Liq_{i,t}$ is the difference of our two liquidity proxies, and ∈ is the error term.

Finally, using OLS regression and OLS regression with Newey-West robust estimators of standard errors, we estimate the impact of green bond sustainability ratings on the unobserved specific effect (i.e. the green bond premium). We control for various bond characteristics, namely currency, sector, amount issued and financial rating. Due to the small sample, we group the financial ratings into the two categories A and B, since individual ratings (e.g. AAA) have only a limited number of observations. Here, all bonds with a financial rating BBB and all financial ratings with at least A to AAA are combined. The final equation to answer the research questions is therefore:

$$\hat{p}_i = \alpha_0 + \alpha_1 Green\ Bond\ Rating + \sum_{j=1}^{N_{Currency}-1} \alpha_2 Currency + \alpha_3 Amount\ Issued + \sum_{j=1}^{N_{Financial\ Rating}-1} \alpha_4\ Financial\ Rating + \sum_{j=1}^{N_{Issuer\ Type}} \alpha_5\ Issuer\ Type + \in \tag{6}$$

Table 6.2: Descriptive distribution of different characteristics

Variable	Obs.	Relative	Variable	Obs.	Relative
Sustainable Bond Rating	56	100%	Issuer Type	56	100%
a	2	4%	AGCY	12	21%
a-	5	9%	CORP	8	14%
b+	18	32%	FIN	13	23%
b	12	21%	SOV	2	4%
b-	11	20%	SSOV	5	9%
c+	0	0%	SUPR	16	29%
c	7	13%			
c-	0	0%	Currency	56	100%
d+	1	2%	A$	3	5%
			C$	1	2%
Financial Rating	56	100%	Eur	31	55%
A	48	86%	MP	1	2%
B	8	14%	SK	9	16%
			U$	11	20%

The table shows various characteristics of the 56 green bonds examined, whereby all characteristics are identical for the green bonds and the conventional bonds with the exception of the sustainable bond rating (see matching process).
The abbreviations for the issuer type stand for Agency (AGCY), Corporate (CORP), Financial Institution (FIN), Sovereign (SOV), Sub-Sovereign (SSOV), Supranational (SUPR).
The currency abbreviations stand for Australian Dollar (A$), Canadian Dollar (C$), Euro (Eur), Mexican Peso (MP), Swedish krona (SK) and U.S. Dollar (U$).

A total of 56 bond triplets with 43201 daily observations in an unbalanced panel are studied. The observation period is from February 24, 2014 to the end of 2020. All bonds have a fixed coupon to eliminate the impact of varying coupons. In addition, all bonds are investment grade. The issuers are dominated by government (SOV), subgovernment (SSOV, i.e. North Rhine-Westphalia) and agency (i.e. NRW Bank) as well as supranational organizations (SUPR; i.e. Asian Development Bank, European Investment Bank). The most common bond currencies are Euro (Eur), Swedish krona (SK) and U.S.-dollar (U$). In terms of Sustainable Bond Ratings, most bonds have a rating of at least b- (85%), placing them in the upper half of possible ratings. In contrast, the top quarter (a- and above) of possible ratings is achieved by only a small proportion of bonds (13%). No green bond receives the best possible sustainability rating of a+.

6.4 Results

6.4.1 First matching approach

In the first step of the analysis, the differences in yields between a green bond and its synthetic conventional counterpart are explained by liquidity. Table 6.3 shows that $\Delta Liq_{i,t}$ takes a positive value in each case, since the min value is >0. This shows that the liquidity of green bonds is higher than the liquidity of synthetic bonds, since the values of $\Delta Liq_{i,t}$ are calculated using equation (4).

Table 6.3: Liquidity proxy distribution

	Min.	1st Qu.	Median	Mean	3rd Qu.	Max.	Std. Dev.
Δ Liq$_{i,t}$	0.01	0.11	0.18	0.22	0.3	0.66	0.16

The table shows the distribution of the values of the liquidity proxy ΔLiq. Here, we subtract the liquidity of the synthetic conventional bond from the liquidity of the green bond.

The associated regression in Table 6.4 has similar value as Zerbib (2019). The sign of the variable $\Delta Liq_{i,t}$ (ΔBA in the case of Zerbib (2019)) is negative, indicating that an increase in

$\Delta Liq_{i,t}$ leads to a decrease in $\Delta\bar{y}_{i,t}$. Thus, it would mean that as liquidity differences increase, yield differences would decrease. However, the value of R^2 is very small at 0.005 (0.013 for Zerbib (2019)). Zerbib (2019) argues here that the small value of the R^2 should not be thus highly valued because (i) he repeats the regression with different (Newey-West; Beck-Katz) robust standard errors and these are highly significant, (ii) Zerbib (2019) does not want to infer from his results to others, and (iii) he considers the regression useful to develop a general method. However, unlike Zerbib (2019), the present regression is no longer significant once the regression is re-estimated with Newey-West robust standard errors. This result therefore indicates that the assumptions of the regression model are violated in the present regression and thus the estimated model is not significant. Thus, the differences between the yields cannot be explained by liquidity. The methodological problem arises here that the general method developed by Zerbib (2019) cannot be reproduced in the present sample.

Table 6.4: Results of the step 1 regression

	Dependent variable: $\Delta\bar{y}_{i,t}$	
	Fixed-effects	Newey-West robust std. err.
Δ $Liq_{i,t}$	-0.191***	-0.191
	(0.013)	(0.451)
Observations	43.201	
R^2	0.005	
Adjusted R^2	0.004	
F Statistic	226.616*** (df = 1; 43144)	

The table shows the results of the step 1 regression. Here, the difference in yields is explained by the difference in liquidity. In addition, the regression is estimated with Newey West robust standard errors. The standard errors are given in parentheses. Note: *p < 0.1 , **p < 0.05 , ***p < 0.01

Table 6.5: Distribution of the estimated green bond premium

	Min.	1st Qu.	Median	Mean	3rd Qu.	Max.
$\hat{p}_i$	-1.9	-0.05	0	0	0.05	2.96

The table shows the distribution of the green bond premium for the entire sample.

Despite this methodological problem, the distribution of the estimated green bond premium and the step 2 regression can be seen in tables 6.5 and 6. Unlike Zerbib (2019), we also use Newey-West robust standard errors in this second regression, while Zerbib (2019) switches to White robust standard errors without further justification. Table 5 shows that the estimated green bond premium distributes around 0. Consistently, the mean and median values are 0 and the 1st and 3rd quantiles each have the same value of 0.05, although the sign turns from negative to positive. The two hypotheses **H1** and **H2** have to be rejected, as no specific effect can be observed and therefore cannot explain the yield differences between green bonds and conventional bonds. Consequently, we cannot show that a better sustainability rating of a green bond has an effect on the return of the respective bond.

Table 6.6: Results of the step 2 regression

	Dependent variable: $\hat{p}_i$		
		OLS based on Fixed-effects	Newey-West robust std. err.
	Constant	0.000	0.000
		(0.016)	(0.013)
	Green Bond Rating	-0.000	-0.000
		(0.005)	
Currency	C$	-0.000	-0.000
		(0.016)	
	Euro	-0.000	-0.000
		(0.008)	(0.006)
	MP	-0.000	-0.000
		(0.015)	(0.007)
	SK	0.000	0.000
		(0.010)	(0.010)
	U$	-0.000	-0.000
		(0.008)	(0.004)
Financials	Amount Issued	-0.000	-0.000
		(0.000)	
	Rating B	-0.000	-0.000
		(0.005)	(0.002)
Issuer	Corp	0.000	0.000
		(0.006)	
	Financial	0.000	0.000
		(0.006)	
	SOV	0.000	0.000
		(0.009)	
	SSOV	0.000	0.000
		(0.006)	
	Supra	0.000	0.000
		(0.007)	
	Observations	43.201	
	R^2	0	
	Adjusted R^2	-0.003	
	F Statistic	0.000	
		(df = 13; 43187)	

The table reports the results of the step 2 regression. Here, the green bond premium is explained by the sustainability rating of the green bonds and other characteristics, such as currency, issuer, issue amount, and financial rating. The financial rating is summarized in two groups 'A' and 'B', of which 'A' is the reference group in the regression. In addition, the regression is estimated with Newey West robust standard errors. Standard errors are indicated in parentheses. Note: *p < 0.1, ∗∗p < 0.05, ∗∗∗p < 0.01

6.4.2 Second matching approach

Based on the problems with the non-significant results in the first regression, we again focus on the strong impact of liquidity on yields described by Zerbib (2019). Zerbib (2019) takes a double approach to avoid the bias by using interpolation (extrapolation) on the one hand and by setting time bounds already at matching on the other hand. Since the use of interpolation (extrapolation) is difficult to replace, we resort to a robustness check used by Zerbib (2019) and tighten the temporal matching criteria. To do this, we halve the temporal frame constraints at each matching criterion. As a result, we assign to each green bond only those conventional bonds that (i) have an issue amount of at most 2 times and at least 0.5 times the green bond and (ii) have an issue date that is at most 3 years before or after the issue date of the green bond.

Table 6.7: Sample selection for the second matching approach

	Number of green bonds
Total ISS ESG Sustainability Bonds universe	453
- Green bonds with missing matching data	274
Green bonds available for matching	179
- Green bonds discarded in exact matching	18
Green bonds after exact matching	161
- Green bonds discarded in distance matching	140
Green bonds after matching	21
- Green bonds without yields or prices	0
Final green bonds sample	21

The table shows the process for selecting the green bonds sample. In contrast to the first sample selection, stricter matching criteria were used, so that the number of observations decreased.

These changes reduce the number of green bonds examined to 21 bond triples (see Table 6.7) and a total of 14558 observations.

While the results for the distribution of the liquidity proxy change only slightly (Table 6.8), the results for the Step 1 regression change fundamentally. Unlike the first Step 1 regression in Table 6.4, the results are now significant at the 1% level even when using Newey-West robust estimators. This means that in the second Step 1 regression (Table 6.9), the differences in liquidity can explain the differences in yields. In addition, there is an unobserved specific effect, which we defined as the green bond premium.

Table 8: Liquidity proxy distribution for the second matching approach

	Min.	1st Qu.	Median	Mean	3rd Qu.	Max.	Std. Dev.
Δ $Liq_{i,t}$	0.01	0.09	0.18	0.21	0.3	0.56	0.14

The table shows the distribution of the values of the liquidity proxy ΔLiq. Here, we subtract the liquidity of the synthetic conventional bond from the liquidity of the green bond. In contrast to the results, stricter matching criteria were used, so that the number of observations decreased.

Despite this change, the results of the distribution of the estimated green bond premium (Table 10) and the Step 2 regression (Table 11) are comparable to the results for the outcomes. No green bond premium can be shown statistically either descriptively or by regression. The distribution of the green bond premium is around 0, with the mean and median again taking the value 0. The second step 2 regression, analogous to the first step 2 regression, yields only insignificant results. From this it can be deduced that the previously made statement that both hypotheses **H1** and **H2** have to be rejected has passed. In addition, the rejection of both hypotheses remains even if the step 1 regression (Table 6.9) is significant. Thus, the methodological problems of the first Step 1 (Table 6.4) and Step 2 regressions (Table 6.6) did not affect the results.

Table 6.9: Results of the step 1 regression

	Dependent variable: $\Delta\bar{y}_{i,t}$	
	Fixed-effects	Newey-West robust std. err.
Δ $Liq_{i,t}$	0.340***	0.340***
	(-0.022)	(-0.115)
Observations	14.558	
R^2	0.017	
Adjusted R^2	0.015	
F Statistic	244.370*** (df = 1; 14536)	

The table shows the results of the step 1 regression for the robustness checks. In contrast to the first step 1 regression, stricter matching criteria were used, so that the number of observations decreased. Here, the difference in yields is explained by the difference in liquidity. In addition, the regression is estimated with Newey West robust standard errors. The standard errors are given in parentheses. Note: *p < 0.1, **p < 0.05, ***p < 0.01

These results are at odds with Zerbib (2019). If Zerbib (2019) narrows the time periods for the matching criteria, they become insignificant. He reasons that the differences in liquidity are then too small for liquidity to explain the difference in yields. He further concludes that his method and the initial periods are robust, since the distributions of the estimated green bond premium are very similar in both cases, i.e., wide (first matching) and narrow (second matching) matching criteria. He therefore concludes that despite insignificant step 1 regression, the distributions in both versions indicate that, in principle, a green bond premium is observable. As described above, in the present study there are conflicting results because, first, the step 1 regression (Table 4) first becomes insignificant and then significant (Table 6.9) with narrower (second matching) matching criteria. Second, in both step 2 regressions (Table 6.6 and 6.11) the results are insignificant. Thus, it is questionable whether Zerbib's (2019) arguments are tenable that (i) with narrower matching criteria the differences in liquidity become too small to explain the yield differences, since we obtain exactly opposite results as described. Furthermore, it is questionable whether (ii) the very similar distributions of the estimated green bond premium can be taken as an indication of the presence of a premium even in the presence of insignificant results, since we also have very similar distributions of the estimated green bond premium (Table 6.5 and 6.10), but always obtain insignificant results. Third, (iii) the general result of Zerbib (2019) must also be questioned, since despite using the general method developed by Zerbib (2019), we cannot reproduce his results on a different data set.

Table 10: Distribution of the estimated green bond premium for the second matching approach

	Min.	1st Qu.	Median	Mean	3rd Qu.	Max.
$\hat{p}_i$	-1.82	-0.05	0	0	0.06	1.6

The table shows the distribution of the green bond premium for the entire sample. In contrast to the results, stricter matching criteria were used, so that the number of observations decreased.

Table 6.11: Results of the step 2 regression

	Dependent variable: $\hat{p}_i$		
		Fixed-effects	Newey-West robust std. err.
	Constant	0.000	0.000
		(0.069)	(0.057)
	Green Bond Rating	-0.000	-0.000
		(0.021)	(0.021)
Currency	C$	-0.000	-0.000
		(0.021)	
	Euro	-0.000	-0.000
		(0.012)	
	SK	0.000	0.000
		(0.014)	
	U$	-0.000	-0.000
		(0.020)	(0.012)
Financials	Amount Issued	-0.000	-0.000
		(0.000)	
	Rating B	-0.000	-0.000
		(0.012)	(0.003)
Issuer	Corp	0.000	0.000
		(0.027)	(0.012)
	Financial	0.000	0.000
		(0.010)	
	SSOV	0.000	0.000
		(0.009)	
	Supra	0.000	0.000
		(0.013)	
	Observations	14,558	
	R^2	0	
	Adjusted R^2	-0.001	
	F Statistic	0.000	
		(df = 11; 14546)	

The table reports the results of the step 2 regression. In contrast to the first step 2 regression, stricter matching criteria were used, so that the number of observations decreased. Here, the green bond premium is explained by the sustainability rating of the green bonds and other characteristics, such as currency, issuer, issue amount, and financial rating. The financial rating is summarized in two groups 'A' and 'B', of which 'A' is the reference group in the regression. In addition, the regression is estimated with Newey West robust standard errors. Standard errors are indicated in parentheses. Note: *p < 0.1, ∗∗p < 0.05, ∗∗∗p < 0.01

6.5 Conclusion

Since the European Investment Bank issued the first green bond, this new financial product has gone from a niche product to a mainstream product. Nevertheless, not all questions about this new product have been answered so far. Therefore, in this research paper we investigate the question whether a (better) sustainability rating has an impact on the return of green bonds compared to conventional bonds.

From a theoretical perspective, a green bond should provide a lower return than a comparable conventional bond. The background to this is that sustainable investors benefit from holding a sustainable investment. It follows that for sustainable investors the total benefit consists of the benefit of the return and the benefit of holding the sustainable investment. With this total benefit, the return can be lower than for conventional investors, since the benefit from holding the sustainable investment compensates for the lack of benefit from the low return compared to the benefit from the higher return for conventional investors.

Our research does not provide evidence for these theoretical considerations. We cannot show empirical evidence that sustainable investors are willing to forgo returns, nor does the level of sustainability rating affect whether investors forgo returns. Additionally, we must question the results of adjacent research because we follow the methodology developed by Zerbib (2019) for our study and cannot replicate his results with a different sample. In addition, we find evidence that the method developed by Zerbib (2019) is possibly influenced by the chosen boundaries in the matching process and does not provide general results.

Based on the problems of the chosen boundaries in the matching process, the question of whether sustainability ratings have an impact on the return of green bonds should be investigated with another matching process. For this purpose, so-called twin bonds could be used, since in twin bonds the green and the conventional bonds only differ in that one is a green bond. Thus, no complex matching process would be necessary, and the influence of this process could be excluded. However, as described above, we are not aware of any database in which sufficient twin bonds have been evaluated in terms of their sustainability. Therefore, this research approach could not be pursued further so far.

The relevance of this paper for investors, scholars and regulators described above remains and cannot be conclusively clarified in this paper, but all three groups can take away that the underlying research question is still unanswered.

7. Conclusion

Based on the realization at the end of the 19th century that the concentration of CO_2 in the atmosphere has an influence on the global climate and the fact that the human caused emission of CO_2 is large enough to cause such a change in the global climatic conditions, the most countries of this world agreed in 2015 to stop this change. To this end, the global temperature increase is to be limited to below 2.0° Celsius, the resilience of the world community to existing and future climate-related changes is to be strengthened, and financial flows are to be redirected so that they contribute to limiting climate change and building resilience. The redirection of financial flows towards more sustainability goes hand in hand with a restructuring of the entire economic and financial system, so that the influence of CO_2 and sustainability data on the financial markets must be researched in order to continue to have a scientifically sound understanding of (sustainable) finance. This thesis is intended to make a contribution to this strand of research.

Given that chapter 1 provides the introduction and classification of the thesis and chapter 2 merely lays the foundations for the methods used in this thesis, the conclusion is based on chapters 3 to 6. The aim of chapter 3 is to clarify whether the financial participation of private households in the transformation of the economy to a low-carbon economy as demanded by the HLEG (2018) is possible. The background to this is that the OECD (2017) states that a large proportion of human-induced CO_2 emissions are emitted by the energy, buildings, transport, and water consumption sectors. Furthermore, Granoff et al. (2016) describe the so-called lock-in effect, which means that once infrastructure is built, it cannot be reduced below a certain level of CO_2 emissions without completely replacing the infrastructure. In addition, the HLEG (2018) describes that on the one hand there is a huge financial need to reach the Paris climate targets and on the other hand 40% of the savings are controlled by households, which makes it imperative that retail investors participate in the financing of a low-carbon economy. Nevertheless, our analysis shows that while LCIIPs exist and retail investors can invest in such products, investment barriers can discourage retail investors from investing in them. In particular, we can show that it is mainly the lack of transparency of decision-relevant data that constitutes a problem. More precisely, the LCIIPs found either do not provide classical financial ratios or ratios on CO_2 emissions or their reduction by the investment at all, or the data are difficult to compare with other LCIIPs. It follows that retail investors cannot make a fact-based decision on LCIIPs because they do not have the necessary and comparable information to do so, thus creating a relevant investment barrier.

The aim of chapter 4 is to gain a better understanding of the integration of CO_2 data into financial markets by institutional investors and to determine what expectations investors have with regard to climate and sustainability transition risks. The background is that the EU is trying to create transparency with regard to the CO_2 emissions of individual business activities of companies through various regulations and rules. This additional transparency can then be used by investors to adjust their institutional investment processes. In contrast, there are a number of research studies that make it clear that transparency fails to achieve its goal on the part of both companies and investors. In addition, the IPCC's (2021) latest report states that the time to comply with the Paris climate change agreements is limited and that a major transformation of the economy to a low-carbon economy must be addressed as soon as possible. A significant finding of our work is that respondents would like to see mandatory uniform reporting for both real economy and financial products. This desire reflects, among other things, the fact that most investors surveyed consider the current data situation to be inadequate and not very comparable. In addition, this insufficient data situation seems to lead to an underestimation of climate risks, even by sustainable investors, although the majority of those surveyed take CO_2 emissions into account in their investment decisions in a variety of ways.

The objective of chapter 5 is to find out whether taxonomy compliance in energy production has a negative (positive) impact on portfolio returns of energy infrastructure portfolios. The background are the reasons already given for chapters 3 and 4. Here, the high CO_2 emissions in energy infrastructure (chapter 3) and the regulatory pressure to minimize CO_2 emissions through regulations from the EU (chapter 4) are particularly noteworthy. In contrast to chapters 3 and 4, this chapter does not focus on the investors, but on the investment objects. The result of our analysis is that portfolios that follow the taxonomy achieve a higher risk-adjusted return than comparable portfolios of EEUs with a high share of conventional power generation. This result can be explained in part by the fact that there is a carbon and energy mix premium. It follows that EEUs with low carbon emissions have a low cost of capital. After the period studied in this chapter, the EU has decided, contrary to common expectations, that nuclear and gas-fired power generation is now considered taxonomy compliant. This in turn may tempt investors to focus on CO_2 emission-intensive investments in the short term (see Introduction, chapter 4). Therefore, it is possible that a new study will come to a different conclusion.

The aim of chapter 6 is to clarify whether investors are willing to forego (higher) returns if green bonds have a (better) sustainability rating. The background to this chapter is the transformation of the economy mentioned above and, in particular, the financing of this transformation. In addition, the chapter is based on the theoretical considerations that sustainable investors are willing to forego returns. More precisely, sustainable investors derive a benefit from simply holding a sustainable investment. In addition, there is the benefit from the financial return of the sustainable investment and the two benefits together result in the total benefit of the sustainable investor. Therefore, the total benefit of a sustainable investor can be as large as the total benefit of a conventional investor despite lower returns if the benefit from holding the sustainable investment offsets the smaller benefit from the lower return of a sustainable investment. The result of our analysis is that we find no evidence that investors are willing to sacrifice returns when they invest in sustainable investments. At first glance, this finding contradicts the results of chapter 5, which clearly shows that there is a positive relationship between return and low CO_2 emissions, while chapter 6 did not find a relationship between sustainability and return. One reason for this may be that another result of chapter 6 is that the method used in chapter 6 does not provide reproducible results. Another possible explanation may be that different asset classes are considered. In chapter 5, equity returns are considered, while in Chapter 6, bonds are examined. This may be crucial for two reasons, (i) first, we do not exclusively look at corporate bonds, but also at public sector bonds, so it may be that market participants value public sector bonds differently and thus that overall no difference in returns is detectable. Second, (ii) differences between different organizations may be the reason for these different observations, but we always consider bonds of the same organization with each other and use matching procedures to explicitly eliminate the differences between the different organizations.

Overall, the research cited in chapters 3 to 6, as well as this thesis' own findings, show that CO_2 and sustainability data have an increasing impact on financial markets and their participants. Furthermore, this influence is expected to increase over time, as on the one hand the climate crisis and its consequences will have an increasing impact on policy makers and supranational organizations. The EU, as one of these supranational organizations, is adopting increasingly stringent targets (chapter 5) to limit CO_2 emissions and the consequences of climate change. For this purpose, the EU relies on increasing transparency in the reporting of CO_2 emissions and the consideration of these data in decision-making (chapter 4). Although the present study can confirm this fundamental connection (chapter 4), the published data in parts of the study conducted here are or were insufficient and not very comparable (chapters 3 and 4). This circumstance poses an obstacle to research on the relationship between CO_2 and sustainability data and their influence on financial markets. For investors, this problem is even greater, as their decisions on these very data have a real impact on financial markets and thus indirectly on the real economy. It follows that, in implementing its numerous plans and measures (chapters 4 and 5), the EU must take care that implementation and, in particular, unexpected decisions do not lead to short-term aspects being taken into account more than long-term ones (chapters 4 and 5). Especially if these decisions can lead to decisions being made that have long-term implications (chapter 3). An example is the decision that gas-fired power generation is taxonomy compliant and thus investors might decide to invest in gas-fired power plants. Moreover, this short-term view may be a reason why even sustainable institutional investors underestimate the negative impacts of the transformation of the economy (chapter 4). Therefore, the uniform mandatory disclosures demanded by institutional investors for the real economy as well as for financial products are logical. This would make it easier for professional investors to take CO_2 and sustainability data into account through the mandatory disclosure that would then apply and would also give retail investors the opportunity to take such data into account when deciding for or against a financial product. Furthermore, a uniform mandatory disclosure of CO_2 emissions would help to overcome the limitations of the individual studies described in various chapters. Therefore, a uniform and mandatory disclosure is imperative not only to provide market participants with a basis for their decisions, but also to determine the impact of CO_2 and sustainability data on financial markets even more precisely than in this thesis.

Nevertheless, this thesis cannot clarify all questions regarding the influence of CO_2 and sustainability data on financial markets, which is why further research is needed. This research can be put forward to different points. In the future, it must be clarified whether and which effects a uniform regulation has and whether and how this contributes to closing the enormous financing gaps in the transformation of the economic system. In addition, it should be examined whether the theoretical considerations regarding sustainable and non-sustainable investors are correct and whether, in the long term, i.e. after the transition phase described, sustainable investments lead to lower returns than comparable conventional investments. In this context, it should be ensured that not only a comparison between investments in different companies is made, but also that attention is paid to how investments (e.g. bonds) in the same company behave. In addition, research on the impact of CO_2 and sustainability data in all other financial areas not considered in this thesis, such as risk management, should be expanded and the existing research should be deepened, so that the understanding of the impact of CO_2 on financial markets becomes intense and more comprehensive than it is now. Moreover, the HLEG (2018) already indicates that it understands sustainable finance to be much more than simply looking at CO_2 emissions. It follows that the questions examined in this paper should be asked again, only that in this renewed questioning, the question of how, for example, biodiversity data affect financial markets should be explored.

Appendix

Appendix chapter 3

Table 3.3 List of used LCIIPs

Product Name	Group	ISIN
Next Energy Solar Fund	infrastructure funds on stocks	GG00BJ0JVY01
Greencoat UK Wind	infrastructure funds on stocks	GB00B8SC6K54
KBC Eco Fund Alternative Energy	infrastructure funds on stocks	BE0175280016
Etho Climate Leadership U.S. ETF	infrastructure funds on stocks	US26924G8886
Neoen	infrastructure funds on stocks	FR0011675362
Bioenergiepark München Ost	crowdfunding	n.a.
Wattner SunAsset 8	crowdfunding	n.a.
Nachrangdarlehen Megawatt Photovoltaikanlage mit Netzanbindung in Ägypten_8%	crowdfunding	n.a.
Projekt Kuba	crowdfunding	n.a.
KCD-Catella Nachhaltigkeit Immobilien Deutschland	infrastructure funds on stocks	DE000A2DHR68
SwimSol	crowdfunding	n.a.
BlackRock Global Funds -Sustainable Energy Fund D2	infrastructure funds on stocks	LU0252969661
EXYTRON II	crowdfunding	n.a.
Autarq Solarziegel	crowdfunding	n.a.
Deutsche Konsum REIT AG	infrastructure funds on stocks	DE000A14KRD3
Deutsche Euroshop	infrastructure funds on stocks	DE0007480204
Hamborner REIT	infrastructure funds on stocks	DE0006013006
alstria office REIT-AG Aktie	infrastructure funds on stocks	DE000A0LD2U1
fair value REIT-AG	infrastructure funds on stocks	DE000A0MW975
Nachrangdarlehen Emmy Green City GmbH	crowdfunding	n.a.
Nachrangdarlehen_Refinanzierung zweiter Phovoltaikanlagen in Naivasha und Nanyuki, Kenia_6%	crowdfunding	n.a.

Nachrangdarlehen_Salinenpark	crowdfunding	n.a.
Nachrangdarlehen_Solarprojekte_Deutschland-dritte_Tranche_7%	crowdfunding	n.a.
Nachrangdarlehen_Central University Lehre & Administration_5,50%	crowdfunding	n.a.
Nachrangdarlehen_Energetische Modernisierung zweier Wohnhäuser in Thüringen_7%	crowdfunding	n.a.
Nachrangdarlehen_Energieeffizienzhäuser Mylau_6%	crowdfunding	n.a.
HEP Solar Portfolio 1	participation rights	DE000A2JQLP6
Ökorenta erneuerbare Energien 10	participation rights	n.a.
Bürgerenergiegenossenschaft Wolfhagen eG	participation rights	n.a.
Bürger Energie Kassel & Söhre eG	participation rights	n.a.
Gaalbern Bürgersolarpark GbR	participation rights	n.a.
Bürgersolarpark Rhein-Main	participation rights	n.a.
Hornet Infrastructure - Water Fund	infrastructure funds on stocks	LI0034053376
Holzgas BHKW Sonnefeld	crowdfunding	n.a.
Solare Tröpfchenbewässerung Marokko - zweite Tranche	crowdfunding	n.a.
Energieeffizienzhaus Wintersteinstrasse	crowdfunding	n.a.
CS Real Estate Fund Green Property	infrastructure funds on stocks	CH0100778445
SF Sustainable Property Fund	infrastructure funds on stocks	CH0120791253
Lion Umbrella Fund I S.A., SICAV-RAIF - PANGAEA	infrastructure funds on stocks	LU1675428244

The table provides the names, group and ISIN of the analysed LCIIPs.

Appendix chapter 4

In Chapter 4, a survey of institutional inevstors is conducted to collect data. Since this survey was conducted in German, the questionnaire is reproduced here in its original German version for the sake of transparency. The questions analyzed in chapter 4 have been translated into English in chapter 4.

Liebe Teilnehmerin, lieber Teilnehmer,

Die Universität Hamburg und die Universität Kassel führen im Rahmen des vom Bundesminisertium für Bildung und Forschung geförderten Projektes „Klimaberichterstattung als Instrument zur CO_2-Reduktion“ (CRed) eine Umfrage durch. Wir möchten Sie daher bitten, uns einige Fragen zu der Verwendung von Treibhausgasinformationen in Ihrer Organisation zu beantworten. Die Daten werden anonym erhoben und können Ihnen oder Ihrer Organisation nicht zugeordnet werden. Wir bedanken uns herzlich für Ihre Teilnahme an dieser Umfrage.

Teil A: Selbstauskunft

A1. Bitte ordnen Sie Ihre Organisation einer der folgenden Organisationsarten zu...

- Asset Manager
- Kapitalanlagegesellschaften
- Banken und Finanzinstitute
- Kirchliche Institutionen und Wohlfahrtsorganisationen
- Versicherungsunternehmen und Vereine auf Gegenseitigkeit
- Stiftungen
- Öffentliche Pensions- oder Reservefonds
- Genossenschaftliche und betriebliche Pensionsfonds
- Öffentliche Hand
- Universitäten und andere wissenschaftliche Einrichtungen
- Sonstiges

A2. Welche(n) Titel/ Position haben Sie?

- Fonds-/ Portfoliomanager(in)
- Investmentanalyst(in)
- ESG/ Nachhaltigkeits-Investment Spezialist(in)
- Leiter(in) Nachhaltigkeit
- Chief Investment Officer
- CFO / COO / Vorstandsmitglied / Other Executive
- Geschäftsführer(in) / geschäftsführende(r) Direktor(in)
- Chief Executive Officer
- Keine Angabe
- Sonstiges

Teil B: Selbstauskunft

B1. Wie hoch ist das von Ihrer Organisation verwaltete Vermögen in Milliarden €?

- < 0,1
- > 0,1 - 0,5
- > 0,5 – 1
- > 1 – 5
- > 5 – 10
- > 10 – 25
- > 25 – 50
- > 50 – 75
- > 75 – 100
- > 100
- Keine Angabe
- Sonstiges

B2. In welchem Land ist der Hauptsitz/ das Headquarter Ihrer Organisation (Muttergesellschaft)?

Teil C: Selbstauskunft

C1. Wie lange ist die durchschnittliche Haltedauer eines Investments in Ihrer Organisation?

- Weniger als 6 Monate
- 6 Monate bis unter 2 Jahre
- 2 Jahre bis unter 5 Jahre
- 5 Jahre bis unter 10 Jahre
- Mehr als 10 Jahre
- Keine Angabe

C2. Wie hoch ist der prozentuale Anteil der nachhaltigen Finanzanlagen gemessen am gesamten verwalteten Vermögen Ihrer Organisation?

- 0 - 1%
- > 1 - 5%
- > 5 - 10%
- > 10 - 25%
- > 25 - 50%
- > 50 - 75%
- > 90 - 95%
- > 95 - 99%
- > 99%
- Keine Angabe
- Sonstiges

C3. Wie hoch ist der Anteil aktiver und passiver Investments in Ihrer Organisation (Angaben in %)?

- Anteil aktiver Investments
- Anteil passiver Investments

Teil D: Materialität von Treibhausgasemissionen

D1. Ihrer Einschätzung nach sind die Auswirkungen einer Reduktion der Treibhausgasemissionen auf die finanzielle Performance in den nächsten zwei Jahren für Unternehmen der jeweiligen Branche...

	Sehr negativ	Negativ	Keine Auswirkung	Positiv	Sehr positiv	Keine Angaben
Öl & Gas						
Rohstoffe						
Industrie						
Konsumgüter						
Nahrungsmittel						
Gesundheits-Versorgung						
Finanzen						
IT						
Kommunikation						
Strom-/Gas-/ Wasserversorgung						
Immobilien						

D2. Ihrer Einschätzung nach sind die Auswirkungen einer Reduktion der Treibhausgasemissionen auf die finanzielle Performance in den nächsten fünf bis zehn Jahren für Unternehmen der jeweiligen Branche...

	Sehr negativ	Negativ	Keine Auswirkung	Positiv	Sehr positiv	Keine Angaben
Öl & Gas						
Rohstoffe						
Industrie						
Konsumgüter						
Nahrungsmittel						
Gesundheits-Versorgung						
Finanzen						
IT						
Kommunikation						
Strom-/Gas-/ Wasserversorgung						
Immobilien						

Teil E: Materialität von Treibhausgasemissionen

E1. Bitte bewerten Sie, welche Bedeutung folgende Risiken für Ihren Investmentprozess in den nächsten zwei Jahren haben werden:

	Sehr niedrige Bedeutung	niedrige Bedeutung	Moderate Bedeutung	Hohe Bedeutung	Sehr Hohe Bedeutung	Keine Bedeutung	Keine Angabe
Finanzielle Risiken							
Operative Risiken							
Ökologische Risiken							
Regulatorische Risiken							
Physische Risiken							
Technologische							

Risiken							
Soziale Risiken							
Governance Risiken							

E2. Bitte bewerten Sie, welche Bedeutung folgende Risiken für Ihren Investmentprozess in den nächsten fünf bis zehn Jahren haben werden:

	Sehr niedrige Bedeutung	niedrige Bedeutung	Moderate Bedeutung	Hohe Bedeutung	Sehr Hohe Bedeutung	Keine Bedeutung	Keine Angabe
Finanzielle Risiken							
Operative Risiken							
Ökologische Risiken							
Regulatorische Risiken							
Physische Risiken							
Technologische Risiken							
Soziale Risiken							
Governance Risiken							

Teil F: Berücksichtigung von Treibhausgasemissionen

F1. Wie häufig berücksichtigen Sie Treibhausgasemissionen in Investmentprozessen in Ihrer Organisation?

	Nie	Selten	Manchmal	Häufig	Immer	Keine Angabe
Häufigkeit						

F2. Aus welchen Gründen berücksichtigen Sie Treibhausgasemissionen in Ihrem Investmentprozess? (Mehrfachnennung möglich)

- Treibhausgasemissionen beeinflussen den Investitionserfolg in den nächsten ein bis zwei Jahren
- Treibhausgasemissionen beeinflussen den Investitionserfolg in den nächsten zwei bis fünf Jahren
- Kunden/Stakeholder fragen vermehrt nach der Berücksichtigung von Treibhausgasemissionen
- Eine solche Strategie kann zum Wandel im Unternehmen beitragen
- Die Berücksichtigung ist Teil unserer Investmentproduktstrategie
- Die Berücksichtigung ist Teil unserer ethischen Verantwortung
- Die Berücksichtigung ist Teil unserer Unternehmensstrategie
- Die Berücksichtigung ist Teil unseres Mandats
- Keine Angabe
- Sonstiges

F3. Welche Investmentstrategien verwenden Sie, um Treibhausgasinformationen in Ihren Investmentprozess zu integrieren? (Mehrfachnennung möglich)

- Ausschlusskriterien
- Best-In-Class
- Engagement
- Impact Investment
- Teil der ESG-Integration
- Nachhaltige Themenfonds
- Normenbasiertes Screening
- Stimmrechtsausübung
- Keine Angabe
- Sonstiges

F4. Aus welchen Gründen berücksichtigen Sie Treibhausgasemissionen nicht häufiger in Ihrem Investmentprozess? (Mehrfachnennung möglich)

- Treibhausgasinformationen beeinflussen den Investitionserfolg nicht.
- Kunden/Stakeholder verlangen keine Berücksichtigung von Treibhausgasinformationen.
- Wir haben keinen Zugang zu zuverlässigen Daten.
- Es gibt keine zuverlässigen Daten.
- Eine solche Strategie kann nicht zum Wandel im berichtenden Unternehmen beitragen.
- Die treuhänderische Pflicht gegenüber unseren Kunden würde verletzt werden.
- Die Berücksichtigung von Treibhausgasemissionen steht der Investmentperformance diametral
- gegenüber.
- Die Berücksichtigung von Treibhausgasinformationen ist noch in Planung.
- Durch die Berücksichtigung von Treibhausgasinformationen würden zusätzliche Kosten entstehen.
- Berichtende Unternehmen sind mit den bestehenden Daten untereinander nicht vergleichbar.
- Keine Angabe
- Sonstiges

F5. Aus welchen Gründen berücksichtigen Sie Treibhausgasemissionen nicht in Ihrem Investmentprozess? (Mehrfachnennung möglich)

- Treibhausgasinformationen beeinflussen den Investitionserfolg nicht.
- Kunden/Stakeholder verlangen keine Berücksichtigung von Treibhausgasinformationen.
- Wir haben keinen Zugang zu zuverlässigen Daten.
- Es gibt keine zuverlässigen Daten.
- Eine solche Strategie kann nicht zum Wandel im berichtenden Unternehmen beitragen.
- Die treuhänderische Pflicht gegenüber unseren Kunden würde verletzt werden.
- Die Berücksichtigung von Treibhausgasemissionen steht der Investmentperformance diametral
- gegenüber.
- Die Berücksichtigung von Treibhausgasinformationen ist noch in Planung.
- Durch die Berücksichtigung von Treibhausgasinformationen würden zusätzliche Kosten entstehen.
- Berichtende Unternehmen sind mit den bestehenden Daten untereinander nicht vergleichbar.
- Keine Angabe
- Sonstiges

Teil G: Treibhausgasinformationen

G1. Bitte kreuzen Sie bei den folgenden Punkten jene an, die auf die in Ihrem Investmentprozess verwendeten Treibhausgasinformationen zutreffen. Die von mir genutzten Datenquellen enthalten hauptsächlich folgende Datenarten (Mehrfachnennung möglich):

- Qualitative Daten (z. B. Gespräche mit Unternehmensverantwortlichen)
- Quantitative, absolute Angaben (z. B. Treibhausgasausstoß in t)

- Quantitative, relative Angaben (Carbon Intensität, z.B. Sales/Treibhausgasausstoß in t)
- CO_2-Key Performance Indicators (KPI, Bewertung der Treibhausgasemissionen in der Branche (bspw.
- Notenskala A bis E))
- Szenarios (Analyse von verschiedenen Temperaturanstiegen auf das Geschäftsmodell des
- Investitionsobjekts)
- ESG Rating
- Vorausschauende Daten
- Scope 1 (direkte Emission)
- Scope 2 (indirekte Emission)
- Scope 3 (Emissionen der Lieferkette)
- Keine Angabe
- Sonstige

G2. Aus welchen Datenquellen verwenden sie Treibhausgasinformationen in ihrem Investmentprozess? (Mehrfachnennung möglich)

- Bloomberg
- Thomson Reuters
- ISS ESG
- CDP
- Sustainalytics
- TruCost
- Imug/VigeoEiris
- MSCI/Carbon Delta
- EU ETS
- Eigene Erhebungen aus Unternehmenskontakten
- Eigene Erhebungen aus Nachhaltigkeitsberichten
- Keine Angabe
- Sonstige

G3. Bitte bewerten Sie die von Ihnen im Investmentprozess verwendeten Informationen zu Treibhausgasemissionen hinsichtlich der folgenden Punkte

	Sehr Schlecht	Schlecht	Mittelmässig	Gut	Sehr Gut	Keine Angabe
Glaubwürdig						
Zuverlässigkeit						
Vergleichbarkeit der Treibhausgasemissionen einzelner Unternehmen untereinander						
Vergleichbarkeit der Treibhausgasemissionen einzelner Unternehmen über die Zeit						
Vollständigkeit						

Teil H: Motivation

H1. Stellen Sie sich bitte vor, Sie würden die folgenden Investmentstrategien für Ihren Investitionsprozess verwenden. Wie würde sich die Performance der Investition Ihrer Einschätzung nach verändern, wenn Sie in diesem Prozess Treibhausgasinformationen berücksichtigen (verglichen mit dem Prozess ohne Treibhausgasinformationen)?

	Verschlechtern	Gleich Bleiben	Verbessern	Keine Angaben
Ausschlüsse				
Best-In-Class				
Engagement				
Impact Investments				
Teil der ESG-Integration				
Nachhaltige Themenfonds				
Normenbasierstes Screening				
Stimmrechtsausübung				

H2. Bitte bewerten Sie aus Ihrer Sicht, wie wichtig es institutionellen Investoren in Zukunft sein wird, dass Treibhausgasinformationen in den Investmentprozess eingebunden werden.

	Sehr Unwichtig	Unwichtig	Moderate Wichtigkeit	Wichtig	Sehr wichtig	Keine Angabe
In den nächsten zwei Jahren						
In zwei bis fünf Jahren						
In fünf bis zehn Jahren						

Teil I: Regulierung

I1. Für den Fall, dass eine Regulierung zur Veröffentlichung von Treibhausgasinformationen bei Unternehmen der Realwirtschaft eingeführt wird, bevorzuge ich generell eine….

- auf verpflichtender Berichterstattung basierende Regulierung.
- auf freiwilliger Berichterstattung basierende Regulierung.
- Keine Angabe
- Sonstiges

I2. Für den Fall, dass eine Regulierung zur Veröffentlichung der Treibhausgasinformationen bei Finanzprodukten eingeführt wird, bevorzuge ich generell eine….

- auf verpflichtender Berichterstattung basierende Regulierung.
- auf freiwilliger Berichterstattung basierende Regulierung.
- Keine Angabe
- Sonstiges

Teil J: Regulierung

J1. Eine verpflichtende Regulierung für Treibhausgasemissionen auf der Ebene realwirtschaftlicher Unternehmen würde… (Mehrfachnennung möglich)

- die Datenverfügbarkeit verbessern.
- helfen, das mit Treibhausgasemissionen verbundene Risiko besser einschätzen zu können.
- den Ausstoß von Treibhausgasemissionen senken.
- im Idealfall branchenspezifisch ausgestaltet werden.
- unnötig Arbeit erzeugen.
- keinen Unterschied machen.

- Keine Angabe
- Sonstiges

J2. Eine verpflichtende Regulierung für Treibhausgasinformationen auf Finanzproduktebene würde… (Mehrfachnennung möglich)

- es leichter machen, Daten in den Entscheidungsprozess zu integrieren.
- die Vergleichbarkeit zwischen Finanzprodukten erhöhen.
- die Produktrendite negativ beeinflussen.
- die Produktrendite positiv beeinflussen.
- den Ausstoß von Treibhausgasemissionen bei Unternehmen senken.
- helfen, das mit Treibhausgasemissionen verbundene Risiko besser einschätzen zu können.
- unnötig Arbeit erzeugen.
- keinen Unterschied machen.
- Keine Angabe
- Sonstiges

Teil K: Regulierung

K1. Zukünftige Regulierungen für Treibhausgasemissionen auf Ebene realwirtschaftlicher Unternehmen sollten... (Mehrfachnennung möglich)

- strenge, verpflichtende Standards beinhalten.
- europaweit einheitlich sein.
- Komplexität verringern und mit anderen regulatorischen Maßnahmen abgestimmt sein.
- die gesamte Realwirtschaft betreffen.
- in Zusammenarbeit mit Stakeholdern entwickelt werden.
- konkrete Zielvorgaben beinhalten.
- Möglichkeiten zur Sanktionierung beinhalten.
- kleine Unternehmen nicht benachteiligen.
- nicht eingeführt werden.
- Keine Angabe
- Sonstiges

K2. Zukünftige Regulierungen für Treibhausgasemissionen auf Finanzproduktebene sollten... (Mehrfachnennung möglich)

- strenge, verpflichtende Standards beinhalten.
- europaweit einheitlich sein.
- Komplexität verringern und mit anderen regulatorischen Maßnahmen abgestimmt sein.
- die gesamte Finanzindustrie betreffen.
- in Zusammenarbeit mit Stakeholdern entwickelt werden.
- konkrete Zielvorgaben beinhalten.
- Möglichkeiten zur Sanktionierung beinhalten.
- Finanzproduktspezifisch ausgestaltet sein.
- nicht eingeführt werden
- Keine Angabe
- Sonstiges

Teil L: Regulierung

L1. Bitte geben Sie an, inwiefern sie den folgenden Aussagen zustimmen.

	Stimme gar nicht zu	Stimme eher nicht zu	Teils-teils	Stimme eher zu	Stimme voll zu	Keine Angabe
Wenn Wettbewerber Treibhausgasinformationen zu ihren Finanzprodukten berichten, dann steigt der Druck auf mein Unternehmen, diese ebenfalls zu berichten.						
Freiwillige Berichterstattung macht die Treibhausgasemissionen von Finanzprodukten zu einem Wettbewerbsfaktor.						
Verpflichtende Berichterstattung macht die Treibhausgasemissionen von Finanzprodukten zu einem Wettbewerbsfaktor.						
Freiwillige Berichterstattung zu Treibhausgasemissionen von Finanzprodukten führt zu größerem öffentlichem Druck, die Treibhausgasemissionen der Investments in den Finanzprodukten zu senken.						
Verpflichtende Berichterstattung zu Treibhausgasemissionen von Finanzprodukten führt zu größerem öffentlichem Druck, die Treibhausgasemissionen der Investments in den Finanzprodukten zu senken.						
Freiwillige Berichterstattung zu Treibhausgasemissionen führt zu systematischen Verzerrungen auf den Kapitalmärkten.						
Verpflichtende Berichterstattung zu Treibhausgasemissionen führt zu systematischen Verzerrungen auf den Kapitalmärkten.						

Teil M: Eigene Einschätzung

M1. Das Pariser Klimaabkommen zielt darauf ab, den Anstieg der globalen Durchschnittstemperatur zu begrenzen. Welchen Temperaturanstieg im Vergleich zum vorindustriellen Zeitalter erwarten Sie bis zum Ende des Jahrhunderts?

- Kein Temperaturanstieg
- > 0 - 1 Grad
- > 1 - 2 Grad
- > 2 - 3 Grad
- > 3 - 4 Grad
- > 4 Grad
- Keine Angabe

M2. Wie sicher sind Sie sich bezüglich Ihrer Einschätzung zur vorangegangenen Frage?

- sehr unsicher
- unsicher
- teils-teils
- sicher
- sehr sicher
- Keine Angabe

Appendix chapter 5

Table 5.5 European Electric Utilities

Name	ISIN	Name	ISIN
A2A	IT0001233417	ERG	IT0001157020
ACEA	IT0001207098	EVN	AT0000741053
ALBIOMA	FR0000060402	FALCK RENEWABLES	IT0003198790
ALERION CLEAN POWER	IT0004720733	FORTUM	FI0009007132
ATHENA INVESTMENTS	DK0010240514	GOOD ENERGY	GB0033600353
AUDAX RENOVABLES	ES0136463017	HERA	IT0001250932
BKW	CH0130293662	IBERDROLA	ES0144580Y14
CENTRICA	GB00B033F229	IREN	IT0003027817
CEZ	CZ0005112300	MVV ENERGIE	DE000A0H52F5
CONTOURGLOBAL	GB00BF448H58	NATURGY ENERGY	ES0116870314
DRAX GROUP	GB00B1VNSX38	ORSTED	DK0060094928
E.ON	DE000ENAG999	PGE	PLPGER000010
EDF	FR0010242511	POLENERGIA	PLPLSEP00013
EDP	PTEDP0AM0009	PUBLIC POWER	GRS434003000
EDP RENOVAVEIS	ES0127797019	ROMANDE ENERGIE	CH0025607331
ENBW	DE0005220008	RWE	DE0007037129
ENCAVIS	DE0006095003	S. N. NUCLEARELECT	ROSNNEACNOR8
ENDESA	ES0130670112	SSE	GB0007908733
ENEA	PLENEA000013	TAURON POLSKA	PLTAURN00011
ENEL	IT0003128367	TERNA ENERGY	GRS496003005
ENERGA	PLENERG00022	UNIPER SE	DE000UNSE018
ENERGIEDIENST	CH0039651184	VERBUND	AT0000746409
ENERGIEKONTOR	DE0005313506	ZE PAK SE	PLZEPAK00012
ENGIE	FR0010208488		

The table provides the names and ISINs for the 47 EEU.

Table 5.6 Descriptive Statistics for the Dependent Portfolios in 2020

	Unit	RE_{80}	RE_{60}	RE_{40}	RE_{20}	RE_0	T	NT	NR
Portfolio MC	Bn. €	17.20	76.07	173.26	102.21	72.35	67.15	395.58	8.60
Average MC	Bn. €	1.91	9.51	21.66	12.78	8.04	6.10	14.65	0.96
BTM	Ratio	0.88	0.43	0.54	0.86	1.33	0.47	0.76	2.37
CO_2 intensity	gCO_2e/kwh	0	122.66	239.77	300.23	312.01	45.02	270.79	NA
Renewables	%	100	80.53	40.69	21.55	10.43	90.52	31.85	9.10
Nuclear	%	0	0	13.93	41.10	43.07	0	27.16	NA
n		9	8	8	8	9	11	27	9

This table provides descriptive statistics for each portfolio in 2020. **T** is the portfolio of taxonomy orientated EEU. **NT** is the portfolio of non-taxonomy orientated EEU. **NR** is the portfolio of non-reporting EEU. $\mathbf{RE_{80}}$, $\mathbf{RE_{60}}$, $\mathbf{RE_{40}}$, $\mathbf{RE_{20}}$ and $\mathbf{RE_0}$ are portfolios with a percentage of energy from renewable sources in the top, 4th, 3rd, 2nd and bottom quintile respectively. *Portfolio MC* is the total market capitalization for the entire portfolio, *Average MC* is the average market capitalization of the firms in the portfolio and *BTM* is the weighted average book to market ratio for the portfolio. The *CO_2 intensity* is provided, *Renewables* is the percentage of electricity produced from renewable sources, *Nuclear* is the percentage of electricity produced from nuclear sources and *n* indicates the number of companies in the respective portfolio for 2020.

Table 5.7 Factor Correlations

	mkt-rf	smb	hml	rmc	lmh	oil	gas	coal
mkt-rf	1.00							
smb	-0.39***	1.00						
hml	0.08	-0.11	1.00					
rmc	-0.12	0.08	-0.11	1.00				
lmh	-0.05	-0.03	-0.11	0.53***	1.00			
oil	0.38***	-0.03	-0.03	0.03	0.12	1.00		
gas	0.19*	-0.09	0.07	-0.06	0.13	0.43***	1.00	
coal	0.03	-0.20*	0.23*	-0.13	-0.08	0.09	0.46***	1.00

This table presents the Pearson correlations between the 8 factors used in our model. Significance is denoted by: * p<0.05, ** p<0.01 and *** p<0.001

Appendix chapter 6

Table 6.12 Green bonds first matching

Name	**ISIN**
APPLE INCORPORATED 2016 2.85% 23/02/23 S	US037833BU32
APPLE INCORPORATED 2017 3% 20/06/27 S	US037833CX61
ASIAN DEV.BANK 2018 0.37% 26/06/23 994 - 0	XS1842116961
ASIAN DEV.BANK 2016 1 3/4% 14/08/26 876-00-	US045167DR18
ASIAN DEV.BANK 2017 2 3/8% 10/08/27 936-00-	US045167EC30
ASIAN DEV.BANK 2015 2 1/8% 19/03/25 806-00-	US045167CY77
AXIS BANK LIMITED 2016 2 7/8% 01/06/21 REG.S	XS1410341389
BERLIN HYP AG 2015 1/8% 05/05/22	DE000BHY0GP5
CHINA DEV.BANK 2017 3/8% 16/11/21 REG.S	XS1711173218
CHINA DEV.BANK 2017 2 3/4% 16/11/22 REG.S	XS1711039591
GOTHENBURG 2015 1.455% 30/06/21 REG.S	XS1253847815
DNB BOLIGKREDITT AS 2018 5/8% 19/06/25	XS1839888754
ENGIE SA 2017 1 1/2% 27/03/28	FR0013245867
ENGIE SA 2014 2 3/8% 19/05/26	FR0011911247
EUR.BK.RECON.&.DEV. 2019 0% 10/01/24	XS1933817824
EUROPEAN INV.BK. 2015 1/2% 15/11/23 REG.S	XS1280834992
EUROPEAN INV.BK. 2018 7/8% 30/01/25 REG.S	XS1757428088
EUROPEAN INV.BK. 2018 1 1/8% 15/11/32 REG.S	XS1828046570
EUROPEAN INV.BK. 2014 1 1/4% 13/11/26 REG.S	XS1107718279
EUROPEAN INV.BK. 2016 2 1/8% 13/04/26 S	US298785HD17
EUROPEAN INV.BK. 2018 2 3/8% 18/01/23 REG.S	XS1751357077
EUROPEAN INV.BK. 2017 3.3% 03/02/28 S	AU3CB0245884
EXPORT-IMPORT BOK. 2016 2 1/8% 11/02/21 S	US302154BZ10
HERA SPA 2014 2 3/8% 04/07/24 REG.S	XS1084043451
IBERDROLA FINANZAS 2017 F/R 02/24 REG.S	XS1564443759
IBERDROLA FINANZAS 2016 1% 07/03/24 REG.S	XS1527758145
IBERDROLA FINANZAS 2017 1% 07/03/25 REG.S	XS1575444622
INSTO.DE CDT.OFIC. 2018 3/4% 31/10/23 REG.S	XS1915152000
INTL.FINANCE CORP. 2016 4 3/4% 29/04/21 REG.S	XS1402169848
KFW 2017 1/4% 30/06/25 REG.S	XS1612940558
KFW 2018 0.46% 23/01/23 REG.S	XS1756683659
MITSUB.UFJ FLGP. 2016 2.527% 13/09/23 S	US606822AH76
NAT AUS BK LTD 2014 4% 16/12/21 S	AU3CB0226090
NEDSE.WATERSCHBK. 2017 0.7% 25/01/23 REG.S	XS1555168951
NEDSE.WATERSCHBK. 2017 1% 11/04/25 REG.S	XS1595814465
NEDSE.WATERSCHBK. 2015 1% 03/09/25 REG.S	XS1284550941
NORDIC INVESTMENT 2017 0.448% 29/08/22	XS1673097637
NORDIC INVESTMENT 2016 1/2% 22/09/23	XS1494406074
NORDIC INVESTMENT 2016 5/8% 20/01/21 REG.S	XS1347786797
NRW BANK 2017 1/2% 13/09/27	DE000NWB0AE6

NRW BANK 2018 3/4% 30/06/28	DE000NWB0AF3
NRW BANK 2015 7/8% 10/11/25	DE000NWB0AC0
NORTH RHINE 2016 1/8% 16/03/23	DE000NRW0JF6
NORTH RHINE 2017 1/2% 16/02/27	DE000NRW0KB3
NORTH RHINE 2015 1/2% 11/03/25	DE000NRW0GP1
NORTH RHINE 2018 0.95% 13/03/28	DE000NRW0K03
POLAND 2016 1/2% 20/12/21 REG.S	XS1536786939
POLAND 2018 1 1/8% 07/08/26 REG.S	XS1766612672
SPB.1 BOLIGKREDITT 2018 1/2% 30/01/25	XS1760129608
TENNET HOLDING 2017 1 3/8% 26/06/29 REG.S	XS1632897929
TENNET HOLDING 2015 1 3/4% 04/06/27 REG.S	XS1241581096
UNIBAIL RODAMCO 2015 1% 14/03/25 REG.S	XS1218319702
UNIBAIL RODAMCO 2014 2 1/2% 26/02/24 REG.S	XS1038708522
EVERGY KANSAS CTL. 2016 2.55% 01/07/26 S	US95709TAN00
WESTPAC BKG.CORP. 2017 5/8% 22/11/24 REG.S	XS1722859532
WESTPAC BKG.CORP. 2016 3.1% 03/06/21 S	AU3CB0237683

The table provides the names and ISINs for Green Bonds in the first matching approach.

Table 6.13 Green bonds second matching

Name	ISIN
APPLE INCORPORATED 2016 2.85% 23/02/23 S	US037833BU32
ASIAN DEV.BANK 2018 0.37% 26/06/23 994 - 0	XS1842116961
GOTHENBURG 2015 1.455% 30/06/21 REG.S	XS1253847815
DNB BOLIGKREDITT AS 2018 5/8% 19/06/25	XS1839888754
ENGIE SA 2017 1 1/2% 27/03/28	FR0013245867
EUROPEAN INV.BK. 2018 7/8% 30/01/25 REG.S	XS1757428088
EUROPEAN INV.BK. 2018 2 3/8% 18/01/23 REG.S	XS1751357077
IBERDROLA FINANZAS 2016 1% 07/03/24 REG.S	XS1527758145
KFW 2017 1/4% 30/06/25 REG.S	XS1612940558
KFW 2018 0.46% 23/01/23 REG.S	XS1756683659
NAT AUS BK LTD 2014 4% 16/12/21 S	AU3CB0226090
NEDSE.WATERSCHBK. 2017 0.7% 25/01/23 REG.S	XS1555168951
NRW BANK 2018 3/4% 30/06/28	DE000NWB0AF3
NRW BANK 2015 7/8% 10/11/25	DE000NWB0AC0
NORTH RHINE 2016 1/8% 16/03/23	DE000NRW0JF6
NORTH RHINE 2017 1/2% 16/02/27	DE000NRW0KB3
NORTH RHINE 2015 1/2% 11/03/25	DE000NRW0GP1
NORTH RHINE 2018 0.95% 13/03/28	DE000NRW0K03
UNIBAIL RODAMCO 2015 1% 14/03/25 REG.S	XS1218319702
EVERGY KANSAS CTL. 2016 2.55% 01/07/26 S	US95709TAN00
INBLK.RECON.&.DEV. 2017 2% 12/04/22 S	US45905UG408

The table provides the names and ISINs for Green Bonds in the second matching approach.

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