



Research article

The green finance dilemma: No impact without risk – a multiple case study on renewable energy investments

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Abstract: Recently, European regulation on sustainability preferences has made green finance a mainstream topic for retail investors. On the contrary, green innovation is largely discussed as bearing risks, and renewable energy projects are sometimes referred to as related to high risk. Our article aimed to shed light on retail investors' risk exposure in green finance. In the literature review, we rarely found the retail investor's risk perspective reflected, and green finance risk in terms of major capital loss was not explicitly stated as a research topic. We aimed to close this gap in the literature and apply a multiple case study approach with cases from the renewable energy sector to analyze the components that nurture green finance risk. For case description, we leveraged publicly available online information such as press articles, financial reporting, mandatory disclosure from the represented company, and pre-contractual information of the financial instruments marketed. Our findings suggest that green finance risk (GFR) is nurtured by risk components from the categories of financial instrument risk (FIR), investee company risk (ICR), and operational risk (OR) of renewable energy projects. The cross-case analysis identified red flags that might alert future investors. Additionally, we suggested measures to mitigate green finance risk and propose regulatory improvements. Our research marks a starting point for future quantitative and qualitative research.

Keywords: green finance; green innovation; green finance risk; retail investor; multiple case study

JEL Codes: C40, F36, G15

1. Introduction

The transition to a carbon-neutral European Union (EU) economy requires innovation in technology and huge financing efforts from the public and private sectors, increasing the relevance of and interest in green finance (Matviienko et al., 2022) (*Sustainable Europe Investment Plan, European Green Deal Investment Plan*, 2020). Also, a growing number of publications has been dedicated to green finance globally (Akomea-Frimpong et al., 2022; Debrah et al., 2023; Desalegn & Tangl, 2022). Our research focuses on green finance from the perspective of retail investors and within the context of EU jurisdiction with its specific regulation on financial markets, investor protection, disclosure, and sustainable investments.

A recent working paper on financial markets and green innovation published by the European Central Bank (ECB) recommended increased public funding and encouraged private venture capital markets to establish more favorable conditions for green innovation in the EU (Aghion et al., 2022). The ECB's suggestions to enhance the financing of green innovation do not refer to retail investors. Moreover, European regulation requires intermediaries to explore and consider sustainability preferences when providing investment advice or portfolio management services to private investors (Delegated Regulation (EU) 2021/1235). This regulation makes investments in green economic activities, as defined in the EU taxonomy (Delegated Regulation (EU) 2023/2486), a mainstream topic relevant to retail investors. Given the venture characteristics of green innovation on one side and retail investors' characteristics on the other, we assume a dilemma. Standard financial instruments for retail investors, such as mutual funds and ETFs, provide product-immanent diversification, yet the extent of environmental sustainability in these instruments is still limited due to what Fichtner et al. (2024) identified as the ESG allocation gap. Financial instruments without diversification on product-level as subject to this research directly impact the capital of the investee company pursuing environmentally sustainable economic activities. This article aims to shed light on the question of how retail investors, willing to invest in green and impactful finance, are exposed to green finance risk. Giglio et al. (2023) found the willingness and awareness of retail investors to sacrifice performance compared to the market in ESG portfolios. Other authors have similar findings for professional and institutional investors as agents and portfolio managers. The novelty of our research is that we present cases of substantial capital loss rather than a deviation in performance or risk-adjusted returns, as in Pedersen et al. (2021) and Pástor et al. (2021). We address this question by reviewing green finance literature first. We found few articles mentioning retail investors (Bourcet & Bovari, 2020; Horn, 2024; Polzin & Sanders, 2020; Ringel & Mjekic, 2023). Ringel and Mjekic (2023) dedicated their research to the role of banks as intermediaries addressing retail investors and commenting on the gap between a retail investor's risk profile and the high-risk perception of renewable energy projects. In his perspective article, Horn (2024) stressed the idiosyncratic risk of portfolios with only a few sustainable assets and the lacking awareness diversification of retail investors. Second, we take a multi-case study approach to deep dive into green finance risk related to renewable energy projects. The cases analyzed illustrate the actual capital loss retail investors suffered. In the case analysis, we decompose green finance risk into risk components related to the type of financial instrument, the investee company, and the operational risk of the renewable

energy projects. Thanks to a better understanding of green finance risk, we provide red flags that may alert future retail investors and suggest measurements for green finance risk mitigation. Our results contribute to green finance literature and mark a starting point for future research since our results are limited to the scope of selected cases. In particular, quantitative research could test the significance of our findings. Further, we suggest implications for amending existing regulations.

The remainder of the article is organized as follows. The subsequent section reviews green finance literature, followed by a section on methodology. Our results and discussion are presented in the fourth section and the last section is dedicated to conclusions.

2. Literature review

In recent years, the contribution to green finance and green innovation literature from researchers from China has increased. Fewer studies have focused on the European context (Akomea-Frimpong et al., 2022; Kouwenberg & Zheng, 2023). Different research teams find investments in renewable energy as well as green finance to have a moderating effect on CO₂ emissions (He et al., 2023; Ibrahim et al., 2023; Meo & Abd Karim, 2022; Sun et al., 2023; Wang et al., 2023; Wang et al., 2023). Meo and Abd Karim (2022) overall findings support green finance to reduce CO₂ emissions, though their quantile-on-quantile regression differs across quantiles. This literature review focuses on risks related to green finance and green innovation and derives findings relevant to retail investors' investment in green finance. Well-known financial risks related to climate change and insufficient mitigation (Campiglio et al., 2023; Chabot & Bertrand, 2023; Curcio et al., 2023; D'Orazio, 2021; Ma et al., 2023; Wu et al., 2023) are not in the scope of this section. The meta-study of Desalegn and Tangl (2022) on green finance identified a noticeable gap in green finance due to low finance levels, insufficient project management and selection, and missing skills for project risk assessment or risk-return trade-off. The authors also discussed that the private investor's investment horizon is not in line with the long-term financing needed for green projects. The ECB published a working paper on financial markets and green innovation that reflected climate goals' dependency on technological innovation. The authors identified financial market drivers for green innovation, namely carbon taxes, investment in research and development (R&D), and the ratio of equity-based and debt-based financing (Aghion et al., 2022). The research found that the EU average of green patents, as a measurement of green innovation, is inferior to peers like the United States or Japan. The investment in R&D and equity-based financing is considerably lower in the EU. The authors called for government action and new policies supporting green innovation within the EU, among others strengthening the venture capital market as the driver of innovation. These findings do not strengthen investment opportunities for retail investors since venture investments are not eligible for retail investors.

Polzin and Sanders (2020) answered the research question of how much private investments are needed to finance the EU transition to a carbon-neutral economy by applying a life cycle relating to technology and corporate maturity stages. Again, venture capital is crucial in this life cycle to survive what the authors called the valley of death between R&D and commercialization. Another form of financing mentioned in the article is small and distributed financing, namely equity or debt-based crowdfunding enabling the private investor to contribute to financing the transition of the economy. "Engaging citizens in this way reduces perceived risks of renewable energy (RE) and has the potential to democratize the energy transition" (Polzin and Sanders, 2020). The authors referred to RE projects as large-scale and low-risk, compared with emerging innovations. They concluded that sufficient financial

means are available in theory, but in practice, matching the demand and supply side is not obvious, especially in the early stages of a venture. Based on data from China, He et al. (2022) tested the hypothesis of whether retail investors' attention—measured in an internet search index from a Chinese provider—has a positive impact on Chinese listed companies' green innovation, as manifested in green patents. The authors found a significant positive effect. La Monaca et al. (2018) applied a portfolio analysis approach to test risk-adjusted effects on return for three different sample portfolios. The first included renewable energy exchange-traded funds (ETFs), the second additionally incorporated US yieldcos ETF, and the third added a constructed individual yieldco index, also incorporating non-US yieldcos. It is worth mentioning that yieldcos are publicly listed companies dedicated to routing yields from RE projects to investors. The results showed a slightly positive effect of RE ETFs in two years and no positive effect for longer periods. The integration of US yieldco ETF could not prove beneficial for the portfolio performance; on the contrary, the constructed index of individual non-US yieldcos contributed positively to the risk-adjusted portfolio performance. The authors classify yieldcos as low-risk investments.

The research team Mzoughi et al. (2022) found green bonds as long positions to be effective for portfolio diversification and hedging upside and downside risks. The literature also finds renewable energy investments to be negatively influenced by oil prices. Ozdurak (2021) explained this phenomenon by adding a volatility index to his model and proving that the impact of bad news is more significant than the impact of good news. Afridi et al. (2021) assessed the impact of green loans on banks, finding that a larger share of green finance loans in the loan portfolio reduces a bank's total loan risk. Also, the authors proved that green loans grow at a faster rate. Overall, the results confirm green loans as a business opportunity for banks with a positive effect on growth rate and risk reduction. Bachner et al. (2019) took a macroeconomic view addressing shortcomings in the literature due to a lack of differentiation regarding technology and region. The scope of their study is EU 28 countries plus central EU nonmember states. They criticized that existing models do not reflect the weighted average cost of capital (WACC) correctly, e.g., WACC is overestimated for RE, and RE's effect on gross domestic product (GDP) growth is underestimated. Financing of renewables is mainly debt-based, whereas financing of fossils is mostly equity-based, so the results are biased. The authors suggested that de-risking renewable energy by increasing trust in technology would have multiple positive effects on the economy.

Steffen (2018) stressed the importance of project finance for renewable energy projects in Germany and proved Germany to be a market where project finance exceeds corporate finance by far when financing renewable energy projects. In this context, Germany is considered a low-risk country, and onshore wind power and solar power are considered low-risk technologies. Only offshore wind parks are rated high-risk technology. The conclusion is that project finance needs to be further promoted to also strengthen renewable energy projects in developed, low-risk markets. Again, the retail investor's perspective is not reflected. The period of data evaluation and the nature of projects perfectly present two of the cases presented in this article. Another study from the EU refers to the crowdfunding of renewable energy projects in France (Bourcet & Bovari, 2020). The authors found predictors with a positive effect on the crowdfunding of renewable energy projects, namely opinion on RE, RE propensity, and transparency of the investment process as well as risk perception with a negative effect on the outcome. They concluded that there is a motivation beyond profitability since it was not a significant predictor, referring to Ruedinger (2019) who demonstrated that, especially in local initiatives with higher involvement and participatory nature, such as cooperative societies, financial goals are not the highest priority.

Publications on green bonds are also missing an investor's perspective on risks. Deschryver and De Mariz (2020) assessed the risk from the issuer's perspective. They found institutional investors engaging in green bonds to satisfy the expectations of their retail investors and repeatedly referred to green bonds as a communication instrument. According to the authors, green bonds and loans have the potential to unlock sustainable and green investments into the mainstream. In their analysis of the European green bond market, Frydrych (2021) confirmed the growth potential of green bonds and raised the interest of two different investor types: environmentally conscious investors and investors who are aware of the impact related to climate change. The only context in which investor risk was discussed is by not achieving the investor's intended level of greenness (Jones et al., 2020). Still, the paper discussed the aspect of illiquidity of green bonds due to lower trading frequency and volumes. Illiquidity is increasing the investor's risk, since the investor may not be able to sell a green bond on the secondary market prematurely. Islam (2023) dedicated his article to the topic based on investing organizations but not retail investors.

Other strands in the literature mention extended risks related to green innovation and renewable energy projects. Xiang et al. (2022) provided evidence from China and confirmed the extended risk related to green innovation making it hard or impossible to get external financing. The authors concluded that innovation is rather supported by equity investors thanks to their willingness to award future values, whereas loan investors, on the contrary, expect tangible assets as guarantees (Xiang et al., 2022 citing Hsu et al., 2014). Wasan et al. (2024) focused their research on barriers to green finance and identified the economic barrier demonstrated in higher risk and longer return periods as the second most important. Wang et al. (2023) stressed that green R&D needs incentives, since green R&D is a long-term investment with high risk and low return in their study on corporate green bonds' effect on CO₂ reduction.

Taghizadeh-Hesary and Yoshino (2019) introduced two inducements to improve private investments in green projects. One was to enhance a financing model from Japan, namely hometown investment trust funds (HIT), by leveraging distributed ledger technology such as blockchain. The idea is to strengthen transparency, audibility, and project assessment, thus reducing the risk for individual investors engaging in local green projects. The second was to provide credit guarantee schemes (CGS) either by the state or a third party mitigating the risk of default. On top of the CGS and with some time delay, the investor could be awarded a share of increased tax income triggered by the green project. The theoretical model does not answer detailed questions on operational issues, but the models address the risk-return ratio of green finance effectively by reducing risk and increasing return. The authors continued their research in this area and identified impediments to green projects: long-term investments, low return rates, and various risks next to a lack of capacity (Taghizadeh-Hesary & Yoshino, 2020). They also emphasized the relevance of de-risking, e.g., by providing green credit guarantee schemes (GCGS) by a public credit guarantee corporation (CGC), which mitigates the credit default risk while the investor is paying a premium for the guarantee. In a dedicated study on financing hydrogen projects, Taghizadeh-Hesary et al. (2022) concluded that credit guarantees enforce private investments. Selvapandian et al. (2022) specified the extended risks and financing related to green energy projects as dependency on high-tech, highly skilled staff, weather conditions, risk of component failure, and a fuzzy approval process demanding high initial investments and resulting in high operational costs. Purkayastha and Sarkar (2021) connected the issue of financing green projects to banking regulation in terms of credit pricing, asset allocation, and subsidies, to lower the credit cost. They suggested using revenues from carbon taxation to subsidize the risk premium related to green projects. Eventually, both mechanisms should enforce blended finance and public and private sector financing together.

The findings of a study investigating the intermediate role of German banks in providing green finance to retail investors suggested that the European Investments Bank (EIB) should guarantee investments in renewable energy projects to close the gap between the retail investors' risk profile and renewable energy project risk. Reducing the perceived high-risk profile could attract more retail investors and leverage the financing potential of this investor type (Ringel & Mjekic, 2023). The authors did not comment on whether this high-risk perception of renewable energy projects is justified or refers to actual projects. Agliardi (2022) provided a mathematical approach to innovative green securitization, defined as either collateral debt financing green projects or re-investment of collateral debt in granting green loans. Her findings were that green securitization could increase green project portfolios and reduce transaction costs. Though default risks were implemented in the model, the article missed a dedicated warning related to the financial vehicle of securitization via collateral debt obligations that triggered the financial crisis in 2008 (Andersen et al., 2012; Bock & Tichy, 2016). Even institutional and public investors struggled to understand the risk they were taking with their investments, and EU regulators introduced various directives in the aftermath to prevent a similar excess and chain reaction in the future. This policy goal is falling behind expectations (Navid, 2022).

In the broader definition of ESG portfolios, Giglio et al. (2023) presented findings from a survey of Vanguard's current customer base. Customers have different expectations of the outperformance or underperformance of ESG portfolios compared to the market. Whilst the largest part of customers approving ESG investments indicated ethical reasons as the motive, customers indicating outperformance of ESG portfolios as the motive showed the highest actual ESG allocation. Vanguard is offering index investments and the expectation of a deviation in performance ranges in the lower single-digit percentage.

The literature review shows that green innovation is commonly considered to depend on public funding and venture capital, neither being an investment opportunity for retail investors. Renewable energy projects are considered low risk by some authors and high risk by others. The strand of literature referring to high risk related to green projects suggests de-risking by providing guarantees, tax incentives, or subsidies funded by carbon emission taxation to attract private investors.

3. Materials and methods

The literature review finds the retail investor's perspective underrepresented in research. We aim to mark a starting point for research on green finance risk for retail investors and decide on a multi-case study approach that provides different perspectives and detailed insight at the same time. The benefit of this approach is that it allows an in-depth analysis of the individual case, explaining the origins of risk and, at the same time, comparing results between cases to identify differences and commons in green finance risk.

3.1. Case selection

As for case selection, we focus on the renewable energy sector, which is highly relevant for climate change mitigation: electrification accounts for 40% of the global CO₂ emissions (Santos et al., 2023), and investments in renewable energies are positively associated with energy efficiency (Chen et al., 2022). Analyzing the EU energy market, Koval et al. (2023) identified wind and solar energy as the main transition energy sources within the EU after the Russian attack on Ukraine hindered the further expansion of natural gas as a contributor to the EU's power generation. Investments in renewable solar and wind power have a major impact on the achievement of net zero-related goals

within the EU. Our multi-case study is based on three different cases from the renewable energy sector, each representing a specific financial instrument and investee company from a private investor's perspective. The financial instruments represented in the multiple case study are profit participation rights, corporate bonds, and stocks, hence instruments with a direct impact on the investee company's capital; either equity, debt, or hybrid capital.

3.2. Data

The multiple case study is based on publicly available online information such as press articles, press releases, websites, financial reporting of the investee company, other mandatory disclosure of the investee company, and pre-contractual information required for the specific financial instrument treated in the case. The search terms "> company name < Insolvenz", "> company name < ISIN" or "> company name < Verkaufsprospekt", "> company name < Wind" marked the beginning of the online search. Further, each company's website provides an investor relation download area and financial reporting. Financial reportings were also retrieved from the official database "Bundesanzeiger", the German publication platform for mandatory financial disclosure.

3.3. Case analysis

Following the structure of Osei et al. (2023) in their multiple case study on impact investment in Ghana, we first present the within-case analysis followed by the cross-case analysis. The structure of our case analysis follows a new approach: we decompose green finance risk (GFR) in risk components related to (i) the nature of the financial instrument (FIR), (ii) the investee company (ICR), and (iii) operational risk (OR) as demonstrated in Figure 1.

The cross-case analysis provides a summary of green finance risk components, red flags, and mitigation strategies to derive benefits for future investors, regulators, and investee companies.



Figure 1. Green finance risk components; our own elaboration.

4. Results and discussion

4.1. Within-case analysis

4.1.1. Case A: Prokon Regenerative Energien GmbH (profit participation rights)

The first case study concerns the company Prokon Regenerative Energien GmbH, and Table 1 presents key facts about the company.

Table 1. Key facts about the company Prokon Regenerative Energien GmbH.

Company name and structure	Prokon Regenerative Energien GmbH (limited company) and related companies, holding structure established in 2010, now Prokon Regenerative Energien eG (cooperative society)
Company objectives	Promotion of renewable energy, mainly implementation, and operations of wind energy sites
Founded	1995 in Itzehoe, Germany
Financial instruments issued	Profit participation rights in different tranches, issued from 2003 to 2012. Transformed into cooperative shares and long-duration bonds according to the decisions made by the creditors' meeting in July 2015
Bankruptcy	Insolvency proceedings started on May 1, 2014; proceedings ended with the transition into a cooperative in July 2015
Number of private investors	Approximately 75,000, resulting in approximately 40,000 members of the cooperative
Investment volume	Approximately 1,4bn EUR investments in profit participation rights (several issuances with yearly dividends between 6% and 8%) issued from 2007 onward, resulting in 500m EUR bond capital

Case description case A

Prokon started business in 1995 and was thus an early mover in renewable energies in Germany. To finance growth, the company first acquired limited partnership capital. As of 2003, the company issued profit participation rights targeting private investors. Despite, or due to, the financial crisis in 2008, and with interest rates declining, Prokon successfully acquired new investors by leveraging online marketing, postal mailing, and sales events to transform leads into investors. Prokon's marketing message can be summarized as it's green, it's safe, and it's extremely profitable. The investor was not informed sufficiently about the nature and risk of profit participation rights as confirmed in a higher regional court order in September 2012 (*Unlautere Bewerbung von Genussrechten*, 2012). From 2010 onward, critical press articles emerged (Ahima, 2010). Around the same time, Prokon re-structured the company network and established a holding structure. Since Prokon's sales activities were successful, the company became relevant to a broader public. In 2011 and 2012, critical articles in high-profile German magazines and newspapers were published (Kirchner, 2013; *Unabhängige Analyse: Genussrechte von Prokon im ECOanlagecheck - Teil 1 und 2*, 2012).

As a result, the company ended press relations in the spring of 2013, presenting itself as a victim of media campaigning (Diekmann, 2014). With the new holding structure, the company failed to publish a consolidated annual report for the group (Diekmann, 2014; Resch, 2013a; Resch, 2013b). The more investors canceled their engagement in Prokon profit participation rights, the worse the financial situation became. In January 2014, Prokon management addressed investors in a mailing, aiming to convince them to remain invested or even revoke a cancellation of profit participation rights (Naber, 2014; *Prokon droht Anlegern mit Insolvenz*, 2014). The way that Prokon communicated was considered inappropriate pressure on investors by the federal consumer protection agency. Eventually, Prokon filed for insolvency; insolvency proceedings started on May 1, 2014.

The investors experienced a period of uncertainty. During the restructuring and liquidation process, a large group of Prokon investors formed the association Friends of Prokon (Die Freunde von

Prokon e.V.), aiming to save the renewable energy business and transform it into a cooperative society (*Die Freunde Prokons e.V.*). This group presented the majority of votes in the creditor assembly in July 2015, and succeeded in the alternative plan to sell the business to EnBW, a large German utility (Wulf, 2015). Profit participation right investors engaging in the new cooperative could transfer their investments into the long-duration bond, accepting a major depreciation of their investment capital. The insolvency forced the investors to accept a loss of nearly two-thirds of their invested capital. Only 34.5% was either paid out or re-invested in the bond (*Beschluss Bestätigung Genossenschaftsinsolvenzplan*, 2015). As of August 2023, the cooperative had close to 40,000 members and financial reports stated a 20m EUR profit for the fiscal year 2022. The bond investors are paid a yearly interest rate of 3,5%, according to the terms and conditions of the bond (*Anleihebedingungen 2016–2030*). The issuer is gradually paying back capital over the duration; current assets of the bond amount to 248m EUR, and just over 50% of the initial bond capital has already been paid back (*Jahresabschluss per 31.12.2022*, 2023).

Financial instrument risk (FIR): Profit participation rights

From an investor's protection point of view, the case demonstrates the risks related to profit participation rights. This instrument is classified as hybrid capital, which combines features of equity and debt alike. The issuer risk is the most relevant; once in case of bankruptcy, the investor will suffer a major loss. Since there is no standard definition for this instrument, the individual contractual provisions determine the nature of the instrument (*New Approaches to SME and Entrepreneurship Financing: Broadening the Range of Instruments*, 2015). With a professional issuer on the one side and a non-professional private investor on the other side, there is an asymmetry in knowledge and skills. The absence of standardization and regulation is increasing the risk for private investors. Also, interest payments are not guaranteed but are subject to financial performance. The Prokon case demonstrates that these risks are not purely theoretical; they may actually occur. The return expectation for profit participation rights also depends on the individual interest rate according to terms and conditions. Prokon offered an attractive yearly interest rate for profit participation rights, which varied over issuances between 6% and 8%. The interest payments were not always made, and the investor's actual return was lower than indicated in the prospectus. Profit participation rights define maturity and termination in respective terms and conditions. Prokon issued open-end profit participation rights with restricted termination provisions due to a five-year minimum duration. The downward spiral led investors to start withdrawing their investments, since the group could not cover requested pay-outs and dividend payments with operational profit (Kirchner, 2013).

Investee company risk (ICR): Prokon Regenerative Energien GmbH

Poor governance and management mistakes caused Prokon's bankruptcy. The liquidator criticized Prokon neglected accounting and controlling (Prokon Insolvenz - Hoffnung für Anleger, 2014). Prokon management did not respect the golden rule of maturity matching investments and financing (Janzing, 2014). The issuer within the Prokon group changed with various emissions of profit participation rights. The latest profit participation rights from 2012 were issued by Prokon Regenerative Energien GmbH & Co. KG, a holding company using the funds of profit participation rights to grant loans to related project companies that built and maintained renewable energy plants, mostly wind parks (PROKON Genussrechte - Verkaufsprospekt, 2010 and 2012). With this group structure, the holding company becomes an intermediary for the green investment. In 2011, capital acquired with profit participation

rights was partly used to pay off bank loans and leasing contracts of the newly acquired biomass branch of the group (Unabhängige Analyse: Genussrechte von Prokon im ECOanlagecheck - Teil 1 und 2, 2012). This use is contradictory to and not covered by the terms and conditions of profit participation rights. The group faced allegations of snowballing, but the managing director of Prokon was cleared of such accusations by a German court (*Verfahren gegen Prokon-Gründer eingestellt*, 2017).

Operational risk (OR): Planning and operating wind parks

The first operational profit dip occurred in 2007 when wind yield was poor due to weather conditions (Bergemann et al., 2012). Energy production lagged predictions with nearly three-quarters of Prokon wind parks in 2008, as investigated by Nagel and Neller (2013). The authors also reported on the reasons why new wind park projects in Germany did not even start into the construction phase: resistance from the local community, outstanding permissions of the municipality, or animal protection activists hindering projects. Prokon's planning know-how was diminished as key employees left the company to work with a competitor founded by former Prokon experts (Nagel & Neller, 2013). Despite the massive capital influx between 2011 and 2013 in wind energy, wind yield only increased marginally (Drygala, 2014).

Red flags specific to Case A

Prokon group was overwhelmed with an extensive company network structure, with around 90 companies at peak (*PROKON Genussrechte - Verkaufsprospekt*, 2010 and 2012). Once a holding structure was established and the group network streamlined, new requirements for accounting came into force, resulting in an amended valuation allowance in the balance sheet that deteriorated the financial situation of the group (Kirchner, 2013). The decline of the Prokon group was a process, not a shock. Investors could have found various red flags before bankruptcy: mainstream press and consumer protection organizations warned about investment risks for private investors, misleading advertising, and untransparent financial data from 2010 onward. Nevertheless, private investors kept engaging with Prokon. For a professional audience, even more red flags could be found: German court orders related to misleading sales brochures show how aggressively the group acquired new investors. The frequent corporate actions within Prokon Group, like mergers and splits of related companies, led to belated and non-approved financial reporting in 2012; auditors commented on lacking transparency and cooperation of Prokon group management (*Jahresabschluss zum 31. Dezember 2012*).

Additional finding: willingness to engage in cooperative society

The response of private investors to Prokon's bankruptcy was remarkable. From the Prokon case, it can be derived that even in troubled times with major financial losses for the individual investor, thousands of investors organized with the common objective of saving Prokon's renewable energy plants. This objective ranked higher than the purely financial objective of recovering parts of their invested capital as reflected in the alternative offer made by EnBW, one of Germany's top utilities. In fact, there is an investor type whose willingness to pay financially as well as emotionally is high when the cause is good enough. Even if they did not choose this engagement from the beginning, the majority of investors eventually favored engagement over investment and deliberately became members of a cooperative society. Prokon investors' behavior supports the findings of Bourcet and Bovari (2020) and Ruedinger (2019). Next to financial commitment, the cooperative society is an emotional commitment with high identification of the members with the cooperative society's values (Ribas et al., 2022).

4.1.2. Case B: Green City AG (corporate bonds)

The German Green City group is the subject of the second case study. The key facts on Green City AG are presented in Table 2.

Table 2. Key facts about Green City AG.

Company name and structure	Green City AG (public limited company), a spin-off from Green City e.V. (registered association) as a majority shareholder
Company objectives	Acceleration of the transition into renewable energies, contribution with wind and solar power plants
Founded	2005 in Munich, Germany
Insolvency	Insolvency proceedings started in October 2022, eight months after filing for insolvency, and are still ongoing in March 2024
Financial instruments issued	<p>Corporate bonds are most relevant in insolvency proceedings, in earlier lifecycle direct investments, profit participation rights, crowdfunding, and private loans.</p> <ul style="list-style-type: none"> • Green City AG, ISIN: DE000A3H3KN0 • Green City AG, ISIN: DE000A3E5YL3 • Green City Energy AG, ISIN: DE000A14KJ19 • Green City Smart Mobility I GmbH, ISIN: DE000A2PJ237 • Green City Solarpark 2020 GmbH & Co. KG, ISIN: DE000A3H2VY6 • Green City Windpark 2021 GmbH & Co. KG, ISIN: DE000A3E5WK9 • Green City Energy Kraftwerkspark II GmbH & Co. KG, ISIN: DE000A161MQ1 • Green City Energy Kraftwerkspark II GmbH & Co. KG, ISIN: DE000A161MR9 • Green City Energy Kraftwerkspark II GmbH & Co. KG, ISIN: DE000A14KH45 • Green City Energy Kraftwerkspark II GmbH & Co. KG, Tranche A (registered bond) • Green City Energy Kraftwerkspark II GmbH & Co. KG, Tranche B (registered bond) • Green City Energy Kraftwerkspark III GmbH & Co. KG, ISIN: DE000A2AALN4 • Green City Energy Kraftwerkspark III GmbH & Co. KG, ISIN: DE000A2AALP9 • Green City Energy Kraftwerkspark III GmbH & Co. KG, ISIN: DE000A2G8V82 • Green City Solarimpuls I GmbH & Co. KG, ISIN: DE000A2GSTH8
Number of private investors	Approximately 1,200 bond investors affected by insolvency
Investment volume	Approximately 250m EUR bond investments

Case description Case B

Green City e.V. implemented the first solar power plant in 2003, using the rooftop of a cooperative housing block in Munich, Germany. Citizen engagement, including the financial contribution of citizens, is part of Green City's strategy. The foundation of a public limited company set the basis for growth and expansion, leveraging various forms of capital acquisition from private investors complementing and enabling additional bank loans (*10 Jahre Solarparks von Green City - Auf in die nächste Phase der Energiewende*, 2013). Green City AG was awarded several times for its contribution to sustainability and enabling the transition toward net zero (*Kompetenzprofil Green City AG*). The growth resulted in a complex network of nearly 150 project companies and a wide range of financial instruments issued to finance growth. Retail investors were acquired by the group company Green City Finance GmbH as well as third-party distribution partners. The German credit union GLS Gemeinschaftsbank eG offered Green City bonds Kraftwerkspark II and Kraftwerkspark III to its retail customer base (*Green City AG - Informationen für Anleger*inne*). The complexity of the Green City group network caused trouble. The consolidated financial statement for the business year 2017 was only presented in October 2020, including a remark from the auditor that not all subsidiaries are included as required and bank deposits are not sufficiently proofed (*Green City AG Konzernabschluss, 2017*). Operational losses were caused by delays in project implementation and disruptions in the supply chain of parts. In December 2021, a loss warning was published, and Green City bonds suffered a preliminary trading stop (*Green City Energy: Darum können die Anleihen derzeit nicht gehandelt werden*, 2021).

Green City AG and related companies filed for insolvency in February 2022. Ad hoc notifications from February 2022 indicate that intragroup loans were granted and, with Green City AG filing for insolvency, subsidiaries like Green City Kraftwerkspark III GmbH & Co KG had to write off receivables and file for insolvency themselves. The delisting of Green City bonds from stock exchanges in Munich, Frankfurt, and Luxemburg followed in April/May 2022 (*Green City Refinanzierungsvehikel forcieren Bond Delisting*, 2022). Depending on which group company issued the specific corporate bond, the situation of investors varies. The French, Italian, and operations business was acquired by the French Qair Group in March 2022 (*Qair enters German renewables market*, 2022), thus respective investors dealt with the legal successor. As for the remainder, the latest table published in December 2023 indicates a minimum of 25% capital recovery or outstanding information for bond investors (*Überblick über die betroffenen Emittentinnen, dem Status zum Insolvenzverfahren und eine mögliche Quotenzahlung*, 2023). The restructuring proceedings for the companies not acquired by Qair are expected to be ongoing until 2025. The respective bond investor's interests are represented by a common law firm (*Informationen für Anleihegläubiger der Green City-Gruppe*, 2023), except for registered bond investors. According to the latest press release from December 2023, the operational subsidiaries Green City Energy Kraftwerkspark II GmbH & Co KG and Green City Energy Kraftwerkspark III GmbH & Co KG will not be sold due to unfavorable market conditions with high interest rates and low returns. Instead, restructuring shall provide better long-term opportunities for investors.

Financial instrument risk: Corporate bonds (bearer bonds and registered bonds)

Corporate bonds, just as profit participation rights, are related to issuer risk. Neither interest payments nor the recovery of invested capital is guaranteed. Green City issued subordinated bonds, which face even higher issuer risk because other liabilities are being served with higher priority in case

of bankruptcy. Next to coupon bearer bonds, Green City offered registered bonds, which restrict the transfer of ownership and thus are not exchange traded. With registered bonds, liquidity risk is increased, and securities regulation does not apply.

Green City GmbH & Co. KG issued registered bonds that are hard to distinguish from their sibling bearer bond, e.g., Green City Energy Kraftwerkspark II GmbH & Co. KG, Namensschuldverschreibung, Tranche A, and Green City Energy Kraftwerkspark II GmbH & Co. KG, Inhaberschuldverschreibung, Tranche A (DE000A161MQ1). The return of a corporate bond depends on money market interest rates, duration rating of the issuing company, and seniority of the bond. Green City bond coupons range between 3,5% p.a. and 7% p.a. (*Green City Anleihen*, 2023). These rates are above the average bond yield of German issuers in the same period, thus including a risk premium (*Rendite festverzinslicher Wertpapiere bis 2023*, 2024).

Investee company risk: Green City AG

Mirroring the extensive company network of some 150 companies, Green City established a complex structure of financial instruments to finance their projects: private and loans, profit participation rights, bearer bonds, registered bonds, and registered shares with restricted transferability. Overall, the group had fewer employees than subsidiaries. The extensive group network of project companies, which was even larger than Prokon's network, overwhelmed the management, which failed to provide a consolidated group financial statement for the fiscal year 2017 and the following. Further, Green City heavily relied on debt with debt ratios of around 98% according to the group financial reporting from 2017 to 2019 (*Green City AG Konzernabschluss*, 2017). Excessive debt was mentioned to be the cause of bankruptcy in the respective press release (*Green City AG stellt Insolvenzantrag*, 2022). The group management is also facing allegations of misuse of funds (*Green City: Verdacht auf zweckentfremdete Gelder*, 2022).

Operational risk: Planning and operating wind and solar parks

On the operational side, Green City struggled with delays in project implementation partly caused by disruption in the supply chain of parts and other impediments caused by the COVID-19 pandemic. In 2021, a wind park in Northrhine-Westphalia was dismantled after the collapse of a Nordex onshore turbine (*Abriss nach Windrad-Havarie - Suche nach Ursache geht weiter*, 2021). The collapse also stopped other Green City projects based on the same turbine on other sites (*Verluste bei der Green City AG*, 2021). The reason for the collapse was found to be weak material in the tower. As a consequence, 22 turbines of this type were dismantled or destroyed in Germany (*Schwere Materialmängel: Windrad in Haltern gesprengt*, 2023).

Red flags specific to Case B

Press coverage of Green City AG was relatively low in the years before 2021. Only one consumer protection magazine warned about inappropriate advertising for renewable energy investments in 2015, not disclosing investment risks (*Green City Energy - Unseriöse Werbung für alternative Energien*, 2015). Until then, Green City e.V. and Green City AG were discussed positively in regional media. From 2018 onward, delayed financial statements and auditor notes could have alerted investors.

This default was picked up in special interest media at first and marked the beginning of a publicly discussed financial misery (*Green City AG: Der Jahresabschluss 2018 und die Perspektiven für 2020*, 2020). Ad hoc notifications of 2022 indicate that loans within the group negatively affected the balance

sheets of group companies (*Green City: Verdacht auf zweckentfremdete Gelder*, 2022; *Konzernobergesellschaft stellt Insolvenzantrag*, 2022). Further red flags could be taken from the mandatory sales brochure of bonds eligible for stock exchange trading. If the sales brochure was used in its original purpose as pre-contractual information, meaning before the investment decision was made, it provided valuable information and warnings. In fact, the sales brochure for corporate bonds DE000A2AALN4 indicates risks related to the issuer's company structure, dependencies within the group, and staff that is shared within the group (*Inhaberschuldverschreibungen Kraftwerkspark III Wertpapierprospekt*, 2016). The financial data in this sales brochure shows that all assets of the project company, some 18m EUR, are based on liabilities with a 0.00% equity ratio as presented in Table 3. Even though extensive information is available, it requires financial literacy to process risk disclosure and financial data.

Table 3. Relevant balance sheet values of issuing project company.

Relevant balance sheet values	Nov 17, 2015	Dec 31, 2015	Nov 30, 2016 (unaudited)
Assets side	500.00	128,177.37	18,378,692.78
Fixed assets	0.00	1,000.00	12,351,692.80
Current assets	500.00	500.00	5,499,794.16
Limited partner's share of losses not covered by asset contribution	0.00	126,677.37	527,118.82
Liabilities side	500.00	128,177.37	18,378,692.78
Equity	500.00	0.00	0.00
Provisions	0.00	5,3600.00	24,485.41
Liabilities	0.00	122,817.37	18,354,120.37

Note: Reproduction/translation, original table in German, sales prospectus *Inhaberschuldverschreibungen Kraftwerkspark III Wertpapierprospekt.*, p. 5

4.1.3. Case C: Siemens Gamesa/Siemens Energy (stocks)

The third case study refers to Siemens Gamesa S.A. and its majority shareholder Siemens Energy AG; the key facts on the group are presented in Table 4.

Table 4. Key facts about Siemens Gamesa S.A./Siemens Energy AG.

Company name and structure	Siemens Gamesa/ Siemens Energy Fiscal year from October 1st to September 30th
Company objectives	Production, set-up, and maintenance of onshore and offshore wind turbines
Founded	2017 2020 in Munich, Germany
Financial instruments issued	Stocks ES0143416115 Gamesa (delisted in 2023) DE000ENER6Y0 Siemens Energy
Number of private investors	20% private investors
Market capitalization	9.73 bn EUR (25.09.2023)

Case description Case C

Siemens and Gamesa merged their wind turbine business in 2017, resulting in the listed company Siemens Gamesa Renewable Energy (SGRE). In 2020, Siemens Energy was founded as a spin-off of Siemens, holding some 67% of SGRE shares. SGRE negatively affected the financial results of Siemens Energy due to operational trouble with mainly onshore turbine models (*Schlechtere Entwicklung bei Siemens Gamesa drückt auf Siemens Energy*, 2022). Siemens Energy thus wanted to be in full control of SGRE by acquiring the free flow shares with a voluntary cash tender offer in May 2022, closing on December 13, 2022 (*Voluntary cash tender offer*, 2022). By the end of 2022, Siemens Energy increased its stake to 92.7%. In February 2023, SGRE was delisted from the Madrid Stock Exchange (*Siemens Gamesa's shareholders approve delisting of the company*, 2023). On June 13, 2023, the general assembly of SGRE decided on a capital reduction, forcing the remaining free-flow shareholders to return their shares with a compensation of 18.05 EUR/share (the same price the voluntary cash tender was initially offered). Siemens Energy eventually got in control of 100% of the share capital. Following an ad hoc publication concerning the Siemens Gamesa wind turbine business on June 23, 2023, Siemens Energy's price per share plummeted by 37%, a top ten day-to-day loss in the German stock index DAX (*Die zehn größten Kursstürze im Dax*, 2023). The operational problems with wind turbines persist and are still affecting the financial results of Siemens Energy. The financial statement for the third quarter of 2023 reports a quarterly loss of 2bn EUR due to troubled Siemens Gamesa business. US law firms announced the preparation of class action lawsuits against Siemens Energy and its senior management as of September 2023 (Zieseimer, 2023). The second stock price shock occurred on October 26, 2023.

Siemens Energy's stock price dropped again by 36% after talks between Siemens Energy and the German government were confirmed. The group called for federal guarantees needed to back up large-scale orders. These guarantees do not refer to further wind turbine projects though. The group clarified that no more orders for the troubled onshore turbine model and only selective orders for offshore turbines will be accepted (*Ad hoc: Siemens Energy kommentiert Medienberichte*, 2023). Thus, incoming orders and turnover in the renewable energy sector will fall behind the forecast, and the overall group forecast will only remain thanks to an increase in other business areas, such as gas and network services.

Financial instrument risk (FIR): Stocks

The price risk of stocks is most relevant to investors in this case. Siemens Gamesa investors, the prices for the non-mandatory cash tender offer, as well as the stock price related to the forced redemption of shares remained the same and was probably even to the investor's financial benefit given the major losses published some months later. With the 100% stake in Siemens Gamesa, the devaluation risk of stock prices was transferred to Siemens Energy investors. The extent of the loss is highly individual depending on the purchase price the investor paid. Issuer risk is relevant for any investment in stocks. In case of bankruptcy of the issuer, stock capital as equity is likely to be fully used for servicing liability. Dividend payments are not guaranteed for stock investors and depend on the financial performance of the issuer.

Investee company risk (ICR): Siemens Gamesa/Siemens Energy

For Siemens Gamesa and Siemens Energy, being listed companies, governance and transparency standards are high. Quarterly financial reporting, non-financial reporting, and ad hoc announcements are available to the public. Despite the major losses of SGRE, bankruptcy was not a threat in this case.

Instead, Siemens Energy increased its stake from just over two-thirds to 100% at all costs. Next to the financial aspect, this case illustrates how a formerly environmentally sustainable and independent business unit with 99% taxonomy-aligned revenues (*Consolidated Non-Financial Statement, 2022, 2023*) was integrated into a group with various business units, even fossil energy-related products and services (*Sustainability Report 2022 – Tackling challenges, 2023*). The corporate strategy affected the environmental impact of investors as well as the value of their stocks.

Operational risk (OR): Wind turbine production and maintenance

The operational challenges Siemens Gamesa/Siemens Energy is facing regarding wind turbine models are caused by defects in rotor blades and bearings (Amann, 2023). Repair and maintenance costs will affect the financial situation of the group for years. Further comments in the financial statements of the group disclose market-related impediments such as pressure on prices, changing political support, and protected markets as in China. For offshore turbines, installation and maintenance are challenging and cost-intensive by nature.

Red flags specific to Case C

This case demonstrates the power of a controlling majority shareholder over individual investors in proxy voting. Siemens Gamesa's shareholder structure provided insights into the stake Siemens AG and, from 2020, Siemens Energy AG, held in Siemens Gamesa. The planned increase in the stake was announced before the corporate actions. Further comments in financial reporting and ad hoc announcements of Siemens AG, Siemens Gamesa S.A., and Siemens Energy provided transparency regarding operational challenges with wind turbine models. The press and financial analysts picked up the information disclosed.

4.2. Cross-case analysis

Summarizing the risk components of within-case analysis, strong parallels between Prokon and Green City can be found. Siemens Gamesa/Siemens Energy shows additional risk components for financial instruments risk, investee company risk, and operational risk. An overview of our findings is presented in Figure 2, and a more detailed breakdown is provided in Table 5.

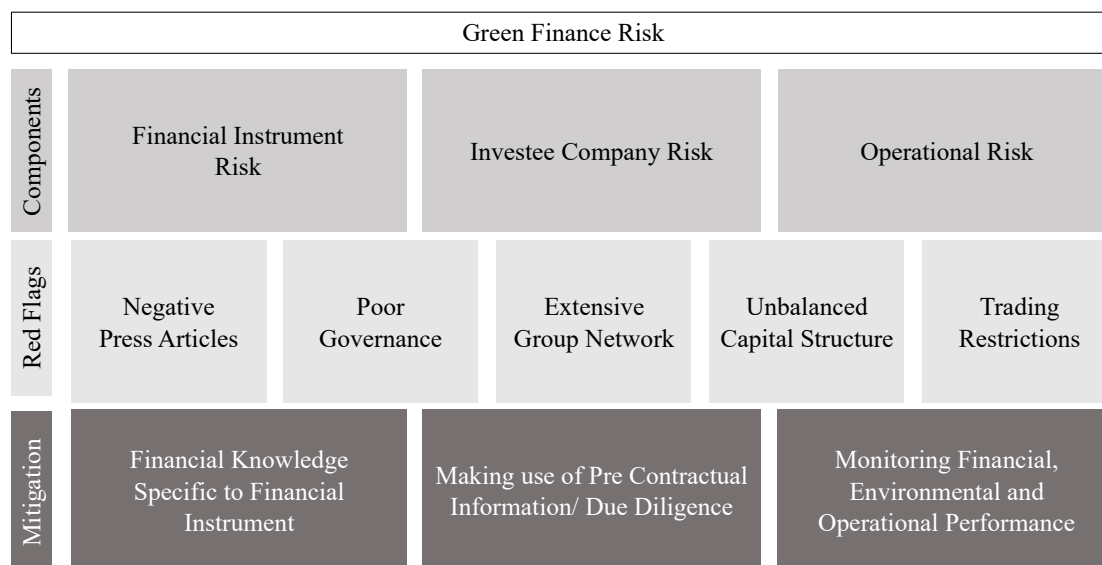


Figure 2. Overview of green finance risk components, red flags and mitigation approach; our own elaboration.

Table 5. Green finance risk components by category and red flags.

Green finance risk components		
Financial instrument risk	Investee company risk	Operational risk
<ul style="list-style-type: none"> • Issuer risk/default risk • Earning risk • Price risk • Liquidity risk • Squeeze out risk 	<ul style="list-style-type: none"> • Governance • Group network • Breach of regulation • Capital structure • Sustainability strategy 	<ul style="list-style-type: none"> • Project planning/implementation (permissions, acceptance) • Quality of hardware • Availability of staff/skills • Natural resources yield
Red flags for investors		
<ul style="list-style-type: none"> • Negative press: Shortcomings and risks reported in the press • Extensive group network: Increased complexity and dependencies, decreased transparency • Capital structure: Low equity ratio, low bank liabilities, high-volume intragroup loans, excessive debt, controlling majority shareholder • Poor governance: Delayed financial reporting, findings of auditor, complaints of consumer protection agencies, lawsuits indicating mismanagement • Restricted tradability: Delayed or suppressed pay-outs, restricted stock trading, or de-listing from the stock exchange 		

Steffen (2018) found the practice of project finance, which is common in the German market, to be beneficial for green project financing. The within-case analysis of Prokon and Green City pictures the downside of project financing: extensive group networks, increased management complexity, decreased transparency, and neglected capital requirements for the individual project company.

Considering green finance risk components and red flags, the investor may mitigate green finance risks. As a precondition, financial knowledge is required to understand risk related to the financial

instrument marketed. Women especially might run into unintended risk since they are more likely to invest according to their values and less knowledgeable in sustainable investments (Grumann et al., 2024). Risk components from this category are not specific to green finance. Any investment in such a financial instrument would be subject to the same risk components. Just because the investment objective is green, the financial instrument remains with its specific risk components. Investments with a direct contribution to an investee's company's capital are, per se, not diversified on a product level and bare issuer risk. The investor should be aware that a lack of diversification in the personal investment portfolio will increase risk (Horn, 2024; Oprean et al., 2009). Making use of information available on the investee company and consuming mandatory pre-contractual information before contracting is essential to mitigate the investee company's risk. If red flags are identified with the type of financial instrument or the investee company, investors should look for alternatives. Depending on the investor type, alternatives could be institutional green bonds, like the European Investment Bank (EIB) green bonds with a long track record and professional due diligence of green projects supported. Also, taxonomy-aligned mutual funds or ETFs that already implement diversification on the product level may pose an alternative. Investors seeking engagement beyond investment may choose membership in a cooperative society or similar forms of citizen participation engaging in local or regional ventures.

Since the cases analyzed confirm renewable energy to be risky in implementation and operations, we suggest regularly monitoring the financial, environmental, and operational performance of the investment. The regulatory disclosure requirements within the EU are in place: financial reports are available to the public, and non-financial reports will increasingly become available to the public according to Directive (EU) 2022/2464, the so-called corporate sustainability reporting directive (CSRD). In a recent study on drivers for the greenwashing behavior of corporations from the renewable energy sector in China, Chen (2024) found that competitive pressure and financial distress increase the likelihood of engaging in greenwashing behavior. For investors, this result suggests being extra cautious; once the financial situation of an investee company is deteriorating, the environmental performance of the investee company might also be affected.

5. Conclusions

Retail investors show a willingness to invest in green finance. Still, literature is missing the retail investors' perspective on green finance risk as a differentiated view on the origin of green finance risk. We contribute to the literature by decomposing green finance risk into (i) financial instrument risk, (ii) investee company risk, and (iii) operational risk, and applying a multiple-case study approach from the renewable energy sector to identify green finance risk components accordingly. The cases analyzed demonstrate that a toxic mixture of risky financial instruments, poor governance within the investee company, and operational risk related to renewable energy projects caused major losses for retail investors. The results of our study confirm that retail investors engaging in green finance are exposed to green finance risk. Awareness needs to be raised that "greenness" in terms of positive environmental effects is not to be mistaken for "greenness" in terms of investment risk. Further benefits of this study are identifying red flags that may alert investors and suggestions for risk mitigation, as summarized in Figure 2 and Table 4.

Limitations to this research are the reliance on non-scientific sources in case studies and the limited, focused assessment of selected cases that only represent German jurisdiction. Regarding future research, we suggest testing the results from our multiple-case study approach quantitatively. Further,

case studies from different regions and financial instruments could complement our results. Behavioral science could answer research questions related to “green-tinted glasses” of investors overruling personal risk preferences.

Suggestions for regulatory improvements are minimum capital requirements for issuers of any financial instrument marketed to retail investors to prevent excess in project financing, intragroup loans, or debt. Consequent punishment for any regulatory breach should apply in practice. Good governance is already implemented in Regulation (EU) 2019/2088 EU, commonly known as Sustainable Financial Disclosure Regulation (SFDR), Article 2, point (17), and named as a precondition for marketing sustainable financial instruments as such. The blind spot in regulation is that a corporation issuing sustainable financial instruments is not considered a financial institution and is thus not subject to SFDR. Further, thresholds of Directive (EU) 2022/2464 could cause a situation where the issuer of a financial instrument is not required to disclose sustainability-related information.

Author contributions

Conceptualization L.G., M.M. and E.V.; Investigation L.G.; Methodology L.G.; Supervision M.M. and E.V.; Visualization L.G.; Writing – original draft L.G.; Writing – review & editing L.G, M.M. and E.V. All authors have read and agreed to the published version of the manuscript.

Use of AI tools declaration

The authors declare they have not used Artificial Intelligence (AI) tools in the creation of this article.

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Conflict of interest

All authors declare no conflicts of interest in this paper.

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