Carbonwashing: A New Type of Carbon Data-related ESG Greenwashing

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Working Paper

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ABSTRACT

Despite the increased attention and capital incentives around corporate sustainability, the development of sustainability reporting standards and monitoring systems has been progressing at a slow pace. As a result, companies have misaligned incentives to deliberately or selectively communicate information not matched with actual environmental impacts or make largely unsubstantiated promises around future ambitions. These incidents are broadly called "greenwashing," but there is no clear consensus on its definition and taxonomy. We pay particular attention to the threat of greenwashing concerning carbon emission reductions by coining a new term, "carbonwashing." Since carbon mitigation is the universal goal, the corporate carbon performance data supply chain is relatively more advanced than that of the entire sustainability data landscape. Nonetheless, the threat of carbonwashing persists, even far more severe than general greenwashing due to the financial values attached to corporate carbon performance. This paper contextualizes sustainable finance-related carbonwashing via an outline of the communication as well as the measurement, reporting, and verification (MRV) of carbon emission mitigation performance. Moreover, it proposes several actionable policy recommendations on how industry stakeholders and government regulators can reduce carbonwashing risks.

SUMMARY

Keywords

JEL Classification

Highlights

- The growing materiality of carbon-related greenwashing (i.e., carbonwashing) justifies a new taxonomical framing.
- An increase in the quality and quantity of carbonwashing is prominent throughout the entire carbon data lifecycle.
- Net-zero announcements represent a strong contemporary case of carbonwashing.
- The majority of carbonwashing scenarios seem to be facilitated by the absence of mandatory reporting frameworks.

State of Play on Corporate Decarbonization

Today, we see a genuine wave of announcements, pledges, statements, declarations, initiatives, calls, and various other forms of public messaging regarding the corporate implementation of decarbonization strategies. In April 2021, Apple announced that they were launching a new fund to "accelerate natural solutions to climate change" (Apple, 2021). Prior, in September 2020, Google announced its new initiative to "invest in enabling 5 GW of new carbon-free energy by 2030 across supply chain regions globally" (Google, 2020). And a few months earlier, in June 2020, Amazon had announced a US$2 billion fund to "invest in companies building products, services, and technologies to decarbonize the economy and protect the planet" (Amazon, 2020). These announcements come on top of a global public call for more decisive climate action and corporate decarbonization efforts.

The future-oriented nature of these decarbonization strategies encourages companies to claim frontloaded impact data that does not exist yet. But momentarily, corporate governance still focuses more on potential market response and reputational factors than on the systematic establishment of solid internal impact data validation processes. The most notable example revolves around the concept of "net-zero" emissions commitments, most of them setting 2050 as the target year and covering two-thirds of the global economy. However, there appears to be a significant disconnect between stated ambitions and value chain greenhouse gas (GHG) monitoring, actionable reduction strategies, efficient governance, and capital allocations towards achieving most of their self-declared targets. For example, a recent study by the Oxford Net Zero initiative revealed that only 20% of these targets currently meet quality tests (Black, et al., 2021). Furthermore, a report by the Climate Action 100+ initiative stated that among the world's largest corporate GHG emitters, "only six companies explicitly commit to aligning their future capital expenditures with their long-term emissions reduction target(s), and none of these companies has committed to aligning future capital expenditure with the goal of limiting temperature rise to 1.5 degrees Celsius" (Climate Action 100+ , 2021).

This massive degree of corporate impact frontloading in the form of climate change mitigation-related public relations (PR), which does not seem to be matched with similar ambition in terms of tangible action in terms of proper measurement, reporting, and verification (MRV) of GHG emissions, more specifically CO_2, could be seen as a form of "greenwashing" that is becoming more material in terms of scope and distribution. However, in identifying variable levels of overall sectoral materiality among different greenwashing practices, we conclude that the term greenwashing is too broad to sufficiently capture the specificity of certain intentional or inadvertently misleading environmental, social, and governance (ESG)-related actions or activities. Climate-related risk disclosure has been gaining immense momentum due to initiatives and frameworks such as the Task Force on Climate-related Financial Disclosures (TCFD), the Carbon Disclosure Project (CDP), the Science-based Target Initiative (SBTi), the Net-Zero Asset Owner Alliance, the RE100+, and the UNFCCC COP-affiliated "Race to Net Zero." In this context, given the overwhelming role that carbon data, we introduce the term "carbonwashing" as an adequate taxonomical framing of carbon-related greenwashing instances.

With the burgeoning interest in global decarbonization efforts, both public and private, incentives for carbonwashing might outstrip the pace of concrete system-wide low-carbon transition action without a comprehensive understanding of industrial ecology. For this reason, this paper aims to illuminate the space of carbon data disclosure in a timely manner. The aforementioned carbon-related initiatives exert significant pressure, regulatory or reputational, on firms to reduce their carbon footprints. In this context, corporates are incentivized to transition to climate-neutral business models and low-carbon supply chains. At the same time,

financial institutions are under increasing scrutiny to decarbonize their investment portfolios as well as refrain from providing financing or underwriting to carbon-intensive projects, activities, or assets (PAAs). As many reports and studies have been documenting (Alliance for Corporate Transparency, 2019; Climate Disclosure Standards Board, 2020; Task Force on Climate-Related Financial Disclosures, 2020; Riding, 2021), corporates and financial institutions are continuing to struggle with proper reporting of ESG-related data, especially carbon data. Therefore, companies might take advantage of the current systemic inconsistencies, such as regulatory gaps or lack of disclosure framework standardization. The benefits include reputational gains for being able to communicate strong decarbonization efforts, direct positive impacts on corporate ESG ratings and scores, as well as alignment with investor-level or regulatory carbon benchmarks.

In response, there have been attempts to remedy and configure system-level shortcomings. Many economists see climate change as a market failure: carbon emissions are generated through economic activities, and their adverse effects on social welfare are external to the market (Bowen, Dietz, & Hicks, 2014). Economists representing these views insist on public interventions to internalize the negative externalities through carbon pricing instruments such as a carbon tax. In "Revising the Social Cost of Carbon," Nordhaus (2017) emphasizes the social cost of carbon (SCC) as the central concept for understanding and implementing climate change policies. However, we have not yet reached a system-wide consensus on how much it should be and who should bear it. Another related market failure is the lack of reliable information on who emits how much carbon. Today, carbon data is primarily generated and traded through economic activities. Incomplete information may negatively affect social welfare but remains external to the market. To address this information asymmetry, countries, companies, and asset owners are now required or urged to disclose their carbon emissions. Nevertheless, many mandatory disclosure criteria continue to be narrowly defined and thus limited to cover the rapidly expanding carbon data market.

Stakeholder concerns about ESG-related greenwashing and data reliability risks are also some of the key drivers behind major regulatory efforts across the global sustainable finance space (European Commission, 2020a; European Commission, 2020b). The European Union has been one of the most active entities to provide proper regulatory framing of what PAAs can be considered green by contributing to sustainable development or environmental objectives. Building on the recommendations of the Commission's 2018 Action Plan on Financing Sustainable Growth, the EU has been adopting a range of legal texts and regulations (European Commission, 2020c). These are, among others, meant to provide a definition of "environmentally sustainable" economic activities to reduce greenwashing, which is defined as the practice of marketing financial products as "green" or "sustainable," when in fact they do not meet basic environmental standards (European Commission, 2019). Clear frameworks and standards are required, especially regarding climate-related carbon data, since many respondents from a research study commissioned by the European Commission stated that the E pillar related to climate change was flagged as the one with the most "insufficient information, requiring some improvement or strong improvement" (European Commission, 2020a). One of the reasons mentioned by respondents of the said study was that climate change data gaps are more evident due to the better understanding of what information is actually required.

Without this additional taxonomical clarity, there is a danger of greenwashing. Despite the increased attention and capital incentives to corporate sustainability, the development of sustainability performance reporting standards and monitoring systems has been progressing at a relatively slow pace. As a result, companies have misaligned incentives to deliberately or selectively communicate information not matching their actual environmental impacts or make promises with little or no substance (Delmas & Burbano, 2011; Marquis & Toffel, 2012; Forbes & Jermier,

2012). The conceptualization of previous literature tends to be narrowly focused on what can be measured and applied to the empirical investigation of greenwashing (Bowen & Aragon-Correa, 2014). Often, the data points included in these studies vary, and the measuring techniques are limited, often making the sample sizes and periods too short to yield statistically significant results. These issues are exacerbated by the continued absence of ESG rating agencies and service provider regulations. The chair of the European Securities and Markets Authority (ESMA) has stated that the "lack of clarity on the methodologies underpinning those scoring mechanisms and their diversity does not contribute to enabling investors to effectively compare investments which are marketed as sustainable, thus contributing to the risk of greenwashing" (ESMA, 2020). In response, ESMA and the European Fund and Asset Management Association (EFAMA) have called for appropriate regulatory requirements to ensure the quality and reliability of ESG ratings and other assessment tools, momentarily supervisory capacity gaps pose the key barrier to implementing these recommendations (ESMA, 2021; EFAMA, 2020). The same applies to the creation of a centralized EU data register that would increase comparability and transparency of, as well as accessibility to ESG data, which faces both logistical, data privacy, and proprietary data hurdles (European Banking Federation, 2020).

In light of corporate decarbonization and its industry ecosystem not having been sufficiently contextualized yet, we pay particular attention to the threat of greenwashing in relation to corporate carbon emission reductions, framed as the aforementioned "carbonwashing." Since carbon mitigation and climate action have been identified as universal sustainable development goals (SDGs), the corporate carbon performance data supply chain is already fairly more advanced in comparison to other sustainability data. Yet, carbonwashing represents an even far more severe threat than general greenwashing due to reputational and financial values attached to corporate carbon performance. In this paper, we review the current carbon data ecosystem and how it has revolved. We then frame carbonwashing within a sustainable finance context via an outline of the ex-ante PR and ex-post MRV elements of the carbon emission mitigation tracking. In theory, impact MRV in the sustainable finance sector is meant to provide adequate documentation and evidence of sustainability performance with data representing the means of assessing such (see Figure 1). But in a context of general regulatory uncertainty, lack of overall standardization between reporting frameworks, and ongoing data gaps, it often remains unclear how MRV of carbon emission mitigation can be carried out in the most transparent and efficient ways; and according to what rules or standards to prevent or reduce carbonwashing. We see carbonwashing as a byproduct of the current methodological shortcomings, reputational incentives, and regulatory pressures. The good news is that it is possible to avoid carbonwashing incidents when some conditions are met.

Figure 1. Finance to Carbonwashing
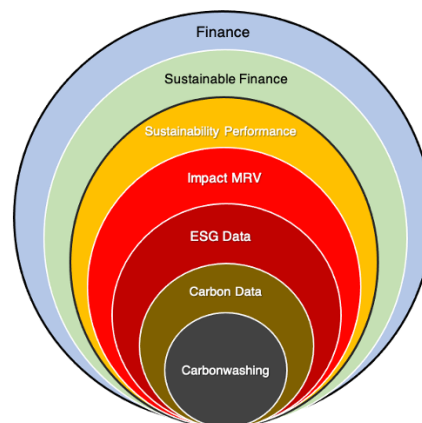
Carbon Data Market Ecosystem

Suppliers of Carbon Data

Today, carbon emissions have become central to current discussions on firm-level environmental performance. This is largely due to the recognition of the need for individual firms to take significant steps towards curbing climate change in the coming years, in line with the broader economy (Newell, 2020). The Paris Agreement stressed the need for state and non-state actors to contribute to the low-carbon economic transition by reducing their carbon emissions (Hale, 2016). In addition, there is a growing concern about financial risks posed to firms by climate change, which are grouped into physical risks and transition risks (Oliver Wyman, 2019). While physical risks relate to the impact of climate change's physical effects on a firm's operations, transition risks concern the policy, societal, and market-based risks associated with a low-carbon transition, such as the implementation of a carbon price or net-zero carbon targets. While physical and transition risks are both relevant, transition risks particularly increase present-day pressure on firms since there is an increasing likelihood of regulatory actions limiting their carbon emissions (Monasterolo, Battison, Janetos, & Zheng, 2017; Andersson, Bolton, & Samama, 2016). The acknowledgment of the importance of financial risks related to carbon emissions has led to further discussions around 'carbon bubbles' and 'carbon risks,' which measure the extent to which a firm's business model is reliant on carbon emissions and therefore threatened by emissions regulation (Jung, Herbohn, & Clarkson, 2018; Benz, Paulus, Scherer, Syryca, & Trück, 2020; Delis, de Greiff, & Ongena, 2019; Strauch, Dordi, & Carter, 2020).

Firms communicate their carbon performance to stakeholders through a variety of channels (In, Rook, & Monk, 2019). Firm-specific sources include corporate social responsibility (CSR) reports, annual filings, and information posted on company websites. In addition, firms can adhere to or fall under carbon emissions disclosure regimes, which can be divided into two broad categories. Mandatory regimes, such as the EU Emissions Trading System (ETS), require firms to disclose some portion of their emissions to a government agency. These schemes are characterized by their focus on a firm's direct emissions and their strict accounting requirements. The second regime category consists of voluntary reporting initiatives, which exist to encourage firm transparency about carbon emissions and to provide diverse groups of stakeholders with access to this information. The CDP is the largest and most comprehensive of these frameworks (Kolk, Levy, & Pinske, 2008). The CDP collects its data via a detailed annual questionnaire sent to firms that cover emissions metrics, strategy, governance, and climate risk management. Voluntary schemes are usually less strict about their accounting practices and more flexible regarding the applicable accounting frameworks than mandatory regimes, particularly regarding the type of emissions firms are encouraged to report. As a result, there often exist significant discrepancies with regard to the types of emissions firms track and disclose.

Once a firm discloses its carbon performance, the data is often aggregated and analyzed by third-party rating agencies. These agencies act as intermediaries between company disclosures and investors looking to access and use that data in a publicly accessible format or centralized database. In addition, rating agencies create indicators and metrics based on data provided by firms with the aim of increasing data comparability and ultimately distinguishing high-carbon performers from low-carbon performers. Figure 2 visualizes the carbon data cycle and shows how carbon data is generated, collected, and distributed. Table 1 describes the processes that reflect the respective carbon data applications throughout the industrial lifecycle. Sectoral benchmarks, which place corporate climate mitigation performance into a financial context, are based on how well firms carry out these processes. These are then often utilized to determine the makeup of ESG or climate-aligned investment portfolios.

Table 1. Carbon Data Lifecycle (II)

Lifecycle	Lifecycle Steps	Data Process Steps	Process Description
Ex-ante	Preliminary Signaling	1. Carbon data-related PR	**Activities:** Public policy statements, announcements, pledges, declarations around carbon reduction targets and carbon MRV activities **Primary industry stakeholders:** Companies
Ex-post	Primary Cycle	2. Raw Data Measurement	**Activities:** PAA-level Scope 1, 2, and 3 under direct control; Quantitative and qualitative sampling (physical); raw data processing and structuring **Primary industry stakeholders:** Companies **Primary civil society stakeholders:** Research institutions, NGOs/NPOs
		3. Institutional Data Collection	**Activities:** Quantitative and qualitative sampling (physical and nonphysical); raw data processing and structuring **Primary political and regulatory stakeholders:** Regulators, government agencies/bodies, intergovernmental organizations **Primary civil society stakeholders:** Research institutions, NGOs/NPOs
		4. Internal Data Calculation	**Activities:** PAA-level Scope 1, 2, and 3 under indirect control; Quantitative and qualitative sampling (nonphysical); raw data extrapolation, processing, and structuring **Primary industry stakeholders:** Companies
		5. Corporate Disclosure and PR	**Activities:** Mandatory or voluntary disclosure of financial and non-financial firm-level performance information **Primary industry stakeholders:** Companies
		6. Primary Data Aggregation	**Activities:** Quantitative and qualitative screening and sampling (nonphysical); primary data extrapolation, processing, and structuring **Primary industry stakeholders:** ESG data service providers (CDP, Bloomberg, Morningstar, Refinitiv, S&P Trucost, Reprisk, etc.) **Primary political and regulatory stakeholders:** National emissions monitoring agencies/bodies (EU ETS), International emissions monitoring bodies (UNFCCC) **Primary civil society stakeholders:** Research institutions, NGOs/NPOs
		7. External Data Validation	**Activities:** Quantitative and qualitative assessment of ex-ante data framework reliability and veracity **Primary industry stakeholders:** ESG data service providers, Advisory services, consultancies, auditors **Primary political and regulatory stakeholders:** National emissions monitoring agencies/bodies (EU ETS), International emissions monitoring bodies (CORSIA) **Primary civil society stakeholders:** Research institutions, NGOs/NPOs (SBTi, PRI, UNEP-FI, etc.)
		8. Independent Data Verification	**Activities:** Quantitative and qualitative assessment of ex-post raw/primary data reliability **Primary industry stakeholders:** ESG verification providers (Cicero), Advisory services, consultancies, auditors **Primary political and regulatory stakeholders:** National or international supervisory bodies (ESAs, central banks, government agencies) **Primary civil society stakeholders:** Research institutions, NGOs/NPOs
		9. Secondary Data Aggregation	**Activities:** Quantitative and qualitative screening and sampling (nonphysical); secondary data extrapolation, processing, and structuring **Primary industry stakeholders:** ESG rating providers (MSCI, Sustainalytics, ISS, Vigeo Eiris, Bloomberg, RobecoSAM); ESG index/benchmark providers (FTSE Russell, Refinitiv, S&P, MSCI, Bloomberg) **Primary political and regulatory stakeholders:** Regulators, government agencies/bodies ((European Commission), intergovernmental organizations **Primary civil society stakeholders:** Research institutions, NGOs/NPOs
		10. Data Interpretation	**Activities:** Quantitative and qualitative screening and sampling (nonphysical); secondary data extrapolation, processing, and structuring **Primary industry stakeholders:** Asset owners, Asset managers, Banking/Insurance, Companies, ESG data service providers, general data service providers (News media), Regulated professions (lawyers, accountants, advisors, consultants) **Primary political and regulatory stakeholders:** Regulators, government agencies/bodies ((European Commission), intergovernmental organizations **Primary civil society stakeholders:** Research institutions, NGOs/NPOs
	Tertiary Cycle	11. End Usage	**Activities:** Use of end products, including ESG ratings, benchmarks, indexes, industry reports, rankings inform investment strategies, risk management, governance structures, regulatory approaches, or financial product design, engagement policies, future data disclosure. **Primary industry stakeholders:** Asset owners, Asset managers, Banking/Insurance, Companies, ESG data/verification/rating/index providers, general data service providers (News media), Regulated professions (lawyers, accountants, advisors, consultants) Primary political and regulatory stakeholders: National government bodies and intergovernmental bodies **Primary civil society stakeholders:** Research institutions, NGOs/NPOs (GRI, SASB, UN Global Compact, Ceres, WBCSD, UNEP-FI, WWF, etc.)

Figure 2. Carbon Data Lifecycle (I)
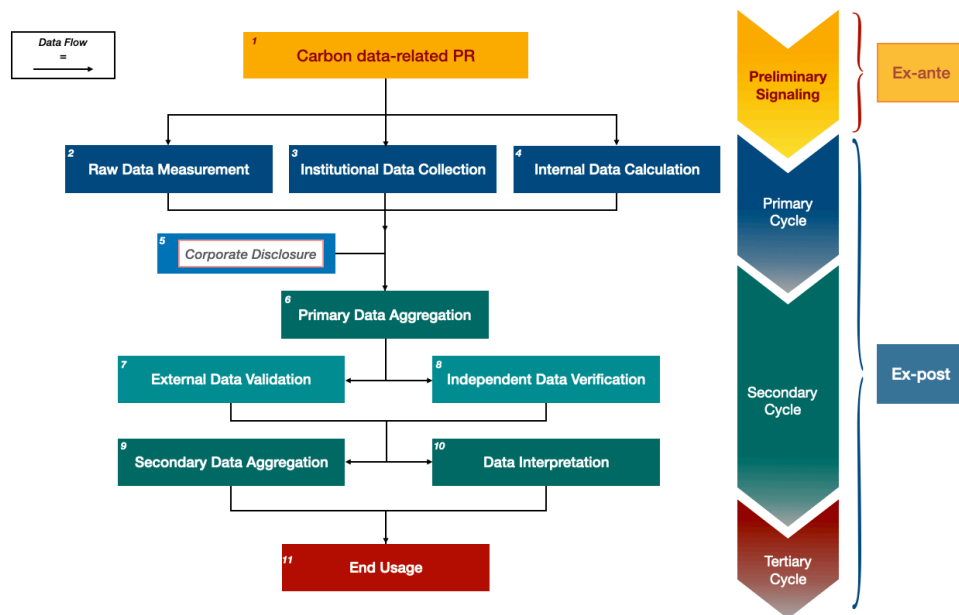
Users of Carbon Data

The amount of capital tied to sustainable investing has skyrocketed in recent years, with significant growth in the use of carbon-related data towards financial products and portfolios (Matsumura, Prakash, & Vera-Munoz, 2014; Clapp, Alfsen, Torvanger, & Lund, 2015; Chasan, Eckhouse, & Roston, Low-Carbon Investing Is Growing, 2018). Investors are interested in carbon data for a variety of reasons. As the profile of climate change has increased in the public consciousness, there is significant retail demand for products with a link to the low-carbon transition (Deloitte, 2020). This has led to competitive pressures around green products, as well as pressure for decarbonization of standard product offerings (Benz, Jacob, Paulus, & Wilkens, 2020). Industry advocacy groups have also played an important role in raising the profile of green finance, one the earliest being the UN Environmental Program Finance Initiative (UNEP FI), created in 1992, following the Earth Summit in Rio de Janeiro. In particular, the Principles for Responsible Investing (PRI) and the TCFD are two high-profile initiatives advocating for investors to integrate ESG data through transparent risk assessment (KfW, 2017). There are legal requirements in some countries to pursue decarbonization, such as the French Energy Transition Law that requires investors to report on their CO_2 reduction strategy and climate risk management under its Article 173 (Gianfrate & Peri, 2019). A myriad of empirical studies has investigated the relationship between carbon emissions and the financial performance of both firms and portfolios, providing additional incentives for investors (In, Park, & Monk, 2019). Finally, genuine climate risk assessments, particularly pertaining to transition risks around carbon emissions regulation, have increased practitioner interest in managing those risks (Andersson, Bolton, & Samama, 2016; BlackRock, 2020). Portfolios can also be evaluated based on their carbon footprint, comparing the average portfolio-level carbon emissions of firms. As a result, the use of carbon data is no longer confined to targeted ESG funds but is instead increasingly considered in the policies of traditional products (Barzuza, Curtis, & Webber, 2020).

Investors use both historical and forward-looking carbon information in determining firm-level carbon performance, in line with the practices of third-party rating agencies. Regarding index funds, Andersson et al.

(2016) segment these strategies into two broad categories – exclusionary models focusing on divestment from high emitters and "pure-play" models focusing on driving impact in a green sector such as clean energy. This choice between exclusion and impact is mirrored across the broader asset management business, where managers have the choice of creating new ESG product offerings or removing carbon-intensive stocks from existing funds. In practice, the former strategy is preferred, either via thematic or exclusionary low-carbon funds (Jahnke, 2019). Prominent funds focusing on the exclusionary decarbonization strategy include the MSCI Global Low Carbon Leaders Index product family, which is based on existing indices but excludes the worst performers based on carbon intensity and fossil fuel reserves. Similar strategies are pursued by the S&P 500 Carbon Efficient Index product family or the iShares MSCI ACWI Low Carbon Target ETF. Many index families offer a variety of options depending on investor preference for decarbonization methods – for example, the S&P 500 Carbon Efficient Index weights companies based on carbon intensity, while their Carbon Efficient Select Index weights based on firms' overall carbon footprint. Notably, the Amundi Equity Global Low Carbon index tempers the exclusionary strategy by reducing the representation of carbon-emitting companies rather than excluding them entirely. The more impact-driven model of product construction features a greater diversity of approaches. The Low Carbon Risk Index from Morningstar uses data from Sustainalytics, a prominent ESG rating agency, in choosing stocks with a lower carbon risk score, resulting in high exposure to tech and healthcare with low exposure to energy and utilities. A different strategy is employed by two S&P Indices, the S&P Eurozone Large MidCap Paris-Aligned Index and the Climate Transition Index. In each, companies are selected and weighted based on their compatibility with a 1.5°C global warming climate scenario. In terms of data used to construct these two broad types of products, carbon intensity remains a common choice, either relative to sales or market capitalization. However, firms often employ other emissions-based metrics, such as ETHO Capital's Scope 4 emissions that consider the emissions reductions produced by a firm or its products. This growth and diversification in the climate-related index product segment have also caught the attention of lawmakers and regulators. For example, the EU has recently adopted a series of legislative and regulatory acts around climate benchmarks and benchmarks' ESG disclosures to address the risk of greenwashing via the introduction of disclosure requirements that improve transparency and comparability of information across benchmarks not only regarding climate-related information but also on a variety of ESG indicators (European Commission, 2020d). Through the introduction of an EU Climate Transition Benchmark (EU CTB) and an EU Paris-Aligned Benchmark (EU PAB), the EU tries to streamline minimal standards for carbon-related benchmarks that are rooted in the latest climate science by requiring year-on-year self-decarbonization of at least 7% on average per annum, in line with or beyond the decarbonization trajectories of the Intergovernmental Panel on Climate Change (IPCC) 1.5°C scenario (State Street Global Advisors, 2020).

In response to investor interest, firms have offered financial products highlighting current or projected carbon performance, particularly in the debt markets. Flammer (2020) defines green bonds as instruments whose proceeds are committed to financing low-carbon projects. Tolliver et al. (2019) examined publicly reported green bond proceeds allocations from 53 organizations to projects and assets throughout 96 countries from 2008 to 2017. They found that their study sample projects and assets were associated with over 108 million tons of carbon dioxide equivalent (tCO2e) in GHG reductions and over 1500 gigawatts in renewable energy capacity. Moreover, a green bond has become a representative designation for a large variety of ESG-related fixed-income instruments that support a wide range of ESG-related projects or activities (Schumacher, 2020a). For example, in recent years, the expansion gave rise to products such as sustainability-linked bonds (focused on other ESG metrics), transition bonds (for carbon-intensive firms), and climate bonds (specifically focused on developing climate resiliency). These tools are widely seen as a critical part of the economic transition and have been successful in helping firms to market their environmental credentials and communicate their goals. While there is some self-regulation, such

as the Green Bond Principles and certification regimes, there is still a great deal of ambiguity as to the precise definition of what constitutes an eligible green project (Schumacher, 2020b). The EU, for example, proposes a currently voluntary "EU-wide standard to encourage market participants to issue and invest in EU green bonds and improve the effectiveness, transparency, comparability, and credibility of the market" (European Commission, 2020e). The proliferation of green bonds has also led to thematic ETFs focused on green bond investments, such as the VanEck Green Bond ETF and the BlackRock iShares Global Green Bond ETF.

Weakness of the System: Fast-Growing Market vs. Slow-Moving Institutions

The discussed green finance tools rely on objective, accurate carbon data to distinguish high-carbon performers from low-carbon performers. Kolk (2008) describes how the effectiveness of carbon disclosure, as a tool for determining sustainable investment allocation, depends on its reliability and usefulness, which in return incites investors to pressure additional firms to disclose and improve their carbon performance. This progression from firm-level disclosure to investor action in the green finance sphere is mentioned repeatedly in the literature (Andersson, Bolton, & Samama, 2016; O'Dwyer & Unerman, 2020). However, most available information or disclosed data about carbon performance is currently not subject to regulation; as a result, carbon data is first and foremost a form of primarily self-disclosed firm-level environmental communication (Guo, Zha, Lee, & Tang, 2020).

Carbon footprint is a common measure to account for the emissions associated with a specific product, activity, or unit. It is often cited by sustainable finance practitioners when assessing the emissions reduction potential of given financing and the carbon footprint of PAAs frequently reported by firms. However, In et al. (2021) discuss that companies often remain preoccupied with reducing their operational footprint, notably Scope 1, 2, and 3 emissions, and thus may miss out on opportunities to invest in decarbonization initiatives that result in system-wide and scalable impacts. The TCFD (2020) encourages firms to disclose additional carbon-related information regarding governance, strategy, risk management, reduction targets, and accounting metrics. Therefore, firms report this information in line with investor expectations, and the CDP collects this data through its annual questionnaire (Luo, 2019). Firms may also include investments they are making towards carbon reduction as a forward-looking measure, including "carbon-neutral," "net-zero" or "carbon-negative" targets. Over 800 firms have committed to science-based targets (SBTs), which aim to align firm-level climate mitigation strategies with IEA climate models to meet the Paris Agreement's 2°C emissions target (Newell, 2020; Walenta, 2020). This uptake has in large part been driven by the SBTi, a collaboration of non-profits. Finally, large firms, such as Microsoft and Unilever, have implemented internal carbon prices as a form of self-regulation, though the efficacy of such tools has been debated (Addicot, Badahdah, Elder, & Tan, 2019; Bento & Gianfrate, 2020).

Within this disclosure environment, concerns have been raised about the inconsistency of firm-originating carbon data. Hahn et al. (2015) outline an ongoing debate on the suitability of voluntary and mandatory disclosure regimes for achieving transparency. They conclude that empirical research on the efficiency and effectiveness of such schemes could complement the conceptual discussion. Busch (2020) identifies three dimensions of carbon data relevant to consistency: scope of emissions, disclosure scheme, and disclosure source. Disclosure under voluntary regimes such as the CDP remains unaudited in large parts, and firms have been found to employ a variety of methods for disclosing both direct and indirect emissions, potentially rendering this information unreliable (Stanny, 2018; Andrew & Cortese, 2011). Furthermore, other studies have shown that many companies from carbon-intensive sectors do not disclose climate-related data at all. For example, in Japan, only a few listed companies from sectors with the highest transition risks reported their emissions under the CDP disclosure framework (Schumacher,

Chenet, & Volz, 2020). This situation increases the risk that firm-level carbon data continues to display low levels of transparency and will remain largely dependent on voluntary disclosure.

Moreover, even mandatory reporting requirements are often ineffective at increasing data comparability (Matisoff, 2013). Although the TCFD recommends that firms communicate information in financial filings, it is common practice for firms to place this information in largely unaudited sustainability reports (Eccles & Krzus, 2018). As a result, there arises significant ambiguity about the methods employed with these reports (Dragomir, 2012). Severe divergences regarding the rating methodologies of ESG raters and service providers means that the problem of inconsistent carbon data is compounded by ambiguity about how this data should be used (In, Park, & Eccles, 2021). Rating agencies are themselves inconsistent, choosing different dimensions, metrics, and weights when evaluating firm-level ESG performance (Berg, Kölbel, & Rigobon, 2020). This has led to low convergence between ratings, even when corrected for explicitly named differences in rating construction (Chatterji, Durand, Levine, & Touboul, 2016). For example, evaluations can be based on firm-level processes or process-level outcomes and the different dimensions impacting firm-level performance (Delmas, Etzion, & Nairn-Birch, 2013). It is difficult to determine whether ratings and indicators are meant to illuminate past behavior or provide forward-looking estimates (Chatterji, Levine, & Toffel, 2009). Rating agencies also attempt to generate forward-looking information, but these have questionable predictive power (Kalesnik, Wilkens, & Zink, 2020). Forward-looking information is demanded by investors seeking to assess firm-level performance regarding risks and opportunities, but without clarification on how ratings are constructed, it will remain difficult to distinguish between high-performing and low-performing firms (Benz, Jacob, Paulus, & Wilkens, 2020).

There also persists considerable ambiguity in the carbon accounting process. The latitude in measurement and evaluation of carbon performance leaves room for firms to overstate or present misleading accounts on their capabilities and carbon-use reduction efforts. For instance, Scope 3 emissions are generally optional under voluntary regimes, and the share of reporting firms only accounted for around 22% of their full Scope 3 emissions on average (Blanco, Caro, & Corbett, 2016). This lack of reporting, combined with the fact that for many firms, Scope 3 emissions represent a significant portion of their total footprint, creates the potential for numerous firms to present an inaccurate account of their true carbon performance (Mercereau, Neveux, Sertã, Marechal, & Tonolo, 2020). Concerns have been raised that firms may outsource their carbon emissions to their supply chain, reducing reported emissions while maintaining or increasing the overall emissions generated in connection with their PAAs (In, Park, & Monk, 2019; Blanco, Caro, & Corbett, 2016; Bowen & Aragon-Correa, 2014).

Similar concerns have been raised regarding the communication of corporate emissions reduction targets, particularly as they relate to the use of voluntary carbon offsets (Bumpus & Liverman, 2008; Elgin, 2020). These tools theoretically work by allowing firms to invest in carbon reduction projects outside of their line of business, thus offsetting emissions produced by the firm (Dhanda & Hartman, 2011; Lovell, Bulkeley, & Liverman, 2009). However, criticism has been directed towards the perceived lack of transparency and additionality of carbon offsets, with these tools potentially creating 'non-existent' negative emissions (Anderson & Peters, 2016; Backstrand & Lovbrand, 2006). This criticism of the lack of additionality is similar to that expressed in the context of green bonds, hinting at the broader issue of general ambiguity around the efficacy of disclosure and firms' proposed mitigation efforts (Maltais & Nykvist, 2020). When it comes to the misrepresentation of carbon reduction efforts, the lack of accountability is combined with high incentives for firms to publicly highlight their climate mitigation activities or ambitions as more progressive than they actually are. For example, firms generally experience improvements in stock price valuation in response to green bond issuance, thus suggesting concrete, high incentives to impression

management (Flammer, 2020). Furthermore, Li et al. (2019) showed that even if firms engage in symbolic instead of substantive CSR, markets view this mostly immaterial engagement positively following a corporate controversy, hence providing strong incentives for virtue signaling and unsubstantiated ex-ante ESG performance claims.

Therefore, communication strategies, such as disclosing unaudited data or unsubstantiated self-reporting, are highly problematic due to the future-oriented nature of risks. Suppose one can exhibit a higher return for reporting misleading or wrong information. In that case, the disproportionate risk-reward ratio provides a strong incentive for engaging in inadvertently or intentionally dishonest disclosure practices. An examination of greenwashing theory and its intersection with the current state of firm-level carbon disclosure are therefore critical in understanding the incentives behind such instances of corporate carbon performance misrepresentation, all the while outlining ways in which said disingenuous or negligent practices can be tracked.

CLAIMING SPACE FOR CARBONWASHING

Carbon Promotion Vocabulary

Industry stakeholders and regulators widely acknowledge the practice of greenwashing. As aforementioned, it has the potential to gradually transform into a systemic risk to the sustainable finance and ESG investing sectors, as it has been one of the driving forces behind most EU sustainable finance-related legislative and regulatory actions (European Commission, 2021). In the context of sustainable finance and non-financial disclosure, the EU frames greenwashing as "the practice of marketing financial products as 'green' or 'sustainable,' when in fact they do not meet basic environmental standards" (European Commission, 2019). Therefore, it becomes essential to analyze what elements of greenwashing are of primary materiality to establishing a solid and transparent sustainable finance sector. In arguing how a third of top UK firms' carbon emissions were not in line with global climate goals, Jolly (2021) described that high emitter companies have recently committed to setting SBTs, which are "based on United Nations benchmarks and are viewed by environmentalists as the gold standard of audited plans to cut emissions." However, frameworks like the CDP or the SBTi rely almost exclusively on self-reported corporate carbon data.

Given the ongoing lack of standardization between major corporate sustainability reporting frameworks, as well as the continuing absence of genuine independent peer review of the raw and primary ESG data reported by companies, carbon data reliability is still at risk from excessive PR-level impact frontloading and MRV-related carbonwashing practices (Schumacher, 2020c). For example, the SBTi states in their most recent Target Setting Manual Version 4.1 that one of the main business cases for setting science-based carbon emission targets is to "build credibility and reputation" (Science-Based Targets Initiative, 2020). On top of that, the SBTi's Corporate Manual provides additional reasons and outlines the business benefits of joining the SBTi, listing that it "enables companies to demonstrate their leadership on climate action by publicly committing to science-based GHG reduction targets" and "build credibility and reputation" with investors and consumers (Science-Based Targets Initiative, 2021b). Yet, the SBTi largely relies on the same self-reported CDP data, and the same issues in terms of reliability of the reported data apply as outlined above in several instances (Carbon Disclosure Project, 2021).

This creates a similar "low risk - high reward" environment for carbonwashing practices that is also present for non-carbon-related greenwashing (Schumacher, Baek, & Nishikizawa, 2021). This means that corporates and

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investors can derive concrete financial and reputational benefits from climate action exaggeration or carbon data misrepresentation. These instances will flourish without strong regulatory oversight capacities in combination with mostly voluntary disclosure in many jurisdictions, lack of standardization, absence of central ESG data registers, and significant rewards for showcasing numerous ex-ante decarbonization ambitions or strong but self-reported ex-post carbon data. Instances of potential carbonwashing become most apparent in observing corporate communication of climate action, where announcements, statements, pledges, joint initiatives, or target setting represent instances of firm-level impact frontloading. The latter materializes through the practice of generating positive ex-ante impacts, which results in concrete reputational benefits. In most instances, this corporate inaction is not penalized by the market since many of these climate-related announcements are either too vague or have long-term target horizons, besides a lack of broad industry-wide ex-post impact monitoring.

The main reason for using self-reported ESG data, including carbon data, in a cautious way are the indications of high levels of endogeneity and significant positive bias in current company-initiated material ESG data or information. Schumacher et al. (2021) found early-stage evidence that the majority of seemingly unbiased business news eligible for consideration under several ESG scoring methodologies are still indirectly reproducing significant portions of direct company messaging on material ESG issues. These findings are of high relevance in terms of adequately evaluating corporate ESG performance evaluations. They signify that in the presence of a fragmented and still largely unregulated ESG regulatory environment and the absence of centralized, widely accessible, and transparent ESG data platforms, companies find themselves in a position in which engaging in greenwashing becomes a "low risk - high reward" practice (ESMA, 2021). Through specific forms of selective ESG disclosure, they can theoretically engage in ESG sentiment engineering, which again feeds directly into common industry ESG ratings and scores (Schumacher, Baek, & Nishikizawa, 2021). This partially explains the more frequent usage of targeted messaging in the area of climate-related corporate virtue signaling. Common words associated with climate action and carbon data are the following: climate, carbon-neutral, climate-neutral, TCFD, net-zero (and its variations), Paris-aligned, CO2, carbon-free, decarbonization, carbon-capture, carbon clean, carbon removal, tree planting (and its variations), carbon/CO2/GHG emissions, RE100, SBTi, science-based, low-carbon, emissions, SDG, coal, transition.

Forms of Carbonwashing

In order to identify instances of carbonwashing, we propose a list of potential scenarios and corresponding materiality factors that enable or incentivize misrepresentation of carbon-related data. This structure offers the advantage of allowing relevant stakeholders to properly map climate-related disclosure based on factors likely to influence the quantity and quality of carbon data. Analogous to the flows outlined in Figure 2, we differentiate between carbonwashing across the ex-ante and ex-post stages of the lifecycle process. Establishing an additional sub-divisional layer to the original ex-ante/ex-post processual juxtaposition enabled us to categorize all primary forms of carbonwashing within the previously outlined PR and MRV contexts. We then proceeded to define ten categories that cover the most common and material factors that could lead to carbonwashing, two ex-ante PR-related ones and eight ex-post MRV-related ones. The identified carbonwashing scenarios do include:

1. *Disproportionate share of endogenous ex-ante decarbonization plans*, which often comprises carbon data-related ex-ante announcements, including net-zero targets, carbon reduction pledges, and other forms of overly ambitious or ill-documented carbon management plans that are not met with an equal level of ambition in ex-post MRV messaging.

2. *Immaterial virtue signaling*, such as announcements of limited tree planting efforts to display carbon awareness while constituting an immaterial component in overall carbon footprint.
3. *Insufficient, incomplete, or inconsistent measurement*, which comprises lack of material data collection across business-related projects, activities, and assets across supply chains
4. *Ill-defined and obscure carbon metrics*, illustrated by the use of vague, poorly defined, or methodologically opaque carbon measurement metrics.
5. *Overreliance on carbon offsets*, which describes the practice of formulating carbon reduction plans that do rely to large extents on the use of carbon offsets; thus, any carbon reduction targets remain mostly speculative.
6. *Insufficient, incomplete, or inconsistent reporting*, of the results of lack of material data disclosure, frequent or material data gaps, or the use of different disclosure methods, formats, or units.
7. *Selective disclosure*, often underpinned by the divergent reporting of material data depending on the progress expectations or reputational influence of respective data users.
8. *Fragmented disclosure*, which constitutes the practice of spreading out material group-level carbon data throughout several reports and other means of disclosure like websites or blogs.
9. *Insufficient, incomplete, or inconsistent internal verification*, meaning the lack of internal governance and data assurance mechanisms to verify collected and calculated carbon emissions.
10. *Insufficient, incomplete, or inconsistent external verification*, meaning the lack of genuine independent external carbon data verification by qualified and accredited assurers.

PR-related scenarios have gained traction as the global momentum and awareness around climate-related risks since the 2015 Paris Agreement and the publication of the 2017 TCFD recommendations. As the number of TCFD supporters, SBTi commitments, net-zero targets, and overall climate action pledges have been growing at exponential rates, the PR side of carbon-related disclosure has evolved into a major source of potential risks. Several publications and news have illustrated the disconnect between the increasing carbon-related reduction announcements or declarations on one side, and tangible climate action or concrete internal institutional measures on the other. The former often prove overly ambitious and not backed up by proper organizational adjustments; in contrast, the latter often seems to be only supported by immaterial capital expenditures that constitute only a fraction of the amounts required to reduce overall organizational carbon footprints (Climate Action 100+ , 2021). Several reports and studies have detected that TCFD-aligned reporting among observed companies did either only increase marginally or remain flat, indicating that public support for the TCFD recommendations did not necessarily lead to more granular climate-related disclosures (Bingler, Kraus, & Leippold, 2021; Climate Disclosure Standards Board, 2020; Task Force on Climate-Related Financial Disclosures, 2020; Alliance for Corporate Transparency, 2019; ClientEarth, 2021).

Table 2 presents the first comprehensive attempts to link instances of carbonwashing to specific materiality factors. These include, among others, the key drivers such as market pressures, societal value shifts, and regulatory contexts. Risks and rewards represent other determinative factors in engaging in carbonwashing. We observed that a largely unmitigated risk-reward imbalance incentivizes corporates and financials to put a disproportionate emphasis on ex-ante climate action-related messaging and underperform in the ex-post MRV-related categories of the carbon data lifecycle.

Table 2. Carbonwashing scenarios and data supply chain materiality matrix

Lifecycle Process			Materiality Factors		
	PR/MRV	Carbonwashing Category	Key Drivers	Risks	Rewards
Ex-ante	PR	1. Disproportionate share of endogenous ex-ante decarbonization plans	- Market and societal pressures to align with recent sustainability and ESG trends	Mostly low (except for medium-level for large EU-based companies and financials with more than 500 employees; see Key Drivers)	High reputational and economic yields for apparent display of industry leadership
		2. Immaterial virtue signaling			
Ex-post	M	3. Insufficient, incomplete, or inconsistent measurement	- Mostly voluntary (notable exceptions in the context of large EU-based companies that have to comply with Non-financial Reporting Directive (NFRD) and/or the Sustainable Finance Disclosure Regulation (SFDR))		
		4. Ill-defined and obscure carbon metrics			
		5. Overreliance on carbon offsets			
	R	6. Insufficient, incomplete, or inconsistent reporting			
		7. Selective disclosure			
		8. Fragmented disclosure			
	V	9. Insufficient, incomplete, or inconsistent internal verification			
		10. Insufficient, incomplete, or inconsistent external verification			

Based on these framings and definitions, the accelerating pace of net-zero carbon reduction announcements serves as a timely example of the structural mechanisms that incentivize carbonwashing and facilitate its perpetuation. Directing our focus on the various climate alliances and the corresponding pledges, declarations, commitments to achieve net-zero carbon emissions by 2050 enables us to illustrate imminent and emerging carbonwashing risks. These bear, if left unaddressed, significant potential to only generate short-term reputational benefits for its authors and consequently undermine more meaningful and tangible long-term climate mitigation progress.

Applied Contextualization of Carbonwashing Risks: Net-zero Target Announcements

To explore how carbon data is processed and to what extent it is currently being measured, reported, and verified, we look at current practices around net-zero target announcements and the associated carbonwashing risks surrounding their exponential growth. Specific scrutiny should also be paid to the various initiatives and alliances that promote the adoption of net-zero carbon reduction commitments because they serve as platforms for investors and corporates to amplify their messages of self-declared climate action. Moreover, several of them also act as gatekeepers and monitors to assure compliance with any commitments, pledges, or targets set under the frameworks of the respective organizations. The most notable ones are the Climate Action 100+, the We Mean Business Coalition, the SBTi-initiated Business Ambition for 1.5 C, the UN-convened Net-Zero Asset Owner (NZAOA) and Net Zero Banking (NZBA) Alliances, the Net Zero Asset Managers Initiative (NZAMI), the UNFCCC "Race to Zero" Campaign, and last but not least the recently created Glasgow Financial Alliance for Net Zero (GFANZ), which " brings together over 160 firms (together responsible for assets over $70 trillion) from the leading net-zero initiatives across the financial system to accelerate the transition to net-zero emissions by 2050 at the latest" (Climate Action 100+ , 2021; UNFCCC, 2021; Data-driven EnviroLab and New Climate Institute, 2020).

Albeit it should be noted that many of the formative members of these initiatives are identical, and considerable overlaps do exist, both in terms of scope and aims. While most companies and investors indicating 2050 as the target year, there have been many criticisms directed at these announcements. Many commentators and researchers question either the underlying motivations as well as the general vagueness around many of the commitments by highlighting the general ease of issuing any net zero-related statements of intent and the lack of the corresponding scrutiny and ramifications in case of perceived lack of action (Hodgson, 2021; Nature, 2021; Rogelj, Geden, Cowie, & Reisinger, 2021; Lobrana & Hodges, 2019; Eavis & Krauss, 2021; Berman & Taft, 2021; Kyte, 2021; Mackenzie, 2021; Nauman & Morris, 2021; Smith, 2021). Based on these critical assessments and opinions, ex-ante target validation and ex-post impact monitoring represent key components in establishing high degrees of transparency and high levels of trust in net-zero carbon reduction commitments (Schumacher, 2020c; Schumacher, Baek, & Nishikizawa, 2021).

We investigate the primary voluntary target validation and progress monitoring platforms, SBTi and the UNFCCC "Race to Zero" campaign, to outline potential risk elements that could facilitate carbonwashing (Science-Based Targets Initiative, 2021b; Climate Action 100+ , 2021). First, we analyze the target setting and data tracking processes of the SBTi, one of the first and currently the largest climate reporting and carbon reduction target setting framework. This aims to procure additional transparency regarding its most recent progress report, which serves as a key global source in tracking current net-zero target-related carbon data processing practices and how carbon data influences market sentiment (Science-Based Targets Initiative, 2020; Science-Based Targets Initiative, 2021b). Albeit it should be noted that as of April 2021, the SBTi net-zero criteria are in development, and the SBTi has not yet approved any net-zero targets under these criteria (Carbon Disclosure Project, 2021). The SBTi utilizes many data sources, including public and private CDP disclosure data, information retrieved from company sustainability reports and websites, other publicly available data related to global emissions figures and market capitalization, and data collected by the SBTi (Science-Based Targets Initiative, 2021a). The SBTi states that their MRV protocol, which is currently under development, will provide further guidance for companies on target achievement assessments and claims. In the report, they caution that significant portions of the progress data are presented as reported publicly by the companies themselves, and therefore such data presented should not be interpreted as confirmation or validation of a company's apparent progress towards or achievement of targets. This is a key indicator pointing towards the often highly endogenous and insufficiently verified nature of most voluntarily reported corporate carbon data.

This situation raises numerous ethical and procedural questions, as the SBTi depends on public trust supported mostly only by the fact that is being "backed by four of the most prestigious environmental organizations", which indicate that they "conduct a comprehensive, independent quality assessment of the targets against the latest climate science and provide multiple opportunities to showcase approved targets" (Science-Based Targets Initiative, 2021b). However, the SBTi's methods have recently been viewed in an increasingly critical light, as there is little transparency around what specific scientific criteria are used as the basis to determine which science-based targets methods are eligible through the SBTi (Farand, 2021; Bjørn, Lloyd, & Matthews, 2021). Given the strong reliance on the SBTi performance figures to measure corporate decarbonization efforts, it is important to note that the SBTi target validation process is not conducted in line with best practice in terms of publication of scientific results, such as an independent double-blind peer review process (McNutt, et al., 2018; Allen, et al., 2019; COPE, 2021). It is carried out entirely internally by the initiative's technical partner organizations, the CDP, the World Resources Institute (WRI), or the World Wide Fund for Nature (WWF), and neither the internal reviews, review discussions or the final approval are disclosed publicly (Carbon Disclosure Project, 2021).

Conclusion

The surge in climate pledges and net-zero carbon reduction targets has brought a lot of attention to the reliability of carbon data. Demand for and spending on carbon data have been particularly acute within sustainable finance and ESG investing, which consist of various financial products, strategies, and initiatives that take carbon mitigation into account, ensuring investment in 'green,' 'sustainable,' or 'ESG-aligned' firms (Chasan, 2020). Nonetheless, current carbon reporting standards and related regulations are not sufficiently inclusive in driving companies towards mobilizing more effectively behind low-carbon energy transition and net-zero economic goals. Companies engage in various decarbonization efforts, both regionally and globally, but most of them have not been fully incorporated into the current carbon reporting frameworks or climate-aligned evaluation strategies. These incomplete impact criteria are not providing adequate incentives for companies to align their capital expenditures (CAPEX) and operational expenses (OPEX) with long-term sustainable growth objectives or become active beyond their own business activities.

As evidenced by the many frameworks, studies, and drivers discussed in this paper, the evaluation of corporate carbon performance constitutes a complex undertaking. Due to the diverse ways that firms can communicate their performance, it can be challenging to differentiate carbonwashing genuinely sincere and material environmental communication. The central problem identified in this paper pertains to the mostly anticipatory nature of the majority of carbon data reporting, meaning that the focus of most climate-related disclosure has shifted from actual ex-post performance data to theoretical ex-ante performance goals. For instance, companies used to report their carbon emissions reductions versus an established baseline, but now they are more vocal about promoting carbon reduction targets. The gap between corporate decarbonization claims and tangible action has widened. As of writing this paper, a majority of corporate capital markets still relies primarily on unaudited, unverified, and largely self-reported data to bridge these information gaps. Due to the absence of rigorous validation processes, the incentives to pursue misinformation-related "low-risk/high-return" strategies have not substantially subsided.

Carbonwashing represents a systemic market-level disclosure failure and negative externality that impacts firms, stakeholders, and society at large in materially significant ways. Throughout this paper, we document the benefits that financials and corporates derive directly and indirectly from presenting themselves as leaders in the area of climate mitigation. Moreover, carbon data has emerged as the primary currency to validate and communicate said action in the public sphere. As a result, we see the number of incidents of carbonwashing expanding, both in terms of quantity and quality. The spread of misleading information or unsubstantiated claims occurs in every phase of the carbon data lifecycle, becoming highly embedded in the general carbon disclosure process and hence even more challenging to eradicate. Without proper checks in place, facilitated by mandatory, structurally solid, and science based MRV frameworks, carbonwashing could transform into one of the most severe and material risks to meaningful and broad climate action. Carbon data based on mostly theoretical ex-ante impact frontloading as opposed to concrete ex-post carbon reductions would render the modeling of informed Paris-aligned transition pathways highly unreliable.

Finally, by proposing a taxonomical framing of carbon data-related misinformation incidents, this paper outlines various avenues for lawmakers, regulators, and sustainability reporting framework organizations to classify carbonwashing as a distinct branch of green. We do this by mapping the carbon reporting ecosystem – including the stakeholders that generate and distribute corporate carbon data and those that use it. This diagnosis facilitates the comprehension of the carbon data landscape evolution and where the most acute risks are situated. Thereby, we see this paper as a valuable contribution to developing more reliable carbon disclosure frameworks and transparent data platforms.

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