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Beyond conventional corporate responses to climate change towards deep decarbonization: a systematic literature review

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Abstract

Over the past 20 years, the literature on corporate responses to climate change has offered a vast array of theoretical and practical insights into organizational efforts to reduce business-related carbon emissions. However, it remains unclear whether these efforts will result in significant reductions of carbon emissions. Presently, it becomes crucial to understand, if, why, and how companies can effectively respond to the current challenges of deep decarbonization, defined as the process of emission reduction down to, or close to, zero to limit global warming. By means of a systematic literature review with 370 identified papers, we are able to categorize the main findings of the literature according to the four most common areas of investigation, including drivers, actions, barriers, and facilitators. Additionally, we conduct a comparative analysis of the literature along these four areas of investigation according to two categories: conventional responses and deep decarbonization responses. The results show that the literature on conventional responses to climate change (n=321) extensively covers all four areas of investigation; however, it only touches on the descriptive (i.e., 'what') aspects of decarbonization. The recent and emerging literature on deep decarbonization responses (n=49) provides novel insights on the prescriptive (i.e., 'why' and 'how') aspects of deep decarbonization. However, this literature is restricted to mostly regional and industrial foci, and it does not connect drivers, barriers, and facilitators in a systematic way. Thus, we highlight key implications for future research and practice in order to effectively address corporate deep decarbonization.

Keywords Carbon emissions · Corporate responses · Climate change · Decarbonization · Low carbon · Systematic review

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1 Introduction

To avoid the worst possible scenarios of global warming, including life-threatening storms, droughts, and flooding as well as the disastrous ripple effects on economies and societies, many global actors are stressing a drastic decrease in carbon-equivalent emissions (henceforth abbreviated as CO_2e; as indicated by the IPCC 2022). The urgency and legitimacy of climate change have taken center stage in global politics, witnessed by the unanimous adoption of the Paris Agreement in 2015 (UNFCCC 2015) and progressive development at the UN Conferences of the Parties, most recently COP27 in Sharm El Sheikh, Egypt. Since companies remain primary contributors to CO_2e (Griffin and Heede 2017), they have increasingly been pushed to respond to political and societal demands to significantly reduce CO_2e through various mandatory (e.g., EU ETS) and voluntary initiatives (e.g., Science Based Target initiative; henceforth abbreviated as SBTi). These coercive and normative policies emphasize the need for companies to aim for deep decarbonization, defined as reducing CO_2e down to, or close to, zero emissions, with the goal of limiting global warming to 1.5° C above pre-industrial levels (Åhman et al. 2017; Wesseling et al. 2017).

While previous academic articles and literature reviews have advanced theories and empirical insights related to corporate responses to climate change, including political shifts and developments (Wimbadi and Djalante 2020), management theories related to climate change (Daddi et al. 2018), bibliometric analyses of the most common authors and trending concepts (Díaz Tautiva et al. 2022), and drivers and barriers of low-carbon operations (Lopes de Sousa Jabbour et al. 2019), the literature still has not grasped if corporate efforts will lead to significant reductions of CO2e, referred to as deep decarbonization in this paper. Furthermore, no systematic review has yet paid close attention to the use of language dealing with significant CO2e reductions. Rather, the literature commonly offers a more generic view of various corporate mitigation efforts with little association to deep decarbonization.

Thus, we conduct a systematic review of the academic literature to investigate what has been recorded about corporate responses to climate change over 20 years (2001–2022), paying particular attention to deep decarbonization and associated concepts, including absolute reduction, carbon neutrality, low carbon, and net zero. In order to distinguish between conventional responses to climate change and deep decarbonization responses, we conduct an additional comparative analysis between the literature on conventional corporate responses to climate change and the literature related to deep decarbonization. The motivation behind this comparative analysis is to evaluate the extent to which deep decarbonization is proposed, studied, and evidenced in the existing literature. Additionally, comparative analyses can detect minor variations even when similar concepts are applied. When conducting this comparative analysis, we are motivated to compare corporate mitigation efforts between none and relative reductions on the one hand, and absolute CO2e reductions on the other hand (Slawinski et al. 2017).

To refine the scope of this systematic review, we concentrate on four areas of investigation identified as most commonly mentioned in the literature, including *drivers* behind corporate responses, *actions* that companies execute as responses,

barriers explaining why companies fail to adopt actions or stall in emission reductions, and *facilitators* that can overcome barriers and promote mitigation strategies. These four areas are interrelated, forming a narrative to corporate responses to climate change. Additionally, these four areas enable the comparative analysis between the literature on conventional responses to climate change and the literature on deep decarbonization responses. Inspired by a previous review (Wimbadi and Djalante 2020), the literature on deep decarbonization responses was aided by the inclusion of additional search terms, including absolute reduction, carbon neutrality, low carbon, and net zero. This permitted the synthesis and comparison of a vast amount of academic literature in a concise way. A key advantage of conducting a systematic literature review is the ability to provide additional perspectives and conceptualizations that the individual articles could not achieve on their own (Rousseau et al. 2008).

This systematic review makes several contributions to the existing literature on corporate responses to climate change. First, the review provides an overview of four commonly mentioned and interconnected areas of investigation on corporate responses to climate change (e.g., Lopes de Sousa Jabbour et al. 2019; Okereke 2007). Second, it provides a comparison of the literature between conventional responses to climate change and deep decarbonization. Hence, researchers and practitioners can easily recognize the practical differences and research gaps between the literature on conventional responses and the literature on deep decarbonization responses. In the academic literature on conventional responses to climate change (n = 321), we find a strong connection between all four areas of investigation; however, this literature touches mostly on descriptive (i.e., 'what') aspects of decarbonization without providing any evidence of significant reductions. Finally, we are able to enhance the growing body of academic literature by demonstrating the prescriptive (i.e., 'why' and 'how') aspects of deep decarbonization (n = 49). As a result, we are able to identify and highlight key CO_2e reduction drivers, actions, barriers and facilitators. Nevertheless, we do recognize that there exist several research gaps in the academic literature on deep decarbonization, which provides limited implications for only a few industries.

In order to help contribute to substantial CO_2e reductions by corporations and to the academic discourse on corporate responses to deep decarbonization, the academic literature must embrace new theoretical perspectives and broader empirical insights (Geels et al. 2017). In a similar fashion to Armstrong and Grobbelaar (2022, p. 3), we can relate these interconnected areas of investigation (i.e., drivers, actions, barriers, and facilitators) to various components that are "distinct, heterogenous, and yet inseparable", and stress that they should not be examined in isolation, as corporate actions may only be as effective as the drivers and incentives reinforcing them. Furthermore, barriers might emerge during implementation as well as in the long-term planningconsiderations, and a concentration on several key facilitators may help to overcome these barriers. As the literature on deep decarbonization is still emerging, we suggest that corporate responses should be examined under both critical theoretical frameworks, such as symbolic versus substantive efforts (e.g., Dahlmann et al. 2019) as well as multilevel analyses (e.g., Slawinski et al. 2017). Furthermore, future research could concentrate on comparing actions between various industries

and how they can be synthesized to contribute to deep decarbonization. Thus, we highlight significant research gaps and areas for future research.

2 Background: from organizational inaction towards deep decarbonization

To meet the 1.5° C limit set by the Paris Agreement, it is agreed that fundamental changes are required in many industries, including agriculture, energy, construction, production, and transportation (Böttcher and Müller 2015; Geels et al. 2017). Due to multi-decade investment cycles in key industries, the transition to low-carbon development must begin immediately to avoid further lock-in effects and stranded assets (Levin et al. 2012). Thus, the literature has been increasingly interested in how and why corporations respond to these increasing challenges of climate change from multiple fronts, including physical, institutional, and organizational risks and opportunities (Wright and Nyberg 2017).

The majority of industries and markets where businesses operate are based on the dominant logic of short-term profit maximization rather than functioning within safe, long-term planetary boundaries (Wright and Nyberg 2017). Thus, this constrains companies from investing too many resources towards proactive environmental strategies and management behavior (Bhatt and Ghuman 2022), which also includes barriers for climate change action (Okereke 2007). This highlights the issue of organizational inaction to climate change, defined as "the failure to reduce absolute greenhouse gas (GHG) emissions due to a lack of effective measures" (Slawinski et al. 2017, p. 254). According to Slawinski, corporate mitigation actions that produce no or relative emission reductions are considered organizational inaction. We adopt this concept of organizational inaction to explain *conventional responses to climate change* as those actions that do not lead to CO2e reductions or only limited to relative reductions of CO2e. Even when companies make sincere climate mitigation efforts in their business practices, these strategies and structures can dissolve over time, leading companies back to conventional performance measures without substantial progress (Wright and Nyberg 2017).

Companies must find a way to overcome these vicious circles of organizational inaction, described as conventional corporate responses leading to no or relative CO2e reductions, in order to mitigate the worst-case scenario of anthropocentric climate change (Slawinski et al. 2017). To present an alternative to the conventional perspective, the literature presents the term *deep decarbonization* (Geels et al. 2017). In this paper, deep decarbonization is defined as reducing CO_2e down to, or close to, zero emissions with the goal of limiting global warming to 1.5° C above pre-industrial levels (Åhman et al. 2017; Wesseling et al. 2017). Deep decarbonization can be observed on institutional (Geels et al. 2017), industrial (e.g., Falter et al. 2020), and organizational levels (Liu 2014). Key societal drivers, including consumer preferences, intergovernmental policies, social movements, and knowledge transfer, will have to work in tandem with corporate responses, aligning in complementary, facilitative ways to foster a transition towards a low-carbon society by 2050 at the latest (Geels et al. 2017; Stammer et al. 2021). Thus, this paper aims to answer the

following research question: *To what extent does the literature discuss the corporate responses to climate change, especially those related to deep decarbonization*?

3 Methodology

3.1 Conducting the systematic literature review

To answer the research question and to develop evidence-based knowledge, we examined the literature on corporate responses to climate change with a particular focus on decarbonization. The goal was to determine factors emerged in this specific literature dealing with how companies deal with climate change, especially on mitigation efforts, over the past two decades (i.e., from January, 2001 until November, 2022). This article used systematic literature review proposed by Tranfield et al. (2003). According to Tranfield et al. (2003, p. 214), there are five key interrelated phases in a systematic review: (1) identification of the main research focus; (2) selection of studies in relevant academic databases; (3) quality assessment of literature; (4) data extraction and collection; and (5) data synthesis and reporting of main findings.

In the first phase, we identified the main research focus by considering the literature in the business, environmental and social sciences that deals with corporate responses to climate change and decarbonization. Next, we considered a search strategy to identify keywords in several academic search engines and databases, inspired by a recent review on the subject of climate change and organizations (Díaz Tautiva et al. 2022). It was important that keywords reflect corporate responses to climate change and deep decarbonization, which makes it different from previous reviews. The research team agreed on the most commonly used terms in the academic literature and developed the following search string in three parts – terms associated with *corporate*, those associated with a *response*, and those associated with *carbon and climate*. After several rounds of discussions, the final search string was established:

> (compan* OR corporat* OR business* OR enterpris* OR organization) AND (strateg* OR respons* OR mitigat* OR adopt*) AND (carbon* OR decarboni$ation OR "greenhouse gas" OR ghg OR emission OR climate).

This search string sequence was entered the exact same way into four prominent research databases using the advanced search function, including EBSCO Business Source Complete, Elsevier ScienceDirect, JSTOR, and Clarivate Web of Science. The process of using the advanced search function follows similar evidence-based reviews in the management literature (e.g., Rousseau et al. 2008). Our review was finalized in November, 2022, and the search produced 32,384 papers for the entire timeframe.

The second phase of the systematic review selected the most relevant papers through a careful screening of all entries using the well-established PRISMA Flow Diagram (Page et al. 2021), including several inclusion and exclusion criteria (see Fig. 1). In the identification stage, we were able to remove 6,695 duplicates, i.e.,

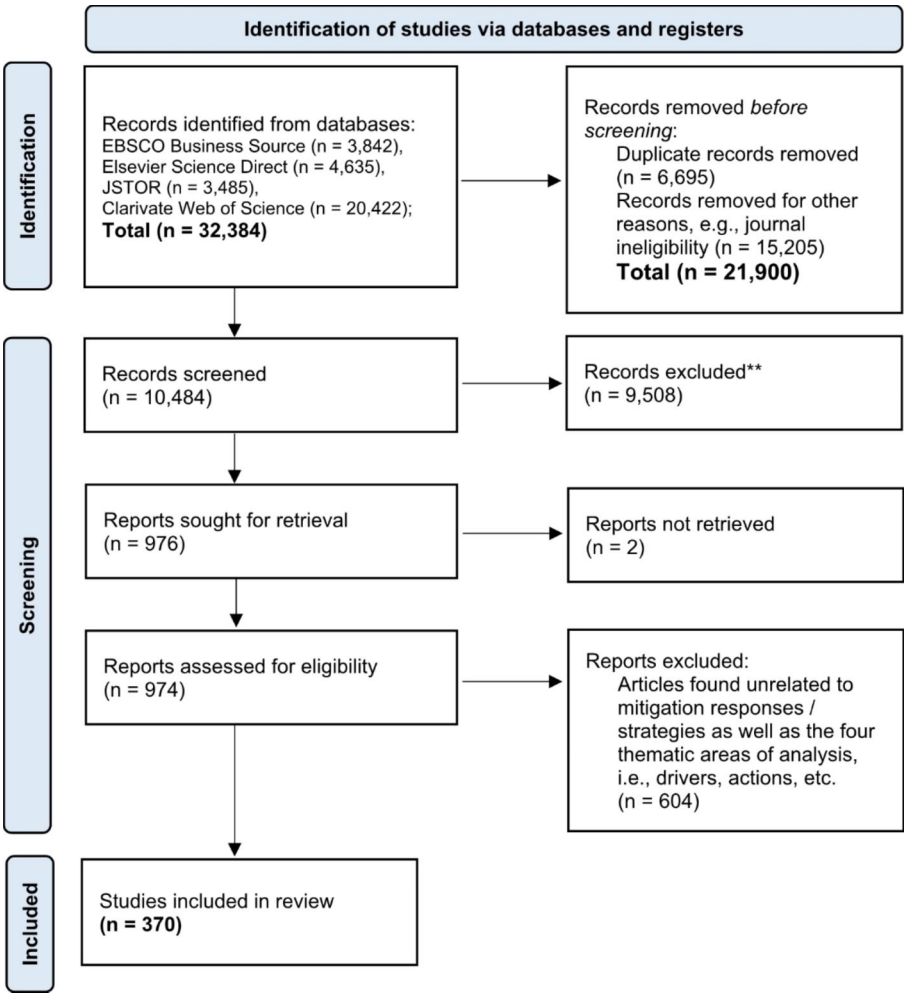

Fig. 1 PRISMA Flow Diagram for Systematic Literature Review

double-entry articles between the four databases, as well as 15,205 papers according to journal ineligibility. This resulted in 21,900 papers already removed before the next stage – screening.

In the screening stage, we scanned titles, abstracts and keywords of 10,484 papers. Of this amount, 9,508 papers could be removed because they were not related to the core focus of this systematic review. For example, several papers would mention climate change, but only on a country level and failing to mention corporations or business organizations. Thus, we aimed to retrieve 976 papers; however, 2 papers were not available, so we removed them from the final count.

This resulted in a pre-final collection of 974 papers. We thoroughly read these papers to determine whether they contained the research focus for this systematic review, and were able to remove an additional 604 papers that mentioned several

keywords but did not cover any of the four thematic areas of investigation. This resulted in a final list of 370 papers for the systematic review (see Fig. 1).

This process was repeated to control for consistency and reliability of results. This replication confirmed the consistency of our final list of 370 papers for the systematic review.

3.2 Data analysis

To strengthen the qualitative and comparative analyses, we highlighted and coded the papers using a combination of Microsoft Excel and MaxQDA, which appears a common approach in recent systematic literature reviews (Heidingsfelder and Beckmann 2020). First, we used Microsoft Excel for initial categorization and sorting of papers. Once the initial qualitative data was gathered, a general categorization was made within each area of investigation via hierarchical data structuring and pattern-matching (Langley 1999). Pattern-matching is a method that complements hierarchical data structuring to search for and locate broad matches in the given data (Yin 1994).

Second, we conducted a further qualitative analysis for all papers mentioning these four terms related to deep decarbonization. For this step, we entered all papers into MaxQDA to conduct lexical searches – one round for each term. When conducting this lexical search, we focused on the following: (1) pinpointing the selected papers in the systematic review that mention one or more of these terms related to deep decarbonization, and (2) discerning how these terms are used in the text, including their association with the four themes of investigation, i.e., drivers, actions, barriers, and facilitators. For example, we searched for whether deep decarbonization was mentioned in combination with drivers, actions, barriers, and facilitators. The results of all lexical searches identified 211 papers (i.e., over half the entire sample) that mention at least one of the related terms. Upon further review, however, we found that 49 papers from the entire sample were the terms used in combination with one or more of the four key areas of investigation. These results are highlighted in Sect. 5.

Although the literature on business responses to climate change from the last 20 years has been relatively vague concerning deep decarbonization, we have been able to discern clear indications of corporate responses. To help pinpoint these responses, our systematic review integrates four additional terms related to deep decarbonization when searching for conceptual and empirical clarity on these issues: *absolute reduction, carbon neutrality, low carbon, and net zero*. These terms represent responses considered essential for contributing to significant reductions in corporate carbon emissions (Böttcher and Müller 2015; Dahlmann et al. 2019; Slawinski et al. 2017). A recent systematic literature review used similar terms (Wimbadi and Djalante 2020) covering the political and regional developments for decarbonization and low carbon transition. However, the present paper extends the keywords to reflect the distinct terminologies used for explaining decarbonization.

Absolute reduction entails a decrease in a company's total CO_2e reductions irrespective of growth, mergers/acquisitions, and any fluctuations of production due to disruption or relief. Absolute reduction should be permanent (Slawinski et al. 2017), thus it should not be reversed via future rebound effects (De Stefano et

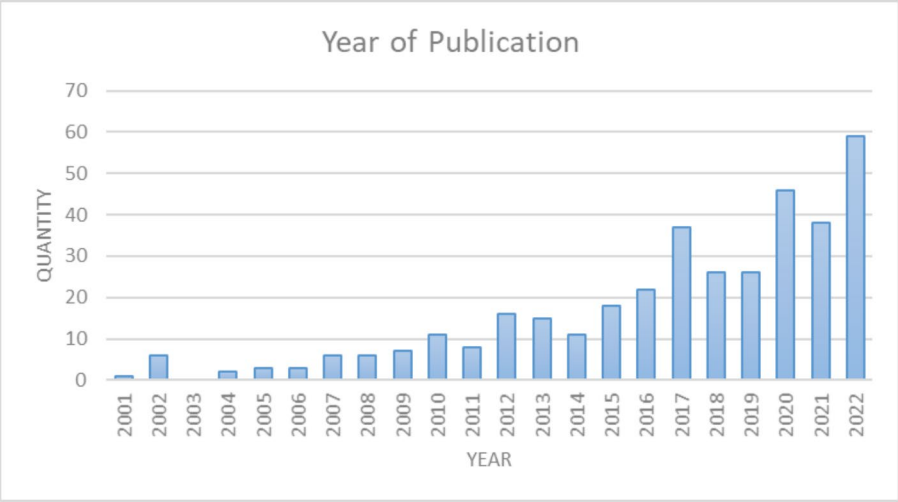

Fig. 2 Number of publications by year (2001–2022)

al. 2016). Absolute reduction can be clearly distinguished from relative reduction and intensity targets, which are connected to some type of economic measure, e.g., annual revenue, products, full-time employees, etc. (Dahlmann et al. 2019). *Carbon neutrality* can be described as the balance between emitting carbon and absorbing carbon emissions from carbon sinks. According to the IPCC (2022), carbon neutrality can lead to lower carbon emissions when "anthropogenic CO_2e emissions are balanced globally by anthropogenic CO_2e removals over a specified period." *Net zero* is similar to carbon neutrality, but goes further by considering all greenhouse gases (i.e., CO_2e in this paper). According to SBTi (2021), net zero has been recently reclassified for companies, which now covers all emission scopes. Finally, *low carbon* can be defined as relatively minor net emissions of CO_2e into the atmosphere, such as low-carbon operations, low-carbon production, and low-carbon logistics (Böttcher and Müller 2015).

The following section will present the initial quantitative results of the 370 papers. The following section will present the qualitative findings according to the four areas of investigation, split between general findings and specific findings on deep decarbonization.

3.3 Initial quantitative results

The statistics from the selected papers provide an overview of the initial quantitative findings from the 370 publications reviewed, including the number of publications per year and type of journal along with names of exemplary journals on the topic. First, the publication years demonstrate a steady increase of articles over the past two decades (Fig. 2).

Next, an overview of academic journal types (Table 1) highlights that most papers are in journals focused on *Sustainability & Ethics* (176). Within this journal type, three journals have a large number of publications: Journal of Cleaner Production (57

Table 1 Journal types and top journals

Journal type	Top Journals	No.	Totals
Ethics & Sustainability			
	Journal of Cleaner Production	57	
	Business Strategy and the Environment	35	
	Journal of Business Ethics	11	
	Business & Society	10	
	Other 'Ethics & Sustainability' Journals	63	176
General Management			
	'Reviews' (e.g., Harvard Business Review, California Management Review, etc.)	12	
	European Management Journal	7	
	Organization Studies	4	
	Other 'General Management' Journals	47	70
Climate & Energy			
	Climate Policy	9	
	International Journal of Climate Change	7	
	Energy Policy	7	
	Other 'Climate & Energy' Journals	40	63
Environmental Sciences			
	Environmental Innovation and Societal Transformation	3	
	Environmental Science & Policy	3	
	Nature Climate Change	2	
	Other 'Environmental Science' Journals	20	28
Accounting & Finance			
	Accounting, Auditing & Accountability	3	
	Accounting & Finance	3	
	British Accounting Review	2	
	Other 'Accounting & Finance' Journals	15	23
Other	*e.g., Applied Economics*		10
Overall total			370

papers), Business Strategy and the Environment (35 papers), and Journal of Business Ethics (11 papers). The second most frequent journal type is *General Management* (70 papers); and the third most frequent journal type is *Climate & Energy* (63 papers). The remaining categories include *Environmental Sciences* with 28 papers, *Accounting & Finance* with 23 papers, and the category *Other* with 10 papers. This shows that the topic of climate change and decarbonization has arrived in multiple disciplines, including the general management field.

4 Qualitative findings in the four areas of investigation

Based on the systematic literature review, the qualitative findings are categorized according to the four most common areas of investigation, including drivers, actions, barriers, and facilitators. This establishes the baseline for the comparative

analysis between the literature on conventional responses to climate change and deep decarbonization responses in the next Sect. (5).

4.1 Drivers associated with corporate responses to climate change

The vast majority of the literature contains numerous drivers, which can also been termed as motivations and pressures. Thus, we found a categorization of such drivers as useful. We categorized drivers in three parts – institutional, organizational, and individual. This classification is similar to other papers adopting a multilevel perspective (e.g., Okereke 2007; Slawinski et al. 2017). Unlike these other papers, however, we avoid theoretical underpinnings that would limit the understanding of drivers. For example, institutional isomorphism as a theoretical lens explains why companies' climate-related actions converge over time (e.g., Lee 2012). Instead, we focus on drivers as both external pressures and internal motivations, including financial incentives, organizational drivers (e.g., cost savings, risk reduction, new markets, and innovation; see Schaltegger et al.,2012), and individual or personal drivers (Wright and Nyberg 2012).

4.1.1 Institutional drivers

- *Political and regulatory pressures* usually stem from national governments, and supranational and international regulatory bodies (e.g., EU Emission Trading Scheme). Pressures are usually presented as formal policies, but also take form as "informal prodding" via green nudging and revised political agendas (Okereke 2007; Wright and Nyberg 2017).
- *Financial and market-related drivers* include pressure from investors, customers, and other market-related actors (Busch and Hoffmann 2011; Kolk and Pinkse 2008; Okereke 2007). According to Hirsch (2019, p. 52), "Investors and investment analysts, having woken up to the potential financial consequences (positive and negative) of the coming apocalypse, want to know what companies are doing to manage the operational risks of climate change today."
- *Media and public drivers* include pressures from media and the wider public. Media coverage may emphasize great achievements, but might also expose high emitting companies to the public. For example, "interests over increasing electricity and gas prices and corporate intentions to improve its profitability while contributing to the national efforts to shift to lower carbon fuels were perceived as the drivers for managing its carbon emissions levels" (Wahyuni and Ratnatunga 2015, p. 400).

Additional institutional drivers were mentioned, but these remain too vague to classify, such as unspecified stakeholder groups (Jin et al. 2014; Weinhofer and Hoffman 2010). For example, Jin et al. (2014, p. 460) state that "…stakeholders will fight hard to reach an agreement of the [carbon] caps."

4.1.2 Organizational drivers

- *Cost reduction* is presented as a frequently mentioned organizational driver, which includes cost savings through opportunities for energy efficiency and process improvements (e.g., cleaner production methods). This driver is typically directly associated with concrete action. For example, Cadez and Guilding (2017, p. 1054) emphasize that carbon efficiency practices were "not ecologically motivated, [but rather…] stemmed from cost minimisation interests, as energy use represents a significant cost."
- *Risk minimization* deals with the incentive to decrease or eliminate operational risks associated with climate change, which can stem from regulatory risks, competitive risks, or physical risks (e.g., extreme weather) (Cadez and Guilding 2017; Okereke 2007). According to Kihiko and Kinoti (2016, p. 150), "the majority of the companies agreed that […] they are vulnerable to climate change, and therefore they need to be really prepared."
- *Reputation improvement* is presented as a high priority for companies when dealing with climate change, especially NGOs and customers. The literature suggests that proactive climate strategies can have a positive impact on a firm's reputation (Dahlmann et al. 2019).
- *Profit and sales growth* are closely related drivers that encourage companies to find ways to incorporate new or enhanced process, products, and services related to positive action on climate change.

Several other organizational drivers have been mentioned, including *business model innovation* (Zhou and Wen 2020), becoming an *attractive employer* for current and prospective employees with a goal of increasing climate change efforts (Dahlmann et al. 2019), and the desire to improve *organizational culture* (Jeswani et al. 2008).

4.1.3 Individual drivers

Some of the drivers are related less to organizations and more to individuals, although overlaps do exist, including *visionary leaders, employee initiatives*, and *ethical motivations*.

- *Visionary leaders* are able to detect opportunities and express these effectively throughout the company (Jiang et al. 2020; Subramaniam et al. 2015). According to Bui and de Villiers (2017, p. 1287), "vision statements send strong signals to unlock employee potential and encourage positive behavior."
- *Employee initiatives* are considered bottom-up, employee activism initiatives in the form of proposals, schemes, or social movements within the organization to galvanize corporate commitment and responses to climate change (Böttcher and Müller 2015; Wright and Nyberg 2012). For example, Littlewood et al. (2018, p. 1444) state that "Our results first identify a role for employees in driving commitment to climate change action."

- *Ethical motivations* include normative motivations to look after the environment and actors within. This takes the form of personal responsibility (Okereke 2007; Wright and Nyberg 2012) as well as adopting a stewardship role (Galbreath 2014; Lopes de Sousa Jabbour et al. 2020).

4.2 Actions associated with corporate responses to climate change

The next area of investigation deals with corporate actions, including operational and managerial activities (Lee 2012). Classification is also useful for grouping corporate actions in a meaningful way. Inspired by two seminal papers (Jeswani et al. 2008; Kolk and Pinkse 2004), actions can be distinguished along four categories: *administrative* (i.e., managerial activities for internal initiatives), *applicative* (i.e., operational activities related to internal goals), c*ommunicative* (i.e., managerial activities to external initiatives), and *collaborative* (i.e., operational activities involving external stakeholders to achieve common goals). Table 2 provides an overview of all these corporate actions according to the year published, the regional focus, and the thematic focus. As Table 2 demonstrates, most of the studies were published after 2010 in high-emitting countries (Friedrich et al. 2020), and associated with conventional responses to climate change. We provide basic descriptions of the most commonly mentioned actions below.

4.2.1 Administrative actions

- *Target setting* entails planning a carbon reduction path, which can vary between science-based and non-science-based, and can also have different implications depending on the industry and regional context (Gouldson and Sullivan 2013; Rietbergen et al. 2015). Target setting can be considered science-based if it is in line with a scale of reductions required to keep global temperatures below 1.5° C pre-industrial temperatures. Dahlmann et al. (2019, p. 6) establish a further distinction between symbolic and substantive targets.
- *Data collection and monitoring* is part of a wider carbon emission accounting scheme (e.g., GHG Protocol), which depends on methodology, boundaries (i.e., operational control, financial control, or equity share), and emission factors (Busch et al. 2022). According to Bottrill et al. (2010, p. 2), "a systemic GHG accounting framework enables businesses to track emissions over time and monitor effectiveness of reduction efforts."
- *Management systems* include formal systems that companies adopt, e.g., environmental and energy management systems according to the International Organization for Standardization (ISO 14,001; ISO 5001), as well as informal systems that companies create, such as a Carbon Management System (Liou 2015; Subramaniam et al. 2015). According to Liou (2015, p. 359), "an effective carbon risk management system…includes planning, assessing, and implementation… within the system function that is effective and efficient to tie it all together."

Table 2 Overview of corporate actions – temporal, spatial and thematic distinctions

Corporate action (as a response to climate change)	No. of studies (N=370)	Temporal distinction		Regional distinction*			Thematic distinction	
		2001–2010 (N=44)	*2011–2022 (N=326)*	*High emitting (N=186)*	*Low emitting (N=44)*	*Both (N=60)*	*Conventional response (n=324)*	*Deep decarbonization (n=49)*
Administrative actions								
Target setting	**95**	18	77	52	8	19	80	15
Data collection and monitoring	**67**	12	55	40	9	8	54	13
Management systems	**55**	6	49	17	6	11	45	10
Applicative actions								
Process improvements	**127**	19	108	57	20	13	107	20
Energy efficiency	**127**	18	109	63	17	20	106	21
Product innovation	**95**	12	83	40	17	17	77	18
Renewable energy	**94**	20	74	47	12	13	83	11
Communicative actions								
Reporting	**81**	9	72	35	15	22	70	11
Political activities / lobbying	**48**	13	35	28	1	12	45	3
Public relations / marketing	**30**	13	17	15	2	8	26	4
Collaborative actions								
Company participation	**54**	11	43	29	7	7	48	6
Carbon trading	**44**	21	23	20	6	10	42	2
Supply chain coordination	**43**	4	39	21	9	6	35	8
Carbon offsetting	**36**	5	29	24	7	7	32	4

Note: The corporate actions were distinguished according to temporality (i.e., year published), regionality (i.e., location of study according to high-emitting, low-emitting or both; Friedrich et al. (2020)), and thematic aspects (i.e., conventional response versus deep decarbonization response).

* Not all publications are included in the category "regional distinction," as 80 studies were either reviews or conceptual papers without a regional focus.

4.2.2 Applicative actions

- *Energy efficiency* is a measure concentrating on improving performance via the increase of economic outputs, decrease of environmental inputs (e.g., energy use, CO_2e), or both (Bows-Larkin 2015; Kouloukoui et al. 2019). In fact, "the most widespread climate strategy among companies is energy efficiency" (Kouloukoui et al. 2019, p. 8).
- *Process improvement* in the context of corporate responses mainly deals with energy efficiency enhancements and reductions of CO_2e (Kolk and Pinkse 2004; Lee 2012). However, process improvement is heterogeneous and implemented in various ways depending on the industry. For example, process improvements in high-emitting heavy industries (e.g., cement, metals, logistics) frequently include costly investments in low-carbon technologies (Böttcher and Müller 2015; Kolk and Pinkse 2004), while in low-emitting industries (e.g., service, banking, insurance, telecommunications), the focus rests on energy conservation programs (Galbreath 2010; Kolk and Pinkse 2004).
- *Product innovation* refers to the design of new products and the improvement of existing products, which is directly associated with reduced CO_2e (Backman et al. 2017; De Stefano et al. 2016). In this sense, product innovation "implies creating new products or modifying existing ones as a response to the new market reality that values climate change impact mitigation" (Backman et al. 2017, p. 555).
- *Renewable energy* can refer to switching offers for purchased energy (e.g., Scope 2) as well as onsite technology installations, most commonly photovoltaic panels (Busch et al. 2022; Cadez and Czerny 2016). Often, companies do not make a full transition to renewable sources, but only a partial one, "substituting a part of their fuel consumption with solar, wind, biomass…" (Jeswani et al. 2008, p. 53).

4.2.3 Communicative actions

- *Reporting* is a frequent communicative action related to climate change, often including stated strategies, CO_2e relevant data, and concrete actions (Hrasky 2012; Thaker 2020). These reports communicate responses to both internal and external audiences. Although they might appear to transparently convey climate-based reporting, reports can be unclear if they are "… "…disseminating information about the instrumental actions taken by a company to reduce its carbon footprint, [such as] rhetorical statements designed to create an impression of environmental responsibility, not necessarily accompanied by relevant action" (Hrasky 2012, p. 179).
- *Political activities*, as a response to pressures on climate change, can have both direct (i.e., funding of political parties, lobbying) and indirect influences (i.e., public statements, funding of scientific studies) on political and legislative bodies (Damert et al. 2017; Delmas et al. 2016; Paul et al. 2017). Frequently, political action can be in opposition to current and upcoming regulations on climate change

mitigation, but can also support stricter forms of mitigation policies (Åhman et al. 2017).

- *Public relations and marketing* are often communicated much faster than reporting, and target various stakeholders via press releases, social media, print ads, etc., either through internal (i.e., corporate websites) or external channels (e.g., third-party news programs) (Herold and Lee 2019). Similar to reporting and political activities, PR and marketing can be used to support climate mitigation, but can also "involve the presentation of ceremonies to persuade stakeholders that the company's operations are legitimate" (Herold and Lee 2019, p. 66).

4.2.4 Collaborative actions

- *Company participation* relates to membership in business networks, public-private partnerships, and other voluntary multi-stakeholder programs (e.g., the UN's "Race to Zero" in Luo and Tang 2021) to exchange knowledge and initiate collaboration, both within and outside an industrial focus. In addition to other actions (e.g., energy efficiency), Toft and Rüdiger (2020, p. 10) suggest including "more comprehensive political approaches to combat climate change in collaboration with global institutions like the UN, as well as governments and civil society partners."
- *Supply chain coordination* considers collaborative efforts and joint activities to measure and reduce carbon emissions across the entire supply chain, and, if possible, finding low-carbon solutions. According to Lee and Klassen (2016, p. 580), "to reduce CO_2 emissions across the entire supply chain, the focal firms needs to first calculate the accurate carbon emissions […] and second leverage this data to design and develop less carbon-intensive products and processes."
- *Carbon trading* covers both mandatory trading schemes (e.g., EU ETS), where high-emitting companies are required to cap emissions through buying or selling of allowances (i.e., carbon certificates), as well as voluntary carbon markets, where companies benefit by selling their carbon credits (i.e., avoided carbon) and earn profits for their carbon saving activities (Cadez and Czerny 2016). Nevertheless, the literature critically points out that emissions trading might be a symbolic attempt to mitigate climate change, as Cadez and Czerny (2016, p. 4140) indicate that "this practice does not directly reduce CO_2 emissions".
- *Carbon offsetting* deals with payments made for a certified unit of emission reduction or removal carried out by a third-party actor (Kolk and Pinkse 2004; Littlewood et al. 2018). In this sense, "companies are able to achieve reductions of GHG emissions…[by joining] an offset project" (Kolk and Pinkse 2004, p. 311).

4.3 Barriers associated with corporate responses to climate change

The barriers are mostly classified as external barriers (e.g., regulatory uncertainty) or internal barriers (e.g., lack of awareness). A small number of barriers could not be grouped into either of these categories, so we created a third category *additional barriers* to capture as many important barriers as possible.

4.3.1 External barriers

- *Regulatory uncertainty* refers to companies' uncertainty regarding climate regulations, policy frameworks, and governmental action, which in turn limits the range of strategic decisions to mitigate climate change (e.g., Okereke 2007; Slawinski et al. 2017). Furthermore, the perceived uncertainty may be used as justification for delayed corporate responses and may even be reinforced by the companies themselves through political lobbying (Bumpus 2015).
- *Lack of pressure and incentives* can often be attributed to external actors, such as governments and policy makers (e.g., Chen et al. 2018; Hrasky 2012). This is the case for Scope 3 emissions in particular, which are often not subject to regulation. Hence, companies lack incentives to reduce these emissions (Wang 2017). In addition, a lack of market incentives may delay corporate efforts to engage in emission reductions (Chen et al. 2018).
- *Complexity* acts as a barrier in two different ways. First, companies are embedded in a complex social system of interactions with various actors and institutions (Liu 2014). As Pinkse and Kolk (2012, p. 338) noted for multinational enterprises (MNEs): "In view of the global relevance of the issue, the multiple levels involved and the variety in policy approaches to climate change, MNEs cannot approach it on a country-by-country basis". Second, climate change itself is a complex issue, and possible solutions to mitigate climate change may appear to be complex to develop and implement uniformly (Chen et al. 2018).
- *Consumer resistance* is, for example, reflected in consumers' purchasing decisions, where price sensitivity results in a reluctance to buy more sustainable products (Morgan et al. 2018). Acceptance of green products may also vary by industry or market, thus companies that do not adapt or innovate their products' attributes may face rejection by prospective consumers (De Stefano et al. 2016). Furthermore, businesses intend to influence consumer behavior to achieve emission reductions. However, the study of Morgan et al. (2018) on laundry practices suggests that despite huge efforts, business initiatives failed to change consumer practices to the extent that they would result in substantial emission reductions.

4.3.2 Internal barriers

- *Lack of awareness and commitment* among employees and managers is the most frequently mentioned internal barrier in the literature. Amran et al. (2016) linked the lack of awareness to the limited ability of political regimes to enforce climate change regulations. Even if managers are aware of climate change issues, the literature finds a lack of commitment to be a major barrier. Top management and employees may exhibit resistance to supporting or implementing mitigation measures (Baranova and Meadows 2017).
- *Lack of knowledge and expertise* relates to a lack of knowledge about possible climate change mitigation options (Böttcher and Müller 2015) but also to a lack of information about climate change in general (Kihiko and Kinoti 2016). This category is closely related to the lack of resources, as knowledge can be regarded as a resource when it comes to the implementation of mitigation practices (Böttcher and Müller 2015).
- *Lack of resources* is mainly tied to financial resources. Companies perceive that they lack – or they do in fact lack – these resources to implement climate change measures (e.g. Böttcher and Müller 2015; Mistage and Bilotta 2018).
- *Short-term planning* is often prioritized instead of pursuing long-term solutions (e.g., Slawinski et al. 2017). This also includes the demand for short payback-periods of investment into carbon reduction actions or a focus on immediate profits.
- *Cost factor* deals with high costs of mitigation actions, which impede action to reduce emissions or work towards decarbonization (e.g., Zhang et al. 2012). This is closely related to *short-term planning* and *lack of resources*.
- *Technological constraints* refer to the availability and affordability of technologies that could enhance emission reductions in the future. However, at present, companies may be prevented by exploiting opportunities due to technological constraints (Okereke 2007).

4.3.3 Dimensional barriers

- *Temporal barriers* entail a mismatch between present and future planning, where future impacts are not included in present decisions related to climate change. This disconnected view is related to a lower tolerance for uncertainty, thus companies avoid setting long-term targets and may therefore delay climate-related decisions (Slawinski and Bansal 2012).
- *Spatial disconnect* refers to the regulatory and physical effects of climate change, which are deemed too far away from central business operations (Slawinski and Bansal 2012). Furthermore, supply chains covering operations in various countries increase the risk of carbon leakage, as "emissions are displaced from a regulated to a non-regulated source or area" (Roeser and Jackson 2002, p. 52).

4.4 Facilitators to overcome barriers

The last area of investigation focuses on facilitators to overcome barriers that impede effective corporate responses to climate change. Again, we found many diverse facilitators, and we organized these into several categories. We used common themes proposed in the literature, including organizational change (Slawinski et al. 2017), organizational capabilities (Lee and Klassen 2016), and external support (Baranova and Meadows 2017).

4.4.1 Organizational change

For organizational change, we found two main facilitators, including top management commitment and level of ambition.

- *Top management commitment* deals with the awareness and communicated engagement of C-suite managers and the board of directors that initiates organizational change towards decarbonization. For example, Aldy and Gianfrate (2019, p. 97) emphasize that "Getting the business carbon-ready requires real commitment and a cultural transformation that should start with the board and top management."
- *High ambition* may be a source of higher CO_2e reduction, e.g., by setting absolute rather than intensity emission targets (Caritte et al. 2015). However, it is not frequently mentioned as a facilitating criterion.

Other facilitators mainly focus on structural changes, such as restructuring of the board (e.g., Galbreath 2010) or the formation of cross-functional teams (Levy and Kolk 2002).

4.4.2 Organizational capabilities

- *Knowledge and learning* facilitate the efficient and effective use of resources and the anticipation and prevention of risks (e.g., Pinkse and Gasbarro 2019). It can also lead to quick adaptation of changes in regulations (e.g., Delmas et al. 2016) and to fostering innovation (e.g., Levy and Kolk 2002).
- *Shared vision* refers to the extent that a manager's vision and commitment is accepted as worthwhile and supported by many employees. This support may be incentivized using monetary rewards (e.g., Aldy and Gianfrate 2019).
- *R&D / Innovation* entails the ability to develop and implement product innovations and process improvements, which are necessary for effective climate change mitigation (e.g., Lee and Klassen 2016).
- *Long-term focus* refers to the shift from short-termism to long-term strategic planning and investments in long-term projects to ensure safe future practices (e.g., Slawinski et al. 2017; Wright and Nyberg 2017).
- *Stakeholder engagement* deals with the ability to establish trust-based collaborative relationships with a wide variety of stakeholders, which is considered a crucial

element for corporate decarbonization (e.g., Esen and Caliskan 2016) and facilitates overcoming barriers to low-carbon practices (e.g., Lopes de Sousa Jabbour et al. 2020).

4.4.3 External support

- *Public policies* are national and international policies aimed at reducing emissions via the increase of renewable energy and other mitigation actions (e.g., Park 2020). However, for effective and far-reaching policies, "systematic and continuous evaluations are required" (Sprengel and Busch 2011, p. 362).
- *Synergistic relationships* (contractual or non-contractual) between organizations generate synergies, including shared knowledge, resources and technologies, cost savings, reduced risks, etc. (e.g., Kihiko and Kinoti 2016).
- *Public grants and resources* are financial, tangible, and intangible resources (e.g., awareness raising and knowledge) that local and national governments provide to accelerate the transition to a low-carbon society (e.g., Bumpus 2015; Zhang et al. 2012).

5 Comparative analysis between conventional and deep decarbonization responses

In order to make significant contributions to reducing the threat of global warming above 1.5 °C, drastic reductions of CO_2e are necessary, which we call deep decarbonization responses in this paper. In this second part of our findings, we compare the selected literature between conventional corporate responses to climate change and responses related to deep decarbonization, including the terms absolute reduction, carbon neutrality, low carbon, and net zero.

Our in-depth investigation reveals that most of the sampled papers were only using decarbonization and related terms in a very superficial way. For example, the concepts of a "low-carbon economy" and a "low-carbon society" were frequently mentioned (e.g., Cadez and Cerny 2016; Cadez and Guilding 2017; Park 2020); however, the literature did not make specific references to any specific drivers, actions, barriers, or facilitators associated with deep decarbonization. Thus, the literature is narrowed down to 49 papers (circa 13%) of the entire sample that provide greater insights into deep decarbonization responses according to the four areas of investigation.

Table 3 provides a summary of the comparative analysis between conventional responses to climate change and deep decarbonization responses. We review both literature streams again according to the four areas of investigation, which allows us to make a side-by-side comparison.

Table 3 Comparative analysis between conventional responses and deep decarbonization responses

Categories	Conventional responses to climate change	Deep decarbonization responses
Total sample	321 papers (ca. 87% of the entire sample)	49 papers (ca. 13% of the entire sample)
Year range	Spans the entire time range – 2001 (e.g., Kolk and Levy 2001) to 2022 (e.g., Zhang et al. 2022)	More recent – 2014 (e.g., Liu 2014) to 2022 (e.g., Zhu et al. 2022)
Drivers (overall)	***Expansive literature****on all drivers. Drivers are also often directly associated with corporate response actions. In particular…*	***Limited literature****on drivers, which is barely connected with corporate actions. The few findings hint at…*
Institutional	…governmental regulations and stakeholder pressures as well as financial markets interested in operational risks from climate change (Hirsch 2019).	…a need for stricter regulatory pressures via policy-driven constraints (i.e., carbon pricing either via taxes or ETS) and strong incentives for decarbonization in particular industries. Less frequently focused on financial markets (exceptions include Baranova and Meadows 2017; Bui & de Villiers, 2017; Trinks et al. 2022; Vieira et al. 2022)
Organizational	…organizational motivation of cost savings leads to energy efficiency and process improvements.	…cost-saving motivations associated with low-carbon operations. Also, risks and reputation, but very little connection with drivers to actions.
Individual	…visionary leaders (top-down) and ethical motivations often lead to administrative actions (e.g., target setting).	…leadership via vision statements (e.g., being a "carbon neutral company" or "a carbon industry leader" in Bui and de Villiers 2017).
Actions (overall)	***Extensive list of actions****, including all four categories, both in general and industry-specific. However, little indication about how these actions lead to deep decarbonization. The most frequently mentioned actions include …*	***Limited literature****on actions directly associated with deep decarbonization and associated terms. Main actions mentioned are in the categories of administrative and applicative, such as*:
Communicative	… reporting and political action to thwart costly, intensive corporate responses to climate change. Later studies reveal how marketing and PR are necessary to engage important stakeholders (i.e., facilitators → stakeholder engagement).	…reporting, which is deemed essential to encourage knowledge and learning as well as shared vision (facilitators→ capabilities).
Collaborative	…company participation, carbon trading, and supply chain coordination; limited focus on lowering carbon-intensive practices in supply chains (e.g., green procurement and logistics)	…highlight supply chain actions, such as low-carbon procurement and logistics (e.g., Böttcher and Müller 2015; Janipour et al. 2022).

Table 3 (continued)

Categories	Conventional responses to climate change	Deep decarbonization responses
Administrative	…target setting, data collection and monitoring, and management systems. A combination of these actions often considered as a complete carbon management system (CMS).	…focus target setting, internal carbon pricing (ICP), and data management. Papers highlight differences between substantive and symbolic actions in target setting (e.g., Dahlmann et al. 2019), but also substantial improvements, which can be reinforced by ICP (Aldy and Gianfrate 2019; Kuo and Chang 2021; Zhu et al. 2022).
Applicative	…energy efficiency, product innovation, process improvement, and renewable energy, especially the latter for lowering carbon emissions in production processes (Scopes 1 and 2).	…emphasize energy efficiency, renewable energy, process improvements, and product innovation. While it is unclear how energy efficiency leads to deep decarbonization (Orsini and Marrone 2019), other studies focus on substitution of fossil fuels through low carbon energy and renewables by the electrification of industries, such as transport, buildings, and to a small extent manufacturing (Bistline 2021; Campbell et al. 2022).
Barriers (overall)	***Many diverse barriers****are mentioned, but not necessarily excusing why companies do not reduce carbon emissions. The central focus of barriers is implementation of actions with little association of decarbonization. The main barriers include…*	***Few barriers****relate to deep decarbonization, mostly for high-emitting companies and industries, as carbon lock-in and stranded assets present high transformation cost. It remains unseen if these particular barriers prohibit companies from achieving deep decarbonization. Nevertheless, the most common barriers are…*
External	…regulatory uncertainty, complexity, and the lack of external incentives. The vast amount of literature on regulatory uncertainty shows that although climate legislation may have increased, e.g., EU ETS, laws and regulations are inconsistent and not universal.	…regulatory uncertainty and lack of incentives are two main external barriers, especially associated with failure to implement low-carbon operations (e.g., Furlan Alves et al. 2019; Lopes de Sousa Jabbour et al. 2020).
Internal	…lack of knowledge as well as lack of resources. The lack of expertise may prevent firms from engaging in mitigation, as potential benefits are not recognized. Lack of additional capital for R&D remains problematic for firms (Mistage and Bilotta 2018).	…lack of knowledge and awareness as well as carbon lock-in effects in high-emitting companies, which act as barriers via high transition costs towards low-carbon operations, practices, and supply chains (Bauer et al. 2022; Janipour et al. 2022; Zhu et al. 2022).
Dimensional	…temporal and spatial barriers, but to a limited extent. Thus, compared to internal and external barriers, these barriers do not appear to inhibit corporate action to a great extent.	…no references to temporal and spatial barriers with regard to deep decarbonization, which shows that they have not yet been considered in connection with deep decarbonization responses.
Facilitators (overall)	***Comprehensive examination of facilitators****to overcome the barriers. The main facilitators include…*	***Few facilitators****towards decarbonization. Several exceptions include…*

Table 3 (continued)

Categories	Conventional responses to climate change	Deep decarbonization responses
Organizational change	…. awareness and top management commitment. Leadership can play a crucial role for increasing the awareness among employees and encouraging action (e.g., Caritte et al. 2015).	…awareness and top management commitment can aid in overcoming barriers to low-carbon operations (e.g., Aldy and Gianfrate 2019). However, further criteria to achieve deep decarbonization is not provided.
Organizational capabilities	…key organizational capabilities, including knowledge, R&D improvements, and stakeholder engagement to easily advance mitigation efforts (Luo and Tang 2021; Pinkse and Kolk 2012).	…training and education of employees (Bui and de Villiers 2017) as well as stakeholder engagement can be considered important facilitators for achieving extensive emission reductions (Baranova and Meadows 2017).
External support	…public policies and synergistic relationships. Regarding relationships, Finke et al. (2016, p. 94) emphasize "collective action [being] key…. No individual company alone has the necessary resources and capabilities to tackle the unprecedented challenge of climate change."	…public policies and attracting long-term investors. Public-private partnerships can act as a bridge between companies and governments, especially useful in collective action and sharing resources, knowledge and expertise (Janipour et al. 2022; Lopes de Sousa Jabbour et al. 2020).

5.1 Comparison of drivers between conventional and deep decarbonization responses

The entire range of drivers is extensively covered in the literature on conventional responses to climate change. The most of the literature discusses institutional drivers, especially political and regulatory pressures that reveal how governmental regulations force business organizations to respond to climate change (Jin et al. 2014; Levy and Kolk 2002). The literature highly cites mandatory policies, such as the EU ETS (Engau and Hoffmann 2009; Jeswani et al. 2008). Another frequently cited institutional driver is financial markets (Busch and Hoffmann 2011; Kolk and Pinkse 2008). The most frequently cited organizational drivers include cost savings (Bui and de Villiers 2017; Cadez and Guilding 2017) and risk reduction (Busch and Hoffmann 2011). On the individual level, visionary leaders (Jeswani et al. 2008; Jiang et al. 2020; Subramaniam et al. 2015) and ethical motivations (Okereke 2007; Wright and Nyberg 2012) are the most frequently cited.

By contrast, the literature on deep decarbonization responses only provides us with a limited set of drivers. The most frequently identified driver is political and regulatory pressures, which manifest in the form of stricter carbon policies, efficiency standards, and mandatory carbon tax schemes (Bows-Larkin 2015; Lagouvardou et al. 2020; Zhou and Wen 2020). Less commonly discussed in the literature is how financial markets and investors may support companies' deep decarbonization efforts, although several exceptions can be found (Baranova and Meadows 2017; Bui and de Villiers 2017; Trinks et al. 2022; Vieira et al. 2022). Nevertheless, these pressures and incentives can be considered missing for certain regions and industries, such as international aviation and overseas shipping, as they are not currently covered by national climate policies (Bows-Larkin 2015). However, it appears most drivers are

not impactful enough to embolden drastic carbon reductions, such as cost savings (Furlan Alves et al. 2019) and innovation (Böttcher and Müller 2015; Falter et al. 2020) on the organizational level. Several research gaps emerge when comparing the two sets of responses, including missing information on financial market incentives for deep decarbonization, cost reduction and profit increases, new markets, and reputation increases on the organizational level, as well as bottom-up employee initiatives demanding deep decarbonization on the individual level.

5.2 Comparison of actions in the two literature streams

For conventional responses to climate change, the actions most frequently cited include reporting and political action (i.e., communicative actions), supply chain management and carbon trading (i.e., collaborative actions), target setting, data collection and monitoring, and management systems (i.e., administrative actions), and energy efficiency and process improvements (i.e., applicative actions). Several actions act as interfaces and catalysts for additional action. For example, carbon management systems draw together various managerial and operational activities for a desired outcome (Sullivan 2010). Furthermore, process improvement combines the implementation of energy efficiency in operations and production as well as the increased use of renewable energy sources. However, process improvement is not a one-size-fits-all approach. For example, process improvements in high-emitting industries frequently include major investments in energy-efficient technologies (Kolk and Pinkse 2004), while in low-emitting industries (e.g., service-oriented) they focus on the implementation of energy conservation programs (Galbreath 2010; Kolk and Pinkse 2004;).

When examining the literature on actions for deep decarbonization responses, it appears that actions are rather limited to mostly administrative (i.e., target setting and internal carbon pricing – e.g., Aldy and Gianfrate 2019; Kuo and Chang 2021; Zhu et al. 2022) and applicative actions (i.e.,, energy efficiency, process improvements, and product innovations – e.g., Böttcher and Müller 2015; Dahlmann et al. 2019; Schneider et al. 2020) and more concentrated on sector-specific solutions, such as for the automotive (Böttcher and Müller 2015), construction (Orsini and Marrone 2019), or shipping industries (Bows-Larkin 2015; Schneider et al. 2020). This suggests that actions towards deep decarbonization should definitely consider sector-specific solutions, such as focused product innovation and process improvements; however, it should consider the ability for certain actions to act as catalysts for further action.

The main differences between the literature streams regarding corporate actions is the focus and combination of actions. The conventional literature focuses on all four actions areas, whilst deep decarbonization responses is rather focused on the internal aspects (i.e., administrative and applicative actions). Additionally, we find that the deep decarbonization responses rarely consider multiple corporate actions in comprehensive responses, such as management systems. Nevertheless, the systematic review highlights that several managerial measures in particular lend themselves to being integrated with other actions, including target setting (Gouldson and Sullivan 2013; Rietbergen et al. 2015), management systems (Liou 2015; Subramaniam et al. 2015), and data collection and monitoring (Kolk and Pinkse 2008; Zhang et al.

2012). Furthermore, the literature hints that companies considering a coordinated set of internal and external activities may be able to achieve a more progressive and substantial response to climate change (Damert et al. 2017; Jeswani et al. 2008; Weinhofer and Hoffmann 2010), but this should be tested in specific context of deep decarbonization.

5.3 Comparison of barriers in the two literature streams

The most cited external barriers for conventional responses to climate change include regulatory uncertainty (Engau and Hoffmann 2009; Okereke 2007), complexity (Pinkse and Kolk 2012; Roeser and Jackson 2002), and lack of external incentives (Chen et al. 2018; Wang 2017). In addition, various external factors act as a barrier to corporate responses to climate change. One example includes the absence of a unified standardization of reporting (Busch et al. 2022). These barriers have far-reaching implications, as definitions and standardization can be considered preconditions for scalable actions and comparability between corporate mitigation efforts. Lack of knowledge and expertise as well as lack of resources represent the most pressing internal barriers for companies according to the reviewed literature (e.g., Mistage and Bilotta 2018). Sufficient funding for corporate actions remains problematic for firms. Furthermore, the lack of expertise may even prevent some firms from engaging in mitigation, as the perception of trade-offs overshadows the recognition of potential benefits (Amran et al. 2016).

The barriers for deep decarbonization are fewer, concentrating on a few issues, including regulatory uncertainty (Bows-Larkin 2015; Dahlmann et al. 2019) and lack of resources (Lopes de Sousa Jabbour et al. 2019; Orsini and Marrone 2019). While it may appear that regulatory pressure has intensified in recent years, especially in some regions, e.g., Europe's stricter carbon policies for reporting, imports, and operations (e.g., Fit for 55, EU ETS), many governments around the globe continue to stall or backslide on existing policy measures (Bows-Larkin 2015; Lopes de Sousa Jabbour et al. 2020). Policies and governmental support go beyond simple rhetoric to push for low-carbon innovation, but political and financial stability lead to many nations to have ineffective policies (Lagouvardou et al. 2020).

5.4 Comparison of facilitators in the two literature streams

For the literature on conventional responses, a comprehensive examination of facilitators suggests an ability to overcome barriers to implementing actions to fight climate change (Esen and Caliskan 2016; Finke et al. 2016; Kihiko and Kinoti 2016). Top management commitment leads to further capabilities, including knowledge and learning, as well as shared vision (Aldy and Gianfrate 2019). Additionally, stakeholder engagement matched with governmental support can help companies make progress on climate mitigation (Esen and Caliskan 2016).

As for deep decarbonization responses, only few references are made to facilitators. The most frequent facilitators include increased training and education as well as stakeholder engagement. Knowledge and training can help change employees' perception of climate issues (Bui and de Villiers 2017). Furthermore,

restructuring of the board is displayed as a facilitator for organizational change, both for addressing climate change in general (e.g., Galbreath 2010) and for a transition to low-carbon (Luo and Tang 2021). Particular organizational capabilities, such as shared vision, R&D innovation, and long-term focus, are only mentioned in rare cases in deep decarbonization literature, despite these being important capabilities to advance conversational response strategies (Lee and Klassen 2016; Pinkse and Gasbarro 2019).

5.5 Comparison of the connections of all areas of investigation

Finally, we examined the relationship between all four areas of investigation between both literature streams. *Drivers → actions*: For conventional responses to climate change, the literature indicates a strong connection between institutional drivers – such as governmental regulations and market drivers – and corporate actions, including reporting and political activities (Gouldson and Sullivan 2013) as well as target setting and management systems (Jeswani et al. 2008; Kolk and Pinkse 2007; Wang and Sueyoshi 2018). Organizational drivers, including cost savings, risk reduction, and improved reputation, are linked to implementing actions, including energy efficiency and process improvements (Gouldson and Sullivan 2013). From our review, it appears that individual drivers exist, but have little to no association with corporate actions for climate change.

On the contrary, the drivers to deep decarbonization responses are rarely connected to corporate actions. We observe that stricter regulations and the perception of higher competitive pressures can have a strong impact on organizing an effective response for low-carbon operations (Baranova and Meadows 2017; Böttcher and Müller 2015; Lopes de Sousa Jabbour et al. 2020; Zhou and Wen 2020). However, competitive drivers might not be witnessed in all industries and even small and medium-sized companies, as Böttcher and Müller (2015, p. 450) state, "for small companies, competitiveness expectations are not a significant driver of low-carbon production." Thus, future research could further investigate institutional (e.g., regulatory pressures and financial markets), organizational (e.g., sales, reputation, and new markets), and individual drivers (e.g., employee activism) as drivers for corporate actions towards deep decarbonization.

Barriers → actions: In the literature on conventional responses, many authors have examined barriers to corporate actions toward climate change (Chen et al. 2018; Eberlein et al. 2009; Sullivan 2010; Wright and Nyberg 2017). Two major reasons are the lack of incentives coupled with regulatory uncertainty, which leads to actions not being implemented in the first place (Eberlein et al. 2009; Sullivan 2010) as well as a deterioration in the interest and efficacy of actions over time (Rietbergen et al. 2015; Wright and Nyberg 2017). Furthermore, the examination of the academic literature on target setting displays distinct barriers. First, a company may refrain from setting targets in the first place arguing that economic growth and the unavailability of technology inhibit emission reductions (Bui and de Villiers 2017). Second, firms seem to set unambitious targets, such as intensity targets that can easily be achieved and do not lead to significant emission reductions (Bui and de Villiers 2017; Rietbergen

et al. 2017). Thaker (2020) calls this a "science-business expectation gap" (p. 255), as targets are not based on scientific demands to meet the Paris Agreement. Third, proactive firms may commit to absolute emission reduction targets, but then face difficulties developing strategies to attain the established targets (Sullivan 2010).

In the literature on deep decarbonization, the identified barriers that limit corporate actions are very few. Although barriers to low-carbon practices have been researched (e.g., Liu 2014; Lopes de Sousa Jabbour et al. 2020), it remains unclear how much these contribute to deep decarbonization. The most common barriers mentioned in conjunction with the identified terms are regulatory uncertainty and lack of resources. Schneider et al. (2020) focus explicitly on deep decarbonization, and outline potential risks hindering the achievement of substantial emission reductions. Furthermore, they indicate several opportunities to mitigate the identified barriers.

Facilitators → barriers: The literature on conventional responses reveals some connections between facilitators to overcome barriers. External support in the form of inter-firm collaboration and governmental promotions are frequently mentioned. For example, Kolk et al. (2017, p. 54) find that "in view of the complexity of climate change it can be seen as requiring cooperation across sectors (and countries) with stakes for all partners as they share a common goal of resolving the issue." Regulatory uncertainty and lack of incentives can be overcome by developing strong international and national policies and by providing financial support for proactive companies working towards extensive emission reductions (Backman et al. 2017; Bumpus 2015). Furthermore, creating organizational change through increased awareness of climate change and the enhancement of capabilities, such as increased knowledge or the development of skills for innovation and risk management (Busch and Hoffmann 2011), constitute facilitators for overcoming barriers in the areas of lack of awareness and expertise.

Regarding facilitators to overcome barriers in recent deep decarbonization literature, two key facilitating criteria for overcoming barriers stand out: (a) governmental support and (b) company-led stakeholder engagement, especially along supply chains (Lagouvardou et al. 2020; Lopes de Sousa Jabbour et al. 2020). The literature finds that governments should pressure companies not only through stricter policy requirements, but also by leveling the playing field by providing much needed market-based mechanisms (e.g., efficiency standards for low-carbon transitions) that can spark a shift towards deep decarbonization (Lagouvardou et al. 2020). Regarding stakeholder engagement, Lopes de Sousa Jabbour et al. (2020, p. 1378) find that "companies can overcome barriers by working with the stakeholder to engage them in LCO practices through workshops, meetings, and training, working together towards finding a solution where it is feasible to adopt the practice."

As we have indicated above, comparison of the literature along the lines of two types of responses – conventional versus deep decarbonization responses – highlights research gaps and avenues for further research, which will be discussed in the next section.

6 Discussion and conclusions

For more than 20 years, the literature on corporate responses to climate change has greatly increased. While this literature offers a vast array of theoretical and practical insights into companies' efforts to mitigate carbon emissions, it is still not clear if these efforts will translate into significant reductions in carbon emissions. It has become crucial to understand, if, why, and how companies can effectively respond to the current global challenge of climate change. Slawinski et al. (2017) claim that corporate activities must lead to absolute emission reductions to be effective, or else they are considered the conventional responses of organizational inaction.

This systematic literature review observes the academic literature on corporate responses to climate change, especially the identified drivers, actions, barriers and facilitators, and thus far, the focus has mainly been on conventional responses to climate change with little mention of significant CO_2e reductions. However, the topicality of the publications focusing on deep decarbonization and the related concepts may indicate the uptake of these as an emerging research field. In this review, we find some strong indications that deep decarbonization will be motivated and enabled through particular drivers, actions, and facilitators. Nonetheless, future research will have to expand on these areas of investigation.

This systematic review makes several contributions to the existing literature on corporate responses to climate change. First, it provides an updated overview of four key areas related to corporate responses to climate change, including drivers, actions, barriers, and facilitators (e.g., Lopes de Sousa Jabbour et al. 2019; Okereke 2007). Second, it compares the academic literature on profound deep decarbonization responses with more conventional ones to climate change. Researchers and practitioners can more easily see how this literature differs and overlaps in certain areas via a comparative analysis. Finally, we add to the body of literature by demonstrating the prescriptive ('why' and 'how') elements of deep decarbonization. As a result, we are able to highlight major CO_2e reduction processes, make recommendations for further research, and empower practitioners to plan and achieve deep decarbonization. However, these processes are limited to several industries (e.g., energy production and transportation), suggesting that a sector-specific approach may be essential to understand these transitions (Bows-Larkin 2015).

We have several suggestions for future research. We found that recent literature has attempted to offer corporate pathways towards deep decarbonization, both theoretically (e.g., symbolic versus substantive target setting; in Dahlmann et al. 2019) and practically (e.g., via scenario analyses and/or LCA analyses; in Orsini and Marrone 2019; Schneider et al. 2020). We suggest that both theoretical and practical aspects can be combined. On the one hand, actions may be considered symbolic responses if they have little or no connection to actual performance change. For example, corporate reporting, target setting as well as scenario analyses might be rewarded by investors in the short-term (Busch et al. 2022; Hahn et al. 2015). However, this may lead to serious reputational problems and financial consequences if an organization does not attempt to achieve significant progress in the medium- and long-term. On the other hand, substantive actions can be considered genuine efforts to mitigate environmental impacts, including target setting to reduce GHG emissions

(Dahlmann et al. 2019). Future research should investigate actions, individually and collectively, if they resemble either symbolic or substantive responses, and the consequences these have on progress towards (or away from) deep decarbonization.

Another potential aspect for future research could be creating more transparency in the supply chains for deep decarbonization. This could include material, process, traceability, commitment, and impact information as well as supply chain visibility and disclosure (Schäfer 2022). This may enable further collaboration, support, and resources required for companies to achieve significant CO2e reductions in the most difficult area to do so – Scope 3 emissions. Finally, future research should consider corporate strategies and actions in the context of external environments. As we are witnessing a global pandemic for more than two years and a breakout of war in Ukraine, organizational actions are highly exposed to the instability of geopolitical and market changes. Financial losses, scarcity of capital, bottlenecks in supply chains, etc., will force managers to develop crisis-induced strategies (Durugbo and Al-Balushi 2022). This, in turn, means that companies can be constricted in their efforts and resources towards deep decarbonization, which may not be the highest priority at the moment (Le Billon et al. 2021). However, companies are now searching for more sustainable and secure sources of energy and raw materials, which may indicate a positive spill-over effect for deep decarbonization. Research would thus benefit from assessing the influence of global pandemics, supply chain shortages, and military conflicts on deep decarbonization efforts over time and determining under which circumstances companies are able to maintain andperhaps even improve their course of action.

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Declarations

Competing interests The authors have no competing interests to declare that are relevant to the content of this article.

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