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Perspective

That's none of my business: A holistic framework for evaluating corporate decarbonization at the core business



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Keywords: Deep decarbonization Companies Core business Inflection points Climate change	The contribution of large companies is needed to decarbonize energy systems and the production of goods and services. Many companies respond actively to increasing pressures for contributing to the Paris Agreement's temperature goal, but is this more than greenwashing? A realistic assessment of companies' climate responses proves methodologically challenging. Previous literature highlighted a loose coupling of "symbolic" and "substantive" measures and organizational inertia for explaining companies' inaction toward deep decarbonization. We argue that such a distinction and isolated analyses of climate management activities are not enough for understanding the status and dynamics of corporate decarbonization. Instead, it requires a holistic approach that investigates how all these activities interrelate and how deeply they are integrated in the core business. In response to this gap, we propose to conceptualize the core business as a construct of the three dimensions management, value chain, and investments and present a novel framework for assessing corporate decarbonization on company-level. We test the framework in an exemplary study of three companies, emphasize the interdependencies between its elements and suggest four types of interrelations as focal areas for further research.

1. Introduction

Large companies play a pivotal role in the decarbonization of global energy systems and thereby in meeting the temperature goal of the Paris Agreement [1,2]. In their role as providers of fossil-based energy or in their holding on to fossil-based business models, they can block global energy transitions [3-5]. Increasingly, companies experience decarbonization pressures at various political and regulatory levels. To understand companies' contributions to global energy transitions, we think that realistic assessments of companies' decarbonization efforts are needed, even more so since the US elections of 2024 and its aftermaths opened pathways to lessen the pressure or even to openly re-embrace carbon business futures. While climate action has become prevalent in businesses, tracking whether their activities are in line with Paris Agreement targets still proves methodologically challenging. Even with a growing number of companies declaring net-zero commitments [6–8], their actual developments reveal that, in many cases, these commitments are merely window dressing. This becomes especially evident where companies simultaneously seek to protect their fossil-based business models by influencing climate policy or by negotiating deals behind the scenes of UN climate conferences [9]. We argue that existing concepts poorly capture the complexity of a deep decarbonization of the economy and underestimate the radical change required for such a transformation by relying too much on isolated assessments of single response mechanisms, such as disclosure, target setting, or other climate management activities [10]. Thus, we propose to shift the focus toward the fundamental questions of how these response mechanisms interrelate and how deeply decarbonization is integrated in companies' core business practices. Even though the companies' actions also depend on national or industry specific regulatory, financial, and market conditions, we focus our analysis on the internal processes inside the companies. The goal of the suggested framework is to generate a realistic assessment of the companies' position on a pathway toward deep decarbonization.

Existing studies paint a sobering picture of the speed of decarbonization [2,5,11-13] and point to several obstacles, including the proliferation of greenwashing [14,15], selective target setting [6,8,16], and inconsistent emissions data unsuitable for comparisons [17-19]. A number of market-based and regulatory instruments have been developed to address these problems, such as CDP (formerly the Carbon

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Disclosure Project), the Science-Based Targets Initiative (SBTi), the Task Force on Climate-Related Financial Disclosure (TCFD), the European Sustainability Reporting Standards for climate change (ESRS E1), and the EU taxonomy for sustainable activities. While transparency and ambition has increased, several limitations of these approaches have been observed. Among them are exaggerated expectations of their potential for redirecting investment to low-carbon assets [20] or driving organizational change [21], a lack of transparency of evaluation methodologies [22], the acceptance of ineffective reduction measures [23], and the ignorance of the politics and inequalities inherent in the diffusion of global norms [24–28].

In the literature, a common explanation for organizational inertia and companies' inaction toward deep decarbonization has been the loose coupling of symbolic (talk) and substantive measures (walk) [29–32]. Contextualizing these theoretically informed concepts with our empirical observations during a long-term panel study of 20 highemitting companies in Brazil, Germany, Hong Kong, Japan, and the United States, we argue that for understanding corporate climate action a distinction between symbolic and substantive is insufficient for two main reasons: First, companies may engage in a range of substantive actions but still fail to achieve the necessary levels of emissions reductions for deep decarbonization. Second, presumably symbolic actions can promote organizational change and be important enabling conditions for (more) substantive actions [33]. For example, setting climate targets without a clear plan can initiate the development of governance structures or the liberation of financial resources. Therefore, we argue that isolated analyses of prominent climate management activities are not enough to fully understand the status and dynamics of corporate decarbonization. Instead, it is necessary to take a holistic approach that assesses the extent to which all these activities interrelate and how deeply they are integrated in the core business. This core business incorporates the very essence of what a company is doing, how it defines its identity as an organization, and how this changes over time. We are aware of the low probability of a complete elimination of fossil fuel use, and the existence of residual emissions or unabated fossil fuels. Yet, taking deep decarbonization seriously means nothing less than an insignificant role of fossil fuels.

Assessing to what extent deep decarbonization is integrated in a company's core business is complicated by many factors, such as the complexity of organizations, industry-specific characteristics, and restricted availability of public information. Previous research from management studies has described the core business as the key processes, functions, and capabilities of firms primarily related to areas that create the most success [34–36]. Literature on Corporate Social Responsibility (CSR), sustainable finance, and sustainable management typically addresses the question of how to integrate non-financial values into the core business of companies [37,38]. However, this literature mostly looks at isolated company areas or climate management activities without providing a holistic perspective on the core business.

In response to this gap, we present a novel multi-dimensional framework that aims to understand the core business of a company through three interrelated, industry-independent dimensions: (1) management, (2) value chain, and (3) investments. From our perspective, these three dimensions capture the essential strategic, operational, and financial elements that distinguish the core from other businesses activities. Management covers a company's identity, strategic focus, and communication within and beyond organizational borders. The value chain encompasses the ways a company creates and delivers goods to the market, from their origin to their very end, with all processes involved. Investments reflect the priority of financial resources allocated to sustain and grow the core business. Focusing on these dimensions enables a holistic and solid understanding of a company's core business and an assessment of how deeply decarbonization is integrated in it. As the entity of analysis are companies, these dimensions shall make observable how these organizations translate external pressure or external support for decarbonization into internal processes and organizational

practices. The framework is the result of an iterative process [39] involving observations from three years of interaction with highemitting companies as part of an ongoing long-term panel study and a review of literature. It builds on our prior work on carbon markets [40–43], corporate decarbonization [10,13,44,45], and sustainability management [46]. We integrated several types of data from the panel study into the development of the framework: semi-structured interviews with sustainability managers; a review of CDP questionnaires, company reports, and websites; and ongoing exchanges with company representatives. These were complemented by a continuous review of existing frameworks, standards, and literature which fed into the development of the framework.

2. A framework for a realistic assessment of companies transforming their core business

The findings are presented in three steps. First, we present the framework itself. Second, we apply it to three example companies from our panel study and summarize to what extent they are changing their core business. Third, we point to the interactions and interdependency between dimensions and categories and suggest four types of interrelations as focal areas for further research.

2.1. First step: a holistic framework for assessing corporate decarbonization

We propose a framework for conceptualizing the core business as a construct of the three dimensions *management*, *value chain*, and *investments*. Every dimension comprises three categories that represent its main elements. Table 1 summarizes each dimension and category, describes how to assess them with qualitative indicators, and suggests how to position companies on a spectrum between defined opposing poles. Together, the three dimensions and nine categories allow for a nuanced assessment of how integrated decarbonization is in different elements of a company's core business.

We defined four requirements for the framework: (1) It should be comprehensive and dynamic, i.e., applicable across sectors/industries and adaptable over time; (2) it should be relational and complementary, i.e., considering different weights and interactions between elements without implying a specific sequence, hierarchy, or linear course of change; (3) it should consider internal and external factors, i.e., recognizing companies' unique internal characteristics and their external social, political, and market environments; (4) it should reflect the relevance of historically grown identities, values, and practices, as well as future prospects of growth, competitive advantage, and change.

2.2. Second step: testing the framework

We analyzed three companies from our ongoing panel study to test the framework's applicability Table 2. These companies are headquartered in high-emitting countries with different national models of climate governance: Brazil, Germany, and the United States [67]. The companies belong to different industries from the fossil fuel extracting industry to energy intensive producers and producers of carbonintensive products (A: integrated oil & gas, B: diversified chemicals, C: home furnishings) and show different overall levels of climate-related activities (A: low, B: middle, C: high). We used data from three rounds of annual company interviews carried out between November 2020 and March 2023 as well as company and CDP reports from 2021, 2022, and 2023, based on availability.¹ The results are structured along the three dimensions and include a brief description of the categories and how they interact with each other; what an integration into the core business

 $^{^1\,}$ CDP and company reports refer to the previous fiscal year, so that the 2023 report presents data from 2022, etc.

Table 1

Framework for assessing corporate decarbonization at the core business level.

	DIMENSION	CATEGORY	DEFINITION	INDICATORS		INTEGRATION INT	O CORE BUSINESS	
		0		Organizational structure		No formal structure/processes, uncoordinated activities	Formal structure, clear processes, coordinated activities	
	0.	nance	The system, structures, and processes by which	Status within company		Isolated department with little budget/responsibility	Well-connected team with large budget/responsibility	Ξ
	ation	iover	related to decarbonization. [47,48].	Top management involvement		No top-management involvement nor qualification	Strong involvement/qualification of top management	£
	rboniz	6		Employee engagement		No or rare employee engagement	Frequent and focused employee engagement	
	e deca			Risk/opportunity assessment		No assessment nor awareness of risks/opportunities	High risk/opportunity awareness and central to strategy	
	rganize	egy	The development of a decarbonization strategy and its relevance for the corporate identity, including	Climate targets	N	No climate targets or unspecific, ambiguous claims	Externally certified targets for high absolute reduction	Ξ
	and o	Strat	climate-related risks and opportunities, mitigation targets, and measures to achieve these targets, [22,49,50].	Transition plan	Ć	No transition plan and no implementation of measures	Clear plan with implementation measures and financing	£
	roach			Corporate identity		No relevance to corporate identity	Central pillar of corporate identity	
Ň	nies app			Information quality		No or generic information on climate-related issues	Full, detailed coverage of climate impact and activities	
	o compa	ication	The dissemination of public information on a	Standards and verification	N	No standard adoption, no external verification	Extensive standard adoption, strong external verification	I
	How do	unuu	decarbonization action, including the nature, scope, and reliability of such information. [47, 51, 52].	Internal communication		No information exchange within the company	Extensive, regular discussions on decarbonization	IGH
		S		External communication		No support of climate policy or lobbying against it, no stakeholder interaction for decarbonization	Public support of climate policy, high engagement with stakeholders on decarbonization	
	in?			Scope 1 and 2 data		No emissions data and methodology	Extensive, goal-oriented emissions data management	
	ue cha	tions	The implementation of emission reduction	Reduction activities	N	No measures to reduce operational emissions	Numerous, focused, effective reduction activities	Ξ
	he valı	Opera	measures within a company's own operations and its controlled business [53,54, 55-57].	Energy consumption	Ć	No energy efficiency measures, no renewable energy	High energy efficiency, high share of renewable energy	କ କ
	along tl	U		Production processes		Production processes heavily reliant on fossil fuels	Production processes with no/marginal fossil fuel use	
2	iness a	_		Scope 2 and 3 data (upstream)		No emissions data and methodology	Extensive, goal-oriented emissions data management	
	eir bus	chair	Activities related to decarbonizing processes and activities associated with suppliers, alongside	Requirements		No requirements for suppliers	Strong requirements included in contracts	Ξ
	ize the	Vlqqu	efforts to optimize supply chains for a transition toward decarbonization. [58, 59].	Education and training	Ē	No supplier education and training	Regular data-driven training and information sharing	£
	carboi	S		Collaboration		No collaboration with suppliers	Joint solutions for decarbonized supply chains	
	nies de			Scope 3 data (downstream)		No emissions data and methodology	Extensive, goal-oriented emissions data management	
	ompai	mers	Activities related to decarbonizing processes and activities associated with the further processing,	Incentives / Promotion	M	No incentives for/promotion of decarbonized products	Strong incentives for/promotion of decarbonized products	H
	v do c	Custo	use, and disposal of companies' products/services. [60, 61]	Education and training	-	No customer education and training	Regular training on conscious choice/use of products	또
	Hov			Collaboration		No collaboration with customers	Joint solutions for circularity, distribution, packaging	
	~	and		Financing instruments		No financing tools (e.g., internal carbon price)	Extensive and prioritized application of financing tools	
	nization	goods sets	Investments in physical assets a company owns or uses, such as buildings, facilities, and machinery,	Budget	MC	No budget for decarbonizing capital goods	Adequate budget with clear focus and spending	HIG
	carboi	pital g as	i.e., typically long-term investments. [62,63]	Maintenance		No relevance for maintenance of existing assets	Central criteria for maintenance of existing assets	I
	for de	Cal		Construction		No relevance for development of new assets	Central criteria for development of new assets	
	liture 1	olio		Revenue		No revenue from decarbonized products	Vast majority of revenue from decarbonized products	
TAAE	sthend	portf	Investments related to decarbonizing existing products/services over their entire lifecycle, such as	Product adaptation	N	No adaption of products to decarbonization needs	Clear prioritization of product adaptation where needed	H
NEC.	their e	duct	substituting carbon-intensive raw materials or discontinuing high-carbon products. [64,65]	Portfolio management	-	No relevance for portfolio management	Clear prioritization in portfolio management	£
	es use	Pro		Infrastructure		No investment in related infrastructures	High investment in related infrastructures	
	npanie	ŧ		Mergers and acquisitions		No relevance for mergers and acquisitions	Central criteria for acquisitions and mergers	
	do con	ness	Exploring new opportunities for decarbonized markets through the commercialization of net-zero	Divestment	IN	No relevance for divestment	Central criteria for divestment decisions	H
	How c	Busi evelo	technologies or the development of new decarbonized products. [50, 66]	Product innovation	-	No investment in product innovation (e.g., R&D)	Product innovation clearly focused on decarbonization	E
		ō		Partnerships and alliances		No relevance of partnerships or alliances	Central criteria for partnerships or alliances	

Table 2 Overview test companies.

COMPANY	INDUSTRY	LEVEL OF CLIMATE ACTIVITIES	EMPLOYEES (2022)		GHG	EMISSIONS (2022)
				Scope 1		10,000,000-50,000,000 MtCO ₂ e
•	Integrated		10,000, 50,000	Scope 2	Location based	100,000-500,000 MtCO ₂ e
	oil & gas	LOW	10,000-30,000	Scope 2	Market based	100–500 MtCO ₂ e
				Scope 3		100,000,000-500,000,000 MtCO ₂ e
				Scope 1		10,000,000-50,000,000 MtCO ₂ e
Р	Diversified	MEDIUM	100 000 500 000	Second 2	Location based	1,000,000–5,000,000 MtCO2e
D	chemicals		100,000-500,000	scope z	Market based	1,000,000-5,000,000 MtCO ₂ e
				Scope 3		50,000,000-100,000,000 MtCO ₂ e
				Scope 1		1,000–5,000 MtCO ₂ e
C	Home		1,000–5,000	Coore 2	Location based	10,000–50,000 MtCO ₂ e
L	furnishings	HIGH		scope 2	Market based	5,000–10,000 MtCO ₂ e
				Scope 3		100,000–500,000 MtCO ₂ e

would mean; and a summary of our observations for each dimension.

2.2.1. Management

The first dimension, management, assesses how companies approach and organize decarbonization. It includes the categories governance [47,48], strategy [22,49,50], and communication [47,51,52]. Though presented separately for analytical reasons, these are interdependent. For example, the governance approach is closely linked to those who take responsibility in developing strategies and targets, and how the company communicates to stakeholders. Likewise, publicly disclosed targets and decarbonization strategies require the tracking and disclosure of emissions data and further climate-related communication. A high level of integration of decarbonization in the core business would mean: (1) The governance structure has a clear focus on decarbonization, considerable budget earmarked for decarbonization strategies, responsibilities at all levels of the organization, and sufficient allocation of human resources. (2) Climate targets and transition strategies are ambitious, credible, and verified with intermediate goals and detailed information on the planned activities including their reduction potential and financing. 3) Communication provides complete, verified information on GHG emissions and the methodologies used to quantify them,

clearly supporting decarbonization policies.

Over the three years, we observed a general trend toward deeper integration of decarbonization into the core business in these three categories (see Table 3). However, this occurred on different, typically low to medium levels. Even the most advanced company (C) had not realized full integration. All test companies changed their organizational structure and strengthened their decarbonization governance. Most increased the ambition level of their climate targets and provided more comprehensive disclosures. However, this did not necessarily produce greater integration of decarbonization in core business activities. The creation of senior positions, regular board meetings, or elaborated risk assessments alongside public commitments and increased transparency can also be used to find ways to protect carbon-intensive core businesses instead of switching toward decarbonization [30,32]. Interlinking the three categories is key to understanding how a company approaches decarbonization as a management issue. However, genuine integration of decarbonization in core business activities requires more than public commitment, ambition, and organizational structures. It also needs alignment and connection with the other two dimensions.

Summ	ary of	the test ass	essi	nent	t for	the	dir	nen	S101	n m	lar	iag	em	ent	(ye	ear	refe	ers	to fi	sca	I ye	ar).				
NO	JRY			COMPANY																						
ENSI	EG	YEAR				Α			В											C						
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Σ	ation	2020	C)													C)							0	
	nunic	2021		0														0							0	
	Com	2022		0														C	5						c	>

Table 3

Summary of the test assessment f	for the dimension manage	ement (year refers to fisc	al year).
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2.2.2. Value chain

The second dimension assesses how companies decarbonize their business activities along their value chain. It emphasizes the relevance of addressing the entire lifecycle of products and services and all processes involved, from procurement and production to downstream processing, consumption, and disposal. The three categories-operations [53-57], supply chain [58,59], customers [60,61]—cover different focal areas but are closely interrelated. Energy and fuel use is essential at all stages, but so are the choice of feedstock, the infrastructures for distribution, and technologies for production processes. From our perspective, an integration of decarbonization into the core business would mean: (1) Operational emissions are reduced to a minimum. Energy is used efficiently and stems from clean, renewable sources, while fossil fuels are completely eliminated, or at least rendered insignificant. (2) Suppliers are selected based on the most decarbonized materials and the lowest possible climate impact, and there is close collaboration for further decarbonizing materials, products, and processes. (3) Decarbonized products have priority in customer relations and there is close collaboration on decarbonizing the further processing, use, and disposal of products through mutual learning, joint solutions, and implementation of measures.

The overall results of our test assessment show that companies are increasingly aware of the need to consider their entire value chains in their response to decarbonization pressure (see Table 4). However, they had not integrated this in their core business to a significant extent. Even the most advanced company (C) had not realized high integration in any of the categories. Emissions reductions were mostly the result of a mixture of energy efficiency measures, renewable energy (certificates), weaker sales, offsetting, and raw material innovation. Without offsetting, these reductions were small in face of the drastic reductions needed for deep decarbonization, and two of the companies continued to have very high emissions in all scopes. The test companies showed different levels and strategies of engagement with their suppliers, ranging from widespread ignorance (A), to data collection and evaluation (B), and collaboration on developing low-carbon materials and creating circular supply chains (C). Interaction with customers was centered on providing product carbon footprints and the promotion of lower-carbon or climate-neutral product lines, as all test companies have a B2B business model. A holistic assessment of the three categories helps to make visible whether companies decarbonize beyond "low-hanging fruits" and illustrates how activities in one category are connected with effects in others. For example, emissions reductions related to the raw materials bought from suppliers directly translate into lower product carbon footprints which can in theory-i.e., with adequate data-be

used as attractive selling point in promoting decarbonized products. However, in our sample, these efforts were at early stages and frequently failed to be effective under conditions of limited customer demand but significant costs.

2.2.3. Investments

The final dimension assesses how companies use their expenditure for decarbonization and how decarbonization is integrated in investment decisions. The three categories-capital goods & assets [62,63], product portfolio [64,65], business development [50,66]-represent different areas where large investments are made but are closely related: For example, product adaptation or development requires new or adapted machinery and facilities and is typically connected with a strategic expansion of the respective business area. From our perspective, an integration of decarbonization into the core business would mean: (1) Decisions on long-term investments in capital goods and assets strongly prioritize climate impacts and effects on decarbonization targets. (2) The vast majority of investment in existing products is related to adapting them to decarbonization needs along their whole lifecycle. (3) Business development focuses on new decarbonized opportunities and divesting from facilities, product lines, and business units that are carbon-intensive and/or cannot be decarbonized.

Our test companies developed investment plans and tools to integrate decarbonization into their financial steering. However, there were few indications that decarbonization was being prioritized. Rather, it appeared as a supplementary criterion for substantial investment decisions, with the exception of research and development (R&D). All test companies increased their expenditure on decarbonizing their existing product portfolio, for example through investing in R&D related to raw materials and feedstock, electrification of energy-intensive processes, and technologies for reducing the emissions intensity of production. However, large-scale reductions of GHG emissions would have required a huge amount of not yet available clean energy, a change of strategic focus away from fossil-fuel-based products, and scaling up existing decarbonized product lines that were still rather a side business. In sum, we observed a slow and incremental move toward a deeper integration in core business activities, but at low to moderate levels and still far from a high integration throughout all test companies (see Table 5).

2.3. Third step: identifying interdependencies and interrelations

In the gradual and long-term transition process of decarbonization, change is often heterogeneous, non-linear, and multi-directional (i.e., alternately toward and away from decarbonization). Due to its holistic

NO	ЛRY									C	0	MP	A١	٩Y								
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	suo	2020		0							(0									0	
-	eratic	2021		0								0									0	
A	g	2022			0							0									0	
E	lain	2020	0							0									0			
Ë	ply ct	2021	0							(C									0		
ALI	Sup	2022	0							(D									0		
	sua	2020	0							0								0				
()	stom	2021	0							0									0			
	5	2022	0							0									0			

Table 4

Summary of the test assessment for the dimension value chain (year refers to fiscal year).

Table 5

Summary of the test assessmen	t for the dimension	investments (y	year refers to	fiscal year).
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NO	ORY	-										CC	٥N	1P/	A١	٩Y									
ENSI	EGC	YEAR				Α					В								C						
DIM	CAT		12	3	4	5 10	6	7	8	91	2	3	4	5 10	6	7	8	91	2	3	4	5 10	6	7	89
	oods ets	2020	0									0									C)			
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	devi	2022	0										C	c								С)		

perspective, our framework is a useful tool for discerning where companies stand and where they are heading in their decarbonization journey. Central advantages of our framework are its capacity to highlight the multiple connections between dimensions and categories and its possibility to display developments over time. It captures whether and to what extent activities are aligned or contradictory and identifies areas that need further incentives, regulation, or research. Our framework makes clear that accelerating corporate decarbonization cannot be limited to isolated consideration of individual categories but requires efforts in each of them and, above all, interlinking them. Empirically, we observe some attempts by companies to do so, for example by strengthening the collaboration of finance and sustainability departments or joint product innovation with suppliers. At the same time, we observe only minimal efforts to absorb stakeholder and regulatory pressure while avoiding real change.

In the final step of our findings, we want to stress the significance of using our framework in an integrated way and point to the interdependencies and interrelations between its elements. Generally, there are several interdependencies between dimensions and across categories. For example, the measurement and quantification of GHG emissions data along the whole value chain is necessary to track the effects of climate management activities and make them visible to customers, regulators, investors, and other stakeholders. Furthermore, emissions data inform the level of climate targets and the prioritization of reduction measures. Transition plans, a governance structure, and the implementation of measures to reduce emissions require targeted and sufficient investment in capital goods or product development which will most likely affect operations and the whole supply chain. A comprehensive assessment attentive to these interdependencies can identify types of interrelations that are helpful for understanding the factors that enhance, counterbalance, or block a more rapid transformation.

Four types of interrelations seem particularly promising for further research: missing links, contradictions, partial alignment, and thresholds. *Missing links* are combinations where a company shows a high activity level in one or several categories but fails to connect these activities to other categories that would make them effective, e.g., when a company carries out many reduction activities targeted at operational emissions, but ignores its impact further up and down the value chain. *Contradictions* occur when activities in one or more categories counteract efforts in other categories. An illustrative example is the publication of ambitious climate targets without dedicating sufficient investments in measures to meet these targets. *Partial alignment* happens when activities in some interdependent categories are synchronized, but their effects are neutralized by at least one category necessary for a successful connection. A common example from the data was the existence of a robust governance structure, clear plans, and sufficient investments in product development, outweighed by lack of customer interest or the incapacity to sell decarbonized products on the market. Finally, in *thresholds* the combined activities in several categories enable transcending critical moments for transformative change, and a reversion becomes improbable. An example are circular supply chains with near-zero emissions from cradle to grave and the ability to prove that they work in the market and can be scaled up.

3. Discussion

Companies do much to address climate change and keep themselves from regulatory risks and stranded assets. It is difficult for outsiders to assess whether all these activities will eventually lead to change with sufficient decarbonization effects, bringing companies' GHG emissions down to net-zero and transforming energy systems. For this purpose we developed and tested a framework that allows a fine-grained assessment of corporate decarbonization. Being in line with the Paris Agreement requires companies to integrate decarbonization into their core business. This implies radical changes in the way companies are managed, in their activities along entire value chains, and in their investments made for sustaining or developing their future business. A test assessment of three companies demonstrated the feasibility and usefulness of the framework while suggesting that companies still have a long road ahead toward decarbonization. Our framework avoids simplified, unifactorial explanations for why decarbonization is not proceeding more rapidly and helps conceptualize decarbonization as a transition process in which change can be both gradual and disruptive, but not necessarily unidirectional or irreversible. Only by adopting a holistic point of view that defies a simple classification into either symbolic or substantive actions can we identify all key areas and understand their interdependencies. We advise looking out for certain combinations of interrelations, such as missing links, contradictions, partial alignment, and thresholds. This broader perspective can clarify why deep decarbonization is not happening at the necessary speed and highlight potential ways for accelerating transformative change. Using the framework can inform decarbonization's potential key actors such as institutional investors, and policymakers can derive a more realistic understanding of the effectiveness of regulation from the framework's application.

4. Appendix on methods

4.1. Overall approach

The research article combines an explorative, qualitative research design with an extensive literature review. Qualitative research remains powerful in providing insights into relationships and dynamics that more complex than those captured by the statistical or numerical methods dominant in climate change research [68]. The framework was developed based on the analysis of a multiple-case study realized within an ongoing longitudinal research project covering three years (to date) of interaction with 20 companies from Brazil (4), Germany (4), Hong Kong (3), Japan (5), and the United States (4) [69]. We integrated three different types of data in the analysis, including three rounds of semi-structured group interviews with company representatives; a review of publicly available documents relating to these companies, such as CDP questionnaires [70] and company reports; and interaction with company representatives as part of an ongoing research cooperation.

4.2. Sampling and sample description

The theoretical sampling deliberately aimed for variety to avoid industry- or country-specific biases common in other studies. The sample cannot be regarded as representative, as selection was not randomized but based on pre-selected criteria and level of field access. The following guiding criteria were applied for selection: A minimum of three companies per country, from a variety of sectors or industries that have high direct or indirect emissions. Additionally, all companies must publicly express an intention to reduce GHG emissions in order to limit the effects of anthropogenic climate change. The companies selected in this sample met all the required criteria. Twenty companies participate in a longterm study with annual interviews and regular exchange.

The panel covers the following industries: power generation, integrated oil and gas, diversified chemicals, agricultural products, industrial manufacturing, engines, construction, logistics, retail, home furnishings, cosmetics, beverages, real estate, pharmaceuticals and electronics. All companies included in the panel operate internationally and are at least indirectly affected by regulation from multiple countries due to their supply chain or major customers. The selected companies vary in terms of size, revenue, business model, and product portfolio, and show significant differences in terms of scale, feasibility, and degree of transformation achieved. Some are at the core of the energy transition or heavily dependent on fossil fuels and require disruptive technological innovation and infrastructure or radically different products. For others switching to other raw materials, sourcing processes, or solutions for logistics would suffice. All companies provide public information on their climate strategies, activities and GHG emissions data. Companies have different levels of carbon transparency and performance. Their CDP ratings for climate are mostly favorable; sixteen companies received an A or B rating in 2022. At the time of writing, all but two companies have set a public climate target. Fifteen companies have committed to set a climate target aligned with the criteria of the Science Based Targets initiative (SBTi), and most of these targets have already been approved by SBTi.

4.3. Semi-structured interviews

The project team carried out interviews with company representatives annually, starting in November 2020. The last interviews used for this article were conducted in April 2023. The average duration of interviews was around 80 min, ranging from 51 min to 136 min. Local academic partners assisted in organizing and conducting interviews in Hong Kong, Japan, and the United States and in establishing initial contact with one large company in Brazil. The interview guide was developed by the Hamburg-based project team and covers four recurring topics to guarantee consistency and observe changes over the years: (1) climate strategies, targets, and trade-offs; (2) climate management activities, achievements, and barriers; (3) internal implementation and communication; (4) external influence and stakeholder interaction.

Interviewees were responsible for managing climate-related topics within their respective companies. In most cases, they were associated with the sustainability department. However, some of the larger companies also have a dedicated area dealing with climate issues only.

4.4. Data analysis and test assessment

The material used to develop the framework comprised interview transcripts, CDP reports (2021-2023), and different types of company reports, such as (integrated) annual reports along with sustainability and climate-focused reports. All 20 companies who participate in the research cooperation provide public information on their climate strategies and activities. The most recent CDP report (2023) was publicly available for 15 out of 20 companies. For the remaining part of the sample, company reports were used. Data analysis for developing the framework was done with MAXQDA software in several steps. First, a pre-assessment of selected companies, covering a variety of industries and countries, was carried out to identify suitable variables and categories and discussed among the project team. Second, the lead author conceptualized a coding scheme by engaging with existing literature, current disclosure standards such as CDP, and initial readings of interview transcripts. The scheme was further refined in collaboration with the Hamburg-based project team through ongoing analysis of interview and public data in regular meetings between July 2023 and February 2024. The final version is included in the article (see Table 1). Third, the framework was tested in a detailed assessment of three companies. These were selected based on the following criteria: diversity of industry, country, and level of decarbonization-related activities (high, medium, low). For the selected companies, all three rounds of interviews and available CDP reports (2021,2022,2023) within the research period of three years were analyzed independently by the lead author and one other project team member. Where CDP reports were not available, company reports were used. Each coder wrote a detailed qualitative assessment following the categories and indicators formulated in the framework. This included an assessment of each dimension and category on the spectrum from low to high and giving quotes from interviews and (CDP) reports as evidence. The assessments were discussed and harmonized in ongoing dialogue between all coders and reviewed in project team meetings between March and June 2024.

4.5. Ethical guidelines

Our research involves the collection of data and the cooperation of people. We are aware of the special relationship between researchers and those taking part in the research and ensure that the dignity and integrity of the participants are not compromised by the research. We take appropriate measures to ensure the safety and wellbeing of participants and to anticipate, appropriately communicate, and reduce any potential risks. As guidelines for our understanding of research ethics and good scientific practice serve our institution's and funder's rules.

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Credit authorship contribution statement

Thomas Frisch: Writing – original draft, Methodology, Formal analysis, Conceptualization. **Anita Engels:** Writing – review & editing, Funding acquisition, Formal analysis, Conceptualization. **Theresa**

Rötzel: Writing – review & editing, Validation, Formal analysis. **Matthew P. Johnson:** Writing – review & editing, Validation, Formal analysis. **Brigitte Frank:** Writing – review & editing, Validation. **Solange Commelin:** Writing – review & editing, Validation. **Timo Busch:** Writing – review & editing, Validation, Funding acquisition.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Data availability

The interview data that support the findings of this study are not publicly available because they contain information that would compromise the research participants' confidentiality and undermine the process of informed consent. Company and CDP reports are publicly available but company names cannot be shared for the same reasons.

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