

**Decarbonizing, together, faster:
How configurations of (open) innovation and governance advance corporate
decarbonization**

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Abstract: Firms must undergo fundamental transformations to thrive in a low-carbon economy and mitigate climate change. While existing research has explored firms' environmental reporting behaviors and begun to identify barriers to decarbonization efforts, little is known about the actual implementation of corporate decarbonization journeys. We adopt a configurational perspective and employ Qualitative Comparative Analysis (QCA) to illuminate the multifaceted nature of corporate decarbonization. Through empirical examination of various configurations of governance and (open) innovation factors, we assess their combined impact on corporate decarbonization. Our findings contribute to the literature on climate change management and open innovation in two key ways. Firstly, we integrate governance and innovation perspectives to identify combinations enabling corporate decarbonization. Secondly, we highlight the importance of open innovation in corporate decarbonization, showing that effective innovative efforts for high decarbonization progress entail collaborations across organizational boundaries.

Every company and every industry will be transformed by the transition to a net-zero world.

The question is, will you lead, or will you be led? (Larry Fink, CEO BlackRock 2022)

Anthropogenic climate change is one of the most pressing grand challenges of our times (UN 2015, George et al. 2016). Mitigating climate change requires fast and deep decarbonization of the global economy (IPCC 2022). Consequently, climate change is becoming increasingly important to organizations as they need to develop strategies for reducing carbon emissions (Nyberg & Wright 2022) within and across value chains (Stern and Valero 2021). With rising stakeholder pressure (e.g. Murillo-Luna et al. 2008) and physical climate risks (Pankratz et al. 2023), many firms have initiated their journey to decarbonize now and succeed in future low-carbon economies.

Correspondingly, extant research has begun to uncover how businesses respond to climate change by, for example, reporting on environmental information (e.g. Flammer et al. 2021, Guenther et al. 2016), setting emission reduction targets (e.g. Ioannou et al. 2016, Rogelj et al. 2021), or adopting environmental standards (e.g. York et al. 2018). Yet, we know surprisingly little about the “implementation” part of corporate decarbonization journeys. As firms scale back in their net-zero ambitions (Carbon Tracker, 2023) and fail to deliver on their targets (Cenci et al. 2023), we require a better understanding of how firms can decarbonize effectively. In this study, we conceptualize decarbonization progress in terms of corporate decarbonization targets and the extent to which these are (relatively) ambitious and completed over time (see also Ioannou et al. 2016).

An important lever for setting and progressing on decarbonization targets is corporate governance, such as linking executive compensation to CO₂ emission reductions (Flammer et al. 2019) or setting an internal price for carbon (Zhu et al. 2022). Such governance practices may serve as effective tools for influencing corporate actions and thus drive the outcome of interest. Second, for most firms, a deep commitment to and progress towards net-zero

necessitates innovation in low-carbon technologies, processes, and business models (Stern & Valero 2021). Rapidly increasing investments in clean technologies and business models indicate that many of the required solutions for decarbonization are available (Bumpus and Comello 2017), but corporates often lack the capabilities to adopt novel solutions at adequate scale and speed (Eklund and Kapoor 2019). In addition, some solutions do not yet exist, are currently not commercially viable (IEA 2021), or come with significant “Green Premiums” (Gates 2021). Hence, corporate decarbonization requires innovative efforts to adopt and generate low-carbon solutions.

In this context, it is unlikely that internal innovative efforts alone will allow firms to complete their corporate decarbonization journeys, especially within the narrowing time window of mitigating the worst consequences of climate change. Novel low-carbon solutions are often generated by startups who can then provide these solutions to corporates through startup engagement models (Weiblen and Chesbrough 2015). Furthermore, low-carbon innovations are often systemic in nature, such as in energy systems or electric mobility ecosystems, and thus call for coordination and innovative efforts across organizational boundaries (Falcke et al. 2023). Indeed, anecdotal evidence suggests that firms are turning to open innovation in their attempts to decarbonize more quickly (Zobel et al. 2023).

So far, the literature streams on governance and innovation for environmental performance or ‘green’ transitions have been largely developing in parallel, with limited understanding of how firms can combine governance and innovative efforts in their corporate decarbonization journeys. Do governance mechanisms and innovative efforts compete in the quest for decarbonization? Or do they complement each other? And are different combinations of these dimensions equally suited for different types of firms? Given the multi-faceted nature of corporate decarbonization and the intricacies of firm-internal and external efforts in governance and innovation, it is unlikely that there is one clear pathway to decarbonization. As such, investigating decarbonization progress is theoretically and empirically challenging as it

encapsulates multiple interdependent dimensions. In this study, we adopt a configurational perspective (Fiss 2011, Furnari et al. 2021, Ragin 2008) and draw from the perspectives of governance and (open) innovation to address the following question: *which combinations of governance mechanisms and (open) innovative efforts that unlock corporate decarbonization?* Based on Qualitative Comparative Analysis (QCA), we empirically examine multiple configurations of relevant governance and innovation factors and their joint impact on corporate decarbonization.

Our study makes the following contributions to the literature of management of climate change and open innovation. First, we introduce corporate decarbonization as a novel dependent variable in strategy and innovation research. Second, we combine a governance and innovation perspective and shed light on which combinations of these dimensions enable our outcome of interest: corporate decarbonization. Finally, we uncover the importance of open innovation for corporate decarbonization by revealing that “effective” innovative efforts, yielding high decarbonization progress, entail collaborations across organizational boundaries.

THEORETICAL BACKGROUND

Decarbonization through corporate governance mechanisms

A well-established body of work has investigated how, in the absence of public governance, private governance might induce companies to engage in decarbonization-related activities. While public governance refers to rules, regulations, and frameworks established by governments and regulatory authority which would then call for compliance by firms, we understand private governance as the internal mechanisms and frameworks that firms establish to regulate their own operations. For instance, shareholder activism – as one particular form of private governance – is effective in eliciting corporate disclosure of climate change risks (Flammer et al. 2021). Another private governance mechanism is the integration of environmental performance criteria in executive compensation (Flammer et al. 2019). Such

incentives can serve as an effective tool to influence corporate action. The underlying mechanism is that these tools help direct managers' attention toward issues that may not immediately deliver financial performance, such as investing in the development of clean technology, sustainable energy, and other environmental initiatives (Flammer et al. 2019). Thus, managers – when properly incentivized – may take actions and implement solutions to improve their environmental performance.

Another prominent instrument or tool for driving decarbonization efforts via private governance mechanisms is carbon pricing. Governmental institutions are increasingly implementing mechanisms such as carbon taxes that account for the “true” damage (i.e., the externalities) of CO₂ emissions (e.g., Delmas & Toffel, 2004; Flammer, 2013). Corporates have begun to mimic this mechanism by adopting internal carbon prices. Internal carbon pricing is a mechanism by which companies can place a monetary value on their carbon emissions in a way that drives business towards sustainability (Zhu et al. 2022, Ben-Amar et al. 2022). Prior work shows that internal carbon prices are positively associated with a firm's environmental performance (Zhu et al. 2022). Setting an internal carbon price requires firms to estimate direct and indirect emissions, and it incentivizes emission reductions by making emissions a key cost driver.

Following prior work, we would thus expect direct associations between private governance mechanisms – in the form of executive incentives coupled to emissions and internal carbon prices – and corporate decarbonization, as these internal mechanisms direct managerial attention to climate change and drive decarbonization efforts. However, there might also be indirect effects if we consider governance mechanisms in conjunction with innovation efforts. For instance, an internal carbon price might encourage managers to think more deeply about how to use the resulting funds for leveraging low-carbon innovations. Similarly, executive compensation coupled to environmental performance may facilitate innovation in low-carbon

technologies that promise sustained decarbonization progress in the longer-term (Flammer and Bansal 2017)

Corporate decarbonization through (open) innovation

Achieving decarbonization requires firms to innovate their existing products, services, and processes (Demirel and Kesidou 2019, Varadarajan 2017). Thus, scholars have been calling for more research on the role of firms and their innovative efforts to tackle climate change (e.g. Chandy et al. 2021, Eisenhardt et al. 2016, Howard-Grenville et al. 2014). A related stream of literature has begun to investigate the importance of firm-internal innovation in addressing environmental problems – also called sustainable or environmental innovations (e.g. Slotegraaf 2012, Varadarajan 2017, Watson et al. 2018). Through internal innovation efforts – e.g. investments in research and development – firms may generate novel solutions for achieving their decarbonization targets. We would thus expect a positive association between internal innovation efforts and corporate decarbonization. Yet, sustainable innovations may require integrating low-carbon technologies, which are characterized by novelty and complexity, thus often unfamiliar to the focal firm (Barbieri et al. 2020). Sustainable innovations therefore often build upon a green knowledge base and green capabilities that may be distant to the traditional industry knowledge and not internal to the firm (Barbieri et al. 2020, De Marchi 2020, Ghisetti et al. 2015)

As such, internal innovative efforts alone may be insufficient for progressing on the corporate decarbonization which is why firms turn increasingly to open forms of innovation (Zobel et al. 2023). Open innovation enables firms to augment in-house capabilities by leveraging external sources of knowledge (Zobel 2017). The literature on open innovation has made progress in understanding how firms utilize purposeful inflows and outflows of knowledge across firm boundaries via various forms of collaboration (e.g. Chesbrough and Bogers 2014, West and Bogers 2014, Lu and Chesbrough 2022). Tapping into external knowledge sources can, for instance, increase the environmental sustainability of products

(Bogers et al. 2020), facilitate best practice sharing for sustainable development in Sub-Saharan Africa (Valente and Oliver 2018), or help firms align with partners in open innovation ecosystems that contribute to the Sustainable Development Goals (Falcke et al. 2023).

While this prior work has begun to explore the relationships between open innovation and various dimensions of sustainability, to our knowledge, it has not yet uncovered whether and how openness may advance corporate decarbonization. Yet, corporate decarbonization entails the decarbonization of a company's entire value chain (Stern and Valero 2021) and often spans across entire sectors, increasingly blurring industry boundaries and requiring collaboration between unlikely allies (Falcke et al. 2023). An example is the decarbonization of mobility which requires innovation and coordination in the automotive sectors – e.g. improvements in the performance of EV batteries – and the energy sectors – e.g. novel solutions for vehicle-to-grid charging infrastructure. Furthermore, novel low-carbon technologies are often developed by startups (Bumpus and Comello 2017). This calls for more startup-incumbent engagement models (Weiblen and Chesbrough 2015), as adopting low-carbon solutions from agile startups has the potential to accelerate incumbents' decarbonization efforts (Falcke et al. 2023). As such, complementing internal innovation with external knowledge sources and paths to market may put more firms on a decarbonization trajectory and advance their progress (Zobel et al. 2023). In the following, we develop two distinct mechanisms that may help to explain a positive association between openness in innovation and corporate decarbonization.

Openness in innovation may facilitate corporate decarbonization through ***knowledge access and transfer***. Knowledge access and transfer have been well established as the underlying mechanisms of why openness leads to higher innovation performance (e.g. Laursen and Salter 2006, Zobel 2017, West and Bogers 2014). We posit that these mechanisms may also operate in the context of corporate decarbonization. First, firms often find it challenging to understand and measure how their carbon footprint is formed, who contributes to it, and what capabilities in- and outside the organization could materially impact the carbon footprint

(Comello et al. 2022). By opening up the innovation process – i.e. collaborating with a larger number of external partners – firms can access knowledge, data and best practices, and collectively make sense of carbon reduction target. Second, corporates face uncertainty in their corporate decarbonization as it is often unclear with what kind of technologies, processes, or business model changes decarbonization can be achieved (Zobel et al. 2023). Open innovation reduces technological uncertainty (Parida et al. 2012) as it enables firms to experiment with a larger portfolio of technologies, learn from others, and reduce the risks and costs associated with such experimentation. Finally, even if suitable solutions are identified, corporates often lack the capabilities to generate or adopt novel solutions at an adequate pace (Eklund and Kapoor 2019). Open innovation can help build new capabilities (Zobel 2017) and thus, accelerate corporate decarbonization journeys. As such, we would expect knowledge access and transfer through open innovation to enable more sound and ambitious carbon reduction targets, facilitate the adoption of low-carbon technologies, and help build the capabilities required for implementing a corporate decarbonization.

In addition to knowledge access, ***social influence mechanisms*** among open innovation partners influence strategic decisions and actions (Gerges-Yammine and ter Wal 2023). Although social influence dynamics – triggering patterns of imitation – have been documented in a variety of collaborative contexts, such as investment syndicates (Gaba and Terlaak 2013) or exits from open multiparty alliances (Gerges-Yammine and ter Wal 2023), it is important to understand whether, and under what circumstances, such mechanisms also manifest when it comes to corporate decarbonization. Prior work seems to suggest that social influence dynamics play an important role in environmental strategies. De Mendonca and Zhu (2019), for instance, show that laggard (environmental) companies are more likely to invest in proactive environmental strategies when their leading peers display higher sustainability orientations. We expect this effect to be amplified if a focal firm engages in open innovation relationships with such leading peers. As such, open innovation may not only facilitate corporate decarbonization

through knowledge access and sharing but may reinforce social dynamics whereby we would expect focal firms who partner with low-carbon leaders to achieve more progress in their own corporate decarbonization. Preliminary anecdotal evidence of social dynamics in the context of corporate decarbonization journeys can be found in “joint pledges” such as the “Climate Pledge”, initiated by Amazon and joined by more than 300 organizations. Joint pledges may not only enhance pledge credibility but also leverage inherent peer pressure in the achievement of the joint goal.

In sum, we argue that corporate decarbonization is facilitated by internal and open innovation efforts. The joint effect of these two innovation approaches is, however, less apparent. Prior studies on the joint influence of internal and external innovative efforts on innovation performance are inconclusive regarding whether the two innovative efforts are substitutes or complements (Berchicci 2013, Hagedoorn and Wang 2012).

Combining governance and innovation dimensions for corporate decarbonization: A configurational perspective

Based on the theoretical background, we have identified both governance- and innovation-related dimensions as relevant factors for achieving corporate decarbonization. Regarding *decarbonization governance*, executive compensation tied to emission reductions and internal carbon prices may operate as tools for incentivizing decarbonization. Regarding innovation-related efforts, we differentiate between internal and external innovation activities. Novel solutions for decarbonization can be generated via *internal low-carbon innovation* projects and/or by *openness in innovation*, whereby knowledge relevant for decarbonization can be accessed and shared in partnerships. In the context of open innovation, we argue that *decarbonization ambitions of a focal firm’s partners* may be a relevant factor for shaping the focal firms’ decarbonization efforts through social influence mechanisms.

Having uncovered internal governance and internal/open innovation as relevant dimensions of corporate decarbonization, our aim is now to consider these two dimensions jointly. Adopting a configurational perspective, we argue that we need to better understand whether governance- and innovation-related efforts compete or complement each other in the pursuit of corporate decarbonization.

The substitutive or synergetic relationships may also vary for different types of firms. For instance, while governance-related efforts may be particularly effective for scaling low-carbon solutions that are already available on the market, innovation-related efforts may be required for accessing knowledge and co-developing solutions that are not yet available at scale. The optimal interplay of these two dimensions may thus be contingent on how much a focal corporate has already progressed in its corporate decarbonization. For instance, early-stage companies may benefit more from internal governance mechanisms as these can steer the adoption and implementation of solutions that are already widely available. Those that have already progressed more – i.e. advanced companies – may find it more difficult to progress via governance only, and may need to turn to more innovative approaches to unlock novel solutions for further decarbonization. In the following, we therefore conduct a configurational analysis of how different combinations of governance- and innovation-related dimensions enable corporate decarbonization for companies who are in the early-stage vs. advanced stages of their decarbonization journey. We visualize the preliminary configurational relationships in Figure 1.

INSERT FIGURE 1 ABOUT HERE

METHODS

Sample and Data

To study the relationship between governance mechanisms, (open) innovative efforts and corporate decarbonization, we constructed a sample of U.S companies in the energy sector.

The energy sector is responsible for approx. 25% of total GHG emissions in the U.S. (EPA 2023) and is under increasing pressure to transition from fossil-fuel based and emission-intensive energy sources to renewable and low-carbon alternatives. In fact, the U.S. government has issued the goal of “achieving a carbon pollution-free power sector by 2035” (The White House 2023). We can therefore expect a wide range of energy companies to have already started their corporate decarbonization journey. By focusing solely on U.S. companies, we avoid heterogeneity in country-level policies potentially affecting our analysis.

Our dependent variable is constructed from a dataset compiled by the Carbon disclosure project (CDP). Therefore, our sample is limited to energy companies voluntarily reporting their target progress to the CDP in 2022. By filtering the CDP database for U.S. companies in the sectors “Energy utility networks” and “Thermal power generation”, we built a sample of 26 companies. To construct our dimensions and outcome variables for the Qualitative Comparative Analysis (QCA), we then compiled a unique dataset based on the following data sources.

CDP Data. The CDP is a non-profit organization which sends out annual surveys on climate change-related issues which comprises over 100 questions. In the year 2021, 13,126 firms across industries and countries submitted their responses to the survey, including many of the world’s largest firms across different industries such as Apple Inc., Microsoft, Walmart, or Volkswagen. Thus, CDP data is often considered one of the most comprehensive and useful sources for generating insights into sustainability management in several prior studies (e.g., Flammer, 2021; Ioannou et al. 2016).

Factiva. For collecting data on open innovation partnerships, we followed best practices for using Factiva (e.g., Zobel et al., 2016). Factiva is a search engine and database for full texts from over 32,000 sources, such as newspapers, journals, industry publications, and press releases run by Dow Jones (ProQuest 1).

Science Based Target initiative (SBTi). The Science Based Targets initiative (SBTi) aims to drive and support companies in setting ambitious greenhouse gas emission reduction

targets that align with the goals of the Paris Climate Agreement. The SBTi provides a clear, scientifically grounded methodology and guidelines for companies to set their science-based targets. By adopting science-based targets, companies demonstrate their commitment to taking meaningful climate action and to aligning their business strategies with the transition to a low-carbon economy.

Data analysis: Qualitative Comparative Analysis (QCA)

As we are interested in the interplay of governance- and innovation-related efforts and their role for achieving corporate decarbonization, we apply a qualitative comparative analysis (QCA) (Fiss, 2011; Ragin, 2008). QCA draws from Boolean algebra and set theory to enable a systemic comparison of cases. Specifically, it allows us to investigate how the conjunction of multiple dimensions (e.g., governance, internal innovation, open innovation) consistently leads to an outcome of interest (i.e. corporate decarbonization). QCA is well suited to address research issues characterized by causal complexity (i.e., equifinality, conjunction, and causal asymmetry) that also fits the research issue at hand (Furnari et al., 2021). Achieving corporate decarbonization is challenging, and it is likely that there are multiple “recipes to success” (equifinality) that QCA can identify. Finally, it can deal with causal asymmetry. Causal asymmetry refers to situations where a dimension, under certain conditions (e.g. for an advanced transformer), can contribute positively to an outcome of interest but, under other conditions (e.g. for an early-stage transformer), could not be relevant at all or even detrimental.

We follow the crisp-set QCA approach where both the conditions (i.e. decarbonization governance, internal low-carbon innovation, openness in innovation, and decarbonization ambition of partners) as well as the outcome of interest (i.e. progress on corporate decarbonization) can only take the values of 1 – indicating full membership in a given set (i.e. decarbonization governance mechanisms are in place) – or 0 – indicating full non-membership in a given set (i.e. decarbonization governance mechanisms are not in place) (Ragin 2008).

Following this logic, cases are calibrated by coding each case regarding its membership in the condition sets and the outcome set. Calibration of the cases into these sets requires both theoretical knowledge and case knowledge (e.g. Greckhamer et al., 2018). We developed theoretical knowledge through engagement with prior literature on governance and (open) innovation. We developed in-depth case knowledge through (1) manual coding of large text data from press releases, the CDP data, and public websites and prior practical engagement and research field work within the energy industry, including with companies that constitute cases in our database. Leveraging this theoretical and industry/case knowledge, we calibrated the outcome and conditions sets as described in the following.

Calibrating the outcome set. To construct the outcome set, we draw from question C4.1. in the CDP questionnaire: “Provide details of your absolute emissions target(s) and progress made against those targets”. In our current analysis, we only include data on short-term targets, which usually refer to a target year of 2030-2035. We consider firms as successful in progressing in their corporate decarbonization when they are both (relatively) ambitious in their short-term targets and report (relatively) high progress on the target. To define the threshold for ambitious targets, we draw from recent net-zero projections of the Intergovernmental Panel on Climate Change (IPCC, 2022), experiences from our own engagement in the industry, and descriptive statistics in our sample. We consider firms as ambitious that indicate a short-term emission reduction target of 50% or higher. Following the same logic, we consider firms as successful in progressing on their targets if they have completed at least 50% of their targets. Thus, if a firm has a reduction target of 50% or higher and has completed at least 50% of the target, we code the outcome (corporate decarbonization progress) as 1 – otherwise as 0.

Calibrating the condition sets. To calibrate all conditions, we again draw from our theoretical knowledge and in-depth understanding of the energy industry and case companies. To calibrate the *early vs. advanced-stage transformation* condition, we use data from the CDP

and firms' sustainability reports on the share of renewable electricity generation in a firm's overall electricity generation portfolio. We consider a share of 25% and higher as "advanced" (relatively) in terms of transitioning toward decarbonization (coded as 1) and a share of less than 25% as (relatively) "early-stage" in transitioning toward decarbonization.

To calibrate the *decarbonization governance* set, we used data from CDP questions C1.3a and C11.3a that indicate whether firms implemented (1) incentive mechanisms (e.g., bonuses) for their top management (i.e., board-level) related to progress on emission reduction and (2) internal carbon prices, respectively. As there is a high correlation between the two indicators, we combined both governance mechanisms into one aggregated decarbonization governance condition. A case is coded with 1 for this condition if it has implemented both emission-related top management incentives and internal carbon prizes. We assign a 0 if there is only one of the two mechanisms in place or no mechanism is in place.

To calibrate the *internal low-carbon innovation* condition, we draw from CDP question C-EU9.6a which details the firms' low-carbon R&D projects. Drawing from this data, we count the number of internal R&D projects on low-carbon innovation that do not involve external partners (as they would be captured in the openness condition). We assign a 1 if case companies had a least 1 purely internal low-carbon innovation project. We assign a 0 if a case company does not have any purely internal low-carbon innovation projects.

To calibrate the *openness in innovation* condition, we draw from all press releases related to partnerships on Factiva for the respective focal company. We manually coded 750 press releases from the last three years to identify the number of partnerships of each company in our sample. These can include collaborations with industry partners, startups, universities, and other relevant actors. We only count a partnership as relevant if it is related to innovation, applying coding schemes detailed by Zobel et al. (2016), excluding, for instance, philanthropic engagements. We use the average number of partnerships (5) to define the threshold for this condition. We consider a firm as (relatively) open (i.e., coded with a 1 for this condition) if they

have 5 or more partnerships. We consider a firm as (relatively) less open (i.e., coded with a 0 for this condition) if they have less than 5 partnerships.

When manually coding the partnerships for each firm, we noted down the names of each partner organization. This information was crucial for calibrating the *partners' decarbonization ambitions* condition. This condition captures whether a not a firm collaborated with partners that have ambitious decarbonization targets themselves. Thus, for each firm, we looked up how many of their partners have issued SBTi targets. We assign a 1 for this condition to firms that have two or more open innovation partners with registered SBTi targets. We assign a 0 if they have one or no open innovation partners with SBTi targets

After this calibration, each case (i.e. firm) has a 1 or 0 assigned for each of the five conditions. Introducing five conditions – which can be either true or false – implies that there are 32 logically possible configurations. Prior work suggests that one can include up to five conditions for a sample size of 26, indicating that per design the maximum coverage of possible configurations would be only about one fifth (Greckhamer et al., 2013). However, QCA is suited to overcome this limited diversity in empirical instances through counterfactual analysis (Fiss, 2011).

Finally, we applied the truth table algorithm to identify configurations of these conditions that are consistently associated with an outcome of interest (i.e. corporate decarbonization). In line with prior work, we apply a consistency threshold of 0.8. This indicates that the algorithm only includes configurations in which at least 80% of cases are also part of the “high corporate decarbonization progress” set for calculating the complex solution (Ragin 2008, Greckhamer et al. 2018). From there, the truth table algorithm calculates a parsimonious solution and an intermediate solution, which allow us to extract core and peripheral causal conditions, i.e., the conditions that explain (relatively) high progress in (Fiss, 2011).

RESULTS

The QCA yields three configurations that are consistently associated with (relatively) high progress in corporate decarbonization. Table 1 displays the three configurations. We use black bold circles to indicate the presence and crossed circles to indicate the absence of a condition. Bigger (smaller) circles represent a stronger (weaker) link between the respective condition and the outcome. Empty fields in the table indicate that the condition can be either absent or present (i.e. “don’t care”). The “Overall Solution Coverage” indicates that the three configurations jointly account for 73.3% of the cases that were rated with a high contribution to corporate decarbonization. The measure of “Overall Solution Consistency” indicates that 91.6% of the cases that are part of the three configurations in Table 1 (those that fulfill the identified conditions) are also part of the high corporate decarbonization progress set (those assigned with a 1 in the outcome).

INSERT TABLE 1 ABOUT HERE

Strategy 1: Decarbonization governance to harness “low-hanging fruits” for early-stage corporate decarbonization

The first configuration that is consistently associated with high corporate decarbonization progress is characterized by (1) the *presence* of decarbonization governance, and (2) the *absence* of a large share of renewables (i.e. early-stage transformation) and (3) internal low-carbon innovation. The consistency score of 0.857 implies that 85.7% of those configurations that fulfill these characteristics are also in the high corporate decarbonization progress set. The raw coverage score of 0.4 indicates that out of the 15 cases that are part of the high corporate decarbonization set, 40% (i.e. six cases) are described by this configuration. The result implies that for firms in the early stages of the transformation, a focus on internal decarbonization governance rather than (internal) low-carbon innovation projects is an effective means for accelerating their transformation. When there is no internal low-carbon innovation, openness in innovation, and ambitious partners are less relevant. As such, this configuration

describes a strategy for firms that are in the early stage of their corporate decarbonization, and this strategy focuses on decarbonization governance rather than low-carbon innovation.

To illustrate and better explain this governance-focused decarbonization strategy, we use the case of the energy utility Vistra Corp. Vistra Corp's reduction target is to reduce emissions by 60% by 2030 with a base year of 2010. We consider this an ambitious target. Currently, they have already reached 71.2% of that short-term target, illustrating good progress on the target. However, importantly, the portfolio of their installed capacity entails less than 2% of renewables, thus we consider them as early-stage in their corporate decarbonization. Given the small share of renewables in their portfolio, they might focus their internal resources on adopting readily available low-carbon technologies rather than on pursuing low-carbon R&D projects. Correspondingly, they installed decarbonization governance mechanisms comprising ESG-related incentives for top management, emission-target-related bonuses for all employees, and an internal carbon tax Vistra likely utilizes this comparatively "strong" decarbonization governance to harness "low-hanging fruits" such as the reduction of air travel and the implementation and operation of established renewable energy generation capacity. In fact, Vistra Corp. has set internal targets for both these low-carbon initiatives, which yield immediate short-term effects for decarbonization progress.

Strategy 2: Tapping into the knowledge of ambitious partners to advance early-stage corporate decarbonization

The second configuration that is consistently associated with high corporate decarbonization progress is characterized by the *presence* of (1) internal low-carbon innovation (2) openness in innovation (3) partners with high decarbonization ambitions, and the *absence* of (4) a large share of renewables (i.e. advanced-stage transformation). The consistency score of 1 implies that all configurations that fulfill these characteristics are also in the high corporate decarbonization progress set. The raw coverage score of 0.2 indicates that out of the 15 cases that are part of the high corporate decarbonization set, 20% (i.e. 3 cases) are described by this

configuration. The result implies that there is another path to corporate decarbonization for early-stage companies that, so far, have only a (relatively) small share of renewables. They can leverage the benefits of innovation when they combine internal with open innovation that entails relationships with partners that have ambitious decarbonization targets. Having decarbonization governance in place is not required. Jointly, this configuration describes a strategy for firms in the early stage of transformation that leverage innovation through open innovation with ambitious partners.

An illustrative example of this open innovation-focused strategy for early-stage companies is Duke Energy, based in North Carolina, Charlotte. In CDP, they report a 12% share of renewable energy in their portfolio as their main sources are hard coal and gas. They can thus be considered early-stage in their corporate decarbonization journey. Their short-term target is a 50% reduction until 2030 with 2005 as the base year. In 2021, they reported a progress of 89%. Thus, we consider them as successful in their early-stage corporate decarbonization. In contrast to Vistra Corp, Duke Energy's decarbonization strategy is more innovation focused. In fact, Duke Energy is investing into implementation of renewable energy plants as well as into research of complementary, more long-term-oriented, smart grid and storage technologies, both internally and in cooperation with ambitious partners (i.e., Kroger Co. and Siemens Energy respectively). Siemens and Kruger have both committed to SBTi targets and can thus be considered ambitious partners that may provide social pressure for Duke to catch up with their partners in terms of corporate decarbonization.

Strategy 3: Holistic open innovation and governance strategy for advanced corporate decarbonization

The third configuration that is consistently associated with high corporate decarbonization progress is characterized by the *presence* of (1) decarbonization governance, (2) internal low-carbon innovation, (3) openness in innovation and (4) a high share of renewables (i.e. advanced transformers). The consistency score of 1 implies that all configurations that fulfill these

characteristics are also in the high corporate decarbonization progress set. The raw coverage score of 0.133 indicates that out of the 15 cases that are part of the high corporate decarbonization progress set, 13.3% (i.e. two cases) are described by this configuration. The result implies that decarbonization strategies for advanced companies that already have a (relatively) larger share of renewables are different. They need to leverage the combination of decarbonization governance, internal innovation, and open innovation. However, interestingly, and in contrast to configuration 2, their success does not depend on the decarbonization ambitions of their partners. To summarize, this configuration describes a holistic transformation strategy for firms in more advanced stages of their transformation that leverages both governance and innovation through open innovation partnerships.

To illustrate this strategy, we use the example of Sempra Energy, a utility company headquartered in San Diego, California, USA. This company has a share of renewable energy of about 30% in its portfolio. Thus, Sempra Energy can be considered as advanced in its corporate decarbonization. From 2019 as the baseline year, they target a 50% reduction until 2030 and report 84% progress in 2021. Thus, we consider them as (relatively) successful in their corporate decarbonization. At this advanced stage, they are likely to benefit from investment in internal innovation related to, for instance, hydrogen and clean generation and transportation technology. These benefits are enabled by partnerships with industry partners, startups, and technology firms, including, for instance, collaborative micro-grid projects. Importantly, in addition to their open innovation efforts, they report an 8% weight of ESG performance for executive compensation and leverage an internal carbon price to calculate compliance costs for California's cap and trade program. These governance mechanisms are likely to alleviate the corporate decarbonization benefits of internal and open innovation efforts as they provide additional incentives and funds to scale successful innovation.

DISCUSSION

Based on a qualitative comparative analysis, we have uncovered three configurations of corporate decarbonization governance and (open) innovation efforts that facilitate corporate decarbonization. The following interesting and important implications can be derived from the nature of these configurations.

First, there is no consistent strategy to unlock decarbonization progress that applies to both early-stage and advanced companies. In the early stages of corporate decarbonization, firms can experience some degree of success through the deployment of either corporate governance or innovation-centric strategies. This suggests that during this stage, the individual impact of corporate governance mechanisms or innovation-centric endeavors (i.e., internal low-carbon innovation and openness in innovation) can independently contribute to setting the company on the path towards decarbonization.

Second, we find that corporate governance mechanisms are important tools for driving decarbonization, especially for those firms that have just begun their decarbonization efforts. Indeed, for companies that are in the early stage of their transformation, one effective strategy for decarbonization is to rely on corporate governance mechanisms which provide the foundational structure that allows firms to embark on their corporate decarbonization journeys. However, the role of these mechanisms evolves as firms advance in their transformation journey. It is noteworthy that while governance mechanisms continue to remain germane to firms at advanced stages of their transformation, their efficacy is predicated on their amalgamation with both firm-internal and open innovation efforts. These governance mechanisms facilitate the integration of innovation efforts, thereby maintaining momentum and ensuring that the decarbonization process remains on track. This dynamic function of corporate governance mechanisms underscores their important role in driving a firm's decarbonization efforts at various stages of their transformation.

Third, regarding the innovation-related dimension, we uncover interesting synergies between internal and open innovation efforts. For firms across the transformation continuum –

whether at the early or advanced stages – relying solely on internal innovation initiatives is inadequate for making substantial strides in their decarbonization journey. To unlock progress on ambitious decarbonization targets, internal low-carbon innovation needs to be combined with open innovation in the form of a (relatively) large number of partnerships. For firms in the early stage, it is important that partners have ambitious decarbonization targets themselves. This may suggest that these firms do not only benefit from open innovation because of knowledge access or sharing but also because of social influence mechanisms. For firms that have just started their corporate decarbonization, partnerships thus seem to be an important vehicle for social comparison and peer pressure. For firms who have already advanced in their transformation, it does not seem to be relevant whether or not their partners have ambitious targets as well.

Contributions the Literature

With our insights, we can contribute to literature at the intersection of strategy, grand challenges, and open innovation.

First, we introduce corporate decarbonization as a novel dependent variable in strategy and innovation research. Given the latest findings of climate science (IPCC 2022), regulations and policies, and corporate responses related to climate change, corporate decarbonization becomes of increasingly strategic importance. While prior literature has shed light on the antecedents of firms' reporting behavior when it comes to climate-change related information (e.g. Flammer et al. 2021, Guenther et al. 2016, Lewis et al. 2014), little is known about the drivers of the extent to which firms really progress in their transition from emission-intensive to low-carbon businesses. Our study presents an important first step toward a better understanding of the mechanisms that facilitate firms' corporate decarbonization journeys. We hope that our study inspires further research on strategic issues beyond financial performance.

Second, taking the complexities and interdependencies inherent in grand challenges – such as climate change – seriously (George et al. 2016, McGahan et al. 2021), we combine a governance perspective with an innovation perspective to explore which combinations of these two dimensions are best suited for facilitating our novel dependent variable: corporate decarbonization. We reveal that both dimensions are important but that their relevance and interplay depend on where a firm currently is in its decarbonization journey. Our results suggest that corporate decarbonization requires both: governance and innovation, but that the latter is only valuable in advanced stages of the transformation process when the ‘low-hanging fruits’ are already captured, and innovative efforts are required to further unlock decarbonization.

Third, we uncover the crucial role of open innovation for facilitating corporate decarbonization. While prior anecdotal evidence already suggests that openness in innovation may be an important driver of climate innovation and firms’ decarbonization efforts (e.g. Zobel et al. 2023), to our knowledge, this is the first systematic study that demonstrates an empirical relationship between open innovation and corporate decarbonization. Echoing insights from prior studies on the complementarities of internal innovation and open innovation (e.g. Hagedoorn and Wang 2012), our findings show that firms only benefit from internal innovation – in terms of their corporate decarbonization – when these are combined with open innovation efforts. We thus identify open innovation relationships as a critical enabling factor for unlocking firms’ decarbonization journeys, especially once the ‘easy’ decarbonization levers have been captured via corporate governance.

FIGURES AND TABLES

Figure 1. A configurational framework of corporate decarbonization progress

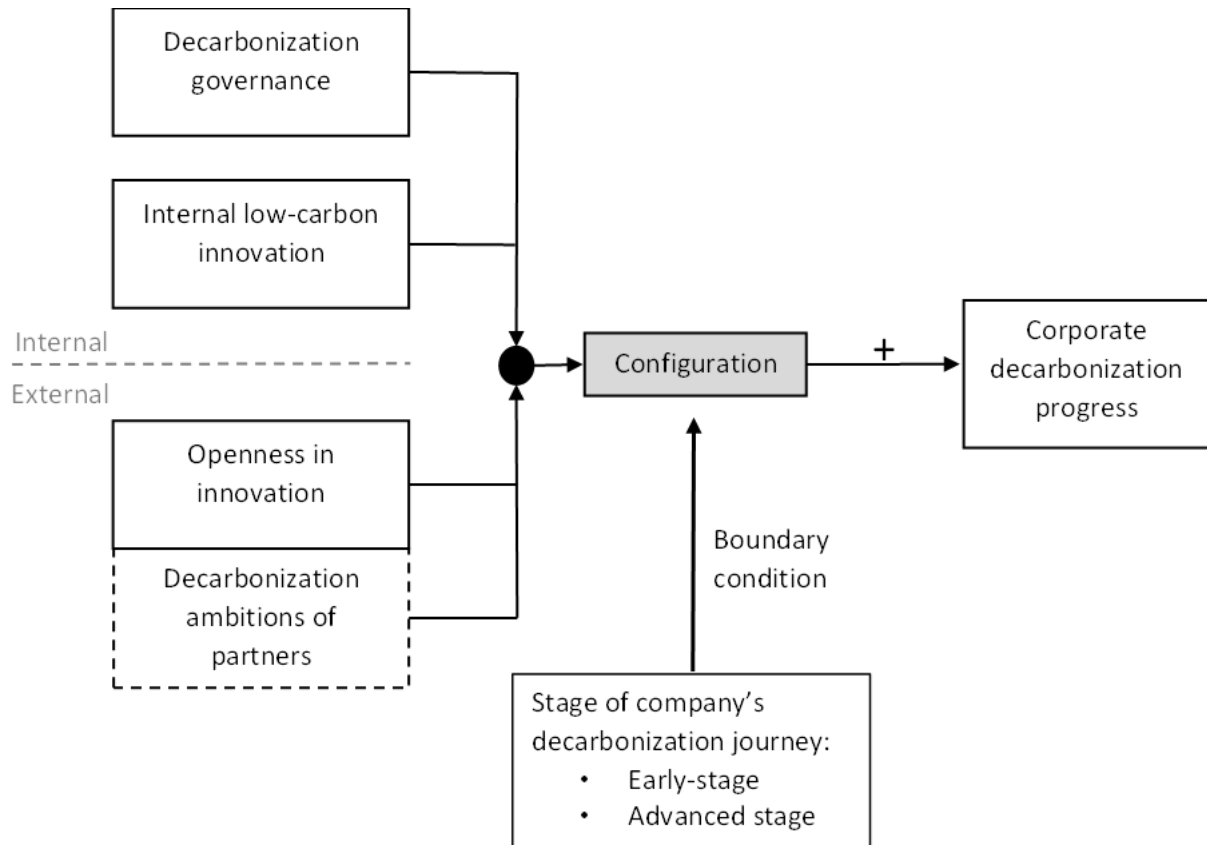


Table 1. Configuration of Governance and Innovation Decarbonization Strategies associated with high progress on corporate decarbonization.

	High corporate decarbonization progress		
	<u>Configuration 1</u>	<u>Configuration 2</u>	<u>Configuration 3</u>
Advanced stage decarbonization (High share of renewables)	⊗	⊗	●
Decarbonization governance mechanisms in place	●		●
Internal low-carbon R&D innovation projects running	⊗	●	●
High number of open innovation partnerships		●	●
Open innovation partners with ambitious targets		●	
Consistency	0.857	1	1
Raw Coverage	0.4	0.2	0.133
Unique Coverage	0.4	0.2	0.133
Overall <u>solution consistency</u>		0.916	
Overall <u>solution coverage</u>		0.733	

REFERENCES

- Barbieri, N, Marzucchi, A, & Rizzo, U (2020). Knowledge sources and impacts on subsequent inventions: Do green technologies differ from non-green ones? *Research Policy*, 49(2), 103901.
- Ben-Amar, W, Gomes,M, Khursheed,H, Marsat,S (2022). Climate change exposure and internal carbon pricing adoption. *Business Strategy and the Environment*, 31:2854-2870.
- Berchicci, L (2013) Towards an open R&D system: Internal R&D investment, external knowledge acquisition and innovative performance. *Research Policy*, 42: 117-127.
- Bogers, M, Chesbrough,H, Strand,R (2020). Sustainable open innovation to address a grand challenge: Lessons from Carlsberg and the Green Fiber Bottle. *British Food Journal*, 122(5):1505-1517.
- Bumpus, A, and Comello.S (2017). Emerging Clean Energy Technology Investment Trends. *Nature Climate Change* 7:382–5.
- Carbon Tracker (2023). Carbon Tracker Assessments for the Climate Action 100+ Net Zero Company Benchmark 2023, <https://carbontracker.org/carbon-tracker-assessments-for-the-climate-action-100-net-zero-company-benchmark-2023/>
- Cenci, S., Burato,M., Rei,M., & Zollo,M. (2023). The alignment of companies' sustainability behavior and emissions with global climate targets. *Nature Communications*,14(1),7831.
- Chandy, RK, Johar, GV, Moorman, C, Roberts, JH (2021). Better Marketing for a Better World. *Journal of Marketing* 85:1–9.
- Chesbrough, H (2020). To recover faster from Covid-19, open up: Managerial implications from an open innovation perspective. *Industrial Marketing Management*, 88: 410-413.
- Chesbrough, H, Bogers,M (2014). Explicating open innovation: Clarifying an emerging paradigm for understanding innovation. *New Frontiers in Open Innovation*. Oxford: Oxford University Press,3-28.
- Comello,, Reichelstein,J, Reichelstein,S (2022). Corporate Reduction Pledges: An Effective Tool for Mitigating Climate Change? In *Frontiers in Social Innovation*, Harvard Business Review Publishing, 2022.
- De Marchi, V, (2012). Environmental innovation and R&D cooperation: empirical evidence from Spanish manufacturing firms. *Research Policy* 41 (3):614–623.
- De Mendonca,T, Zhou,Y (2019). When companies improve the sustainability of the natural environment: A study of large U.S. companies. *Business Strategy and the Environment*, 29(3):801-811.
- Delmas, M, Toffel,MW (2004). Stakeholders and environmental management practices: an institutional framework. *Business Strategy and the Environment*, 13(4): 209-222.
- Demirel, P, Kesidou,E (2019). Sustainability-Oriented Capabilities for Eco-Innovation: Meeting the Regulatory, Technology, and Market Demands. *Business Strategy and the Environment* 28:847–57.
- Eisenhardt, K, Graebner,M, Sonenshein,S (2016). Grand Challenges and Inductive Methods: Rigor without Rigor Mortis. *Academy of Management Journal* 59: 1113–23.
- Eklund, J, Kapoor,R (2019). Pursuing the New while Sustaining the Current: Incumbent Strategies and Firm Value during the Nascent Period of Industry Change. *Organization Science* 30:383–404.
- EPA (2023). Sources of Greenhouse Gas Emissions. Retrieved from: <https://www.epa.gov/ghgemissions/sources-greenhouse-gas-emissions>
- Falcke, L, Zobel,A-K. and Comello,S (2022). How firms realign to tackle the grand challenge of climate change: An innovation ecosystems perspective. *Journal of Product Innovation Management*, forthcoming.

- Fankhauser,, Smith,SM, Allen,M, Axelsson,K, Hale,T, Hepburn,C, Kendall,JM, Khosla,R, Lezaun,J., Mitchell-Larson,E., Obersteiner,M., Rajamani,L., Rickaby,R., Seddon,N, Wetzer,T (2022). The meaning of net zero and how to get it right. *Nature Climate Change*, 12(1):15-21
- Fiss, PC (2011). Building Better Causal Theories: A Fuzzy Set Approach to Typologies in Organization Research. *Academy of Management Journal* 54:393–420.
- Flammer, C (2013). Corporate social responsibility and shareholder reaction: The environmental awareness of investors. *Academy of Management Journal*, 56(3):758-781.
- Flammer, C, Bansal,P (2017). Does a long-term orientation create value? Evidence from a regression discontinuity. *Strategic Management Journal*, 38(9):1827-1847.
- Flammer, C, Hong,B, Minor,D (2019). Corporate governance and the rise of integrating corporate social responsibility criteria in executive compensation: Effectiveness and implications for firm outcomes. *Strategic Management Journal*, 40(7):1097-1122.
- Flammer, C, Toffel,MW, Viswanathan,K (2021). Shareholder activism and firms' voluntary disclosure of climate change risks. *Strategic Management Journal*, 42(10):1850-1879
- Furnari,, Doanl,C, Misangyi,VS, Greckhamer, T, Fiss, PC, Aguilera,RV (2021). Capturing Causal Complexity: Heuristics for Configurational Theorizing. *Academy of Management Review* 46: 778–99.
- Gaba, V, Terlaak,A (2013). Decomposing uncertainty and its effects on imitation in firm exit decisions. *Organization Science*, 24(6):1847-189.
- Gates, B (2021). How to avoid a climate disaster: The solutions we have and the breakthroughs we need. Knopf.
- George, G, Howard-Grenville,J, Joshi,A, Laszlo,T (2016). Understanding and tackling societal grand challenges through management research. *Academy of Management Journal*, 59:1880–1895.
- Gerges-Yammine, R, Ter Wal,AL (2023). Firm exit from open multiparty alliances: The role of social influence, uncertainty, and interfirm imitation in collective technology development. *Research Policy*, 52(4):104-705.
- Ghisetti, C, Marzucchi,A, Montresor,S (2015). The open eco-innovation mode. An empirical investigation of eleven European countries. *Research Policy*, 44(5):1080-1093.
- Greckhamer, T, Furnari,S, Fiss,PC, Aguilera,RV (2018). Studying Configurations with Qualitative Comparative Analysis: Best Practices in Strategy and Organization Research. *Strategic Organization* 16:482–95.
- Guenther, E, Guenther,T, Schienmann,F, Weber,G (2016). Stakeholder relevance for reporting: explanatory factors of carbon disclosure. *Business & Society*, 55(3):361-397.
- Hagedoorn, J, Wang,N (2012). Is there complementarity or substitutability between internal and external R&D strategies? *Research Policy*, 41(6):1072-1083.
- Howard-Grenville, J, Buckle,S, Hoskins,B, George, G (2014). Climate Change and Management. *Academy of Management Journal* 57:615–23.
- Ioannou, I, Li,SX, Serafeim,G (2016). The effect of target difficulty on target completion: The case of reducing carbon emissions. *The Accounting Review*, 91(5): 1467-1492.
- IEA. Net Zero by 2050: A Roadmap for the Global Energy Sector. Paris: International Energy Agency, 2021.
- IPCC. *Climate Change 2022: Mitigation of Climate Change*. Geneva: Intergovernmental Panel on Climate Change, 2022.
- Laursen, K, & Salter,A (2006). Open for innovation: the role of openness in explaining innovation performance among U.K. manufacturing firms. *Strategic Management Journal*, 27(2):131-150.
- Lewis, BW, Walls,JL, Dowell,GW (2014). Difference in degrees: CEO characteristics and firm environmental disclosure. *Strategic Management Journal*, 35(5):712-722.

- Lu, Q, Chesbrough, H (2022). Measuring open innovation practices through topic modelling: Revisiting their impact on firm financial performance. *Technovation*, 114.
- McGahan, A, Bogers, M, Chesbrough, H, Holgersson, M (2021). Tackling Societal Challenges with Open Innovation.” *California Management Review* 63:49–61.
- Murillo-Luna, J., Garces-Ayerbe, C., Rivera-Torres, P. (2008). Why do patterns of environmental response differ? A stakeholders' pressure approach. *Strategic Management Journal*, 29, 1225-1240.
- Nyberg, D, Wright, C (2022). Climate-proofing management research. *Academy of Management Perspectives*, 36(2) 713-728.
- Pankratz, N., Bauer, R., Derwall, J. (2023). Climate change, firm performance, and investor surprise. *Management Science, Articles in Advance*.
- Parida, V, Westerberg, M, Frishammar, J (2012). Inbound open innovation activities in high-tech SMEs: the impact on innovation performance. *Journal of small business management* 50(2), 283-309.
- Ragin, C (2008). *Redesigning Social Inquiry: Fuzzy Sets and Beyond*. Hoboken, New Jersey: Wiley.
- Rogelj, J, Geden, O, Cowie, A, Reisinger, A (2021). Three Ways to Improve Net-Zero Emissions Targets. *Nature* 591:365–8.
- Slotegraaf, R.J. (2012). Keep the Door Open: Innovating toward a more Sustainable Future. *Journal of Product Innovation Management* 29:349–51.
- Stern, N, Valero, A (2021). Innovation, growth and the transition to net-zero emissions, *Research Policy*, 50(9)
- United Nations. (2015). Sustainable development goals. In *Department of Economic and Social Affairs (Ed.), Transforming our world: The 2030 agenda for sustainable development*. New York: United Nations.
- Valente, M, Oliver, C (2018). Meta-organization formation and sustainability in sub-saharan Africa. *Organization Science* 29(4):678-701.
- Varadarajan, R. (2017). Innovating for Sustainability: A Framework for Sustainable Innovations and a Model of Sustainable Innovations Orientation. *Journal of the Academy of Marketing Science* 45:14–36.
- Watson, R, Wilson, H, Smart, P, Macdonald, E, K (2018). Harnessing Difference: A Capability-Based Framework for Stakeholder Engagement in Environmental Innovation. *Journal of Product Innovation Management* 35: 254– 79.
- Weiblen, T, Chesbrough, H. (2015). Engaging with startups to enhance corporate innovation. *California Management Review*, 57(2):66-90.
- West, J, Bogers, M (2014). Leveraging external sources of innovation: A review of research on open innovation. *Journal of Product Innovation Management*, 31(4):814-831.
- White House (2023). Fact sheet: President Biden to catalyze global climate action through the Major Economies Forum on Energy and Climate. Retrieved from: <https://www.whitehouse.gov/briefing-room/statements-releases/2023/04/20/fact-sheet-president-biden-to-catalyze-global-climate-action-through-the-major-economies-forum-on-energy-and-climate>
- York, J. G., Vedula, S., Lenox, M. J. (2018). It's not easy building green: The impact of public policy, private actors, and regional logics on voluntary standards adoption. *Academy of Management Journal*, 61(4), 1492-1523.
- Zhu, B, Chenxin, X, Wang, P, Zhang, L (2022). How does internal carbon pricing affect corporate environmental performance? *Journal of Business Research*, 145:65-77.
- Zobel, A.-K 2017. Benefiting from Open Innovation: A Multidimensional Model of Absorptive Capacity. *Journal of Product Innovation Management*, 34(3):269-288.
- Zobel, A.-K, Balsmeier, B. & Chesbrough, H (2016). Does patenting help or hinder open

innovation? Evidence from new entrants in the solar industry. *Industrial and Corporate Change*, 25(2): 307-331.

Zobel, A-K, Comello, S, Falcke, L (2023). Accelerating the race to net-zero through open innovation. Chesbrough, H, Radziwon, A, West, J, Vanhaverbeke, W (Eds.) *The Oxford Handbook of Open Innovation*: Oxford University Press