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Empirically assessing corporate adaptation and resilience disclosure using AI

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Abstract

The extent to which firms are adapting and building resilience to environmental change is crucial information for financial institutions, regulators and governments. While corporates' physical climate risk exposure of their assets to environmental change can be calculated using models, additional information is needed to evaluate their vulnerability to physical climate change, how well they are adapting and broader alignment with societal adaptation and resilience (A&R) goals. This paper empirically evaluates the extent of A&R-related information in current corporate sustainability reports to provide such insights. We build on established sustainability disclosure frameworks and develop an A&R disclosure framework that we combine with the latest advances in large language models to assess S&P 500 company sustainability reports. We prove that corporate A&R disclosure is lacking, particularly around risks, metrics and targets, underlining the need to consider other data sources when assessing firm-level risks and contributions to societal A&R goals.

1 Main

Irrespective of future emissions trends, there is a need to build resilience to the impacts of climate change and nature loss already locked in. Forty percent of the global population resides in highly climate-vulnerable areas[1], and some systems are already reaching adaptation limits[2], restricting the solutions space for effective responses[3]. Ranger and Oliver[4] further demonstrate the significant dependencies on nature and the financial materiality of nature-related risks and their interlinkages to climate-related physical risks. Yet, adapting to climate change and building resilience to wider environmental risks has received considerably less attention than

mitigation in the business and finance sphere, particularly when considering the status of the policy architecture and the amount of finance deployed[5].

The private sector plays a central role in adaptation and resilience (A&R) as providers of adaptation goods, services, innovation and investment to the wider economy. In adapting and building their own resilience, firms can also contribute to societal resilience by generating resilient services, jobs and growth. Conversely, in failing to adapt or by implementing risk responses that may undermine resilience for others, firms also have the potential to push societies down maladaptive pathways[6].

The financial sector is becoming increasingly interested in adaptation, evidenced by the numerous frameworks and taxonomies published by non-state actors to guide investment (see review[7]). Growing evidence shows that physical climate risks represent material financial risks, with current and expected impacts on asset values[8,9,10] and probabilities of default of firms[11, 12]. Financial institutions (FIs) struggle to access the information that they require from firms to manage these risks, particularly concerning actions being undertaken to adapt.

Adaptation also represents a significant opportunity for FIs. FIs want to identify well-adapted firms that will be outperformers in their markets at future climate, either through adapting their own operations and assets or by providing adaptation products and services that will be increasingly needed to cope with climate change. The market for adaptation-related products and services is expected to be significant. Some estimates suggest a market investment opportunity of around $400 billion per year for climate adaptation alone[13], others as high as $2 trillion per year[14]. Recent research by the London Stock Exchange Group[15] suggested that the size could already be $1 trillion per year, with particular opportunities related to water, food and real-estate sectors. Governments also require information about how firms are adapting to measure progress on societal adaptation and identify policy priorities.

One of the principal barriers to adaptation and to scaling adaptation financing cited is the dearth of reliable information[16]. Unlike with emissions, no detailed, quantified ‘adaptation and resilience trajectories’ disaggregated by sector and technology exist against which the ‘alignment’ of financial flows, companies or whole economies can be assessed. Indeed, arguably despite recent progress on a Global Goal for Adaptation, it is unlikely that an adaptation equivalent of ‘net zero’ will exist, but instead there will likely continue to be a patchwork of inconsistent qualitative goals specific to individual sectors or geographies. As a result, financial institutions (FIs) and regulators rely on evaluating adherence to principles,

such as managing environmental physical risk, doing no significant harm to society and nature, aligning with third-party adaptation plans, and contributing actively and positively to resilience[17], as forms of measuring 'alignment' with societal A&R. This is evident in frameworks such as the EU Taxonomy, where adaptation-related metrics are process-based. Investors, banks and insurers need information on a company's adoption of these principles for multiple uses: to price risk, inform client/investee engagement and stewardship strategies, design products, and make capital allocation decisions. Governments and regulators also need such information to assess the preparedness of economies for environmental risks and appraise where intervention might be required to address the gaps. However, this data is missing – or so is argued.

The lack of decision-useful corporate sustainability data is not a new phenomenon. In fact, a series of disclosure frameworks and guidance, such as those by the Taskforce for Climate-Related Disclosures (TCFD), Taskforce for Nature-Related Disclosure (TNFD), International Standard-Setting Board's (ISSB) IFRS S2 and Transition Plan Taskforce (TPT), have been published to encourage cohesive corporate disclosure of sustainability information. In some jurisdictions, these have even become mandatory (e.g. UK and EU). The ensuing disclosures have given rise to a series of assessments that evaluate the compliance and performance of firms with these frameworks[18,19]. Some have started assessing the quality of disclosures to counteract the risk of greenwashing[20,21], while others have even started using disclosures to estimate firm-level risk[22,23,24]. It may therefore seem that the issue has been sufficiently addressed.

However, there are no dedicated A&R disclosure frameworks, which makes it impossible to assess firm compliance as a proxy for physical risk and alignment with A&R. Equally, while myriad methodologies exist to estimate firm-level exposure to climate risks (e.g. [25,26.27]), there is no authoritative way of integrating the adaptation measures companies have taken to address certain risks or their capacity to take these measures (i.e. a company's adaptive capacity). Given that the firms' own adaptive actions are well known to be a dominant driver of risk, this means that most physical risk assessments in the literature to date are biased or incomplete when it comes to the performance of individual firms. The focus on firm- or asset-level risk profiles in the literature also does not capture the full extent of contribution to and alignment with societal A&R. To date, FIs and regulators are thus reliant on corporate disclosures to evaluate corporate alignment with A&R principles.

Although the various taskforces guiding corporate disclosure have not explicitly centred A&R, there is some overlap. For example, 22.a in the ISSB's IFRS 2 states that "[a]n entity shall disclose information that enables users of general-purpose financial reports to understand the resilience of the entity's strategy and business model to climate-related changes, developments and uncertainties, taking into consideration the entity's identified climate-related risks and opportunities". The CDP questionnaire includes sections on climate adaptation actions taken, as well as freshwater use and land use[28]. Broad principles for integrating adaptation into transition planning have been laid out by the Transition Plan Taskforce, and these have recently been elaborated further by many organisations, including the latest guidance published by the ISSB and the European Financial Reporting Advisory Group. There is, therefore, potential for sustainability disclosures to already include substantial A&R-related information.

This study is the first to empirically analyse the extent to which information being disclosed by corporates includes information on A&R. Assuming that the extent of information disclosed broadly reflects what firms are doing, we interpret the results to indicate how firms are approaching A&R, noting, however, the limitations of the information captured in corporate sustainability reports. The methodology developed can be applied to other forms of disclosure (e.g. US filings or other financial reporting), which may be deemed more trustworthy.

We develop a 91-indicator assessment framework and use it to assess the latest sustainability reports of the S&P 500 companies using a large language model (LLM) to generate 42,030 datapoints for our analysis. In so doing, this study makes four contributions to the literature. First, the paper builds upon existing disclosure frameworks (i.e. TCFD, TNFD, ISSB IFRS S2 and the TPT) and literature (e.g. [29,30]) to develop a common framework for assessing the extent of corporate A&R disclosure. Our assessment framework integrates with existing reporting standards and expands their A&R components. We define resilience to include both physical climate and nature-related risks, given the evidence of the interdependencies between the two. A common framework is expected to enhance firm A&R reporting while making public information more comparable and usable for investors and regulators. Second, the paper develops and applies an LLM to assess the extent of A&R information reported by corporates, allowing interested parties (e.g. firms, investors, governments, regulators, CSOs, and researchers) to action their own assessments with ease. The benefit of making assessments more accessible is that they encourage adoption and further research. Third, the paper is the first to empirically validate claims that existing disclosure is insufficient to enhance A&R decision-making. In using the disclosure of S&P 500 companies as a proxy, the paper provides

a snapshot of the disclosures of firms with a combined valuation of $43 trillion regarding adapting to climate change and building resilience[31]. Based on our findings, we create four archetypes of disclosers. We also consider companies part of the Climate Action 100+ (CA100+) and Nature Action 100 (NA100) initiatives separately, to examine in detail the current state of high-impact companies already committed to enhanced sustainability disclosures. Overall, we show that corporate A&R disclosures are patchy and lacking significantly across certain themes (e.g. targets and metrics).

2 The assessment

The list of indicators comprising the assessment framework presented in this paper draws on best practice in corporate adaptation planning[32], over 25 sustainability disclosure frameworks, and the principles laid out by Mullan and Ranger[33] (see Methodology and Extended Data Table 1 for more information). The Mullan and Ranger paper has been selected, as the principles proposed within the paper have been used to define alignment with adaptation and resilience by jurisdictional adaptation taxonomies[34]. The framework consists of 91 indicators spanning six categories: *Foundation*, *Risk*, *Implementation*, *Engagement*, *Governance*, and *Metrics & Targets* (see Extended Data Tables 2-6 for a full list of the indicators assessed). The category structure aligns with the TPT framework and is used to provide insights into the types of information disclosed by corporates. Indicators were developed by collating existing sustainability disclosure frameworks and plugging the gaps of other decision-useful A&R information points, determined by expert review. Table 1 presents the indicator categories and subcategories to give a sense of the information represented in each.

Table 1. Overview of the indicator categories and sub-categories used to structure the analysis in this paper, with a short description of each. The six indicator categories are marked in grey, and their corresponding sub-categories sit below.

Disclosure element	*Description*
Foundation	
Set priorities	The company has clearly stated its ambition with regards to resilience and this is reflected in its priorities and objectives.
Disclose physical climate risks	The company has disclosed its physical climate risks and opportunities and their locations.
Disclose physical nature risks	The company has disclosed its physical nature-related risks, dependencies and impacts and their locations.
Risk	
Identifying climate risk	The company explains the process it uses to identify physical climate risks and opportunities.

Identifying nature risk	The company explains the process it uses to identify its physical nature-related risks, opportunities, dependencies and impacts.
Risk management process	The company explains the processes it uses to manage its climate- and nature-related risks.
Implementation	
Operations	The company has implemented resilience in its business operations and planning processes.
Offering	The company has implemented resilience in its product and service offering.
Engagement	
with value chain	The company engages with its value chain to foster resilience.
with third parties	The company engages with third parties to foster resilience.
Governance	
Institutional governance mechanisms	The company has integrated resilience across its reporting and governance mechanisms, including the board and management, to institutionalise accountability.
Links	The company has taken measures to encourage resilience across its business practices.
Metrics & Targets	
Targets	The company has set targets to support resilience across climate and nature systems.
Metrics	The company uses relevant metrics to monitors its resilience.

The indicator questions used in this study are binary, which means the assessment only considers whether relevant information is disclosed and not the quality of that information. A company scoring highly across all indicators in this assessment, therefore, simply means a high degree of A&R-related information was found in their disclosures (and not, for example, that the targets they have provided are effective). Notwithstanding the limitations mentioned previously, the types of information disclosed give insights into how companies are approaching adaptation and resilience. The Methodology section of the paper provides additional details.

The companies part of the S&P 500 benchmark index were selected, as they give a wide coverage of sectors and represent around 80% of US market capitalisation with a combined valuation of US$43 trillion[35].

3 Results

Analysis on aggregate

Our analysis shows that on average, S&P 500 companies report against 20% of indicators in the framework (see Fig. 1 – bell-shaped curve). Within this dataset, there is a high degree of variation in reporting, with the least reporting company only providing information for 1 of the 91 indicators and the most-reporting company providing information for 50, which still only

covers just over half of decision-useful A&R indicators. Companies part of the NA100 and CA100+, on average, report on more indicators in the framework than other S&P 500 companies, though this variance is not statistically significant. There is high variability in the types of indicators companies report on. An overview of the indicators over half of the assessed companies report on, and that 5 or fewer companies report on, can be seen in Table 2 (the full list of indicators and proportion of S&P500 companies reporting on these can be found in Extended Data Tables 2-6).

Figure 1. Normal distribution of the number of indicators reported on aggregate by S&P 500 companies. The x-axis demonstrates the percentage of A&R indicators the LLM determined companies report on. The y-axis demonstrates the number of companies at each percentage interval. The orange line represents the normal distribution.

Table 2. *Indicators for which information is disclosed by more than 50% and less than 1% of S&P 500 companies surveyed.*

Most

ID	Disclosure element	Sub-element	Indicator metric	% Yes
71	Governance	Institutional governance mechanisms	Has the company assigned the responsibilities of assessing and managing climate- and nature-related issues to a management-level position or committee that reports to the board?	91%
46	Implementation	Operations	Does the company report any policies or conditions used to ensure no significant harm is done to societal resilience through its business activities?	85%
75	Governance	Institutional governance mechanisms	Does the company have a process in place to escalate any issues that may cause significant harm to climate, nature and society?	68%
45	Implementation	Operations	Does the company report any policies or conditions used to ensure no significant harm is done to nature or ecosystem services?	67%
18	Risk	Identifying climate risk	Does the company have a specific process in place to identify physical risks arising from climate change?	66%
57	Engagement	with value chain	Does the company report any current or anticipated changes to upstream sourcing practices and interactions with downstream partners to address physical nature-related issues? (e.g. adoption of improved tracing, certification practices, collaboration with suppliers, customers and other stakeholders, or extended producer responsibility schemes)	66%
35	Risk	Risk management process	Are the company's processes for identifying, assessing, prioritising and monitoring physical climate- and nature-related risks integrated into its overall risk management process?	64%
73	Governance	Institutional governance mechanisms	Does the company have a mechanism for individuals and communities to raise complaints when they may be adversely affected by the company?	64%
56	Engagement	with value chain	Does the company report any current or anticipated changes to upstream sourcing practices and interactions with downstream partners to address physical climate-related risks and opportunities?	55%
74	Governance	Institutional governance mechanisms	Does the company have a policy of non-reprisal against complainants, including human rights defenders, whistle-blowers, and community spokespersons?	55%
66	Governance	Institutional governance mechanisms	Does the company report the processes used through which the board or board committees are informed about physical climate-related risks or opportunities?	51%

Least

ID	Disclosure element	Sub-element	Indicator metric	% Yes
10	Foundation	Disclose physical nature risks	Does the company report the physical risks to its business operations arising from nature loss and ecosystem degeneration?	0%
42	Implementation	Operations	Does the company refer to external definitions or taxonomies to classify its products and services as resilience aligned?	0%
51	Implementation	Operations	Does the company report on the scenario tools and methodologies used to test the resilience of its financial business strategy on nature-related issues?	0%
90	Metrics & Targets	Metrics	Does the company report its climate adaptation-aligned capital expenditure?	0%
34	Risk	Identifying nature risk	Does the company report the frequency at which it carries out assessments of nature-related risks and opportunities?	0%
79	Governance	Links	Are the company's performance metrics for nature-related dependencies, impacts, risks or opportunities included in its remuneration policies?	0%
86	Metrics & Targets	Targets	Are the company's climate- and nature-related targets validated by an independent third party?	0%
24	Risk	Identifying climate risk	Does the company report whether fat-tail risks or tipping points were considered when identifying physical climate-related risks or opportunities?	0%
32	Risk	Identifying nature risk	Does the company report whether ecological thresholds or tipping points were considered when identifying nature-related dependencies, impacts, risks and opportunities?	0%
33	Risk	Identifying nature risk	Does the company report the frequency at which it carries out assessments of nature-related dependencies and impacts?	0%
65	Governance	Institutional governance mechanisms	Does the company report the number or proportion of board members with competence in nature-related issues?	0%
83	Metrics & Targets	Targets	Does the company provide an explanation of how its climate adaptation-related targets align with the Sharm-el-Sheikh Adaptation Agenda or other similar adaptation goals?	0%
91	Metrics & Targets	Metrics	Does the company report its nature-aligned capital expenditure?	0%

The most disclosed indicators include areas such as board oversight, social and environmental safeguards, and engagement with value chains. Notably, over half of the companies report having a process in place to assess climate-related physical risks – though less than 5% assess nature-related physical risks (ID26). Generally, these indicators represent areas that are easily implemented with minimal disruption (e.g. board oversight) and are broad enough for companies to report some information – i.e. they constitute low-hanging fruit. These indicators also encompass issues that companies have been encouraged to take action on as part of a longer-standing and broader sustainability agenda (e.g. DNSH, reducing environmental impact, etc.). On the other hand, the indicators S&P 500 companies report the least on relate to companies' metrics and targets, nature-related financial risks, capital expenditure linked to adaptation or natural capital, and the precise mechanics of their risk assessments, particularly around uncertainty and non-linearity. Reporting against these indicators requires companies to engage in more depth with A&R, going beyond what is currently included in TCFD and other frameworks and make more significant adjustments to business practices. Moreover, the specificity of this set of indicators means that reporting this information requires implementation of best practice (e.g. using scenarios to assess the resilience of the business strategy). Importantly, the indicators in this list suggest a lack of commitment to nature-related issues beyond engaging with their value chain – 66% of companies report some form of nature-related value chain engagement (ID57). Overall, these findings reflect a high degree of variance in corporate reporting on resilience indicators. Our analysis is therefore extended to consider what trends emerge when aggregating indicators across disclosure elements and sub-elements.

Variation between disclosure elements and sub-elements

Some trends emerge when considering differences in indicators between each of the disclosure elements and sub-elements. *Metrics & Targets* indicators are reported on the least frequently by companies (7% of the time on average). The indicators in this element cover the types of metrics, targets and links with remuneration packages companies have instituted for the management of climate- and nature-related risk and A&R solutions more broadly. Publicly reporting on their targets and metrics enables investors and consumers to hold companies to account for their progress. Together with remuneration packages, these indicators can therefore serve as a measure of how committed a company is to addressing A&R. Though not final, companies will be hesitant to re-adjust their targets and metrics once they have been launched, which may explain the lack of targets, metrics and corresponding ties with remuneration packages companies have in place. Similarly, the S&P 500 companies report on only 11% of

Foundation indicators, which means limited information can be found on how their business strategy aligns with resilience and the material risks and impacts they have identified. However, there is high variation within this disclosure element as companies on average report on four times more indicators related to their business strategy than the specific nature-related risks they are affected by (see fig. 2 for a full breakdown across disclosure sub-elements).

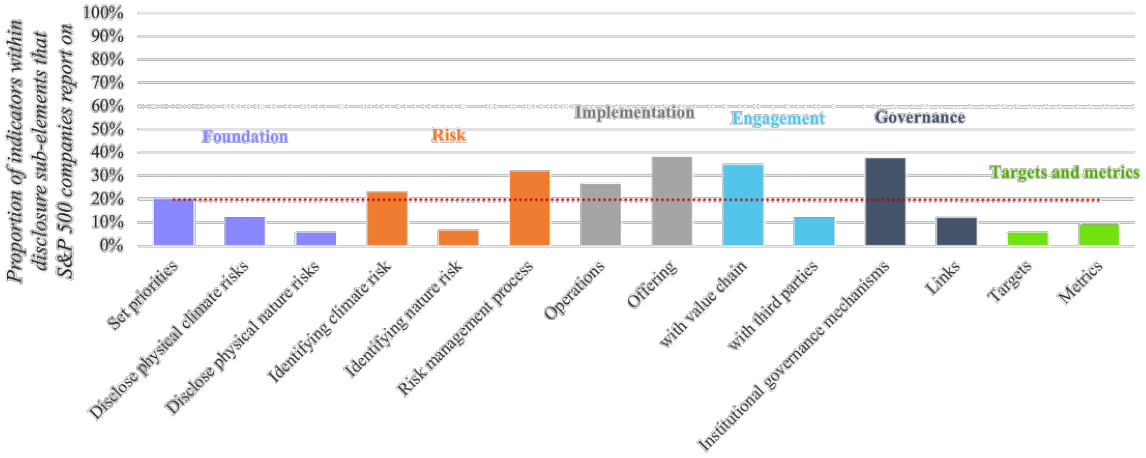

Figure 2. Proportion of indicators within a disclosure sub-element that S&P 500 companies report against on average. Indicators represent decision-useful A&R information points. The y-axis shows the percentage of indicators within a disclosure sub-element from our assessment framework that the LLM determined companies report on, averaged across all companies in our sample. The x-axis lays out the disclosure sub-elements of the assessment framework and groups these further into the underlying disclosure elements (distinguished by different shading). The red dotted line is the average proportion of indicators S&P 500 companies report on.

Looking at the other end of the spectrum, on average S&P 500 companies report against 32% of the indicators in the *Governance* category – the most across all disclosure elements. Within this element, 42% companies report on their board reporting mechanisms (i.e. ID68-70), 91% on their managerial oversight (i.e. ID71) and 53% on how safeguarding is ensured (i.e. ID72-75). While these indicators specifically question whether physical risks and adaptation have been incorporated into existing governance processes, they still constitute low-hanging fruit as they do not require significant changes – the 'environment' is recognised as a source of risk in

conventional risk management and business processes already. However, while 50% of companies explicitly mention that climate-related risks and opportunities are reported to the board, only 3% report the same for nature. This distinction, again, is likely owed to the relative maturity of climate- and nature-related corporate disclosure frameworks. Moving beyond the low-hanging fruit, the analysis finds that only 3% and 0% of companies report whether their board have expertise on climate- (ID64) and nature-related issues (ID65), respectively. Equally, only 1% of companies report having developed a climate change adaptation plan (ID63). Around 19% of companies report having some initiatives in place to educate staff on climate- and nature-related risks (ID76-77), while 4% of companies report having embedded climate- and nature-related performance metrics into their remuneration policies (ID78-79). These indicators require dedicated resilience actions and therefore point to a lack of active engagement by corporates. Similarly, the relatively high degree of reporting from companies on *Implementation* indicators is skewed by companies' longer engagement with practices related to safeguarding, while areas requiring dedicated resilience actions, such as investments and asset disposals in response to climate- and nature-related risks (ID46-47) are not as widely reported (around 5% of companies on average).

The highest observed standard deviation between indicators in a disclosure element is found in *Engagement* indicators (see Extended Data Table 8 for a full overview). Here, one company reports on 85% of the indicators while another reports on zero. This result suggests that the extent to which companies report against these indicators is more polarised – with multiple companies disclosing relevant information for nearly all indicators, while others not reporting any. This could arise from established engagement opportunities not being present for specific companies, given their industry or national context, thus requiring a higher degree of initiative to seek opportunities out. Equally, in some industries such as Utilities, active engagement with the value chain or government may be more central to conventional business activities compared to others. Notwithstanding, S&P 500 companies are not significantly less or more likely to report information on *Engagement* than other disclosure elements.

Variation between climate and nature

We also analysed whether there was variation in company reporting against paired climate-related and nature-related indicators – indicators that are generally the same except for considering climate- or nature-related factors. On average, companies are twice as likely to report on climate-related issues (20% of indicators) compared to nature-related issues (9% of

indicators). These trends are observed more strongly when looking at paired nature- and climate-related risk indicators within disclosure elements. Companies describe 5x and 3x more often how physical climate risks are incorporated into their governance processes and how they are assessed than for physical nature-related risks. However, the differences in reporting on *Metrics & Targets* indicators for climate- and nature-related risks are minimal, while the results show that companies report a bit more frequently on engagement related to nature-related risks than climate (though not significantly). These findings suggest that physical climate-related risk disclosures are more mature than physical nature-related risks, in part due to the legacy of TCFD, which predates TNFD. While companies generally comply with 'mainstream' safeguards, some of the more recent considerations of nature-related risks and dependencies are still lacking.

Variation between sectors

No significant variation emerges when segmenting the average scores of companies by GICS industry level. However, some trends can be identified when further splitting the GICS industry level averages across indicator elements. For example, Real Estate companies report on *Risk* indicators more often than other industries, while Consumer Staples, Utilities and Materials companies report on *Engagement* indicators 2-3.5x times more often than Real Estate and Financial sector companies. This reflects industry characteristics, such as real estate being more exposed to climate-related physical risks, and Consumer Staples, Utilities and Materials companies taking part in more engagement initiatives either as part of engaging with consumers, value chains or governments. Furthermore, Consumer Staples companies report on 6x more *Metrics & Targets* indicators than Financial, Communications, and Industrial sector companies. This latter finding suggests that the Financial, Communications and Industrial industries are lagging when it comes to demonstrating accountability for their work on A&R.

These results can be segmented further when looking at variations between disclosure sub-elements (see fig. 3). Here, Real Estate companies can be seen to perform relatively well on climate-related physical risk indicators and *Operations* indicators compared to other sectors, though it should be noted that these companies still report on less than half of the indicators included (most of which focus on nature-related risks). Utilities companies report on more *Set Priorities* and *Offering* indicators than other sectors, likely due to the closer regulatory supervision and their product offering being an adaptation solution (e.g. water treatment). Similarly, Energy companies report more often on their *Engagement with third parties*,

Institutional Governance Mechanisms and *Links* indicators than other sectors. This again can be attributed to companies engaging more frequently with governments through contractual arrangements and therefore requiring stronger safeguarding policies. Overall, these results indicate that some inter-industry variation exists in the type of information disclosed by different companies. In a lot of these cases, these differences reflect the type of product offered or the extent to which it is a competitive requirement to engage with other actors or fortify internal policies (e.g. governments, consumers). Interestingly, there are no industries that perform significantly worse than others on specific disclosure elements. This is likely due to the already low average score of companies across the dataset.

Fig 3. Proportion of indicators reported on by S&P 500 companies, aggregated by GICS industry and disclosure sub-element. Only those industries with significantly higher values are highlighted in a different colour. The orange dot signifies higher reporting compared to other industries with a 95% confidence interval.

Variation by cluster

Given the large number of companies, a k-means cluster analysis was carried out on the mean number of indicators companies report information on across the different disclosure elements to identify any relationships between these. In running the analysis, four clusters emerged as the optimum number for k-means clustering (see fig. 4-7). Cluster 1 covers 126 companies that report higher than average on *Risk*, *Foundation*, *Implementation* and *Governance* indicators, but lower than average on *Engagement* indicators. Cluster 2 consists of 132 companies that report lower than average across all indicators. Cluster 3 includes 140 companies that report on more Metrics & Targets, Foundation, Engagement, Implementation and Risk indicators (in that order) – all disclosure elements except *Governance*. On the other hand, Cluster 4 is comprised of 69 companies that report higher than average on *Engagement* indicators and lower than average on *Metrics & Targets*, *Implementation*, *Risk* and *Foundation* indicators.

Fig. 4-7. Mean percentage of indicators reported on by different clusters, disaggregated by disclosure sub-element (represented in dark blue). The orange dotted line represents the percentage of indicators reported on by the sample average company. The clusters are composed of S&P 500 companies and were categorised using a k-means analysis.

Fig 4-7 shows the profiles of the four clusters of companies identified. The average number of indicators reported on by companies in each of the clusters is 27%, 11%, 32% and 16% respectively. The means across disclosure elements hide the variation between clusters, due to the high variation between the indicators within a disclosure element (as seen in figs. 4-7). However, when looking at the disclosure sub-elements, characteristics emerge that help profile the clusters. Companies in Cluster 1 report a relatively high degree of information on climate risk, risk management processes, and institutional governance mechanisms, as well as some efforts to strengthen their operations and offering. These characteristics suggest that companies have already taken up some of the recommendations from TCFD, for example, or have started mainstreaming climate-related risk management into their operations, without necessarily explicitly addressing A&R (hence 'Climate Risk Aware'). Companies in Cluster 2 generally do not report on A&R indicators, although there is some information related to *Governance* indicators (hence 'Laggards'). Cluster 3 companies are the relative high-performers of the dataset, often reporting on indicators related to their *Offering*, *Value chain engagement* and *Business priorities*. However, they report less information on *Risk* indicators compared to the 'Climate Risk Aware' companies. Without explicitly considering physical climate- and nature-

related risks, companies are likely scoring highly on A&R due to overlap with existing business practices (hence 'Product Aligned'). On the other hand, Cluster 4 companies are low performers whose A&R-related reporting has focused on value chain engagements. This suggests that some companies may have been engaged on A&R issues through their value chain but are yet to incorporate these into their own business practices (hence the 'Engaged'). Equally, the focus on engagement activities without progressing on A&R in other areas of their business may be interpreted as an attempt to greenwash.

The cluster profiles are corroborated when looking at the industry compositions of the clusters. Over a third of the Utilities, Materials and Consumer Staples companies in the S&P 500 are part of the 'Product Aligned', while only 6% of IT and 7% of Real Estate companies are part of this cluster. Interestingly, only 2% of Healthcare companies are part of this group, suggesting that companies in this industry could benefit from explicitly aligning their reporting with A&R. 60% of the Real Estate companies in the S&P 500 are in the 'Climate Risk Aware' cluster, reflecting the industry's high-level exposure to climate-related physical risks. Just under half of the Communications Services and Financial companies of the S&P 500 fall into the 'Laggards' cluster, while between 34% and 39% of IT, Consumer Discretionary, Healthcare, and Industrials companies fall into the 'Engaged' cluster. This again reaffirms the potential Healthcare companies have to align with A&R, given that this is an industry continuously identified as an adaptation priority[36]. Overall, the results of the cluster analysis align with the descriptive analysis in the preceding section.

Variation by other factors

When segmenting the sample of S&P 500 companies by membership of the CA100+ and NA100 initiatives, differences emerge (see Fig. 8), which vary in significance and effect size (see Table 3). Across all indicators, companies part of either initiative report more A&R-related information on average than companies not part of these initiatives. The effect is most pronounced across *Foundation* and *Implementation* indicators, where both CA100+ and NA100 companies are more likely to report A&R information. The NA100 companies report particularly more information related to *Foundation*, *Engagement* and *Metrics & Targets* indicators than other S&P 500 companies. By contrast, reporting does not differ significantly for *Risk* and *Governance* indicators when comparing NA100 and CA100+ companies with other S&P 500 companies. We find no significant correlation between firm market value and proportion of indicators reported on in our sample, suggesting that the effect of NA100 and

CA100+ membership is not simply a result of firm size. Beyond the slightly higher levels of disclosure though, companies part of neither initiative report on materially different disclosure elements compared to other companies part of the S&P 500.

We also control for the impact of recent 'green' innovation activity (as in [37]) on the proportion of A&R indicator reporting and find no significant relationship, even when narrowing the analysis to *Implementation* and *Offering indicators*. This suggests that the limited 'green' patenting activity that has taken place does not explicitly address A&R issues or is not reported as such.

Fig 8. Average disclosures across indicator sub-categories disaggregated by companies identified in the CA100+ (orange) and NA100 (grey) initiatives and the companies not identified by these (purple).

Table 3. p-value (statistical significance) and d-value (effect size) for the variance in average disclosure of firms part of the NA100 or CA100+ initiatives compared to S&P500 companies not identified in these initiatives, disaggregated by indicator category.

4 Discussion

The fundamental contribution of this paper is to empirically validate the claim that existing disclosures by corporates do not include sufficient information to enhance A&R-related decision-making by FIs and regulators. Our analysis of 42,030 data points shows that surveyed S&P 500 companies report information related to only 20% of a comprehensive set of A&R indicators built on existing disclosure frameworks, best practice and expert input. This percentage is lower than the 36% of decarbonisation-specific indicators reported on by CA100+ companies[38]. The analysis has demonstrated some (though still limited) disclosure in line with existing frameworks, with, for example half of the companies surveyed providing information regarding their climate risk assessments (ID18), in line with TCFD. However, limited reporting persists for indicators beyond existing frameworks. This finding adds weight to the importance of dedicated A&R frameworks to secure comprehensive corporate disclosure. Within the sample of companies, important variations are found. For example, on average companies report on less than 10% of indicators related to metrics, targets, and nature risk, while they report on nearly 40% of indicators related to the governance mechanisms they have introduced and how their product offering is aligned with A&R. In reviewing the most and least commonly disclosed indicators, it becomes clear that companies' average disclosure percentage is being boosted by low-hanging fruit indicators that either require little adjustment to current business operations, are broadly formulated, or have a longer history on mainstream sustainability agendas. These findings suggest corporate engagement with A&R has been limited to date, underscored by improper risk assessments that underappreciate risk and a reluctance to be transparent about the adaptation measures planned and taken to address these (if at all).

In line with the latter, our findings also show that companies are twice as likely to report climate-related information as equivalent nature-related information, reflecting the relative maturities of the TCFD and the TNFD disclosure frameworks – this lends credence to the effectiveness of established disclosure frameworks. Current nature-related disclosures centre around environmental safeguarding, without considering the impact nature loss could have on businesses through dependencies and risks. Even without taking information disclosure as a proxy for the planning and actions taken by firms, the overall lack of information (and potentially inaction of parties) on nature-related risks gives credence to dangers of a green scorpion event materialising[39]. This finding is important to regulators and governments, who may therefore face mounting systemic risk across the economy and financial sector.

The second contribution is to provide a snapshot of the trends in corporate A&R disclosure.. Our initial analysis finds that certain industries on average report more on certain types of indicators. For example, Real Estate companies report more on risk-related indicators. Utilities companies report more information related to aligning with A&R through their business priorities and their product, which hints at the success of closer regulatory supervision in encouraging firms to address A&R. To explore this trend deeper, we construct four idealised types of disclosers (the 'Climate Risk Aware', 'Laggards', 'Product Aligned' and 'Engaged'). The 'Climate Risk Aware' and 'Product Aligned' report more A&R-related information likely due to higher exposure to climate-related physical risks and their product offering enabling A&R outcomes in the first place. However, both still fail to disclose information consistently on other A&R indicators such as *Risk* and *Metrics & Targets*, which betrays a thorough engagement with A&R, given that risk is considered a foundational principle of A&R, and the lack of targets limit credibility. Industries are not uniformly represented in one of the discloser types, and there are notable exceptions of industries, such as Healthcare, that fail to position themselves with A&R despite their aligned product offering. When comparing S&P 500 companies part of the CA100+ and NA100 initiatives and those that are not, a significant positive correlation is found in membership and the level of A&R information reported. While it is not possible here to establish whether this relationship is causal, it is a promising finding nonetheless that the companies considered to have the most outsized impact on climate and nature are already reporting more A&R-related information. However, the results show that these companies simply report more A&R information within the same disclosure elements (e.g. *Governance*, *Engagement*, *Implementation*), while still not reporting on the types of indicators not reported on by the rest of the group (i.e. *Risk* and *Metrics & Targets*).

The implications of these findings for the literature are clear. Over the past four years, there has been a series of methodological innovations to estimate climate-related risk at the firm-level using a variety of novel techniques and data sources, including news, earnings calls, past Form 8-K issuances, and, crucially, sustainability reports. Missing across all methodologies are explicit considerations of A&R actions that may restrict a firm's exposure and vulnerability. Our analysis finds that sustainability reports alone are grossly insufficient in providing the information necessary to incorporate A&R dimensions into these assessments, particularly considering how little *Implementation* and *Risk* information is being reported. Any future methodologies that attempt to holistically assess the extent to which firms are contributing to societal A&R will need to resort to third-party data sources to complement their analysis,

especially in the face of recent withdrawals from governments and firms from various environmental initiatives.

There are three main limitations to our findings and contribution. First, the analysis provided is binary and quantitative. Within reporting on A&R issues, there is, of course, scope for significant variations within indicators, for example, in the types of targets that are set or in how regular risk assessments are carried out. Reporting on a lot of the indicators in this framework, therefore, does not constitute actual contributions to A&R. Second, the assessment framework developed is sector-agnostic and thus focuses only on process-based indicators. Sector-specific indicators are needed for a more comprehensive evaluation of corporate A&R disclosure and performance, especially in the Implementation and Engagement categories, where, for example, indicators could analyse company water and land use. Third, corporates may implement A&R best practices without disclosing the full detail of these in their sustainability reports. The LLM was found to be 'stricter' than the human assessor during validation, in that human assessors were more likely to consider the existence of information in other sources referenced (e.g. published corporate policies), which may distort the findings of the second contribution slightly. Future work will need to consider what metrics and datasets can be developed to accurately assess corporate A&R performance at the output or outcome level. Other work can consider how representative indices can be constructed hand-in-hand with prospective users based on this information, to give weight to certain information points over others and thus create effective at-a-glance evaluations.

The underlying contribution of this paper is the assessment framework used to analyse the extent of A&R-related information being disclosed and the LLM used to automate the analysis. We develop a framework of 91 binary indicators representing an attempt to exhaustively list all decision-useful A&R information points, drawing and expanding on the latest guidance from TCFD, TNFD and the TPT Adaptation Working Group. To our knowledge, the framework is the first detailed, dedicated A&R disclosure framework. As such, it can guide firms, FIs and governments alike on the type of disclosure needed to enhance decision-making.

0 Methodology

The Assessment framework

The assessment framework presented in this paper draws on the conceptual framework for corporate adaptation planning developed by the University of Oxford Resilient Planet Finance Lab with expert input from the UK Climate Financial Risk Forum's (CFRF) Adaptation Working Group (AWG) through a series of consultations in early 2024. The CFRF AWG included 49 experts from financial institutions (insurers, asset managers, asset owners, private equity, banks), government, regulators, industry bodies, professional services and data companies, UK Met Office and research. The framework builds upon the TPT, the ISSB IFRS2, TCFD and TNFD, but combines this with the climate resilience alignment framework of Mullan and Ranger[40] and greater detail on targets and metrics from UNEPFI[41,42] as well as expert inputs from the CFRF AWG to provide 12 specific areas of action. It also explicitly responds to the call for integrated climate- and nature-related risk assessments and the synergies between nature and adaptation actions, including important insights derived from TNFD. The conceptual framework is given in Figure 9 (see also [43]).

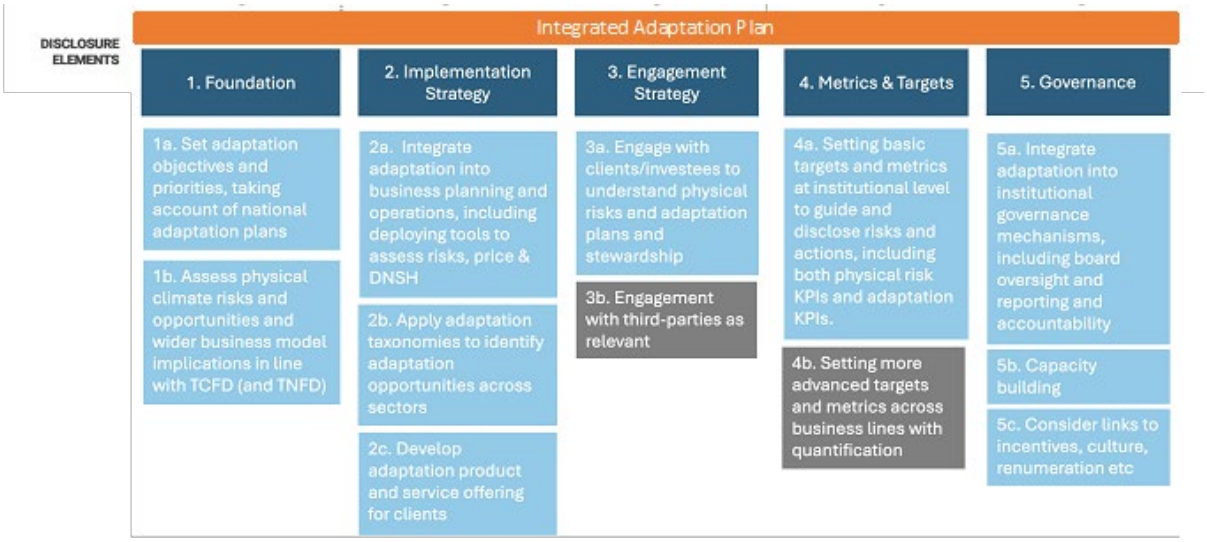

Figure 9. Conceptual framework for adaptation planning, with 12 specific action areas (in light blue and grey, 1a to 5c) developed by the Oxford Resilient Planet Finance Lab with expert input from the CFRF Adaptation Working Group. 'Grey' action areas (3b and 4b) indicate 'stretch' actions, while those in blue are foundational. The top two rows (principles and planning process) and the 5 disclosure elements (in dark blue, labelled 1 to 5) exactly follow the TPT framework. The link to the transition planning process, as defined by the TPT, aims to

demonstrate how ‘resilient transition plans’ or adaptation can be fully integrated within the transition planning cycle.

The above conceptual framework presents best practice in corporate adaptation planning. It was assumed that information demonstrating adoption of or compliance with best practice would constitute effective A&R disclosure. We fleshed out the conceptual framework in Fig. 9 by harvesting metrics from 25+ disclosure frameworks focused on general sustainability-related disclosures, evaluating resilience contributions and categorising adaptation alignment (see Extended Data Table 1 for a full list). This resulted in 300+ unique A&R indicators grouped into the disclosure elements shown in Fig 9. We teased out risk-related indicators into their own separate category, given their quantity and the importance of risk for A&R assessments. The resulting six disclosure elements of our assessment framework, therefore are: Foundation, *Risk*, Implementation, Engagement, Governance, and Metrics & Targets. Upon compiling and categorising all relevant unique indicators, the list totalled over 300. This complete list of indicators was whittled down by focusing only on industry-agnostic and process-based indicators (rather than output- or outcome-based indicators, see[44,45]. for distinction). The former ensures the widest possible application of the assessment, while the latter ensures that relevant information can be found in sustainability reports. In this definition of indicators, we also referred to established A&R principles[46] adopted by UNEPFI ([47]), such as effective risk management, environmental and social safeguards, alignment with external adaptation plans, and robust monitoring processes.

To make these indicators implementable in the context of analysing company reporting through an LLM, they were turned into specific questions. Questions based on the indicators were drafted in a close-ended binary format to assess thoroughness of corporate adaptation reporting, following methodologies developed by Ni et al.[48] and Colesanti Senni et al.[49]. As such, the questions necessarily provide a quantitative snapshot of the types of information being disclosed by firms and not a qualitative assessment of it. The resulting proposed assessment framework spans 91 questions across 6 categories (see Extended Data Tables 2-7 for the full framework).

Retrieval Augmented Generation (RAG)

The RAG system we use is based on the LlamaIndex open-source package.[1] To retrieve the relevant text passages for a question, we first split the underlying company report into chunks of a size of approximately 400 words. We allow a chunk overlap of 50 words to mitigate the loss of context due to random chunking. We use the sentencesplitter() function to obtain full-sentence form chunks.[2] To enable an effective search process, we need to transform chunks and search questions into numeric representations, the so-called text embeddings. This allows us to find semantically similar text chunks to the question. We rely on the OpenAI embedding model "text-embedding-ada-002" to transform the chunks and questions into embeddings. For each question, we retrieve the top 10 most relevant text chunks to answer a question. We use the state-of-the-art OpenAI LLM "gpt-4o-2024-05-13" to answer the questions and restrict the answer length to 200 words. For details on the prompt given to the model, see Extended Data Table 3.

The dataset employed for the illustrative use case encompasses the latest published sustainability reports from S&P 500 companies. Reports were procured for 476 companies. These reports were subsequently processed through the RAG model, which evaluated whether the provided information was adequate to address the indicator questions. The model's output comprised a binary yes/no response, accompanied by an open-text justification derived from the extracted information from the reports. Supplemental directives were added for all (91) indicator questions to exclude certain information points based on expert domain-based knowledge (e.g. emissions reductions, etc) (refer to Extended Data Tables 2-7 for the complete list of indicators and their definitions).

Beyond the comprehensive testing and validation exercises conducted for this model, following the procedure of Schimanski et al.[50], we also verified the accuracy of the tool's outputs by hand. For this, an expert human analyst evaluated 455 indicators. The expert manually responded to a question based on the reports and compared the answer with the output of the LLM. Through this procedure, we identified that 83% of the LLM responses were correct. Discrepancies between the LLM and the human evaluator arose primarily from the human evaluator inferring additional information found in other publicly available sources referenced (e.g. a specific human rights policy), while the LLM relied more strictly on the information provided in the

[1] See LlamaIndex documentation: https://docs.llamaindex.ai/en/stable/.
[2] LlamaIndex sentencesplitter() function:
https://docs.llamaindex.ai/en/stable/api_reference/node_parsers/sentence_splitter/.

sustainability report. The LLM deviated most frequently on *Implementation* indicators, giving both false positives and false negatives when determining whether product offerings and corporate operations were aligned with A&R. This area likely requires enhanced directives or thresholds to determine alignment with more accuracy. It also underlines how vague existing information on *Implementation* indicators is.

Statistical analyses

Post-model execution, averages were computed for each pairing within the analysis framework (i.e., companies, categories, industries, climate/nature indicators). Statistical techniques predominantly focused on assessing normality of data sources, identifying outliers, and using parametric and non-parametric evaluations of variance to determine significant differences.

K-means clustering

K-means clustering uses an unsupervised machine-learning algorithm to create groups of data points with similar characteristics. The groups are created iteratively while optimising for the shortest Euclidean distance to the group centroid for each of its constituent data points. The data used was the average proportion of indicators per disclosure element reported on by each individual company. The elbow method was used to identify that 4 was the optimal value for k.

Raw data

The core data are the most recent sustainability reports published by companies, which were downloaded from their respective websites. The market value data used to control for firm size in the NA100 and CA100+ analysis was obtained from Compustat. The patent data used in that same analysis stems from Leippold & Yu[51].

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Author contributions

R.S. developed the assessment framework with input from N.R. and T.S. R.S and T.S. carried out the analysis in the paper. R.S. wrote the paper with input from N.R. and T.S., and R.S., N.R. and M.L. edited the paper. All authors approved the final manuscript.

Competing interests

The authors declare no competing interests.

Data availability

The data we used for this study are public sustainability reports published by companies. This, together with the data produced by our tool, can be accessed at: https://github.com/robertospacey/A3F_SP500/

Code availability

The code used the develop the model on which the findings of this paper are based on, can be accessed via the accompanying paper here: https://arxiv.org/abs/2406.09818

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1. Extended Data Table 1

Notes: To ensure complementarity and integration with existing frameworks, indicators from various frameworks were compiled and synthesised to inform the Adaptation Alignment Assessment Framework. The list of frameworks synthesised includes disclosure standards, performance measurement frameworks and taxonomies.

Extended Data Table 1. Full list of frameworks considered for indicator design.

Framework	Link
UNEP FI Physically Fit Report	link
ISSB IFRS S2 Climate-related Disclosures	link
IIGCC Working towards a climate resilience investment framework	link
CFRF Climate Disclosures Dashboard 2.0	link
SASB Industry Standards	link
TCFD 2021 Report, Appendix 2	link
TCFD Metrics & Targets Workshop Slides	link
IADB A Framework and Principles for Climate Resilience Metrics in Financing Operations	link
World Bank Resilience Rating System: A Methodology for Building and Tracking Resilience to Climate Change	link
GCA Adaptation Metrics Current Landscape and Evolving Practices	link
GBP Impact Reporting Working Group: Suggesting Impact Reporting Metrics for Climate Change Adaptation Projects	link
OECD DAC Rio Markers for Climate	link
GRI Reporting Standards	link
OECD Climate Resilient Finance and Investment	link
EBRD GET Technical Guide	link
Joint MDB Assessment Framework for Paris Alignment for Direct Investment Operations	link
Race to Resilience	link
Adaptation Solutions Taxonomy	link
FAST-Infra Sustainable Infrastructure Label	link
ACT Physical Risks & Adaptation	link
CDP Climate Change 2023 Scoring Methodology	link
IRIS+ System | Standards	link
Adaptation Resilience Impact Collaboration (ARIC): A measurement framework for investors	link

Equator Principles	link
EIB - MDBs Joint Methodology for Climate Finance	link
SBTN Technical Guidance: Step 1 - Assess	link
SBTN Technical Guidance: Step 3: Freshwater - Measure, Set & Disclose	link
Green Bond Principles / ICMA - Harmonised Framework for Impact Reporting	link

Extended Data Tables 2-7

Notes: The tables in Extended Data Table 2-7 show each of the indicator questions in the Adaptation Alignment Assessment Framework for each disclosure element. “ID” refers to the identifying number for the indicator. “Question” demarks the question developed for each indicator. “Definitions” covers supplementary information provided to the large language model used in the analysis to enhance the generated answers. The disclosure sub-elements are marked out in grey, with corresponding indicator questions appearing below these.

[tables made available overleaf]

Extended Data Table 2. List of indicators for *Foundation*.

ID	*Question*	*Definition*
Set priorities		
1	Does the company explicitly outline adapting to climate change as a priority in its business strategy?	Answer "Yes" only if the company prioritises either reducing its exposure to climate-related hazards (e.g. storms, floods, etc.) or enabling others to reduce their exposure to climate-related hazards. This statement can be general and not necessarily tied to a company's sector or industry. Do not consider any information related to emission reductions, decarbonisation or greenhouse gases.
2	Does the company commit to avoid and reduce its contributions to key drivers of nature loss and/or restore and regenerate ecosystems?	Key drivers of nature loss are broad processes that can lead to nature loss, such as land use change, overexploitation of resources, pollution or invasive species, among others. Do not include any information related to mitigating climate change or reducing greenhouse gas emissions. Answer "Yes" only if the company acknowledges through which drivers it contributes to nature loss and it commits to reducing its contribution to these drivers. Answer "No" if the company takes broadly about reducing environmental impacts.
3	Does the company reference any external laws, national policies or voluntary commitments relating to climate change adaptation in its business strategy?	Climate change adaptation refers either to reducing exposure to physical climate hazards (e.g. floods, droughts, etc.) or to enabling others to reduce their exposure to physical climate-related risks. Do not include any external laws, national policies or voluntary commitment related to reducing greenhouse gas emissions. Answer "Yes" only if the company outlines how specific parts of its business strategy either align or respond to priorities and commitments set in international-, national- or sector-based climate adaptation plans or laws. Answer "No" if the company only broadly talks about third-party adaptation plans or priorities without linking specific elements of its business strategy to these.
4	Does the company reference any external laws, national policies or voluntary commitments relating to nature loss and/or ecosystem restoration in its business strategy?	Nature loss broadly refers to the significant loss of ecosystem functioning, loss of biodiversity or loss of species abundance. Ecosystem restoration broadly encompasses activities seeking to strengthen 'provisioning' and 'regulating' ecosystem services. Do not include any external laws, national policies or voluntary commitment related to reducing greenhouse gas emissions. Answer "Yes" only if the company outlines how specific parts of its business strategy either align or respond to priorities and commitments set in national- or sector-based nature positive or biodiversity plans and laws. Answer "No" if the company only broadly talks about third-party nature positive or biodiversity plans or priorities without linking specific elements of its business strategy to these.
Disclose physical climate risks		
5	Does the company report the physical risks to its business operations arising from climate change?	Physical climate-related risks are a function of climate-related hazards, such as floods, the exposure of assets and operations to these hazards, and the vulnerability of these operations and assets of being disrupted. Business operations include a company's assets or activities. The risks can extend beyond the company to its value chain. Do not include anything related to climate change mitigation or reducing greenhouse gases. Do not rephrase of the physical climate-related risks mentioned by the company, instead use these in your answer. Answer "Yes" only if the

		company explicitly defines physical climate-related risks and explains how its business operations would be affected by these physical climate-related risks. Answer "No" if the company only broadly outlines different physical climate-related hazards or if the company identifies risks without clearly explaining how their business operations are affected by these.
6	Does the company report on its business opportunities arising from climate change?	Physical climate-related opportunities are a function of climate-related hazards, such as floods, the exposure of assets and operations to these hazards, and the vulnerability of these operations and assets of being disrupted. Business operations include a company's assets or activities. Responses to physical climate-related risks may result in new business opportunities for the company. New business opportunities include setting up new revenue streams, strengthening existing business operations or reducing costs of existing operations. The opportunities can extend beyond the company to its value chain. Do not include anything related to climate change mitigation or reducing greenhouse gases. Do not rephrase the physical climate-related opportunities mentioned by the company, instead use these in your answer. Answer "Yes" only if the company explicitly defines physical climate-related opportunities and explains upcoming or current plans to seize these. Answer "No" if the company only broadly outlines different opportunities from climate change without clearly explaining how they will change business operations to seize these.
7	Does the company disclose the location of its business activities affected by physical climate risks?	Physical climate-related risks are a function of climate-related hazards, such as floods, the exposure of assets and operations to these hazards, and the vulnerability of these operations and assets of being disrupted. Business activities include any operating, financing or investing activities. The locations may be disclosed in a map format or a list format. If you find a list of business operations affected by physical climate-related risks with geographical information for the business operations, then answer "Yes". If the company states that it discloses the locations of business activities affected by physical climate-related risks, then answer "Yes". Answer "No" if the company outlines locations or regions affected by particular physical climate-related risks without identifying its business operations affected by these.
8	Does the company disclose the locations of its assets affected by physical climate risks?	Physical climate-related risks are a function of climate-related hazards, such as floods, the exposure of assets and operations to these hazards, and the vulnerability of these operations and assets of being disrupted. Assets here includes any tangible assets used by the company (e.g. factories, farmland, etc.). The locations may be disclosed in a map format or a list format. If you find a list of company assets affected by physical climate-related risks with geographical information for the business operations, then answer "Yes". If the company states that it discloses the locations of its assets affected by physical climate-related risks, then answer "Yes". Answer "No" if the company outlines locations or regions affected by particular physical climate-related risks without identifying its assets affected by these.
9	Does the company identify the anticipated effects of physical climate-related risks on revenues, expenses, cashflows, asset and liability	Answer "Yes" only if the company provides an explanation of the anticipated effects across two or more timescales (i.e. short-, medium or long-term). Answer "No" if the company only explains the anticipated effects in one timescale, i.e. only short-term effects, only medium-term effects, only long-term effects.

	values or funding sources over the short- medium- and long-term?	
Disclose physical nature risks		
10	Does the company report the physical risks to its business operations arising from nature loss and ecosystem degeneration?	Nature loss broadly refers to the significant loss of ecosystem functioning, loss of biodiversity or loss of species abundance. Business operations include a company's assets or activities. The risks can extend beyond the company to its value chain. Do not include anything related to climate change mitigation or reducing greenhouse gases. Do not rephrase of the physical nature-related risks mentioned by the company, instead use these in your answer. Answer "Yes" only if the company explicitly defines physical nature-related risks and explains how its business operations would be affected by these physical nature-related risks. Answer "No" if the company only broadly identifies nature risks without clearly explaining how their business operations are affected by these.
11	Does the company systematically report the impact of its business activities on nature?	Do not include anything related to carbon dioxide or methane emissions. Business activities include any operating, financing or investing activities. Answer "No" if the company only broadly outlines its impact for some business activities. Answer "Yes" if the company goes through all of its main business activities explaining how they impact nature. Answer "Yes" if the company explains how it has identified select business activities and explains how they impact nature.
12	Does the company report the dependencies of its business activities on ecosystem services?	Do not include anything related to carbon dioxide or methane emissions. Dependencies outlined should either refer to provisioning ecosystem services (e.g. water provision) or regulation ecosystem services (e.g. water quality). Business activities include any operating, financing or investing activities. Answer "No" if the company does not explicitly refer to these relationships as dependencies.
13	Does the company provide a description of the interconnections between its material impacts and dependencies on nature?	Do not include anything related to carbon dioxide or methane emissions. Business activities include any operating, financing or investing activities. Explanations should link the impacts the company's business activities have on nature with the dependencies the same or other business activities on nature. Answer "No" if the company does not outline any impacts or dependencies on nature. Answer "Yes" if the company explains the ecosystem services that are impacted by its business activities and whether any of its business activities depend on these ecosystem services.
14	Does the company report the location of its material nature-related impacts?	Nature loss broadly refers to the significant loss of ecosystem functioning, loss of biodiversity or loss of species abundance. Business operations include a company's assets or activities. The impacts can extend beyond the company to its value chain. Do not include anything related to climate change mitigation or reducing greenhouse gases. The locations may be disclosed in a map format or a list format. If you find a list of business operations that impact nature with geographical information for the business operations, then answer "Yes". If the company states that it discloses the locations of business activities impacting nature, then answer "Yes". Answer "No" if the company outlines locations or regions affected by the company without identifying the business operations that drive these impacts.
15	Does the company report the locations of it material dependencies?	Nature loss broadly refers to the significant loss of ecosystem functioning, loss of biodiversity or loss of species abundance. Business operations include a company's assets or activities. Dependencies outlined should either refer to provisioning ecosystem services (e.g. water provision) or regulation ecosystem services (e.g. water quality). The

		dependencies can extend beyond the company's direct operations to its value chain. Do not include anything related to climate change mitigation or reducing greenhouse gases. The locations may be disclosed in a map format or a list format. If you find a list of business operations and their ecosystem service dependencies with geographical information for the business operations, then answer "Yes". If the company states that it discloses the locations of business activities that are dependent on ecosystem services, then answer "Yes". Answer "No" if the company outlines locations or regions of their business operations without listing their dependencies on ecosystem services.
16	Does the company disclose the locations of its business activities and assets in or close to ecologically-sensitive areas?	Ecologically sensitive areas are areas that are important for biodiversity, areas of high ecosystem intergrity, areas of rapid decline in ecosystem integrity, areas of high physical water risks, and/or areas important for ecosystem services provision. The locations may be disclosed in a map format or a list format. If you find a list of business operations near ecologically sensitive areas with geographical information for the business operations, then answer "Yes". If the company states that it discloses the locations of business activities near ecologically sensitive areas, then answer "Yes". Answer "No" if the company outlines locations or regions that are ecologically sensitive without identifying its business operations affected by these.
17	Does the company identify the anticipated effects of physical nature-related risks on revenues, expenses, cashflows, asset and liability values or funding sources over the short- medium- and long-term?	Answer "Yes" only if the company provides an explanation of the anticipated effects across two or more timescales (i.e. short-, medium or long-term). Answer "No" if the company only explains the anticipated effects in one timescale, i.e. only short-term effects, only medium-term effects, only long-term effects.

Extended Data Table 3. List of indicators for *Risk*.

ID	*Question*	*Definition*
Assessing climate risk		
18	Does the company have a specific process in place to identify physical risks arising from climate change?	Physical climate-related risks are a function of climate-related hazards, such as floods, the exposure of assets and operations to these hazards, and the vulnerability of these operations and assets of being disrupted. Do not include carbon or methane emissions as a climate-related risk. Ignore if the company mentions specific physical climate-related risks and instead focus on whether there is a process. Answer "Yes" if a company says it has a process to identify physical climate-related risks or explains this process.
19	Does the company have a specific process in place to identify business opportunities arising from climate change?	Do not include any information related to carbon emission reductions, decarbonisation or greenhouse gases as a climate-related opportunity. Ignore if the company mentions specific climate-related opportunities and instead focus on whether there is a process. Answer "Yes" if a company says it has a process to identify climate-related opportunities or explains this process.
20	Does the company assessment of physical climate-related risks cover its value chain?	Physical climate-related risks are a function of climate-related hazards, such as floods, the exposure of assets and operations to these hazards, and the vulnerability of these operations and assets of being disrupted. Do not include carbon or methane emissions as a climate-related risk. Ignore if the company mentions specific physical climate-related risks and instead focus on whether the process used to identify physical climate-related risks include only direct operations or also its value chain. Answer "Yes" if a company says it has a process to identify physical climate-related risks and explains that this process covers any business activities of its value chain.
21	Does the company report what assumptions it works with when assessing physical risks arising from climate change?	Provide specific examples of the strategic assumptions that the company reports as basis for its physical climate risk assessments. These could include for instance assumptions about the development of consumer preferences, input prices, sector policies, carbon emission trends, applicable climate hazard types and others. Answer "YES" if you find information about the assumptions underlying the physical climate-related risk assessment. Answer "NO" if you do not find this information.
22	Does the company refer to any third-party scenarios when identifying physical climate-related risks (e.g. IPCC trajectories, NGFS scenarios, etc.)?	Physical climate-related risks are a function of climate-related hazards, such as floods, the exposure of assets and operations to these hazards, and the vulnerability of these operations and assets of being disrupted. Provide specific examples of the scenarios, model ensembles and scenario envelopes used by the company to assess its physical climate-related risks. Scenarios can either be from third-parties or generated in-house. Answer "Yes" if a company outlines the scenarios it uses to assess physical climate-related risks.
23	Does the company report the timescales considered when identifying physical climate-related risks and opportunities?	Physical climate-related risks are a function of climate-related hazards, such as floods, the exposure of assets and operations to these hazards, and the vulnerability of these operations and assets of being disrupted. Timescales during physical climate risk assessments explain how many years into the future the company is looking to identify potential physical climate risks. Answer "No" if the company uses only one

		timescale for its physical climate risk assessments or if the company does not mention any timescales. Answer "Yes" if the company explicitly outlines numeric figures for the timescales it uses when identifying physical climate-related risks.
24	Does the company report whether fat-tail risks or tipping points were considered when identifying physical climate-related risks or opportunities?	Physical climate-related risks are a function of climate-related hazards, such as floods, the exposure of assets and operations to these hazards, and the vulnerability of these operations and assets of being disrupted. Example of tipping points include the melting of the ice caps. Fat tail risks are those risks occurring with a lower probability. Answer "No" if the company mentions tipping points but does not explain how these are embedded into its physical climate risk assessment process.
25	Does the company report the frequency at which it carries out assessments of climate-related risks and opportunities?	Physical climate-related risks are a function of climate-related hazards, such as floods, the exposure of assets and operations to these hazards, and the vulnerability of these operations and assets of being disrupted. Do not consider carbon emission reductions or carbon emission generation as a climate-related opportunity or risk. Answer "Yes" only if the company explicitly states the time intervals at which assessments of climate-related risks and opportunities are carried out.
Assessing nature risk		
26	Does the company have a specific process in place to identify physical risks arising from nature loss and ecosystem degeneration?	c Do not include carbon or methane emissions as a nature-related risk. Ignore if the company mentions specific physical nature-related risks and instead focus on whether there is a process. Answer "Yes" only if a company states it has a process to identify nature climate-related risks or explains this process.
27	Does the company report to have a specific process in place to analyse its dependencies on ecosystem services?	Business operations include a company's assets or activities. Dependencies outlined should either refer to provisioning ecosystem services (e.g. water provision) or regulation ecosystem services (e.g. water quality). The dependencies can extend beyond the company's direct operations to its value chain. Do not include carbon emission reductions as a dependency. Ignore if the company mentions specific dependencies on ecosystem services and instead focus on whether there is a process. Answer "Yes" only if a company states it has a process to identify dependencies on ecosystem services or explains this process.
28	Does the company report to have a specific process in place to analyse its contributions to nature loss and ecosystem degeneration?	Nature loss broadly refers to the significant loss of ecosystem functioning, loss of biodiversity or loss of species abundance. Do not include carbon emissions as a contribution to nature loss or ecosystem degeneration. Answer "Yes" only if the company outlines a process to measure its contribution to nature loss, ecosystem degeneration or biodiversity loss. Answer "No" if the company only carries out environmental impact assessments without analysing the impact on ecosystem services.
29	Does the company assessment of physical nature-related risks cover its value chain?	Nature loss broadly refers to the significant loss of ecosystem functioning, loss of biodiversity or loss of species abundance. Do not include carbon or methane emissions as a climate-related risk. Ignore if the company mentions specific physical nature-related risks and instead focus on whether the process used to identify physical nature-related risks include only direct operations or also its value chain. Answer "Yes" if a company says it has a process to identify physical nature-related risks and explains that this process covers any business activities of its value chain.

30	Does the company refer to any third-party scenarios when identifying physical nature-related risks (e.g. IPCC trajectories, NGFS scenarios, etc.)?	Nature loss broadly refers to the significant loss of ecosystem functioning, loss of biodiversity or loss of species abundance. Provide specific examples of the scenarios, model ensembles and scenario envelopes used by the company to assess its physical climate-related risks. Scenarios can either be from third parties (e.g. NGFS, IPCC) or generated in-house. Answer "Yes" if a company outlines the scenarios it uses to assess physical nature-related risks.
31	Does the company report the timescales considered when identifying nature-related dependencies, impacts, risks and opportunities?	Timescales during physical nature-related risk assessments explain how many years into the future the company is looking to identify potential physical nature risks. Answer "No" if the company uses only one timescale for its physical nature risk assessments or if the company does not mention any timescales. Answer "Yes" if the company explicitly outlines multiple numeric figures for the timescales it uses when identifying physical nature-related risks.
32	Does the company report whether ecological thresholds or tipping points were considered when identifying nature-related dependencies, impacts, risks and opportunities?	Physical nature risks arise from nature loss, which broadly refers to the significant loss of ecosystem functioning, loss of biodiversity or loss of species abundance. Ecological threshold and tipping points include for example the loss of pollinators. Answer "No" if the company mentions tipping points but does not explain how these are embedded into its physical nature risk assessment process.
33	Does the company report the frequency at which it carries out assessments of nature-related dependencies and impacts?	Do not include carbon emission reductions as a nature-related impact or dependency. Answer "Yes" only if the company explicitly states the time intervals at which assessments of nature-related dependencies and impacts are carried out. Answer "No" if the time interval is only outlined for nature-related impacts.
34	Does the company report the frequency at which it carries out assessments of nature-related risks and opportunities?	Physical nature risks arise from nature loss, which broadly refers to the significant loss of ecosystem functioning, loss of biodiversity or loss of species abundance. Do not consider carbon emission reductions or carbon emission generation as a nature-related opportunity or risk. Answer "Yes" only if the company explicitly states the time intervals at which assessments of nature-related risks and opportunities are carried out.
Risk management process		
35	Are the company's processes for identifying, assessing, prioritising and monitoring physical climate- and nature-related risks integrated into its overall risk management process?	Answer "Yes" only if the company explains that climate-related risks and nature-related risks are considered alongside other risks (e.g. operational risks, currency risks, etc.) in risk review meetings or other risk management processes. Answer "No" if the company only mentions one of either climate-related risks or nature-related risks.
36	Does the company report how it determines the relative significance of climate- and nature-related risks to inform its prioritisation of risk responses?	Companies can prioritise certain risks over others by for example estimating their materiality or dealing with higher probability risks. Answer "Yes" only if the company explains the process it uses to prioritise specific risks.

37	Does the company consider multiple physical climate- or nature-related risks occurring in parallel or concurrently?	The relationships of multiple risks occurring can be described as cascading or compounding risks whereby there is overlap in the spatial or temporal dimensions of risks. Answer "Yes" only if the company explicitly mentions concurrent, compounding or cascading risks and explains how it models the impact of multiple physical climate- or nature-related risks occurring at the same time or in quick succession.
38	Does the company intend to improve or expand its location assessment activities over the short-, medium- and long-tern?	Location assessment activities include assessing climate- or nature-related risks in specific geographies rather than generally. Do not include examples of assessments that have been carried out. Instead, focus on content that explicitly outlines how the company intends to improve location assessment activities. Answer "Yes" only if the company sets out plans to improve these assessments across two timescales (i.e. short-, medium- or long-term).
39	Does the company outline areas where it needs to improve data quality for more accurate climate- and nature-related risk assessments?	Climate- and nature-related risk assessments face data constraints. Provide examples where the company acknowledges these data constraints and sets out strategies or initiatives to improve these. Answer "Yes" if the company outlines one or more areas where data quality can be improved for its climate- and nature-related risk assessments.

Extended Data Table 4. List of indicators for *Implementation*.

ID	*Question*	*Definition*
Operations		
40	Does the company require a physical climate-related risk or opportunity assessment as part of key business operations? (e.g. procurement, pricing, etc.)	Do not include carbon emission reductions as a climate-related risk or opportunity. Key business operations include activities such as procurement of goods, materials or equipment, pricing during decision-making, or research and development, among others. Provide examples where the company states that it requires physical climate-related risk assessments to be carried out as part of these processes. If you find one r more operations where this is required, answer "Yes". Answer "No" if the company carries out physical climate-related risk assessment but does not state that these are a requirement for specific business operations.
41	Does the company require a physical nature-related risk or opportunity assessment as part of key business operations? (e.g. procurement, pricing, etc.)	Do not include carbon emission reductions as a nature-related risk or opportunity. Key business operations include activities such as procurement of goods, materials or equipment, pricing during decision-making, or research and development, among others. Physical nature-related risk is a function of a hazard (e.g. invasive species), the exposure a business has to the hazard through its business activities and assets, and the vulnerability of business activities and assets or the ecosystem services to those hazards. Provide examples where the company states that it requires physical nature-related risk assessments to be carried out as part of these processes. If you find one or more operations where this is required, answer "Yes". Answer "No" if the company carries out physical nature-related risk assessment but does not state that these are a requirement for specific business operations. Answer "No" if the company carries out environmental impact assessments but does not link these to physical nature-related risks.
42	Does the company report how adjustments to its policies and conditions address specific climate-related risks or opportunities?	Do not include carbon emissions or carbon emission reductions as a climate-related risks or opportunity. Identify examples where the company explicitly links changes it has made or will make to its policies and conditions with physical climate-related risks opportunities it has identified. Answer "No" if the company identifies no climate-related risks or opportunities. Answer "No" if the company outlines some changes but does not link these to physical climate-related risks or opportunities.
43	Does the company report how adjustments to its policies and conditions address specific nature-related risks or opportunities?	Do not include carbon emissions or carbon emission reductions as a nature-related risk or opportunity. Identify examples where the company explicitly links changes it has made or will make to its policies and conditions with physical nature-related risks opportunities it has identified. Answer "No" if the company identifies no nature-related risks or opportunities. Answer "No" if the company outlines some changes but does not link these to physical nature-related risks or opportunities.
44	Does the company report any policies or conditions used to ensure no significant harm is done to nature or ecosystem services?	Policies or conditions could govern its direct operations but also how it engages with its value chain. Find instances where the company has introduced policies and conditions that reduce the probability or potential impact of negatively affecting nature or ecosystem services. The company may refer to Doing No Significant Harm or DNSH. If you find one or more policies and conditions adjusted to include this, answer "Yes".

45	Does the company report any policies or conditions used to ensure no significant harm is done to societal resilience through its business activities?	Policies or conditions could govern its direct operations but also how it engages with its value chain. Find instances where the company has introduced policies and conditions that reduce the probability or potential impact of negatively affecting society, community and people. The company may refer to Doing No Significant Harm or DNSH. If you find one or more policies and conditions adjusted to include this, answer "Yes".
46	Does the company anticipate any significant investments or asset disposals as a result of climate-related risks and opportunities identified?	Do not include carbon emissions or carbon emission reductions as a climate-related risk or opportunity. Answer "Yes" only if the asset disposals or investments are explicitly linked to a physical climate-related risks. Answer "No" if asset disposals or investments are outlined without explaining how these address specific physical climate-related risks.
47	Does the company anticipate any significant investments or asset disposals as a result of nature-related risks and opportunities identified?	Do not include carbon emissions or carbon emission reductions as a nature-related risk or opportunity. Answer "Yes" only if the asset disposals or investments are explicitly linked to a physical nature-related risk. Answer "No" if asset disposals or investments are outlined without explaining how these address specific physical nature-related risks.
48	Does the company explain how climate- and nature-related risks and opportunities are input into financial planning processes?	Do not include carbon emissions or carbon emission reductions as a climate-related or nature-related risk and opportunity. Do not consider specific amounts invested, instead look for evidence where the company integrates nature- or climate-related risks into financial planning. Do not include executive compensation as a financial planning process.
49	Does the company report on the scenario tools and methodologies used to test the resilience of its financial business strategy on climate-related issues?	Climate-related issues include risks and opportunities. Do not include carbon emissions, carbon emission reductions, decarbonisation, greenhouse gas reductions or carbon footprints as a climate-related issue. Scenarios here could include specific emission pathways or one or more risks materialising. If the company explains the type of scenarios used and how they are constructed or how climate-related issues are included in the methodologies used to assess financial resilience, then answer "yes".
50	Does the company report on the scenario tools and methodologies used to test the resilience of its financial business strategy on nature-related issues?	Nature-related issues include risks and opportunities. Do not include carbon emissions, carbon emission reductions, decarbonisation, greenhouse gas reductions or carbon footprints as a nature-related issue. Scenarios here could include specific emission pathways or one or more risks materialising. If the company explains the type of scenarios used and how they are constructed or how nature-related issues are included in the methodologies used to assess financial resilience, then answer "yes".
Offering		
51	Does the company refer to external definitions or taxonomies to classify its products and services as resilience aligned?	Answer "Yes" only if the company explains what definitions or taxonomies for resilience it uses to classify its product and service offering.

52	Does the company demonstrate actions taken to adjust its product and service offering to physical climate change risks?	Do not include carbon emissions, carbon emission reductions, decarbonisation, greenhouse gas reductions or carbon footprints. Physical climate-related risks include acute risks such as droughts, floods, wildfires and other weather extremes, as well as chronic risks such as sea level rise.
53	Does the company demonstrate actions taken to adjust its product and service offering to physical nature risks?	Do not include carbon emissions, carbon emission reductions, decarbonisation, greenhouse gas reductions or carbon footprints as a climate-related risk or opportunity. Physical nature-related risks include risks impacting a company's assets or operations directly (i.e. not through policies) arising from nature loss drivers, such as pollution, invasive species or others that affect relevant ecosystem services such as water provision, pollination or others. Do not include physical risks arising from climate, such as droughts, floods, or other weather extremes.
54	Does the company offer or intend to offer products that enable others to respond to physical climate risks?	Do not include carbon emissions, carbon emission reductions, decarbonisation, greenhouse gas reductions or carbon footprints as a climate-related risk or opportunity. Physical climate-related risks include acute risks such as droughts, floods, wildfires and other weather extremes, as well as chronic risks such as sea level rise.
55	Does the company offer or intend to offer products that help regenerate or restore damaged ecosystems?	Ignore anything related to carbon emissions, carbon emission reductions, greenhouse gases or decarbonisation.

Extended Data Table 5. List of indicators for *Engagement*.

ID	*Question*	*Definition*
with value chain		
56	Does the company report any current or anticipated changes to upstream sourcing practices and interactions with downstream partners to address physical climate-related risks and opportunities?	Physical climate-related risks arise from acute hazards such as floods, droughts and other, and chronic hazards, such as sea level rise and others. Do not include carbon emissions, carbon emission reductions, decarbonisation or greenhouse gas reductions as a climate-related risk or opportunity. Changes could include, for example, certification practices, requiring risk management processes, or collaboration with suppliers, customers and other stakeholders. If the company has integrated one or more of these, state "yes".
57	Does the company report any current or anticipated changes to upstream sourcing practices and interactions with downstream partners to address physical nature-related issues? (e.g. adoption of improved tracing, certification practices, collaboration with suppliers, customers and other stakeholders, or extended producer responsibility schemes)	Nature-related issues include nature-related dependencies, impacts, risks and opportunities. Do not include carbon emissions, carbon emission reductions, decarbonisation, greenhouse gas reductions, GHG reductions or carbon footprints as a nature-related risk or opportunity. Physical nature-related risks include risks impacting a company's assets or operations directly (i.e. not through policies) arising from nature loss drivers, such as pollution, invasive species or others that affect relevant ecosystem services such as water provision, pollination or others. Changes could include, for example, adoption of improved tracing, certification practices, collaboration with suppliers, customers and other stakeholders, or extended producer responsibility schemes. If the company has integrated one or more of these, state "yes".
58	Does the company report any current or anticipated changes to its engagement processes to incorporate multi-stakeholder planning processes for physical climate-related risks or opportunities?	Climate-related issues include only physical climate-related risks or opportunities. Do not include carbon emissions, carbon emission reductions, decarbonisation, greenhouse gas reductions or carbon footprints. Physical climate-related risks arise from acute hazards such as floods, droughts and other, and chronic hazards, such as sea level rise and others. Multi-stakeholder processes could include landscape approaches, watershed management and marine and coastal spatial planning, among others. Answer "Yes" if the company has integrated multi-stakeholder planning processes for climate-related issues as part of any of its engagements with its value chain.
59	Does the company report any current or anticipated changes to its engagement processes to incorporate multi-stakeholder planning processes for nature-related issues? (E.g. landscape approaches, watershed management and marine and coastal spatial planning)	Nature-related issues include nature-related dependencies, impacts, risks and opportunities. Do not include carbon emissions, carbon emission reductions, decarbonisation, greenhouse gas reductions or carbon footprints as a nature-related risk or opportunity. Multi-stakeholder processes could include landscape approaches, watershed management and marine and coastal spatial planning, among others. Answer "Yes" if the company has integrated multi-stakeholder planning processes for nature-related issues as part of any of its engagements with its value chain.
with third parties		

60	Does the company engage with governments and policymakers to manage physical climate-related risks?	Do not include carbon emissions, carbon emission reductions, decarbonisation, greenhouse gas reductions or carbon footprints as a climate-related risk or opportunity. Physical climate-related risks include acute risks such as droughts, floods, wildfires or other weather extremes, as well as chronic risks such as sea level rise and others.
61	Does the company engage with governments and policymakers to manage physical nature-related risks?	Do not include carbon emissions, carbon emission reductions, decarbonisation, greenhouse gas reductions or carbon footprints, as a physical nature risk. Physical nature-related risks include risks impacting a company's assets or operations directly (i.e. not through policies) arising from nature loss drivers, such as pollution, invasive species or others that affect relevant ecosystem services such as water provision, pollination or others. Do not include physical risks arising from climate, such as droughts, floods, or other weather extremes.
62	Does the company report its process for engaging with Indigenous Peoples, Local Communities and affected stakeholders?	Answer "No" if the company only outlines in general terms the importance of engaging with local communities. Answer "Yes" only if the company explains what type of engagement forms it uses to engage with communities and how regularly these are carried out when communities are affected.

Extended Data Table 6. List of indicators for *Governance.*

ID	*Question*	*Definition*
Institutional governance mechanisms		
63	Does the company have a climate change adaptation plan?	Answer "Yes" only if the climate change adaptation plan is a stand-alone document or is integrated in its stand-alone transition plan.
64	Does the company report the number or proportion of board members with competence in climate-related issues?	Physical climate-related issues includes risks and opportunities. Do not include carbon emissions, carbon emission reductions, decarbonisation, greenhouse gas reductions or carbon footprints as a physical climate-related issue.
65	Does the company report the number or proportion of board members with competence in nature-related issues?	Nature-related issues include nature-related dependencies, imapcts, risks and opportunities. Do not include carbon emissions, carbon emission reductions, decarbonisation, greenhouse gas reductions or carbon footprints as a nature-related issue.
66	Does the company report the processes used through which the board or board committees are informed about physical climate-related risks or opportunities?	Do not include carbon emissions or carbon emission reductions as a climate-related risk or opportunity.
67	Does the company report the processes used through which the board or board committees are informed about nature-related dependencies, impacts, risks or opportunities?	Do not include carbon emissions and carbon emission reductions.
68	Does the company report the frequency at which the board and board committees are informed about climate and nature-related issues?	Do not include carbon emissions and carbon emission reductions. Answer "Yes" only if the time inetervals are specified (e.g. quarterly).
69	Does the company report for which decisions the board considers climate- or nature-related issues?	Do not include carbon emissions and carbon emission reductions.
70	Does the company report to use internal or external audit or assurance resources to monitor progress on the goals and targets set to address climate- and nature-related issues?	Do not include carbon emissions and carbon emission reductions as a climate- or nature-related issue.
71	Has the company assigned the responsibilities of assessing and managing climate- and nature-related issues to a management-level position or committee that reports to the board?	Do not include carbon emissions and carbon emission reductions as a climate- or nature-related issue.
72	Does the company provide a description of how human rights due diligence processes, including but not limited to those covering the rights of Indigenous Peoples and Local Communities, are embedded	Answer "No" if the company only outlines in general terms the importance of engaging with local communities. Answer "Yes" only if the company explains how human due dilligence processes are embedded across the organisation.

	in the organisation’s strategy, policies, codes of conduct, governance structures or best practices?	
73	Does the company have a mechanism for individuals and communitis to raise complaints when they may be adversely affected by the company?	Answer "No" if the company only points to a whistleblower policy without explicitly mentioning a tool or mechanism, such as a portal, webpage or telephone number.
74	Does the company have a policy of non-reprisal against complainants, including human rights defenders, whistle-blowers, and community spokespersons?	Policy of non-reprisal also include sections of policies that prohibit retaliation against complainants. Answer "No" if the company outlines in general terms their commitment to ensuring safety of complainants without mentioning a policy.
75	Does the company have a process in place to escalate any issues that may cause significant harm to climate, nature and society?	Do not include carbon emissions or carbon emission reductions.
Links		
76	Does the company have initiatives in place to educate its workforce on climate-related risks?	Do not include carbon emissions or carbon emission reductions.
77	Does the company have initiatives in place to educate its workforce on nature-related risks?	Do not include carbon emissions or carbon emission reductions.
78	Are the company's performance metrics for physical climate-related risks or opportunities included in its remuneration policies?	Provide specific examples of executive management remuneration linked to progress towards achievement of its climate-related targets. Do not include carbon emissions, carbon emission reductions, decarbonisation, greenhouse gas reductions or carbon footprints. Answer "No" if the company has no relevant climate-related metrics. If you find examples, answer "Yes".
79	Are the company's performance metrics for nature-related dependencies, impacts, risks or opportunities included in its remuneration policies?	Provide specific examples of executive management remuneration linked to progress towards achievement of its nature-related targets. Do not include carbon emissions, carbon emission reductions, decarbonisation, greenhouse gas reductions or carbon footprints. Answer "No" if the company has no relevant nature-related metrics. If you find relevant examples, answer "Yes".

Extended Data Table 7. List of indicators for *Metrics & Targets*.

ID	*Question*	*Definition*
Targets		
80	Does the company set short-, mid- and long-term targets for reducing its exposure to physical climate risks?	Do not include targets related to carbon emissions, carbon emission reductions, decarbonisation, greenhouse gas reductions or carbon footprints. Answer "Yes" if the company provides targets in two or more timescales (e.g. short-term and long-term, or short-term and medium-term).
81	Does the company set short-, mid- and long-targets to improve or maintain ecosystem services?	Do not include targets related to carbon emissions, carbon emission reductions, decarbonisation, greenhouse gas reductions or carbon footprints. Answer "Yes" if the company provides targets in two or more timescales (e.g. short-term and long-term, or short-term and medium-term).
82	Does the company set targets to halt and reverse nature loss and improve or maintain the state of nature?	Nature loss broadly refers to the significant loss of ecosystem functioning, loss of biodiversity or loss of species abundance. Do not include targets related to carbon emissions, carbon emission reductions, decarbonisation, greenhouse gas reductions or carbon footprints.. Answer "yes" only if the company sets its own targets. Answer "No" if the company only mentions targets with explicitly defining these.
83	Does the company provide an explanation of how its climate adaptation-related targets align with the Sharm-el-Sheikh Adaptation Agenda or other similar adaptation goals?	
84	Does the company provide an explanation of how its nature-related targets align with the Kunming-Montreal Global Biodiversity Framework or other similar environmental treaties?	Do not include targets related to carbon emissions, carbon emission reductions, decarbonisation, greenhouse gas reductions or carbon footprints. Answer "Yes" only if the company defines what the third-party goals and targets are. Answer "No" if the company has no relevant nature-related targets.
85	Does the company establish baselines for its climate- and nature-related targets?	Do not include targets related to carbon emissions, carbon emission reductions, decarbonisation, greenhouse gas reductions or carbon footprints. Baselines can be set either in the past or at current standards. Identify all climate- and nature-targets and count the targets with baselines. Answer "Yes" if over half of the targets have baselines. Answer "No" if the company sets not relevant climate- or nature-related targets.
86	Are the company's climate- and nature-related targets validated by an independent third party?	Do not include targets related to carbon emissions, carbon emission reductions, decarbonisation, greenhouse gas reductions or carbon footprints. Answer "No" if the company sets no relevant climate- or nature-related targets.
Metrics		
87	Does the company quantify its climate- and nature-related targets using metrics?	Do not include targets related to carbon emissions, carbon emission reductions, decarbonisation, greenhouse gas reductions or carbon footprints. Answer "No" if the company sets no relevant climate- or nature-related targets.

88	Does the company report any metrics for changes to state of nature or changes in the availability of ecosystem services for any of its listed locations?	Do not include metrics related to carbon emissions, carbon emission reductions, decarbonisation, greenhouse gas reductions or carbon footprints. Listed locations are the locations the company has identified are important to its operations either due to ecological sensitivity of the site, the impact or dependency of its business activities on nature at that location, or any other reason the site may be important from the perspective of nature-related issues.
89	Does the company have metrics in place to monitor the financial effects of climate- and nature-related issues on the organisation?	Do not include metrics related to carbon emissions, carbon emission reductions, decarbonisation, greenhouse gas reductions or carbon footprints.
90	Does the company report its climate adaptation-aligned capital expenditure?	Do not include capital expenditure related to carbon emissions, carbon emission reductions, decarbonisation, greenhouse gas reductions or carbon footprints. Answer "Yes" only if the company explains how it defines climate adaptation alignment for its capital expenditure and then lists its values.
91	Does the company report its nature-aligned capital expenditure?	Answer "Yes" only if the company explains how it defines nature alignment for its capital expenditure and then lists its values.

Extended Data Table 8

Notes: The percentages represent the proportion of indicators reported on by all companies in our sample, disaggregated by disclosure elements.

		Disclosure elements					
	All indicators	Foundation	Risk	Implementation	Engagement	Governance	Metrics & Targets
Mean	20.4%	11.0%	18.3%	29.3%	25.1%	31.5%	7.1%
Min.	1.1%	0%	0%	0%	0%	0%	0%
Max.	54.9%	64.7%	72.7%	81.3%	85.7%	64.7%	41.7%
St. dev.	9.8%	11.1%	14.2%	16.6%	18.8%	13.4%	10.1%

Extended Data Table 9

Notes: This table shows the prompt template for the LLM, where “basic_info” is the basic information about a company, i.e. name, sector, and location, “sources” is the top-10 retrieved information that is used to answer the question, “question” is the question to answer, “explanation” is an optional additional explanation of the question, and “answer_length” is the length restriction for the answer.

```
"""
You are a senior sustainability analyst with expertise in climate science evaluating a company's climate-related transition plan and strategy.

This is basic information to the company:
{basic_info}

You are presented with the following sources from the company's report:
---------- [BEGIN OF SOURCES]\n
{sources}\n
---------- [END OF SOURCES]\n

Given the sources information and no prior knowledge, your main task is to respond to the posed question encapsulated in "||".
Question: ||{question}||

Please consider the following additional explanation to the question encapsulated in "+++++" as crucial for answering the question:
+++++ [BEGIN OF EXPLANATION]
{explanation}
+++++ [END OF EXPLANATION]

Please enforce to the following guidelines in your answer:
1. Your response must be precise, thorough, and grounded on specific extracts from the report to verify its authenticity.
```

2. If you are unsure, simply acknowledge the lack of knowledge, rather than fabricating an answer.
3. Keep your ANSWER within {answer_length} words.
4. Be sceptical to the information disclosed in the report as there might be greenwashing (exaggerating the firm's environmental responsibility). Always answer in a critical tone.
5. Cheap talks are statements that are costless to make and may not necessarily reflect the true intentions or future actions of the company. Be critical for all cheap talks you discovered in the report.
6. Always acknowledge that the information provided is representing the company's view based on its report.
7. Scrutinize whether the report is grounded in quantifiable, concrete data or vague, unverifiable statements, and communicate your findings.
8. Start your answer with a "[[YES]]"" or ""[[NO]]"" depending on whether you would answer the question with a yes or no. Always complement your judgement on yes or no with a short explanation that summarizes the sources in an informative way, i.e. provide details.

Format your answer in JSON format with the two keys: ANSWER (this should contain your answer string without sources), and SOURCES (this should be a list of the SOURCE numbers that were referenced in your answer).
Your FINAL_ANSWER in JSON (ensure there's no format error):
"""