What Companies Say vs. What Matters: LLM Analysis of Biodiversity Disclosures in Oil and Gas

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***Abstract*—The power system ecosystem encompasses infrastructure intensive industries such as electric utilities, hydropower operators, oil and gas producers, and mining companies supplying critical minerals. These industries share a common challenge: their physical assets interact extensively with natural ecosystems, creating dependencies and impacts that increasingly draw investor and stakeholder scrutiny. Many companies voluntarily disclose nature related commitments through platforms like the Carbon Disclosure Project (CDP), often in response to investor and stakeholder pressure. Yet little is known about whether these disclosures reflect substantive, measurable targets aligned with companies' most material impacts. As nature related financial risks gain attention from investors and lenders, understanding the quality of these commitments becomes critical for capital allocation and policy design.**

This paper develops a large language model (LLM) methodology to analyze corporate biodiversity disclosures across infrastructure intensive industries within the power system ecosystem. We demonstrate the approach using oil and gas producers in the United States as a test case, classifying CDP questionnaire responses as goals, commitments, or SMART targets (specific, measurable, achievable, relevant, and time-bound) and assessing their alignment with Global Biodiversity Framework categories and Exploring Natural Capital Opportunities, Risks and Exposure (ENCORE) identified material impacts and dependencies. Our analysis reveals that what companies say is often disconnected from what matters: disclosures are specific but lack measurability and time bound elements, with firms focusing on governance and data related categories rather than their most material ecosystem impacts. Yet peer patterns offer guidance: co-occurrence in disclosure categories reveals common practices that provide roadmaps for companies beginning their target setting journey. These findings point to two paths forward: companies can fill gaps by learning from peers which high materiality areas to prioritize, and can find the right words by using LLMs to articulate their existing actions in alignment with biodiversity frameworks rather than necessarily doing more.

***Index Terms*—Corporate disclosure, energy sector, biodiversity risk assessment, large language models, natural capital, sustainability reporting**

I. Introduction

Investors and regulators increasingly seek standardized information on how energy infrastructure interacts with natural systems. The Taskforce on Nature-related Financial Disclosures (TNFD) released sector-specific guidance for oil and gas and electric utilities in 2024 [1], [2], and CDP reports a 43 percent increase in biodiversity disclosure in the year following the Global Biodiversity Framework's adoption in 2022 [3]. Yet disclosure volume does not indicate whether reported commitments address sector-material issues. A company may report dozens of biodiversity initiatives while omitting dependencies and impacts most relevant to its operations.

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Automated analysis of sustainability disclosures has advanced rapidly for climate. Domain-specific language models such as ClimateBERT [4] improve classification of climate-related text, and systems like ChatReport [5] use large language models to assess reports against TCFD recommendations. Biodiversity remains largely uncharted. The only NLP effort focused specifically on nature-related disclosures, Schimanski et al. [6], developed classifiers to detect whether text mentions biodiversity but does not assess disclosure quality against materiality expectations. Studies using manual methods document gaps: Talbot et al. [7] found only 10.5 percent of Canadian electric utilities participate in national or international biodiversity initiatives. Scalable, materiality-aware assessment of disclosure quality does not yet exist.

This paper develops a Disclosure-Intent and Impact-Materiality (DIIM) alignment framework to evaluate whether corporate biodiversity disclosures address sector-material issues. The framework proceeds through two parallel assessments. First, an LLM parses CDP questionnaire responses into discrete statements, classifies each as a goal, commitment, or target based on SMART criteria, and maps them to GBF categories based on semantic content. Second, the company's primary activity is mapped to ENCORE-identified impacts and dependencies [8], which are translated into an expected set of GBF categories weighted by materiality. Comparing reported GBF coverage against ENCORE-implied categories reveals alignment gaps, identifies high-materiality categories that lack measurable targets, and surfaces co-occurrence patterns that characterize common practice.

We demonstrate this methodology using biodiversity disclosure responses from 24 U.S.-headquartered oil and gas producers that participated in the 2023 CDP questionnaire. Our findings reveal that disclosures tend to be specific but lack measurability and time-bound elements. Companies concentrate commitments in governance and data-related GBF categories while underaddressing categories linked to their most material impacts and dependencies. However, co-occurrence patterns across firms reveal common practices that can serve as roadmaps for improving coverage. These findings contribute to research on LLM applications for sustainability disclosure by extending automated assessment from climate to biodiversity. Our methodology and results provide a blueprint that can be applied to other sectors in the power system ecosystem such as electric utilities, where similar gaps between disclosed commitments and operational dependencies on water, land, and ecosystem services would be valuable to understand.

II. Global Biodiversity Governance and Disclosure Instruments: TNFD and the GBF

Growing investor and regulatory attention to nature-related financial risk has led to the emergence of structured frame-

works that link corporate activities to biodiversity outcomes. Two such global instruments are central to this study: the Taskforce on Nature-related Financial Disclosures (TNFD) Recommendations and Guidance [1], [9], and the Kunming–Montreal GBF [10]. Together, they provide a standardized pathway for identifying nature-related impacts and dependencies (I/D), translating these into financial risks and opportunities, and situating corporate actions within globally agreed biodiversity targets. This study focuses on the first link in this chain: whether disclosed commitments align with material I/D.

A. TNFD Recommendations and the LEAP Framework

TNFD Recommendations and Guidance provide a market-led framework for identifying, assessing, and disclosing nature-related dependencies, impacts, risks, and opportunities. Central to the TNFD Recommendations is the LEAP assessment framework [11], which structures analysis around four steps: *Locate, Evaluate, Assess, and Prepare*.

LEAP guides firms [12]–[14] to locate assets and activities relative to priority ecosystems; evaluate dependencies on ecosystem services and impacts on natural assets; assess associated risks and opportunities; and prepare responses through strategy, target-setting, and disclosure. Critically, LEAP separates the identification of I/D from management responses. This separation enables evaluation of whether disclosed actions correspond to material I/D rather than to governance, planning, or data readiness alone—the central question of this study.

The TNFD Recommendations specify 14 disclosure items spanning governance, strategy, risk and impact management, and metrics and targets, supported by a metrics architecture for translating I/D into measurable indicators. For this study, the key feature is TNFD's explicit alignment with the GBF: TNFD guidance maps categories of I/D to specific GBF targets, enabling firm-level disclosures to be evaluated against global biodiversity priorities.

B. The Global Biodiversity Framework (GBF)

The Kunming–Montreal GBF establishes 23 global targets to halt and reverse biodiversity loss by 2030, spanning ecosystem integrity and restoration, species conservation, sustainable use of natural resources, and enabling conditions such as governance, finance, and data [10]. For instance, GBF Target 15 calls for businesses to assess, monitor, and transparently disclose their biodiversity-related impacts, dependencies, risks, and opportunities [15], [16]. This study uses GBF target categories as the classification scheme for evaluating disclosure alignment with material I/D. Corporate statements are mapped to GBF categories based on content; ENCORE-derived I/D are mapped to GBF categories based on TNFD guidance. Comparing these two mappings reveals coverage gaps and quality mismatches.

C. Framework Application

We Utilize the TNFD and GBF jointly to analyze biodiversity disclosures in the oil and gas sector. Primary activity-level I/D identified through ENCORE [17] are first used to infer GBF categories that are material for oil and gas activities. Corporate disclosure statements from CDP questionnaires are then classified using a large language model (LLM) into goals, commitments, or targets based on SMART [18] criteria, and subsequently mapped to GBF categories using the TNFD–GBF alignment logic. This structure enables comparison of reported GBF coverage against material GBF categories, assessment of target specificity, and identification of systematic gaps and common practices across peer firms.

III. CDP Questionnaire Responses in Oil and Gas

To evaluate corporate biodiversity disclosures against the GBF-aligned materiality expectations described above, we require standardized firm-level disclosure data. CDP [19] provides such data through a global platform where companies self-report environmental information to investors via structured questionnaires. The CDP climate change questionnaire—which since 2022 includes a dedicated biodiversity module (C15)—consists of a set of *general* questions presented to all responding companies, along with *sector-specific* questions assigned to companies in designated high-impact sectors. Sector-specific questions are allocated using the CDP Activity Classification System (CDP-ACS), which classifies companies based on the proportion of revenue derived from primary business activities, ensuring that firms receive questions relevant to their operational profile [20].

Companies provide responses through structured tables, categorical selections, and open-text fields. The questionnaire includes biodiversity-related questions within the general modules applicable across sectors, as well as additional sector-specific content for oil and gas companies. We analyze responses to 134 general and 30 sector-specific questions (164 total), extracting biodiversity-related statements from open-text fields across these items. Data for this study were obtained under a CDP academic data license; all analyzed responses were submitted as disclosures to CDP's 2023 Climate Change questionnaire.

IV. LLM-Based Disclosure-Intent and Impact-Materiality (DIIM) Alignment Framework

This study develops an LLM-based analytical framework, termed the Disclosure-Intent and Impact-Materiality (DIIM) Alignment Framework, to evaluate corporate biodiversity disclosures by explicitly separating disclosure intent from impact materiality. The DIIM framework distinguishes what companies state in voluntary disclosures from what biodiversity frameworks imply they should address given their underlying business activities. This separation is critical for assessing whether observed disclosure gaps reflect substantive misalignment with nature-related materiality or limitations in reporting language and structure.

The framework proceeds through two parallel analytical pathways: a Disclosure-Intent Assessment and an Impact-Materiality Assessment, which are subsequently reconciled to identify alignment, gaps, and common practices. Refer to Appendix A for the implementation details.

A. Disclosure-Intent Assessment: Classification of Stated Intent and Reported GBF Coverage

The first component of the framework evaluates CDP disclosure data defined in §III. We begin with responses to the CDP questionnaire, disaggregated by company primary activity, which for oil & gas were extraction, pipelines and storage, and refining. Biodiversity-related statements are extracted from open-text responses to CDP's oil and gas sector and general questionnaires, and evaluated in the context of two reference frameworks: the Kunming–Montreal GBF and the SMART objective criteria. Refer to Appendix C for further details.

A LLM is used to parse questionnaire responses into discrete biodiversity-related statements. Each statement is classified into one of three intent categories:

- **Targets** are fully SMART-compliant objectives: specific, measurable, achievable, relevant, and time-bound.
- **Commitments** are specific statements of intent that lack one or more SMART elements, typically measurability or time-bound deadlines.
- **Goals** are broad aspirational statements that lack specificity and do not define metrics, baselines, or timelines.

Beyond classification, the LLM evaluates each statement against individual SMART criteria, enabling graded assessment of disclosure quality and identification of systematic weaknesses.

Each classified statement is then mapped to one or more GBF target categories based solely on the semantic content of the disclosure. This produces a *disclosure-intent profile* for each company, capturing (i) the distribution across goals, commitments, and targets, (ii) SMART criterion scores for each statement, and (iii) the GBF categories explicitly addressed. Importantly, this assessment reflects disclosure behavior as reported, without imposing assumptions about materiality or adequacy.

B. Impact-Materiality Assessment: ENCORE-Derived Impacts, Dependencies, and GBF Expectations

The second component of the framework evaluates biodiversity materiality independent of corporate disclosure choices. Each company's primary activity is mapped to ISIC classifications, which are then linked to the ENCORE database. ENCORE identifies nature-related I/D for each economic activity and assigns qualitative materiality ratings (e.g., very high, high, medium, low) to each interaction. To connect disclosures to materiality, each previously classified statement is mapped—using TNFD guidance—to the subset of ENCORE-derived I/D relevant to the company's primary activity. This constrained mapping ensures statements are evaluated only against activity-consistent I/D. Refer to Appendix D for further details.

Using TNFD guidance linking categories of I/D to GBF targets, the ENCORE-derived I/D profile is translated into an ENCORE-derived set of GBF categories. These categories are weighted by the materiality of the underlying I/D, yielding a company-specific expectation set of GBF targets that should be addressed if disclosures were fully aligned with nature-related exposure.

C. Alignment and Gap Diagnostics

The final step of the framework reconciles reported intent with materiality-based expectations. Alignment is evaluated by comparing company-reported GBF coverage with ENCORE-implied GBF categories.

We identify three primary diagnostics. First, *coverage gaps* are measured as the proportion of ENCORE-implied GBF categories that are not addressed in company disclosures. Second, the materiality of unaddressed categories is assessed by averaging the materiality levels of the underlying I/D associated with each missing GBF category. Third, quality-materiality mismatches are identified where highly material GBF categories are addressed only through goals or non-SMART commitments rather than measurable targets.

This structure enables differentiation between substantive gaps, where companies fail to address high-materiality biodiversity issues, and semantic gaps, where companies may be undertaking relevant actions but do not disclose them in a manner aligned with established biodiversity frameworks. Finally, co-occurrence analysis of GBF categories across firms is used to identify common disclosure practices, revealing peer-based pathways for improving both coverage and target quality.

V. Results

A. Disclosure Classification: Goal, Commitment, or Target?

We first classify the corporate CDP disclosures into goals, commitments, or targets as described in §IV-A. Figure 1 reports the counts by company. In absolute terms, targets typically range from 5 to 30 per firm, while goals are usually limited to 0–5 statements and commitments commonly fall between 5 and 15 (occasionally exceeding targets). Expressed as shares of total disclosed statements, this implies that goals generally constitute a small fraction of reporting, whereas the balance of disclosures is split between commitments and targets, with substantial variation across firms.

There is strong dispersion in total disclosure volume, spanning roughly 5 to over 40 statements per company. Framing this dispersion in percentage terms clarifies that higher disclosure volume does not necessarily translate into a higher share of targets. For example, CNX Resources reports approximately 40 total nature-related statements, including about 12 targets (roughly 30% of its disclosures). Occidental Petroleum reports about 20 statements with a similar number of targets ($\approx$10–12), implying a target share of roughly 50–60%—about 20–30 percentage points higher than CNX. Put differently, CNX reports about twice as many total statements as Occidental, but not twice as many targets; the additional volume is largely commitments rather than targets. A similar pattern appears for Devon Energy and Pioneer Natural Resources: while total disclosure differs by nearly 10 statements, both report fewer than 10 targets, implying that the firm with higher total volume has a lower target share and that the incremental disclosures are primarily commitments. Overall, these comparisons indicate that increases in disclosure volume are driven more by additional commitments than by a proportional increase in targets, suggesting companies default to easier-to-articulate

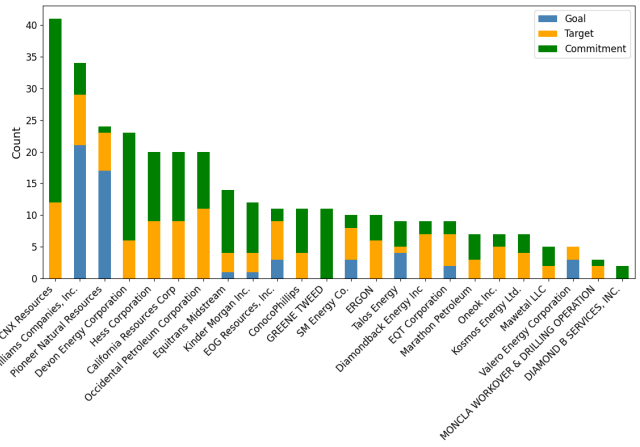


Fig. 1: Count of nature-related statements disclosed by each oil and gas company, disaggregated into goals, commitments, and targets.

commitments rather than investing in the measurement infrastructure required for SMART targets.

B. GBF Alignment

We compare company-reported GBF priorities with GBF categories implied by ENCORE based on primary activities using CDP. This comparison reveals a clear misalignment. ENCORE-implied design priorities (Figure 2a) emphasize I/D-driven GBF categories, most notably Species & Genetic Diversity, Ecosystems, Drivers of Biodiversity Loss, and Sustainable Use. In contrast, company-reported GBF priorities (Figure 2b) are dominated by Planning & Governance, with Sustainable Use and Climate Resilience appearing as secondary areas of focus.

This divergence indicates that companies' reported goals, commitments, and targets are weakly aligned with GBF categories that are directly linked to material I/D. In particular, ENCORE identifies Species & Genetic Diversity as the most relevant GBF category for primary activity–level exposure, yet this category is substantially underrepresented in corporate disclosures. The contrast between these priorities raises a central question: how material are the GBF categories that companies fail to address, as implied by ENCORE?

Figure 3 plots the percentage of ENCORE-implied GBF categories that are unaddressed by each company against the average materiality of those unaddressed categories. Where the materiality-levels are mapped to increasing numbers from 1 to 5 for quantitative categories very low to very high. Most companies fall in the High Gap, High Priority quadrant, with roughly 60–100% of ENCORE-implied GBF categories unaddressed and average materiality scores between approximately 3.5 and 4.5. This indicates that companies are not primarily omitting low-relevance categories; instead, a large share of the categories they fail to address are among the most material given their primary activities.

Ecosystems (GBF Target 2) illustrates this pattern clearly. ENCORE identifies ecosystem impacts as highly material for oil and gas extraction, yet several firms with more than 70% unaddressed GBF categories do not address this category in their disclosures. In contrast, firms such as Pioneer Natural Resources fall in the Low Gap, High Priority quadrant, addressing a larger share of high-materiality GBF categories despite similar activity profiles. This demonstrates that higher coverage of material GBF categories is achievable within the sector and that the observed gaps reflect firm-level disclosure choices rather than sector-wide constraints.

Overall, this figure shows that the dominant disclosure gap is substantive rather than marginal: companies systematically leave unaddressed GBF categories that ENCORE identifies as both relevant and high priority based on I/D.

C. Target Planning and GBF Alignment

We next assess whether the GBF categories that companies address are supported by well-defined, actionable targets. To do so, we evaluate the SMART compliance of reported goals, commitments, and targets, where a statement is classified as a target only if it satisfies all five SMART criteria. Figure 4 summarizes average compliance with each SMART dimension across company-reported biodiversity statements. Companies perform relatively well on *Specific* and *Relevant* criteria, with average compliance exceeding 0.7, and on *Achievable*, with compliance close to 0.9. In contrast, compliance is substantially lower for *Measurable* and *Time-bound*, both below 0.3. This pattern indicates that most disclosures articulate clear intent but lack quantitative metrics and explicit timelines, preventing many statements from qualifying as operational targets.

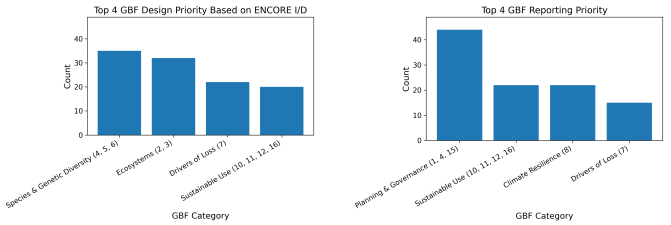
Figure 6 examines how target quality relates to ENCORE alignment for the GBF categories that companies address. Most firms fall in the low-alignment, low-SMART region of the figure, with fewer than 50% of addressed GBF categories aligned with ENCORE-implied priorities and fewer than 50% supported by SMART targets. Among oil and gas extraction companies, firms such as EOG Resources, Kosmos Energy, and Talos Energy primarily report targets related to Knowledge/Data (GBF Target 21) and Planning & Governance, categories that are weakly aligned with their ENCORE-identified impacts and dependencies.

This focus on planning- and data-oriented categories contributes directly to low ENCORE alignment. Highly material categories for oil and gas extraction—such as Ecosystems (GBF Target 3) and Drivers of Biodiversity Loss (GBF Target 7)—are comparatively underrepresented in disclosures from firms in this region. As a result, reported targets emphasize management processes rather than the impact- and dependency-driven GBF categories identified as most material by ENCORE.

Importantly, higher SMART compliance does not imply higher ENCORE alignment. Several firms achieve 60–70% SMART compliance while aligning fewer than 40% of their addressed GBF categories with ENCORE-implied priorities. This demonstrates that improvements in target specificity and planning quality alone are insufficient to ensure coverage of the most material impacts and dependencies.

Together, these results show that current biodiversity target-setting falls short along two dimensions: many targets lack

measurability and time bounds, and those that are well specified are not systematically focused on the GBF categories most closely linked to material impacts and dependencies.



(a) ENCORE-implied GBF design priorities derived from impacts and dependencies.

(b) Company-reported priority of GBF categories.

Fig. 2: Comparison of top four ENCORE-implied and company-reported priorities across GBF categories.

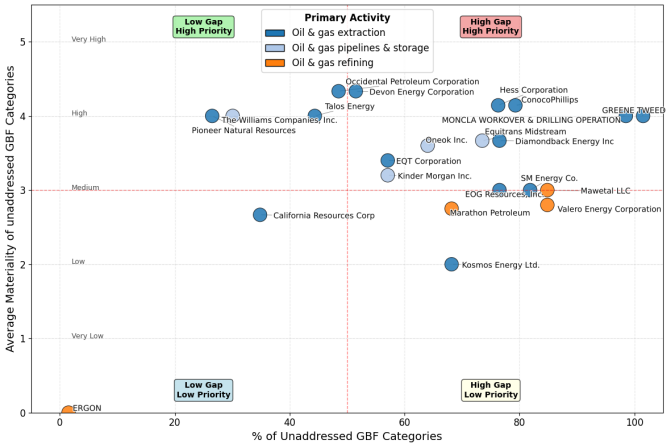


Fig. 3: Percentage of ENCORE-implied GBF categories that are unaddressed by each company versus the average materiality of those unaddressed categories.

D. Common Practice

To identify common practices in biodiversity target-setting, we analyze co-occurrence patterns of GBF categories across company disclosures. Co-occurrence reflects pairs of GBF categories that are addressed together by multiple firms, indicating shared reporting structures and focal areas within the sector.

Figure 7 visualizes GBF category co-occurrence patterns, highlighting a dense cluster among governance-, capacity-, and climate-related categories and comparatively sparse connections involving biodiversity state and impact categories. Table I lists the most frequently co-occurring GBF category pairs. The strongest co-occurrence is observed between Planning & Governance (GBF 15) and Climate & Resilience (GBF 8), appearing together in 27 disclosures. This is followed closely by Climate & Resilience paired with Capacity & Technology (GBF 20) in 25 disclosures, and Planning & Governance paired with Sustainable Use (GBF 14) in 24 disclosures. Additional high-frequency pairs include Species & Genetic

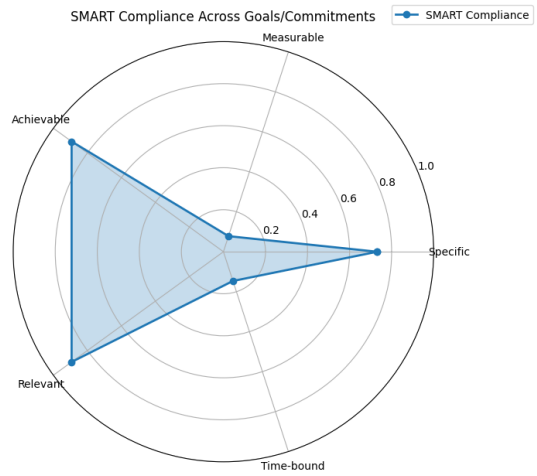


Fig. 4: Average compliance with SMART criteria across company-reported biodiversity goals and commitments.

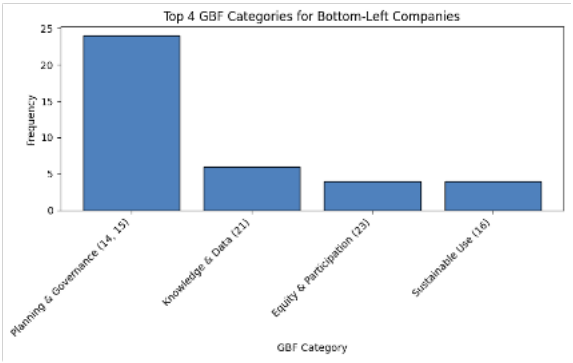


Fig. 5: Top four addressed GBF categories among ”Low Alignment, Low SMART” quadrant firms in Figure 6.

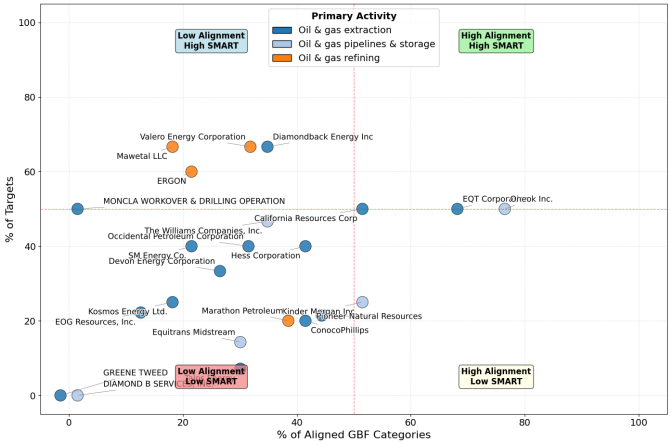


Fig. 6: Percentage of addressed GBF categories that qualify as SMART targets versus percentage aligned with ENCORE-implied GBF priorities.

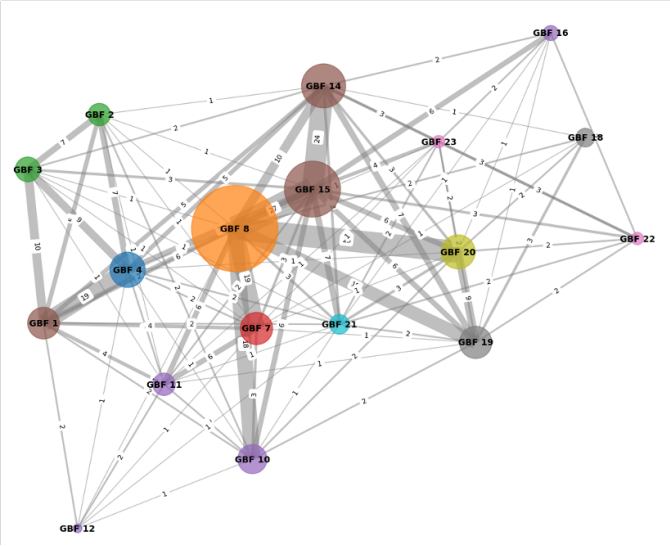


Fig. 7: Co-occurrence network of GBF categories across company biodiversity disclosures, where nodes represent GBF categories and edge thickness reflects the frequency with which category pairs are jointly reported.

TABLE I: Most frequent co-occurring GBF category pairs across company disclosures.

GBF Category Pair	Co-occurrence Count
Planning & Governance (15), Climate & Resilience (8)	27
Capacity & Technology (20), Climate & Resilience (8)	25
Planning & Governance (14), Sustainable Use (15)	24
Species & Genetic Diversity (1), Ecosystems (4)	19
Drivers of Loss (7), Climate & Resilience (8)	19

Diversity with Ecosystems (GBF 1, GBF 4) and Drivers of Loss with Climate & Resilience (GBF 7, GBF 8), each appearing in 19 disclosures.

These patterns show that companies tend to bundle governance, planning, and resilience-oriented GBF categories, forming a shared disclosure backbone across the sector. In contrast, impact- and dependency-driven categories, such as ecosystems and species, appear less frequently and primarily when paired with higher-level management categories rather than as standalone focal areas. The key implication is that common practice already provides a peer-based roadmap for nature-target explorers. Companies beginning their biodiversity target-setting journey can leverage these shared category combinations as entry points, while more advanced firms can expand beyond this common core to address less frequently reported but highly material GBF categories identified by ENCORE.

VI. Conclusion

A. LLMs to Find Words to Align Disclosures with Frameworks

Investors have access only to what companies disclose, and based on current reporting many firms appear weakly aligned with the biodiversity issues they are expected to address. Our results show that disclosures are often specific, which is encouraging, but tend to focus on GBF categories related to planning, governance, and data, rather than on ENCORE-identified high-materiality I/D. As a result, companies may appear misaligned even when relevant actions exist in practice.

A key challenge revealed by our analysis is that misalignment is often driven by language, not necessarily by a lack of underlying action. Companies may be addressing ENCORE-relevant GBF categories, but fail to disclose them using explicit, grounded terminology that maps clearly to their impacts and dependencies. As a result, alignment cannot be inferred from reported data.

Large language models (LLMs) provide a scalable tool to help companies bridge this disclosure gap. By assisting in report drafting, LLMs can explicitly link actions to impacts, dependencies, and global frameworks such as ENCORE and the GBF. Widespread adoption of a common, framework-aligned language would allow investors to better assess true company performance, improve comparability across firms, and enable more effective cross-company learning, without requiring changes to underlying operations.

B. Peer Learning to Fill Target Coverage Gaps

Shared GBF categories across the sector provide a peer roadmap for companies exploring nature-related targets.Companies at an early stage can look to pioneers within the same sector to identify which high-materiality GBF categories are being addressed and how targets are framed. More advanced firms can benchmark against frontiers to identify remaining gaps and next-step targets. This peer-based approach offers a practical pathway to expanding target coverage, particularly for GBF categories that are consistently identified as high-priority by ENCORE but remain underrepresented in disclosures.

VII. AI Usage Disclosure

Large language models were used to assist with text editing and organization of the manuscript. All research design, analysis, interpretation of results, and conclusions were conducted by the authors. No data generation, modeling, or result derivation was performed using AI.

Appendix

A. Implementation Details: DIIM Alignment Pipeline

This appendix documents the end-to-end implementation of the Disclosure-Intent and Impact-Materiality (DIIM) Alignment Framework used to analyze biodiversity-related disclosures for oil and gas firms using CDP responses, ENCORE impacts/dependencies, and TNFD-to-GBF mapping data.

B. Data Inputs and Canonical Data Structures

1) CDP disclosure data (company-reported): For each firm, we construct a structured JSON record from CDP responses of O&G firms for general and O&G sector sepcific CDP responses and store responses as question contexts:

- **Primary Activity**: CDP-ACS primary activity label used to define the firm's dominant operational profile.
- **Questions**: list of selected question blocks, each containing:
  - `QuestionID`
  - `Main Question` (retained for context only)
  - `SubQA`: list of sub-question / open-text answer pairs (treated as evidence-bearing text)

Only `SubQA.Answer` text is used for extraction; `Main Question` and `SubQA.Question` are used only for contextual disambiguation.

2) Activity mapping and ENCORE profiles: Each CDP-ACS primary activity is mapped to ISIC codes via a deterministic crosswalk. For each ISIC code, ENCORE provides activity-level ecosystem *Dependencies* and *Impacts* (I/D), along with qualitative materiality levels. We store these in a canonical schema:

- **Dependencies**: grouped by ecosystem service class (e.g., provisioning; regulating/maintenance), each entry containing (name, materiality, ENCORE rationale).
- **Impacts**: list of pressure categories, each entry containing (name, materiality, ENCORE rationale).

3) GBF taxonomy and Recommendations of TNFD linkage context: We represent the Kunming–Montreal GBF as a fixed set of targets with short descriptions. Recommendations of the Taskforce on Nature-related Financial Disclosures [9] is used as a translation layer that links classes of I/D to GBF targets. Although this document includes mappings between GBF targets and impact drivers, its naming conventions do not exactly match those used in ENCORE. Therefore, the I/D to GBF mapping was performed using an LLM, with the TNFD Recommendations document provided as contextual input.

C. Disclosure-Intent Assessment Implementation

1) CDP question-context construction: For each firm and each selected `QuestionID`, we create a single *question context* by concatenating all `SubQA` pairs. This preserves the within-question structure and prevents sentence-level extraction from losing context across related sub-questions.

To reduce failure modes in long-context generation, we apply:

- **Deduplication**: remove repeated boilerplate passages using exact-match hashing and near-duplicate filtering.
- **Length control**: truncate very long answers using head+tail retention (preserving early commitments and late numeric/time-bound clauses).
- **Redaction**: remove organization names, specific facilities, and personal identifiers before model ingestion.

2) LLM intent classification and SMART scoring: We prompt an LLM to parse each question context into discrete biodiversity-related statements and classify each statement as *Goal*, *Commitment*, and/or *Target*. In addition, each statement is evaluated on individual SMART criteria (Specific, Measurable, Achievable, Relevant, Time-bound), enabling graded quality assessment.

Operational rules applied in classification:

- **Commitment** is triggered by pledge/alignment language (e.g., commit/pledge/join/sign; external initiatives).
- **Target** requires SMART compliance; partial SMART statements are retained with per-criterion flags.
- **Interim vs long-term**: horizon $\leq$10 years is interim; $>$10 years is long-term.
- **Emission flag**: set to Yes if the statement concerns emissions (directly or via explicit emissions-related terms).

3) Disclosure-to-GBF mapping (reported coverage): For each extracted statement, the LLM maps the statement to one or more GBF target categories based on semantic content. This produces a firm-level *company-reported biodiversity profile* consisting of:

- distribution of goals/commitments/targets,
- SMART criterion prevalence,
- reported GBF coverage set.

This phase is treated as purely disclosure-driven (no materiality assumptions applied).

4) Output validation and normalization: LLM outputs are validated for JSON structural correctness. We normalize:

- **GBF target IDs**: map variants (e.g., "Target 8", "GBF 8") to canonical IDs.
- **Dates/years**: normalize time-bound expressions to numeric years where possible.
- **Quantitative markers**: extract numeric quantities (percentages, absolutes, currency amounts) into structured fields to support later aggregation.

If parsing fails, we re-prompt once with a strict "JSON only" instruction; otherwise the question context is marked missing and excluded from statement-level aggregates.

D. Impact-Materiality Assessment Implementation

1) ENCORE I/D retrieval and materiality encoding: For each firm's ISIC code, ENCORE I/D are retrieved. Qualitative materiality labels are converted to an ordinal scale for aggregation:

$$\text{Very High} = 5,\ \text{High} = 4,\ \text{Medium} = 3,\ \text{Low} = 2,\ \text{Very Low} = 1. \tag{1}$$

All reported results retain qualitative labels; numeric encoding is used only for computation of weighted expectations and diagnostics.

2) ENCORE I/D to GBF expectation set: Using TNFD recommendations [9], ENCORE I/D are translated into an *ENCORE-implied GBF expectation set*. Each expected GBF target is assigned a materiality weight derived from the underlying I/D items mapped to that GBF category.

E. Bridging Disclosures to Activity-Consistent I/D

1) Statement-to-I/D mapping: To connect disclosed statements to materiality, we map each question context to the subset of ENCORE I/D consistent with the firm's primary activity. The model is provided:

- the question context (answers only),
- the activity-specific ENCORE I/D list (names + materiality + rationale),

- sector LEAP context (compressed) to define dependency and impact concepts.

A hard constraint is applied: extracted dependencies/impacts must match items in the provided ENCORE list; unmatched outputs are discarded.

LLM Validation: We employed the `gemini-2.5-flash-preview-05-20` large language model for all classification and mapping tasks in this study. To assess output stability and reduce stochastic variation, each prompt was executed ten independent times under identical settings. Final classifications were determined using a maximum-voting (majority agreement) rule across runs [21]. This procedure improves robustness by retaining only the most consistently generated outputs and limiting the influence of single-run variability.

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