To Disclose, or Not to Disclose: Evaluating the Effectiveness of Mandatory Climate-Related Disclosure *

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Abstract

This study provides the first empirical evaluation of comprehensive mandatory climate disclosure, focusing on New Zealand's world-first TCFD/ISSB-aligned regime. We assess its effectiveness using a survey exploring reporting motivations/challenges, a novel Large Language Model (LLM)-based tool quantifying disclosure compliance, and analyzing reporting trends before and after the mandate. We also compare changes in fund manager capital allocation between mandated and non-mandated entities. Findings reveal the mandate significantly increased reporting quantity and quality, particularly for corporate issuers, improving alignment with Aotearoa New Zealand Climate Standards. Mandated fund managers demonstrated improved portfolio ESG performance and decreased Carbon Intensities versus non-mandated peers post-mandate. While challenges like data reliability and resource constraints persist, especially for complex metrics, the results show that the mandate effectively enhances transparency and influences capital allocation towards sustainability. This offers crucial early evidence supporting similar global regulatory efforts.

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1 Introduction

The global financial landscape is undergoing a significant transformation as regulators worldwide implement mandatory climate-related financial disclosure requirements. Jurisdictions such as the United States, the European Union, China, Singapore, Hong Kong, Australia, Nigeria, and the United Kingdom have introduced new regulations for comprehensive climate-related financial reporting [see e.g., Institute for Agriculture and Trade Policy, 2024]. These frameworks inform investors and other stakeholders about climate risks while also facilitating more efficient capital allocation in the face of environmental uncertainty [e.g., European Commission, 2024]. The first country to implement this new phase of disclosure mandates is New Zealand, making it the ideal, and currently only, candidate to study the effects of such regulations.

The standard in New Zealand is highly representative of the the entire wave of disclosure mandates as they all follow the recommendations of the Taskforce for Climate-related Financial Disclosures [TCFD, 2017] and/or the International Sustainability Standards Board (ISSB) International Financial Reporting Standards (IFRS) on Sustainability (S1) and Climate-related disclosures (S2).[1] Primarily, the TCFD recommendations and ISSB standards require organizations to disclose information on Governance, Risk Management, Strategy, and Metrics and Targets, ensuring transparency on climate-related financial risks and opportunities to support investor, creditor and stakeholder decision-making. The Aotearoa New Zealand Climate-related Disclosure Standards (ANZCS) are interoperable with both the TCFD recommendations and ISSB climate-related reporting standards.[2]

The current era of comprehensive climate-related financial reporting requirements follows an earlier wave of non-financial (ESG) disclosure regulations around the world [Krueger et al., 2024]. The earlier phase of non-financial disclosure requirements covered much smaller portions of the economy, often focusing only on the largest companies or those with the most emissions. They were often voluntary (comply or explain), inconsistent, and qualitative, allowing companies excess flexibility in reporting and lacked standardized metrics. Some of the early phase mandates did

[1] As of July 2023 the TCFD has completed its objectives and was disbanded in October 2023. The ISSB has now absorbed the TCFD monitoring responsibilities.

[2] The External Reporting Board (XRB) provide comparison tables for both here: `https://www.xrb.govt.nz/standards/climate-related-disclosures/resources/`

require specific Greenhouse Gas (GHG) emission disclosures, but beyond that, comparability was limited. For example, the 2008 Climate Change Act in the UK required the largest companies to report some specific Greenhouse Gas Emission metrics, which is only a small subset of the requirements in line with the new comprehensive standards.

Notably, New Zealand has emerged as a pioneer in this movement by enacting the *Financial Sector (Climate-related Disclosures and Other Matters) Amendment Act 2021*.[3] This legislation mandates that approximately 200 of the country's largest corporate issuers, insurers, creditors (Banks and Building Societies) and fund mangers disclose their climate-related risks and opportunities, against the Aotearoa New Zealand Climate Standards[4], published by the External Reporting Board (XRB), with reporting obligations commencing for financial years starting in 2023 (2024 calendar year disclosure) [New Zealand Government, 2021]. As a result, New Zealand became the first country to implement mandatory climate-related financial reporting, while other nations with enabling policies in place, are now in the process of phasing in or initiating their own comprehensive climate-related disclosure requirements.

New Zealand's advanced financial system, unified roll out and predominantly english language (e.g., in comparison to the EU) and proactive regulatory stance[5] make it an ideal case study for understanding the implications of mandatory climate-related disclosures on corporate behavior, investor decision-making, and capital allocation. This study explores Climate-Reporting Entities' (CREs') motivation and challenges with climate-related disclosures and the effects of the mandate on reporting by CREs aas well as the portfolio level sustainability performance, and therefore capital allocation decisions, of New Zealand fund manager.

This study focuses on analyzing the effects of mandatory disclosure in three steps contributing to several strands of literature. Firstly, we conduct a novel survey allowing us to contribute to the understanding of the motivations for voluntary reporting before the mandate and challenges faced by reporting entities extending the insights of the literature (Flammer et al., 2021); Setzer and Byrnes, 2020; Christensen et al., 2021; among others). Second, we provide the first empirical

[3]Financial Sector (Climate-related Disclosures and Other Matters) Amendment Act 2021

[4]The full standards can be found here: https://www.xrb.govt.nz/standards/climate-related-disclosures/aotearoa-new-zealand-climate-standards/

[5]New Zealand was also one of the first countries to implement other climate-related policies, such as an Emissions Trading Scheme (second in the world in 2008)

analysis of the effects of the new era climate-related financial disclosure regulations, on reporting practices, building on the extensive literature studying the effects of the early phase mandates (Krueger et al., 2024); Gibbons, 2024; Miller et al., 2023; among other). We do this by designing a novel report collection framework and Large Language Model (LLM)-based system to quantify the quality of the disclosures against the ANZCS, implementing a state of the art Retrieval Augmented Generation (RAG) model. Importantly we analyze voluntary reporting leading up to the mandate and mandatory reporting for the 2023 Financial Year. Lastly, we explore the effect of the mandate on capital allocation, by examining New Zealand fund manager portfolio level ESG performance.

In the first analysis, we analyze the effects of the introduction of mandatory disclosure on company reporting practices by surveying CREs and PUs on disclosure practices, attitudes, and challenges. This survey was distributed at the end of 2023 until early 2024, so right before mandatory climate-related reporting came into effect in New Zealand. We find that those companies voluntarily reporting early predominantly started to do so around the time of the passing of the Financial Sector (Climate-related Disclosures and Other Matters) Amendment Act 2021. When asked about their motivations for voluntary early reporting, the most common were to improve for reputational benefits and to integrate climate-related risks into their entity's strategy. The next most common motivation was to prepare for the upcoming disclosure mandates, reducing the resource cost to meet the requirements. When all respondents were asked about the biggest challenges with climate-related reporting, the most pressing issues were a lack of reliable data, resource constraints, and having to grapple with multiple disclosure frameworks. Further, a lack of capabilities and challenges around scenario analysis were also common. Interestingly, those entities that had engaged in voluntary reporting before the mandate perceived all of the potential challenges less frequently than those entities that had not started reporting. So the mandate has motivated some early reporting, but also raised many challenges for companies.

Next we investigate the realized changes in the reporting behavior of all CREs, not just those responding to our survey. We can observe the increase in the quantum of reporting climate-, or broader sustainability-, related information by CREs in Figure 1. We design a novel framework for collecting and classifying voluntary reporting by CREs, as this is no trivial task, which is summarized in Figure 3 and described in Section 4.1. To evaluate companies' compliance with the

ANZCS, we design a Retrieval Augmented Generation (RAG) model to develop a compliance index (CI_t), which measures disclosures against the requirements of the ANZCS. Through a Interrupted Time Series (ITS) analysis, we find that CREs are improving their reporting gradually leading up to the mandate, but there is a significant increase in both the number of reports and the (CI_t) as the mandate takes effect. Therefore, the New Zealand Climate-related Financial disclosure mandate improves the climate-related information available to investors, creditors and other stakeholders, both in quantity and quality.

Our RAG model also allows us to extract which adoption provisions CREs are making use of in the first year of reporting. A summary of this analysis is provided in Table 1.[6] We can observe that all of the adoption provisions are heavily used by CREs. The most used provisions are regarding the disclosure of financial impacts, which are difficult and resource-intensive to quantify, and comparative metrics, which are expected as many CREs are measuring these metrics for the first time.

Third, we scrutinize the effects of the mandate on investment decisions. Specifically, we employ a Difference-in-Difference (DiD) model to test the effect of the mandate on fund-level Sustainability performance and carbon intensities. We find that CRE fund managers, that is, those captured by the mandate, significantly increase their Morningstar Sustainability Rating and reduce their portfolio level carbon intensities after the policy is implemented. However, the effects of the passing of the Financial Sector (Climate-related Disclosures and Other Matters) Amendment Act 2021 yields more mixed results. This shift in capital allocation aligns with investors' non-financial preferences, potentially reflecting the high demand for sustainable options in New Zealand, which can now be enacted by investors with the increased transparency due to the disclosure mandate, beyond the purely financial motivations for reducing climate-related risk exposure.

This research has important implications for policymakers around the world as it provides the first empirical evidence showing that mandating climate-related disclosures does improve the availability and depth of climate-related disclosures as well as driving significant capital re-allocations. In future research, the focus should lie on understanding how the reporting mandate is affecting

[6]The available adoption provisions for CREs are described here: `https://www.xrb.govt.nz/standards/climate-related-disclosures/aotearoa-new-zealand-climate-standards/aotearoa-new-zealand-climate-standard-2/`

emissions reductions and transition planning of CREs and non-reporting New Zealand entities, but for this, we will need some time before the outcomes and associated data are realised.

2 Literature

2.1 The Importance of Climate-related Information

There are two promising approaches to obtain favorable climate outcomes. Carbon pricing policies, one of the key policies to achieve climate action, to date have been applied by many countries, including New Zealand, but often with a price far below the social cost of carbon [Klenert et al., 2018]. The other touted approach for encouraging a transition to a low-carbon economy is through bottom-up engagement and capital reallocation by companies and capital providers. However, to engage with firms or reallocate capital, primary Users (investors, insurers and creditors) need to be able to evaluate climate-related risks and opportunities, which requires information that is not readily available.

Starks [2023] explains investors may consider ESG information in their investment decisions for two main reasons: either because firms' ESG activities influence firm risks and cash flows ("value") or because, even if not financially relevant, such information helps them align their investments with their ethical preferences or policies ("values"). There is a growing literature empirically demonstrating the demand for climate-, and broader sustainability-, related disclosures. Institutional investors globally value and are demanding climate risk disclosures (Borghei, 2021; Ilhan et al., 2023b; Cohen et al., 2023; Heath et al., 2023) as they see these risks as important and already beginning to materialize, in particular transition risks (Amel-Zadeh and Serafeim, 2018; Krueger et al., 2020). Gillan et al. [2021] reviews the literature and show that in many published studies, institutional investor ownership is related to ESG performance of companies, further making the point that institutional investors are using this information in their capital allocation decision making. Dyck et al. [2019] show that institutional investors increase the Environmental and Social performance of investee companies, while Botsari and Lang [2020] show that even venture capital and angel investors have a preference for socially responsible investments.

The increased demand for climate-related information also exists in New Zealand as fund man-

agers believe ESG risks are, or will become, financially material, that climate-change is the most important of these risks and that there is currently a dearth of relevant information and metrics [Diaz-Rainey et al., 2024]. Beyond the potential return implications, asset managers are also observing the exceptional growth in demand for sustainable investment products from investors (Hartzmark and Sussman, 2019; Bauer et al., 2021; Ceccarelli et al., 2024). Some studies even show that investors would be willing to forego some financial return to achieve positive environmental and social impacts (Barber et al., 2021; Brodback et al., 2021). In a study of Dutch households, Degryse et al. [2023] find two types of sustainable investors, those that invest in sustainable funds for financial return and those that do so due to social preferences.

2.2 Drivers of Voluntary Climate-related Reporting

Engagement by investors, who are seeking climate-, and broader sustainability-, related information, has increased voluntary disclosures [Reid and Toffel, 2009]. Flammer et al. [2021] show that investors, especially institutional investors, engaging with companies on climate-risk disclosure have been successful in attaining improved disclosures. Dimson et al. [2015] show that successful engagements by investors on sustainability issues leads to improved financial performance, while Dimson et al. [2021] show that the chances of success in coordinated engagements relating to environmental and social issues are improved if there is a lead investor from the same country as the target firm.

Another channel of external pressure for climate-related disclosure is significant pressure from other stakeholders, especially governments and regulators (Liesen et al., 2015; Reid and Toffel, 2009). Chithambo et al. [2022] show that company's emissions disclosure is most affected by capital providers (primary users), then government regulators, then internal stakeholders and lastly by broader stakeholders such as NGOs, media and competitors.

This external pressure, and stakeholder demand, may also be driven by the increase in climate litigation in recent years [Setzer and Byrnes, 2020], with some litigation focusing specifically on the lack of disclosure [Wasim, 2019]. However, Robinson et al. [2025] suggest that firms respond to peers' lawsuits by providing less verifiable, forward looking and meaningful disclosures in order to minimize the risk of being sued.

Beyond the external determinants of voluntary climate-, and broader sustainability-, related

disclosure there is a growing literature on the company features and internal drivers of such disclosures. Disclosure theory (Core, 2001) suggests that outperforming firms would report on this out-performance, while socio-political theories, such as legitimacy theory (Liesen et al., 2015), suggest that poor Corporate Social Responsibility (CSR) performing firms provide selective disclosures to deceive users of their performance.

Companies which have higher exposure to climate-related risks, often measured by emissions, tend to disclose more (Sullivan, 2009; Dawkins and Fraas, 2011; Hassan and Romilly, 2018; Siddique et al., 2021). Christensen et al. [2021] reviews the literature and shows that company sustainability performance is also related to voluntary disclosure, although the findings are mixed. Beyond this, the industry in which the firm operates in also matters, as research has shown that firms in more polluting, controversial or 'sin' industries tend to disclose more on sustainability issues to shape public opinion (Gamerschlag et al., 2011; Grougiou et al., 2016; Byrd et al., 2017). Part of this may be driven by the early phase of disclosure mandates, which often focussed on these high risk sectors and activities. Further, there is more disclosure after significant environmental or social events, such as oil spills or nuclear disasters (Heflin and Wallace, 2017; Christensen et al., 2021; Bonetti et al., 2024).

One of the most common company factors that drives the quantity of voluntary disclosures is the firm size (Hahn and Kühnen, 2013; Thorne et al., 2014 Qiu et al., 2016). This has been attributed to the level of attention on larger firms (Thorne et al., 2014) or that the relative proportionate cost of reporting on sustainability issues may be lower (Wickert et al., 2016). Firm financial performance also seems to increase environmental disclosures (Clarkson et al., 2008;Luo, 2019). Another stream of literature reports association of voluntary reporting with manager characteristics, such as education, personal views, ethnicity, whether the CEO has a daughter, confidence, prior expertise with CSR issues, and manager capabilities (Haniffa and Cooke, 2005, Adams and McNicholas, 2007; Parker, 2014; Lewis et al., 2014; Peters and Romi, 2015; Cronqvist and Yu, 2017; McCarthy et al., 2017; Davidson et al., 2019; Daradkeh et al., 2023). Another factor related to climate-related disclosure by firms is board diversity (Ben-Amar and McIlkenny, 2015; Cordeiro et al., 2020).

Overall, the external and internal factors outlined above can lead to voluntary climate-related disclosure, however this information is still highly incomplete and non-comparable and therefore

not decision useful. In this study we focus on exploring the effects of the climate-related disclosure mandate in New Zealand. However, we also explore the drivers of voluntary disclosures through our novel survey executed before the mandate came into affect.

2.3 The Need for Mandatory Climate-related Reporting

Although disclosure of climate related risks is increasing globally [Christensen et al., 2021] and in New Zealand (see figure 1), researchers have raised concerns regarding the diverse approaches in voluntary climate-related disclosures regarding quality, credibility, and comparability (Sullivan and Gouldson, 2012; Depoers et al., 2016; among others). Globally, most disclosure regulations do not require much-needed climate-related information, although the adoption of mandatory climate-, and other sustainability-, related disclosure regulations is growing.

One issue with voluntary disclosure frameworks, such as the TCFD, is that they allow companies to pick and choose which elements of the recommendations to follow, therefore leading to incomparability and a lack of information. The 2023 TCFD status report (TCFD, 2023) shows that although overall disclosure is increasing, companies voluntarily reporting on climate-related risks are selective in which parts of the recommendations they disclose on. For example, in 2022, only 11% of the examined companies are reporting climate-related scenario analysis. Bingler et al. [2022, 2024] use a sophisticated machine learning model to analyze the disclosures of firms which are in support of the TCFD and find that TCFD support is mostly cheap talk and that these firms are predominantly cherry picking to report non-material climate risk information. Further, the authors show that much of the information disclosed after the TCFD recommendations were released may not be new information, but rather information structured in a new way.

Further, there is some evidence on the lack of quality or even green-washing in corporate voluntary climate-related reporting. Pitrakkos and Maroun [2020] show low-quality carbon reporting by listed firms on the Johannesburg stock exchange, arguing that firms only report to mitigate stakeholder pressure. Wedari et al. [2021] provide some initial evidence pointing to green-washing by high emitting companies in Australia. Elliott and Löfgren [2022] show that although Banks, which finance fossil fuel companies, are disclosing more actions on climate change there are very few clear commitments in relation to the financing fossil fuels.

An emerging stream of literature has investigated asset manager 'greenwashing', or lack of capability, where institutions overstate their commitment to responsible investing (Kim and Yoon, 2023; Gibson Brandon et al., 2022, among others). By appearing more responsible than they truly are, greenwashing enables funds to profit from the increased demand for ESG investing Gibson Brandon et al. [2022]. Several studies have shown that investor public commitments, such as signing up to the United Nations Principles for Responsible Investing (UNPRI), do not mean much in actual sustainability performance (Kim and Yoon, 2023; Gibson Brandon et al., 2022, among others). Further, the labelling of funds to indicate they are a responsible or sustainable option, does not mean much in term of their portfolio sustainability performance [Raghunandan and Rajgopal, 2022]. Diaz-Rainey et al. [2022] find similar evidence of greenwashing for retail investment funds in New Zealand.

Some of the information required to determine the climate-related risks and opportunities of companies is available through media, scientific analyses, and new methodologies incorporating earth observation through satellites and Artificial Intelligence [Burke et al., 2021]. However, even these new and sophisticated methods, which implement earth observation, are limited by asset-level data, to tie physical risks/emissions estimates to a particular company. Currently, many investors, creditors, and other stakeholders must rely on estimated emissions, let alone other climate-relevant information, in their analysis of companies. However, estimated emissions of non-disclosing firms can be inaccurate (Nguyen et al., 2023b; Nguyen et al., 2023a).

Issues of unreliable data become even more prevalent when investors and lenders want to incorporate broader Environmental and Social factors, which is often done using ESG scores, rankingss and/or ratings. A majority (56%) of asset managers surveyed by Eccles et al. [2017] identified a lack of standardization as a barrier to ESG integration. Major data providers include Refinitiv, Bloomberg, Sustainalytics, MSCI and many more, supply ESG data formed using different methodologies, measurement techniques, categories, and scoring methods. These differences in approahces which compromises their comparability and consistency (Chatterji et al., 2016; Berg et al., 2022). Additionally, there is some evidence of historical ESG scores, by providers, changing without any announcement in methodology change, compromising their use in back-testing or evaluating sustainability performance of companies or portfolios [Berg et al., 2021], which is likely driven by

incentives to provide financially material data points.

Mandatory disclosures will not eliminate the potential for Greenwashing as firms may respond with boilerplate reporting [Dyer et al., 2017]. Therefore an important element of an effective climate-related disclosure regime is the need for effective enforcement and assurance. Enforcement is not only important to the effectiveness of climate-related disclosures (Byrd et al., 2017), but disclosure rules in general (Bhattacharya and Daouk, 2002; Landsman et al., 2012; Christensen et al., 2013; Christensen et al., 2016). Peters and Romi [2013] show that even the compliance with SEC disclosure rules for environmental sanctions is low, despite the use of bright-line materiality thresholds. In climate-related disclosures enforcement is even more challenging than in financial disclosures, as the reported information is more difficult to verify with many different measurement systems and use of external information[O'Dwyer, 2011]. With the introduction of a mandatory regime, regardless of assurance requirements, demand for third-party assurance is likely to go up, as it did in China, Denmark, Malaysia and South Africa [Ioannou and Serafeim, 2019], for these countries' early phase disclosure mandates.

The early phase disclosure requirements, as studied by Krueger et al. [2024], Gibbons [2024] and others, also face some of the issues of voluntary disclosures, as they do not provide standardized, consistent and comparable information.

Overall, the literature supports the need for mandated climate-related disclosure and the insufficiency of voluntary reporting, to support the enormous reallocation of capital required to mitigate and adapt to climate change, to avoid mis-pricing of risks, and to address green-washing. Not only can mandatory climate-related reporting improve information flows for investors, creditors and other stakeholders and therefore support the capital reallocation and investor engagement process, but it can also accelerate transitions of companies as it incentivizes an internal learning process [Armour et al., 2021].

Our study is the first empirical analysis of the new era of comprehensive climate-related disclosure mandates, testing the effectiveness of the ANZCS in achieving the policy aim of improving reporting practices and capital allocation toward the ultimate goal of a low-emission climate-resilient economy.

2.4 Effects of Reporting and Reporting Mandates

The incorporation of climate risks into market prices is essential to efficiently channel resources to sustainable projects and to mitigate the risk of abrupt repricing of highly exposed assets. However, the overall evidence on the relationship between climate, and broader ESG, risks and financial performance of firms is somewhat mixed, although most recent studies show a positive or neutral relationship (Gillan et al., 2021; Friede et al., 2015). There is evidence that emissions and climate risks are already being priced in stock markets (Chapple et al., 2013; Matsumura et al., 2014; Clarkson et al., 2015; Griffin et al., 2017; Choi and Luo, 2021; Bolton and Kacperczyk, 2021a; Aswani et al., 2024; Sautner et al., 2023; Ilhan et al., 2023b), bond markets (Duan et al., 2023; Seltzer et al., 2022; Gehricke et al., 2024) and in derivatives (Ilhan et al., 2021; Ford et al., 2022). However, these results are sensitive to how emissions are measured or estimated [Aswani et al., 2024]. Berg et al. [2024] show that MSCI ESG ratings of firms (not the other 4 major providers) significantly affects fund holdings of those firms, by investment funds with ESG labels. Further, it has been shown that climate risks are affecting the cost of capital and leading to less favorable financing terms (Chava, 2014; Herbohn et al., 2019; Zerbib, 2019; Javadi and Masum, 2021; Bolton and Kacperczyk, 2021b; Huang et al., 2022; Ehlers et al., 20222; Ginglinger and Moreau, 2023). So markets are pricing these risks to some degree, when the information is available.

The most relevant strand of literature to this study is studying the effects that the early phase disclosure regulations have. Here we need to be distinct in how we define different types of these disclosure regulations. As described earlier, there is the early phase of disclosure mandates requiring specific disclosures on emissions and other topics and focusing on a subset of climate-related risk and covering specific sectors of the economy, usually those that have large impacts. Also as part of this early phase are reporting requirements set out by specific stock exchanges, often on a comply or explain basis. These mandates have been studied by some authors, as they have existed for some time. According to Krueger et al. [2024] the earliest of these is disclosure rules set in Australia in 2001, altohugh this focussed only on corporate governance. Gibbons [2024] shows that improved non-financial disclosure requirements affect investment and outcomes, while Krueger et al. [2024] show that they improve firm liquidity. Bauckloh et al. [2023], show that the Greenhouse Gas Reporting Programme (GHGRP), launched in the U.S. in 2009, decreased effected firm

carbon emission intensity, but not absolute emissions. Fiechter et al. [2022] show that mandatory non-financial disclosure in the EU improved Corporate Social Responsibility (CSR) reporting and activities, with firms preparing for the disclosure requirement with some early reporting. Several studies have shown that mandated emission reporting by companies listed on the London Stock Exchange, which was initiated in the U.K. in 2013, led to decreases in subsequent emissions of the reporting companies in the U.K. (Tang and Demeritt, 2018; Jouvenot and Krueger, 2019). Miller et al. [2023] show that U.S. insurance companies reduced their investments in fossil fuels by 20% relative to non-disclosers after a law required such disclosures and this effect remained even after that policy was rescinded.

The EU has also passed several directives that mandate increased sustainability disclosures and Fiechter et al. [2022] show an increase in sustainability related activities and that this occurs in the lead up to the Non-Financial Reporting Directive(NFRD), which was adopted in 2014 and replaced by the Corporate Sustainability Reporting Directive CSRD at the start of 2024, which is being simplified under the omnibus package in 2025.The EU regulations also face an implementation delay as the member states have to ratify the rules into their own jurisdiction. Brié et al. [2024] show that the NFRD improved the quality and comparability of disclosures in Europe. Mésonnier and Nguyen [2020] show that the French Article 173, which required investors and insurers to disclose on climate risk exposure and became effective at the start of 2016, reduced the regulated entities financing of fossil fuel energy companies.

Overall, the evidence in this literature provides support for the hypothesis that mandated climate-related disclosures can affect company and investor/creditor behavior. However, there is not yet any research examining the effects of comprehensive climate-related disclosure mandates. These mandates require reporting in line with the full recommendations of the TCFD and ISSB, and this study is the first to explore the effect of the first of these mandates.

3 Data

3.1 Survey Design and Distribution

The initial survey was drafted by the authors based on the published literature employing relevant surveys [see e.g. Amel-Zadeh and Serafeim, 2018, Krueger et al., 2020, Diaz-Rainey et al., 2024, Ilhan et al., 2023a] as well as insights from the interviews of New Zealand CREs executed and analysed by Walton et al. [2024] in 2023.

The draft survey underwent revisions based on feedback from the Director of Sustainable Reporting and her team from the XRB, with questions adjusted accordingly. The survey is organized into five streams for different stakeholders: investor, creditor, insurer, corporate, and other stakeholder. The final version of the survey contains a maximum of 41, 37, 34, 30, and 8 questions for the streams mentioned above, respectively.

To prevent respondent fatigue, we used a branching logic to tailor questions based on prior responses (see Figure 5). While most questions were uniform across streams, we changed wording slightly to reflect the different nature of these organizations.

The survey includes a large number of questions, but in this paper, we will focus on those questions related to voluntary reporting practices, motivations and challenges.

The survey was open from November 2023 to January 2024, a crucial time right before the mandatory reporting period commenced, to try and elicit a representative sample of CREs and Primary Users. It was distributed through various channels including emails, LinkedIn messages, inclusion in various industry body newsletters and others. Next LinkedIn posts inviting participation were developed by the XRB and the Centre for Sustainable Finance: Toitū Tahua, in early November and shared by others. Further, the research team asked several industry bodies such as the Institute of Financial Professionals New Zealand (INFINZ), the Financial Services Council (FSC), Boutique Investment Group (BIG), who shared the invitation via their newsletters and/or other mailings.

The final sample for the survey is composed of 70 usable responses from CREs, PU and voluntary reporters (those entities making voluntary non-financial disclosures not compelled by the mandate). Table 2 provides a summary of the respondent sample demographics. In the table we can see that

the survey respondents present a well distributed sample for our analysis in terms of size of entity, voluntary and mandatory reporters (CREs), capital allocaiton horizons (lending and investing), and entity type. Further, most of the respondents are in a position of middle and upper management.

3.2 Non-Financial Disclosures

In order to analyse non-financial disclosures of CREs using a Large Language Model (LLM)-based system (explained in section 4.1) and their reporting practices, we need to collect their disclosure documents.

First, we collect all relevant voluntary non-financial disclosures by CREs. The collection and classification of these disclosures is a non-trivial task. We download all voluntary non-financial disclosures made by CREs from the financial year 2015-2022. These reports are sourced from entity websites and classified. In short, when a company does not have a voluntary standalone climate or sustainability-related report, we check whether the group entity (parent company) has such a disclosure. If that is not the case, we check whether the annual report includes some Climate-related or broader Sustainability-related disclosure. The logic for this classification is presented in Figure 3.

Second, we need to collect the mandatory non-financial disclosures by the CREs, which is made much easier due to the database of climate reporting managed by the regulator. For these reports, we simply download them from the registrar and classify them into Climate-related report (1), broader Sustainability-related report (2) or annual report (3).

3.3 Investment Manager Portfolio Data

In order to evaluate how fund managers are changing their investment strategies and decision-making, both due to the policy and in relation to the reporting by New Zealand companies, we retrieve quarterly portfolio-level sustainability-related metrics from Morningstar for the period from 2015 until 2025. These metrics include the Morningstar Sustainability Rating, Carbon Risk Score, ESG Managed Risk Score, ESG Risk Exposure Score, and Scope 1 and 2 Carbon Intensity. Beyond this, we also download additional portfolio-level data for the control variables, as described in the methodology section below.

4 Methodolodgy

4.1 Textual Analysis of Climate-related Reporting in New Zealand

Our goal is to analyse whether the reporting of a company is aligned with the ANZCS issued by the XRB. For facilitating the analysis, we proceed in three steps.

First, we create indicators along which we want to analyze companies' disclosures. We use the individual mandatory disclosure elements proposed by the XRB. We formulate each of them in a question form that can be answered using a Yes or a No (e.g., "Does the entity explain which governance body is responsible for climate related risks or opportunities?"). A "Yes" answer indicates that the element is disclosed, while a "No" answer indicates a gap in reporting. Additionally, we create a question explanation to ensure a clear and precise understanding of what the question refers to for models and humans. As a result, we obtain 58 yes/no questions with explanations to analyze a single report. In line with the original disclosure standard, all questions can be differentiated in the four categories: Governance, Strategy, Risk Management, and Metrics and Targets (see Appendix A.1 for details).

This question structure prepares the second step: we create a Large Language Model (LLM)-based system to analyze corporate climate disclosures. Specifically, we use a method called Retrieval Augmented Generation (RAG). In RAG, the LLM is relying on external context to produce answers rather than internal knowledge seen during training. In our case, we provide the LLM with excerpts of the company's climate disclosures to base the answers on [see e.g., Lewis et al., 2021, Gao et al., 2024]. The model cites the climate report directly to produce an answer. This way, we ensure that we have control over the knowledge base of the model and allow transparency of why the model judges in a certain way. We draw on a wide range of previous literature of RAG models in the computer science [Schimanski et al., 2024b,a] and the sustainable finance domain [Ni et al., 2023, Vaghefi et al., 2023, Senni et al., 2025]. An overview of our RAG pipeline can be seen in Figure 6. For implementation details, see Appendix A.2.

The final RAG system works as follows. It takes a report as input and creates a Yes/No verdict for each of the 56 questions. Additionally, the LLM creates a verdict justification and cites the source pages, increasing both traceability and transparency. This way, we can create a *Compliance*

Index (CI) that indicates how many questions are answered with "Yes", i.e., how many elements are disclosed:

$$CI_{i,t} = \frac{\sum_{j=1}^{\#Indicators} \text{YesVerdict}_{i,t,j}}{\#Indicators} \tag{1}$$

where $CI_{i,t}$ is the Compliance Index for company i in year t. $\text{YesVerdict}_{i,t,j} \in \{0,1\}$ is a binary variable that equals 1 if the verdict to indicator j is "Yes" and 0 otherwise, and $\#Indicators = 58$ is the total number of indicators.

Besides the Yes/No verdict itself, we also calculate a confidence score for the verdict. An LLM will produce a probability between 0–1 for every token (vaguely every word) in its output. Since we know that the LLM will produce either a Yes or a No, we can use the probability of these tokens as a confidence score of the model, as demonstrated in prior research [Liang et al., 2023, Ni et al., 2024]. Knowing the confidence allows us to create a more nuanced version of the *CI* that accounts whether a question is fully or only partially addressed. We calculate a *Compliance Index with Confidence (CIC)* as follows:

$$CIC_{i,t} = \frac{\sum_{j=1}^{\#Indicators} \text{YesVerdict}_{i,t,j} \cdot \text{Confidence}_{i,t,j}}{\#Indicators} \tag{2}$$

where $\text{Confidence}_{i,t,j} \in [0,1]$ is the model's confidence that the answer to indicator j for company i in year t is "Yes". This formulation allows partial credit for verdicts with lower confidence while still preserving the binary nature of the original question. We calculate both the *CI* and *CIC* on the report-level with all indicators as well as on the category-level (Governance, Strategy, Risk Management, and Metrics and Targets).

In our third step, we validate the performance of our RAG system on our task. This is crucial to obtain an understanding of how trustworthy the system is. For this purpose, we annotate all verdicts for all indicators for ten reports. As a result of this process, we find that the model's yes/no verdicts are correct in 91% of the cases. This confirms the usefulness of the methodology. For details, see Appendix A.3.

4.2 Mandate Effect on the Disclosures

In order to test the effect of the climate-related disclosure mandate, effective for the 2023 financial reporting year (2024 calendar year reporting) we employ a interrupted time series analysis (ITS), as below:

$$\overline{CI_{i,t}} = \beta_0 + \beta_1 Year_t + \beta_2 D_t^{Post}, \tag{3}$$

where $CI_{i,t}$ is the average of the annual *Compliance Index* ($\overline{CI_t}$ or the *Compliance Index Confidence* ($\overline{CIC_t}$, described above, accross all CREs, described in section 4.1. $Year_t$ captures the time trend, as it is the number of years since the 2015 financial year (the start of the sample period). Lastly, D_t^{Post} is a dummy variable that is zero for all reports of financial years before 2023 and one from 2023 onward.[7] Therefore, the β_2 coefficient is estimating the effect of the climate-related reporting mandate on the average disclosure CREs, while the improved reporting over time is captured by β_1.

We further estimate the ITS described in equation (3) for the 4 entity types, that is, Corporate Issuers, Licensed Insurers, Bank or Building Society and Manager of a Managed Investment Scheme (MIS). Equation (3) is also estimated using the average disclosure index for each category of the disclosure standards, that is Governance, Strategy, Risk Management, Metrics and Targets. The results of this analysis are presented and interpreted in section 5.2

Further, we need to account for the cross-sectional variation among CREs, so we employ the following Panel regression model:

$$CI_{i,t} = \beta_0 + \beta_1 Year_t + \beta_2 D_t^{Post}, \tag{4}$$

where $CI_{t,i}$ is the log-transform of the company specific *Compliance Index* or *Compliance Index Confidence* $CIC_{t,i}$ at year *t*. $Year_t$ is again the year since 2015 and D_t^{Post} is the dummy variable testing the disclosure mandate's impact. In this panel regression model we include company fixed effects to account for company specific characteristics that may influence climate-related disclosure

[7] in the sample of this study only the 2023 financial year has been included as reporting for the 2024 financial has only just begun.

practices.

4.3 Mandate Effect on Capital Allocation

Next, we turn to the investigation of how the mandate affects capital allocation by New Zealand Investors, particularly exploring the effect on capital allocation of investment managers that are also CREs. Most pertinent to this asset allocation is the fund level ESG performance. To answer this we employ a Difference-in-Difference (DiD) analysis on the portfolio level ESG metrics of New Zealand asset managers, as below:

$$ESG_{i,t} = \beta_0 + \beta_1(\text{Treated}_i \times \text{Post}_t) + \sum_{j=1}^{J} \gamma_j X_{j,i,t} + \alpha_i + \varepsilon_{i,t} \tag{5}$$

where $ESG_{i,t}$ is the portfolio-level ESG metric of interest for fund i in quarter t, *Treated* is the treatment indicator, that is one when the fund is part of a CRE and zero when not. The ESG metrics we test ($ESG_{i,t}$) are all sourced from Morningstar, namely the fund level Sustainability rating, Carbon Risk score, ESG risk exposure score and portfolio level scope 1 and 2 carbon emissions intensity (emissions per $ revenue). Further, we want to test the effect of the climate-reporting mandate announcement and effective date, so *Post* is the indicator for whether the time period is after the policy announcement or effective date. $Treated_i \times Post_t$ is the key DiD interaction term. The individual $Treated_i$ and $Post_t$ are not included as they are perfectly collinear with the fund fixed effects (α_i). $X_{j,i,t}$ represents our various control variables, namely the fund's market value, quarterly return and age, inspired by the literature (Raghunandan and Rajgopal, 2022; Alda, 2020; Diaz-Rainey et al., 2022). The regression is estimated as a panel regression with fund clustered standard errors.

5 Results

5.1 Survey

In this study, we predominantly use the survey, described in section 3.1 to explore the motivations for voluntary reporting, before the mandate takes effect, and the challenges that voluntary reporting

entities face in reporting.

Table 3 first presents the frequency of survey respondents that started voluntary reporting on climate-, and broader sustainability-, related information before the mandate became effective in Panel A. We can see that most of these respondents started reporting after the 2019 financial year which coincides with the passing of the The Financial Sector (Climate-related Disclosures and Other Matters) Amendment Act 2021. Very few of the respondents were reporting before then, which also coincides with our analysis of CRE voluntary reporting presented in the next section. Further, in Panel B of the table, we breakdown respondents reasons for voluntary reporting. We can see that the most common reasons for voluntarily reporting before the mandate are reputational, in line with legitimacy theory, but also to integrate climate-related risks and opportunities into their entity's strategy and risk management. About half of the respondents that engage in voluntary reporting did so in order to prepare for the upcoming mandatory regime.

The Challenges the survey respondents faced with climate-related reporting are presented in Table 4 and broken down by corporate issuer and non-corporate issuer, as well as early (voluntary) reporters and late reporters (those that have not reported beofoe the mandate). We can see that the two most challenging aspects of this reporting are the lack or reliable and comparable data as well as the resource cost of preparing the disclosures, both of which are more common for late, relative to early, reporting entities. Having to grapple with multiple reporting frameworks and uncertainty around regulation were also flagged by about half of the respondents. Some other challenges of note are inadequate capabilities within the organization, climate scenarios and integration of climate-related risk into the risk management processes. However, across all of the challenges early reporters, those that started reporting before the mandate, did not view these as challenging as often as late reporters. This indicates that actually doing the reporting, which is now required by the mandate, may alleviate these challenges for some entities.

The survey results, on a whole, show that New Zealand climate-related Financial reporting mandate motivates voluntary reporting prior to the 2023 Financial Year, but that this is also driven by reputational and business strategy improvements. While respondents face many challenges in developing their climate-related disclosure requirements, thos that have started with reporting face these challenges less frequently. This may indicate that by doing the reporting firms learn and

improve their practices, leading to the desired outcomes of the regime. In the next section we explore, employing our RAG model, how the reporting by CRE evolved over time, including the mandatory reporting after the survey was completed.

5.2 Mandate Effect on the Reporting by CREs

In this section we explore the effect of the Climate-related disclosure mandate on the climate-related reporting practices of the CREs. Firstly, we need to understand the quantum of reporting, which is represented in figure 1 for all the CREs and for each entity type. We can see that the number of companies including some voluntary reporting of of climate-, and broader sustainability-, related information has been gradually increasing over time, with a significant jump after the reporting mandate takes effect.[8] The second graph in Figure 1 shows that the voluntary reporting was dominated by corporate issuers, with a large jump in the number of investment managers reporting after the mandate. This will be partially driven by the fact that fund management CREs need to release a climate-related disclosure for each of their Managed Investment Schemes (MISs) leading to multiple report per entitiy.

Figure 7 displays the annual average of our Compliance Index $\overline{CI_{i,t}}$ and the Compliance Index Confidence $\overline{CIC_{i,t}}$ over time. Visually, we can observe the gradual increase in disclosure quality and quantity elading up to the mandate, with a much steeper increase in the effective year of the mandate. This pattern holds for all categories of the ANZCS, that is Governance, Risk Management, Strategy and Targets and Metrics. Further, in Table 5 we can observe the summary statisctis of the Compliance Index $\overline{CI_{i,t}}$. $\overline{CI_{i,t}}$ improves in the year before the mandate, relative to previous voluntary reporting, and improves again, almost doubling, in the effective year of the mandate. This again shows the improvements in reporting leading up to and after the mandat. Table 6 further breakes down the $\overline{CI_{i,t}}$ by the disclosure standard category, that is Governance, Strategy, Risk Management and Metrics and Targets. The table shows that reproting improves across all catagories, on average. The easiest, or most standardized, category of ANZCS is the Governance section, where we can see that $\overline{CI_{i,t}}$ is almost a perfect score after the mandate. The other categories also improve vastly with the lowest scores being observed in the most useful component of

[8]Note, that the data collection of disclosures by CREs for the 2023 Financial Year was completed in September 2024, so does not capture all of the first year of mandatory reports.

the disclosures, the Metrics and Targets section. This is likely because this is also the most resource intensive section of the ANZCS as it requires the quantification of climate-related risks, which is not yet standardized or easy.

Next, we explore the effect of the disclosure mandate on the information that is reported by entities using a Interrupted Time Series approach as described in section 4.2 above. We first explore the effect on average compliance index scores ($\overline{CI_i, t}$). In Figure **??**, we can see the annual average observations of the index and the fitted ITS model from equation (3), overall, by entity type and by section of the ANZCS. Visually, we can see a jump in reporting after the mandate takes effect. The only outlier is the MIS entity reporting which is quite comprehensice in 2017 and 2018 and then drops before increasing again for 2023 financial year reporting. We believe this is driven by outliers, as the averages for MIS ($\overline{CI_i, t}$) is sourced from only two reporting entities in those years, skewing the data.

Table 7 below presents the results of the model described in (3) using the average CI_t and CIC_t scores overall and for each entity type. We can observe that overall the *Post* indicator is positive and statistically significant at the 1% level of significance. This means that the disclosure mandate significantly improves the reporting by CREs. When we look into the breakdown by entity type we can see that this improvement in reporting is driven mostly by corporate Issuers and Creditors (Banks and Building Societies). Where insurers seem to have a gradual increase in reporting over time with no significant increase after the mandate. Further, we can again observe the MIS outlier, represented by a low *R-square* (goodness of fit) value and an insignificant *Post* coefficient.

Table 8 presents the results analyzing the mandatory disclosure effect on the average CI_t and CIC_t again, but this time broken down by the category of the disclosure standards, that is Governance, Strategy, Risk Management, and Metrics and Targets. The Table shows that all categories of the reporting have improved significantly due to the disclosure mandate, with Risk Management and Governance seeing the largest improvements and Metrics and Targets, arguable the most difficult and useful component of the disclosure standards, improving the least.

The significant increase in average CI_t for most entities and across all categories of the disclosures combined with the increased quantity of disclosures gives us some initial evidence that the mandate has had its intended effect of improving climate-related reporting by the CREs.

In order to explore the effect of the climate-related disclosure mandate further while incorporating the variation across CREs, we run the panel regression as described in equation (4). Table 9 shows the panel regression results overall and by entity type, while Table 10 shows the result by disclosure category.

Table 9 presents an overall consistent result to the average CI_t results, that is reporting improves as a result of the disclosure mandate and that is drven by the improvements from corporate Issuers and Creditors (Bank or Building Society). However, when we interact company fixed effects with the time trend (Panel B) we can see that the results are driven only by the corporate issuers. This, combined with the previously discussed results, shows us that the disclosure mandate is significantly improving CRE disclosures, but this is mainly for corporate issuers, while licensed insurers and creditors were improving their disclosures more over time before the mandate, likely due to their stakeholder demand, the financial materiality of these issues of in anticipation of the disclosure standard. This is consistent with the survey findings which show that...

In Table 10 we can observe that all components of the disclosures are improving over time leading up to the mandate, but also when the mandate becomes effective. The improvements are largest in the Fovernance and Risk Management components, while Strategy and Metrics and targets componensts are improved by a smaller magnitude. In Pabel B, when we include company specific time trends, we can see that the impact of the mandate reduces, but it is still positive and statistically significant for most of components of the disclosure requirements.

Overall, we conclude that the disclosure mandate has significantly improved climate-related reporting by the CREs, in terms of quantity and quality. All entities, but especially Insurers and Creditors improved their reporting in anticipation of the mandate while corporate issuers really improved their reporting once the mandate came into effect. The MIS analysis is somewhat problematic as it is driven by very few entities in the early parts of the sample. However, we will the effect of the mandate on CRE MIS manager investment decision making in the next section. Further, the improvements in disclosures are most pronounced in the Governance and Risk Management components, rather than in the Metrics and Targets component, which likely due to the relative difficulty and resource costs of these and that they had a better disclosure before the mandate, as evidence by larger intercepts.

5.3 Mandate Effect on Capital Allocation

Lastly we turn to the effect of the climate-related disclsure mandate on the capital allocation by New Zealand fund managers. Specifically we are interested in exploring how the portfolio level ESG and carbon performance is affected. To explore these effects we employ a DiD analysis as described in Section **??** and equation (5).

Table 11, presents the estimated coefficients of the DiD analysis first using the treatment date representing the passing of the Financial Sector (Climate-related Disclosures and Other Matters) Amendment Act 2021, in October 2021 (Panel A). We can see that the passing of the act led to a significant (at the 1% level of significance) improvement in the portfolio level Morningstar Sustainability Rating of fund managers that are affected by the policy (*Treated*) and a significant decrease (at the 1% level of significance) in the ESG Risk Exposure. However, it seems to also have increased the Carbon Risk Score and the Carbon Intensity of the portfolios of fund managers that are CREs.

In Panel B of Table 11 we estimate the DiD again for the implementation date, that is January 2024 (2023 Financial Year), when reporting began. We would expect fund managers to improve their ESG and climate performance at this point, if not after the announcement date, as the treated funds will have to prepare climate-related disclosures. We can see that the Sustainability Rating significantly increases and the portfolio level Carbon Intensity significantly decreases, both at the 1% level of signicance. There is also a insignificant decrease in the Carbon Risk Score. This shows that fund managers capital allocation decision seem to be affected by the disclosure mandate, as funds reduce their portfolio carbon intensity and increase their general sustainability performance. However, there is also a positive effect on the ESG Risk Exposure score which is contrary to these results.

Overall there seems to be a positive effect on fund manager capital allocation, in line with the goals of the disclosure mandate once the mandate is implemented. However, the results are somewhat mixed and this effect justifies further investigation, especially as time passes and we can explore a richer data set of observations after the intervention.

6 Conclusion

The shift to mandatory climate-related financial disclosures marks a significant advancement from the early phase non-financial disclosure mandates that have been studied to date (Bauckloh et al., 2023; Krueger et al., 2024; Gibbons, 2024; among others). This represents a evolution in the global financial landscape, influencing corporate transparency, investor decision-making, and capital allocation. This study provides the first empirical assessment of the early effects of the world's first climate-related financial disclosure mandate, offering critical insights into how such requirements shape corporate behavior and financial markets.

From our survey of 70 CREs and investors, we could gleam that early voluntary reporters were motivated primarily by reputational benefits and strategic risk integration, while many entities faced challenges related to data reliability, resource constraints, and the complexity of multiple disclosure frameworks. These challenges were less common for those that started their reporting journey before the mandate came into effect, highlighting the value of learning by doing.

Through our RAG model, rooted in the state of the art of Natural Language Processing techniques, we find that the mandate has substantially increased both the quantity and quality of climate-related financial reporting by Climate-Reporting Entities (CREs). The improvements represent the easy wins, that is improved disclosure in the components of ANZCS that are not too complex, such as the Governance and Strategy sections. However, the reporting of the most decision useful and most difficult component, that is the metrics and targets section of the disclosures, is still developing. Furthermore, the widespread use of adoption provisions indicates that while firms are striving to meet the new requirements, they continue to face difficulties in quantifying financial impacts and reporting comparative metrics.

Using a Difference-in-Differences (DiD) framework, we also examine the decision-making behavior of New Zealand fund managers, as they represent a key channel through which capital allocation effects materialize. Our analysis reveals some evidence, although the results are somewhat mixed with only one year of data since the mandate for implemented, that funds which are Climate-Reporting Entities (CREs) demonstrate significantly greater improvements in portfolio-level sustainability performance, as measured by the Morningstar Sustainability rating and decrease

in carbon intensities, compared to those not subject to ANZCS reporting requirements.

This research contributes to the broader discourse on climate-related financial disclosures by offering empirical evidence that mandatory disclosure frameworks enhance the availability and depth of climate-related information, while also driving meaningful shifts in capital markets. Our findings have significant implications for policymakers worldwide, providing support for similar regulatory initiatives in other jurisdictions, which are already being implemented or planned in many countries.

Future research should investigate the longer-term effects of climate-related disclosure mandates, particularly their impact on emissions reductions, corporate transition strategies, and broader economic outcomes. As more data becomes available, and more countries implement such mandates, further analysis will be essential to understanding how these regulations influence both reporting entities and the broader financial ecosystem. By continuing to refine disclosure standards and addressing implementation challenges, regulators can ensure that climate-related financial reporting remains a robust tool for driving sustainable investment and corporate accountability.

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7 Tables and Figures

Table 1: This Table presents the proportion of CREs that used each of the adoption provision, that is specific aspects of the disclosure that are not required to be disclosed in the first year of reporting. This data is collected using the RAG system described in Section 4.1

#	**Adoption Provision**	**N**	**%**
1	Current Financial Impacts	148	77.49%
2	Anticipated Financial Impacts	154	80.63%
3	Transition Planning	120	62.83%
4	Scope 3 GHG Emissions	123	64.40%
5	Comparatives for Scope 3 GHG Emissions	68	35.60%
6	Comparatives for Metrics	169	88.48%
7	Analysis of Trends	150	78.53%

Table 2: This table presents a breakdown of the Survey, described in section 3.1, respondents in terms of frequency and percentage. This includes entity specific characteristics such a type, country, climate initiative signatory, size and investment horizons. It also presents the respondents position within the entity.

Entity Type	#	%
CRE Only	34	48.57%
VRE Only	4	5.71%
PU Only	6	8.57%
Both CRE and PU	21	30.00%
Both VRE and PU	5	7.14%
Total	**70**	
Investor	25	35.71%
Creditor	7	10.00%
Insurer	3	4.29%
Corporate	35	50.00%
Total	**70**	
Early reporter - CRE	29	41.43%
Early reporter - VRE	2	2.86%
Late reporter - CRE	26	37.14%
Late reporter - VRE	7	10.00%
PU only	6	8.57%
Total	**70**	

Country of HQ		
Non-NZ	4	5.71%
NZ	66	94.29%
Total	**70**	

Respondent Position		
Lower or operating management	8	11.43%
Middle management	33	47.14%
Top management	27	38.57%
Governance-level	2	2.86%
Total	**70**	

Climate Initiative Signatories		
No	22	31.43%
Yes	48	68.57%
Total	**70**	

Investor: Size (Total AUM)	#	%
Less than 100 million NZD	0	0.00%
Between 100 million and 500 million NZD	5	20.00%
Between 500 million and 1 billion NZD	3	12.00%
Between 1 billion and 20 billion NZD	13	52.00%
Between 20 billion and 50 billion NZD	3	12.00%
More than 50 billion NZD	1	4.00%
Total	**25**	

Non-Investor: Size (Total Assets)		
Less than 100 million NZD	3	6.67%
Between 100 million and 500 million NZD	5	11.11%
Between 500 million and 1 billion NZD	5	11.11%
Between 1 billion and 20 billion NZD	29	64.44%
Between 20 billion and 50 billion NZD	0	0.00%
More than 50 billion NZD	3	6.67%
Total	**45**	

Investor: Portfolio Holding Period		
No typical holding period; decide on a case-by-case basis	11	44.00%
Less than 12 months	1	4.00%
1 year to 5 years	6	24.00%
5 years to 10 years	2	8.00%
More than 10 years	5	20.00%
Total	**25**	

Creditor: Average Loan Maturity		
Do not know	1	14.29%
Less than 12 months	0	0.00%
1 year to 5 years	4	57.14%
5 years to 10 years	1	14.29%
More than 10 years	1	14.29%
Total	**7**	

Table 3: This table presents summary statistics from the Survey, described in Section 3.1, regarding voluntary reporting practices. Panel A reports the number and proportion of voluntary reporters who made their first voluntary disclosure in each financial year. Panel B presents the frequency and proportion of voluntary reporters who indicated that a given motivation influenced their decision to voluntarily report before the mandate became effective, broken down by corporate issuers and other entities (Investors, Insurers and Banks and Building Societies).

Panel A: Timing of Voluntary Disclosure

FY of First Report	**Freq.**	**%**
Before FY2018	1	3%
FY2018	1	3%
FY2019	2	6%
FY2020	8	26%
FY2021	11	35%
FY2022	8	26%
Total	**31**	

Panel B: Motivations for Voluntary Disclosure

Motivation	**Non-Corporate**		**Corporate**		**Overall**	
	Freq.	**%**	**Freq.**	**%**	**Freq.**	**%**
To demonstrate corporate social responsibility and environmental stewardship	10	91%	18	90%	28	90%
To integrate climate risks and/or opportunities into our entity's strategy	10	91%	11	55%	21	68%
For potential reputation benefits	9	82%	10	50%	19	61%
To improve risk management	7	64%	10	50%	17	55%
To avoid the time pressure and high costs associated with late adoption	4	36%	11	55%	15	48%
To gain a competitive advantage	5	45%	8	40%	13	42%
Pressure from global sustainability or ESG initiatives (please specify)	2	18%	10	50%	12	39%
To attract capital inflows	3	27%	6	30%	9	29%
Pressure from industry peers or competitors	4	36%	2	10%	6	19%
To enhance employee motivation	2	18%	2	10%	4	13%
Pressure from users	2	18%	2	10%	4	13%
Concerns about potential legal action	1	9%	2	10%	3	10%
Other	1	9%	1	5%	2	6%
Total	**11**		**20**		**31**	

Table 4: This table presents summary statistics from the Survey, described in Section 3.1, regarding the challenges of climate-related financial disclosures. This is reported by number and proportion of respondents reporters and broken down by corporate issuers and other entities (Investors, Insurers and Banks and Building Societies) as well as early and late reporters.

Climate Rerporting Challenge	**Non-Corporate**		**Corporate**		**Early Reporter**		**Late Reporter**		**Overall**	
	Freq.	**%**	**Freq.**	**%**	**Freq.**	**%**	**Freq.**	**%**	**Freq.**	**%**
Lack of reliable and comparable data	24	83%	28	80%	24	77%	28	85%	52	81%
Cost or resource burden of preparing the disclosures	23	79%	25	71%	23	74%	25	76%	48	75%
Aligning with multiple reporting frameworks or standards	16	55%	16	46%	15	48%	17	52%	32	50%
Uncertainty surrounding regulatory frameworks and policies	16	55%	14	40%	9	29%	21	64%	30	47%
Developing or using climate scenarios	14	48%	15	43%	13	42%	16	48%	29	45%
Inadequate capabilities within the organisation for assessing climate risks and/or opportunities	14	48%	13	37%	10	32%	17	52%	27	42%
Integrating climate change considerations into existing risk assessment processes	16	55%	10	29%	11	35%	15	45%	26	41%
Identifying risks and opportunities posed by climate change	14	48%	8	23%	9	29%	13	39%	22	34%
Revealing commercially sensitive information	5	17%	12	34%	9	29%	8	24%	17	27%
Lack of stakeholder demand or interest	7	24%	6	17%	4	13%	9	27%	13	20%
Other	6	21%	5	14%	5	16%	6	18%	11	17%
Lack of support from the board or senior management	3	10%	1	3%	3	10%	1	3%	4	6%
Total	**29**		**35**		**31**		**33**		**64**	

Table 5: This Table presents summary statistics for the Compliance Index $CI_{i,t}$, as described in section 4.1, overall and for sub-sample period. Namely the Mandatory reporting period covering the 2023 Financial Year, the last year before the mandate, the 2022 Financial Year and the entire voluntary reporting period, that is the 2015-2022 Financial Years.

Period	**Mean**	**St. Dev**	**Min**	**Max**	**Report Count**
Overall	34.62	26.07	0.00	93.10	845
Mandatory	64.28	15.00	1.72	93.10	202
2022 Financial Year	38.19	22.22	0.00	79.31	122
Voluntary	25.30	21.43	0.00	79.31	643

Table 6: This Table presents summary statistics for the Compliance Index $CI_{i,t}$, as described in section 4.1. This is presented for the sub-sample period of mandatory (2023 Financial Year) and voluntary (before 2023 Financial Year) reporting periods, by ANZCS category.

		Mandatory (188 reports)		**Voluntary** (634 reports)	
Category	**# Prompts**	**Mean**	**St Dev**	**Mean**	**St Dev**
Governance	10	95.96	6.59	27.44	33.52
Metrics and Targets	15	46.06	21.75	20.62	19.32
Risk Management	5	74.36	17.80	17.95	25.62
Strategy	29	71.52	15.38	32.31	23.10

Table 7: This table presents the results of the Interrupted Time Series (ITS) analysis as described in Section 4.2 and defined in equation (3). The results are presented for the mean Compliance Index $\overline{CI_{i,t}}$ and the mean Compliance Index with the model confidence adjustments $\overline{CIC_{i,t}}$. All results are presented overall and by entity type.

Index	Entity type	R^2	Intercept	Year	Post
$\overline{CI}$	Overall	0.978	10.7319***	3.4215***	3.2720***
	Licensed Insurer	0.869	10.4063*	4.7498***	1.5121
	Issuers	0.975	6.7024**	3.6493***	4.1818***
	Manager of registered MIS	0.212	38.6825***	1.8311	0.7811
	Bank or Building Society	0.796	29.1449***	1.8541	3.9256**
$\overline{CIC}$	Overall	0.978	9.5815***	3.2060***	3.2972***
	Licensed Insurer	0.875	9.5114*	4.4964***	1.5308
	Issuers	0.976	5.8488**	3.3945***	4.2302***
	Manager of registered MIS	0.216	36.2330***	1.6818	0.8979
	Bank or Building Society	0.817	26.2810***	1.8661	3.8951**

Table 8: This table presents the results of the Interrupted Time Series (ITS) analysis as described in Section 4.2 and defined in equation (3). The results are presented for the mean Compliance Index $\overline{CI_{i,t}}$ and the mean Compliance Index with the model confidence adjustments $\overline{CIC_{i,t}}$. All results are presented overall and by ANZCS category.

Index	Category	R^2	Intercept	Year	Post
$\overline{CI}$	Overall	0.979	7.8293***	4.0317***	3.9470***
	Governance	0.964	2.9062	5.8891***	5.6968***
	Metrics and Targets	0.970	12.2127***	2.0300***	2.2047***
	Risk Management	0.988	0.3755	4.2432***	4.9425***
	Strategy	0.984	15.8228***	3.9646***	2.9437***
$\overline{CIC}$	Overall	0.980	6.7896**	3.7745***	3.9793***
	Governance	0.967	1.6424	5.6542***	5.9348***
	Metrics and Targets	0.969	11.2184***	1.8783***	2.1501***
	Risk Management	0.989	0.0498	3.8549***	4.7947***
	Strategy	0.985	14.2478***	3.7107***	3.0376***

Table 9: This table presents the results of the panel Interrupted Time Series (ITS) analysis as described in Section 4.2 and defined in equation (4). The results are presented for the Compliance Index $C_{i,t}$ and the Compliance Index with the model confidence adjustment $\overline{CIC}_{i,t}$. Panel A presents the result with a general time trend, while Panel B estimates the model with entity specific time trends. All results are presented overall and by entity type.

Panel A: General Time Trend					
Index	**Category**	R^2	**Intercept**	**Time**	**Post**
$CI_{t,i}$	Overall	0.764***	1.2259***	0.2557***	0.5505***
	Licensed Insurer	0.673***	1.2770***	0.2636***	0.1423
	Issuers	0.765***	0.1230	0.2730***	0.7313***
	Manager of registered MIS	0.638*	2.7522***	0.1315	0.0565
	Bank or Building Society	0.629***	1.9392***	0.1725**	1.2006***
$CIC_{t,i}$	Overall	0.773	1.1852***	0.2551***	0.6068***
	Licensed Insurer	0.677***	1.2601***	0.2601***	0.1769
	Issuers	0.775***	-0.0040	0.2722***	0.7993***
	Manager of registered MIS	0.653	2.6768***	0.1271	0.1035
	Bank or Building Society	0.642***	1.8404***	0.1756***	1.2367***
Panel B: Company Specific Time Trend					
Index	**Category**	R^2	**Intercept**	**Time**	**Post**
$CI_{t,i}$	Overall	0.873***	-0.6315***	0.5508***	0.3073**
	Licensed Insurer	0.808**	-0.8716	0.5932***	0.1661
	Issuers	0.860***	0.0970***	0.2873***	0.4241***
	Manager of registered MIS	0.786	2.1792***	0.2588***	-0.1857
	Bank or Building Society	0.839***	-6.1953***	1.5283***	0.2159
$CIC_{t,i}$	Overall	0.879***	-0.6506***	0.5470***	0.3619***
	Licensed Insurer	0.815**	-0.9997	0.6086***	0.1565
	Issuers	0.866	-0.0881**	0.2994***	0.4925***
	Manager of registered MIS	0.801*	2.1242***	0.2517***	-0.1544
	Bank or Building Society	0.849***	-6.6495***	1.5906***	0.2507

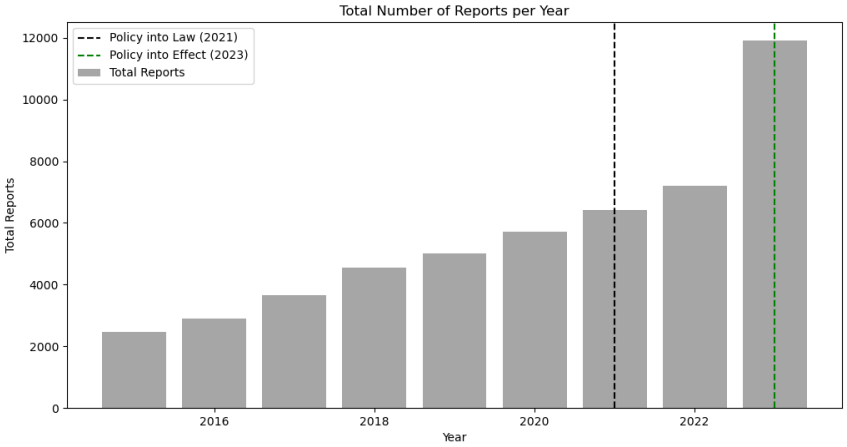
Table 10: This table presents the results of the panel Interrupted Time Series (ITS) analysis as described in Section 4.2 and defined in equation (4). The results are presented for the Compliance Index $C_{i,t}$ and the Compliance Index with the model confidence adjustment $\overline{CIC}_{i,t}$. Panel A presents the result with a general time trend, while Panel B estimates the model with entity specific time trends. All results are presented overall and by ANZCS category.

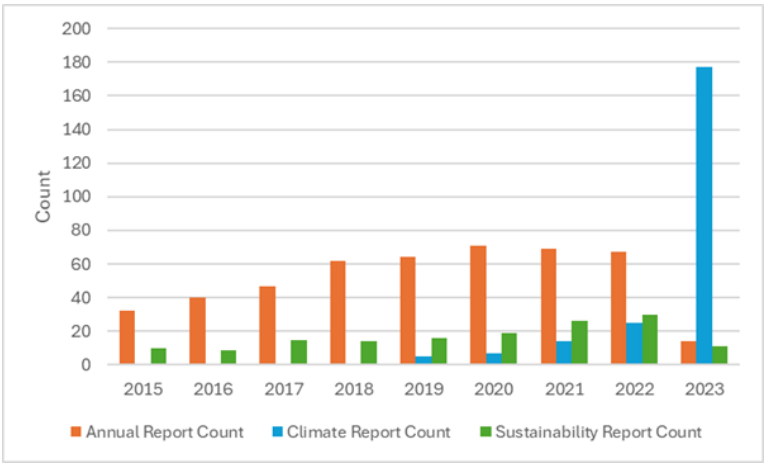
Panel A: General Time Trend					
Index	**Category**	**R2**	**Intercept**	**Time**	**Post-Treatment**
$CI_{t,i}$	Overall	0.553	0.2648*	0.3308***	0.7942***
	Governance	0.710	-0.4113*	0.4503***	0.8825***
	Metrics and Targets	0.697	1.2942***	0.2440***	0.7994***
	Risk Management	0.753	-1.3677***	0.4271***	1.1237***
	Strategy	0.700	1.5440***	0.2019***	0.3710***
$CIC_{t,i}$	Overall	0.565	0.2369*	0.3262***	0.8415***
	Governance	0.726	-0.5417**	0.4473***	0.9543***
	Metrics and Targets	0.704	1.2695***	0.2409***	0.8437***
	Risk Management	0.761	-1.3032***	0.4155***	1.1473***
	Strategy	0.716	1.5228***	0.2010***	0.4208***
Panel B: Company Specific Time Trend					
Index	**Category**	**R2**	**Intercept**	**Time**	**Post-Treatment**
$CI_{t,i}$	Overall	0.615	-2.4319***	0.7554***	0.5417***
	Governance	0.812	-3.3062***	0.9107***	0.4922*
	Metrics and Targets	0.817	0.5447	0.3708***	0.4981**
	Risk Management	0.830	-5.8211***	1.1168***	1.0058***
	Strategy	0.813	-1.1451***	0.6233***	0.1709
$CIC_{t,i}$	Overall	0.627	-2.6300***	0.7767***	0.5946***
	Governance	0.824	-4.2500***	1.0319***	0.5870**
	Metrics and Targets	0.823	0.5779	0.3592***	0.5358**
	Risk Management	0.837	-5.7644***	1.1062***	1.0345***
	Strategy	0.823	-1.0835***	0.6097***	0.2211*

Table 11: This Table presents the estimated coefficients of the Difference-in-Difference (DiD) model described in Section 4.3 and equation (5). In Panel A the the effects of the passing of the Financial Sector (Climate-related Disclosures and Other Matters) Amendment Act 2021 are estimated . In Panel B the effects of the implementation of the climate-related disclosure mandate, January 2024, are estimated. $Treated_i \times Post_t^{Announce}$ and $Treated_i \times Post_t^{Implement}$ are the variables of interest in Panel A and B, respectively. $MarketValue_{i,t}$ is the dollar value of the fund's investments, $Return_{i,t}$ is the quarterly total return of the fund and $Age_{i,t}$ is the age of the fund in years since inception. Both models, in Panel A and B, include fund-level fixed effects.

	Panel A: Announcement Effects				***Panel B: Implementation Effects***			
Independent Variables	**Sustainability Rating**	**Carbon Risk Score**	**ESG Risk Exposure**	**Carbon Intensity**	**Sustainability Rating**	**Carbon Risk Score**	**ESG Risk Exposure**	**Carbon Intensity**
$Treated_i \times Post_t^{Announce}$	0.034***	0.053***	-0.009***	0.121***				
$Treated_i \times Post_t^{Implement}$					0.046***	-0.002	0.021***	-0.129***
$MarketValue_{i,t}$	0.000***	0.000	-0.000	0.000	0.000***	0.000	-0.000	0.000
$Return_{i,t}$	0.002***	-0.001**	-0.000***	-0.002	0.001	-0.002***	-0.000***	-0.003**
$Age_{i,t}$	0.002	-0.033***	0.007***	-0.079***	0.002	-0.035***	0.002**	-0.058***
Fund FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R-Squared	0.004***	0.890***	0.953***	0.869***	0.008***	0.887***	0.954***	0.869***

Figure 1: This Figure presents the Count of voluntary (before 2022 Financial Year) and mandatory (2023 Financial Year) reporting of climate-, or broader sustainability-, related information by CREs from 2015 until 2023 Financial Year. The first figure presents the total count. The second figure presents the count by report type, that is an annual report, climate-related disclosure or a broader sustainability-related disclosure. The last figure presents the count by entity type. The collection of the reports, particularly the voluntary reports, is described in Section 3.2 and Figure 3.





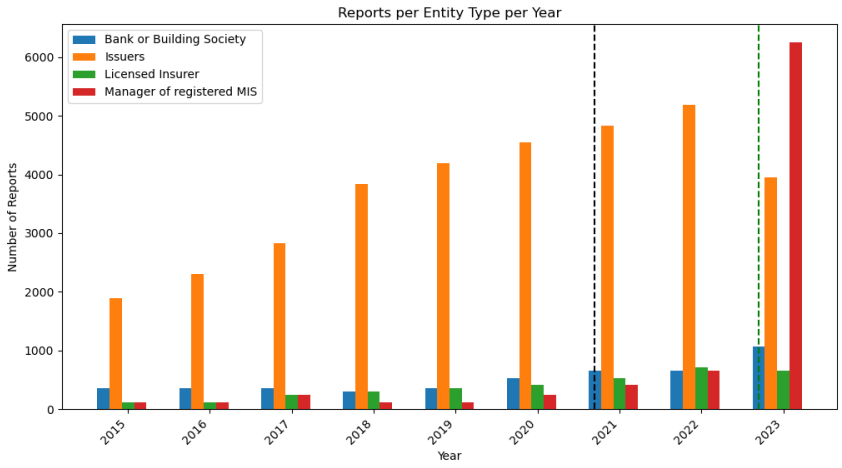


Figure 2: This figure presents a flowchart of how voluntary reporting by CREs is collected for the Financial Years 2015-2022.

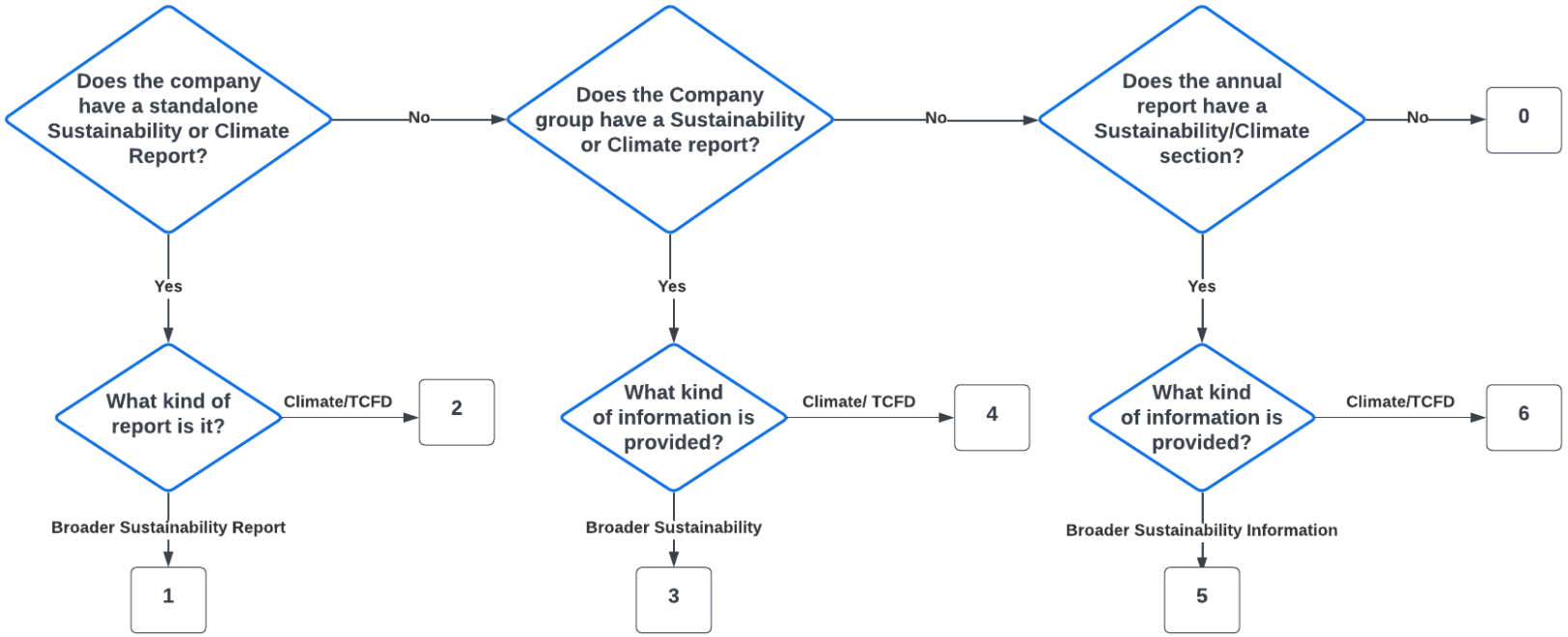


Figure 3: This figure...

Figure 4: This figure presents a flowchart of the survey branching logic for respondents from different entity types.

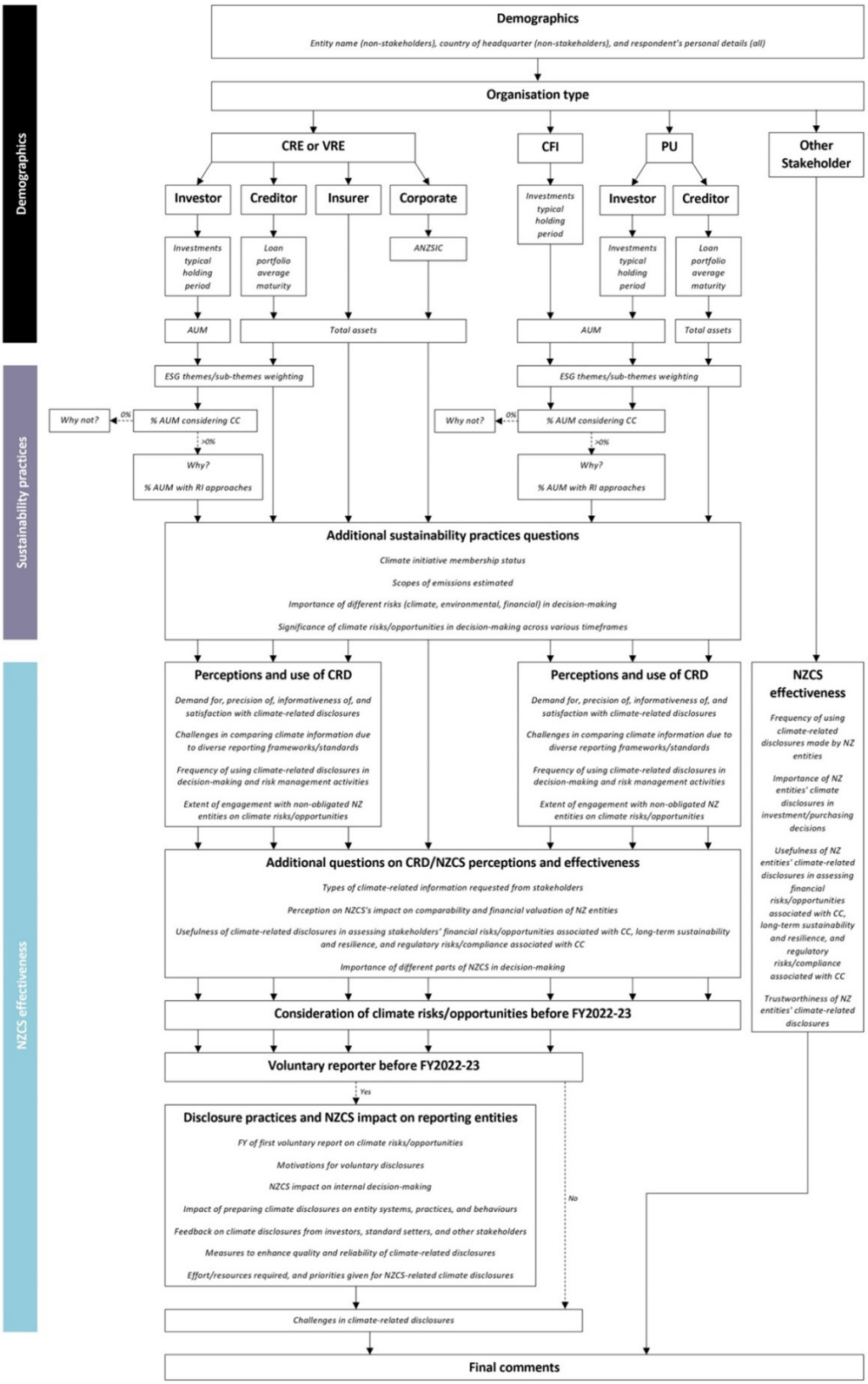


Figure 5: This Figure....

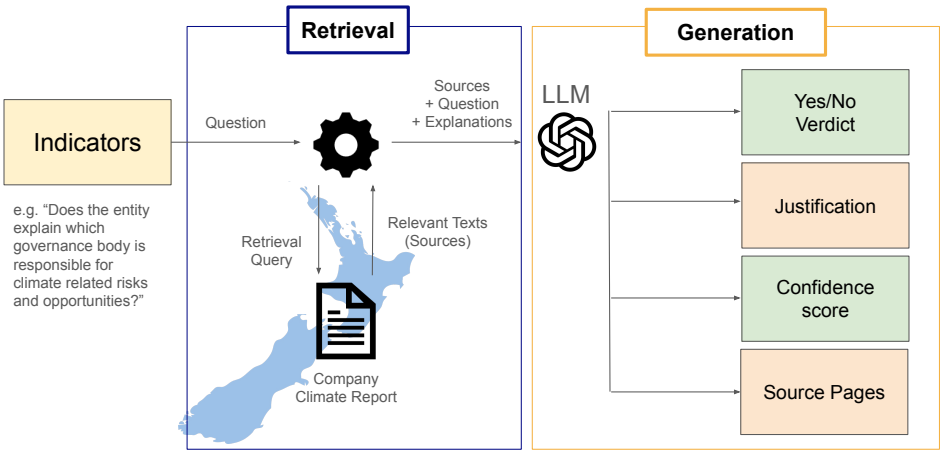


Figure 6: This figure shows the pipeline of the Retrieval Augmented Generation (RAG) system. For every indicator, we retrieve relevant text from a company's climate report (sources). We hand the question, a question explanation, and the sources to a Large Language Model (LLM). The LLM produces an answer comprising a Yes/No verdict, a verdict justification, and outputs the source pages on which the answer is based. Besides, we derive a confidence score based on the probability of the LLM in predicting a Yes or No as a verdict.

Figure 7: This figure presents the time series the Compliance Index (CI_t) time series overall, as well as the Compliance Index adjusted for model confidence (CIC_t), as described in Section 4.1. In the second graph this is broken down by ANZCS category.

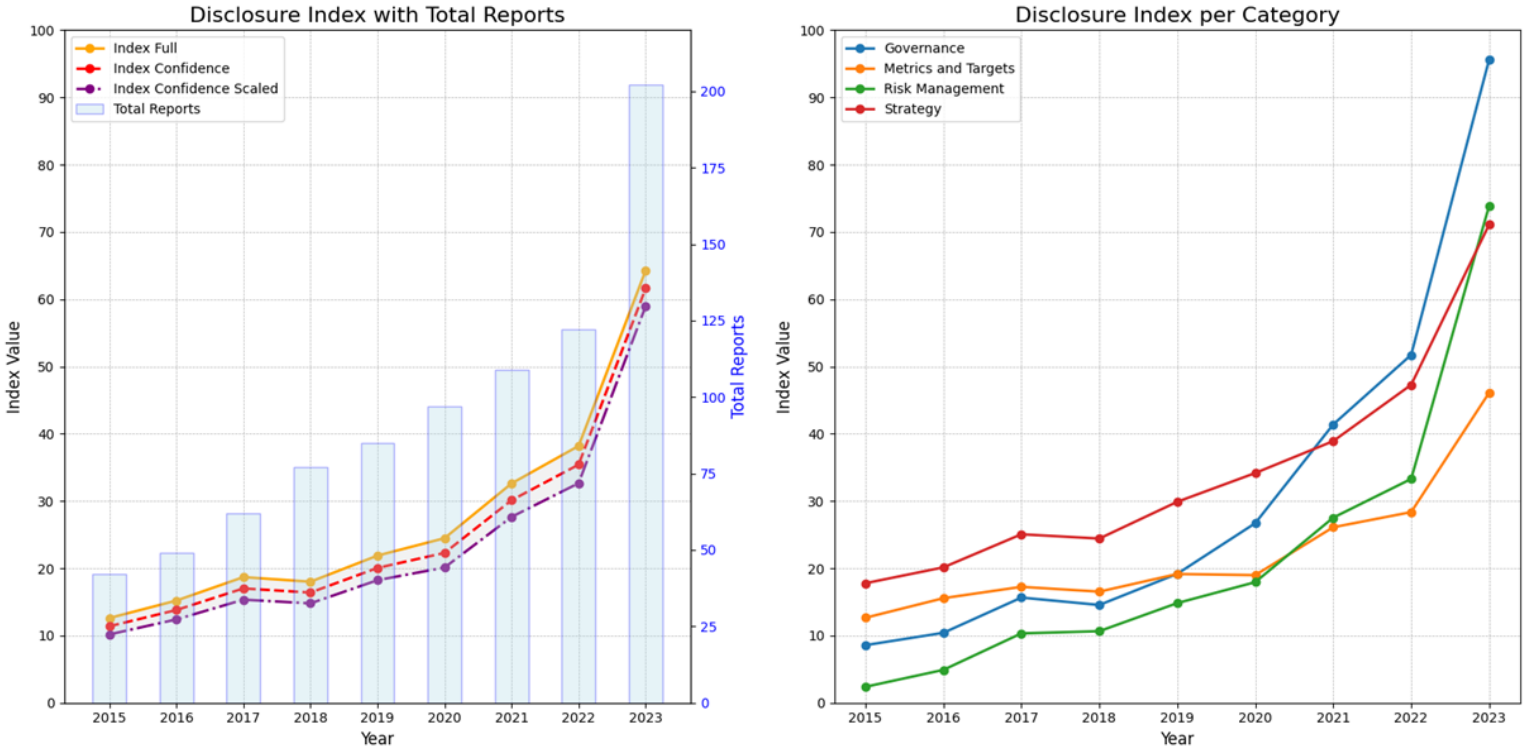
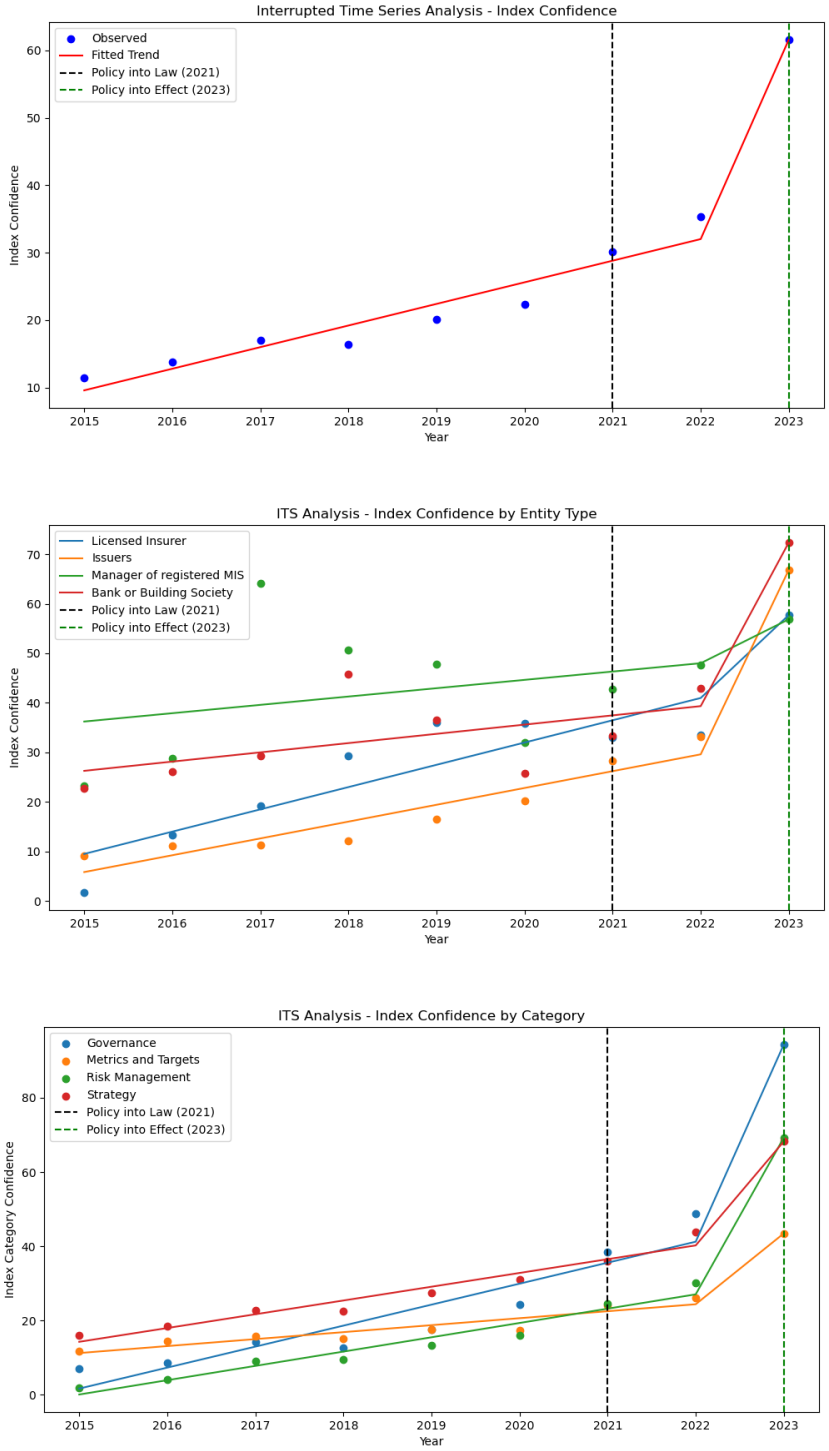


Figure 8: This figure presents the time series of the mean Compliance Index $\overline{CI_{i,t}}$ and the Compliance Index with the model Confidence adjustment $\overline{CIC_{i,t}}$ as well as the estimated Interrupted Time Series (ITS) line of fit. The ITS model is described in Section 4.2 and presented in equation (3). The first chart presents the results for the overall sample while the second and third chart break the sample into entity types and ANZCS categories, respectively.



A RAG System Details

A.1 Concecptual Design

Our conceptual design follows the idea of prior work by Senni et al., 2025. In this study, the authors define a comprehensive set of indicators based on multiple disclosure frameworks for net zero transition plans. Then, they implement and verify an LLM-based tool using these indicators.

In our case, the indicators are not based on multiple voluntary frameworks but on the manatordy Aotearoa New Zealand Climate Standard 1 by the XRB.[9] In line with prior efforts and recommendations such as the TCFD and ISSB, the XRB introduced disclosure criteria for New Zealand companies. It follows the common structure of Governance, Strategy, Risk Management, and Metrics and Targets. Each of these pillars defines elements for disclosure.

Based on this document, we define a set of 66 indicators to analyze companies. To make the indicators compatible with the LLM-based question-answering system, every indicator is formulated as a "yes/no" question. This means, the indicators are a set of criteria that a sustainability report either fulfills (answer is "yes") or not (answer is "no"). We also create an explanation for each question. This ensures that both humans and models have a common understanding of the question. An example for a question and explanation can be seen in Table 12.

[9] For details, see `https://www.xrb.govt.nz/dmsdocument/4770/`.

Indicator ID	Question	Explanation
0	Does the entity explain which governance body is responsible for climate related risks and opportunities?	The Governance Body is a board, investment committee or equivalent body charged with governance.Climate-related risks are the potential negative impacts of climate change on an entity.Climate-related opportunities are the potentially positive climate-related outcomes for an entity. Efforts to mitigate and adapt to climate change can produce opportunities for entities, such as through resource efficiency and cost savings, the adoption and utilisation of low-emissions energy sources, the development of new products and services, and building resilience along the value chain.
2	Does the entity explain how it ensures that the board members have the required skills and competencies to sign off and oversee climate-related risks and opportunities?	The Governance Body is a board, investment committee or equivalent body charged with governance.Climate-related risks are the potential negative impacts of climate change on an entity.Climate-related opportunities are the potentially positive climate-related outcomes for an entity. Efforts to mitigate and adapt to climate change can produce opportunities for entities, such as through resource efficiency and cost savings, the adoption and utilisation of low-emissions energy sources, the development of new products and services, and building resilience along the value chain.
6	Does the entity explain how climate-related responsibilities are assigned to management level positions or committees?	The Governance Body is a board, investment committee or equivalent body charged with governance.Management are the Executive or senior management positions that are generally separate from the governance body.
[...]	[...]	[...]

Table 12: Examples indicators of the disclosure analysis framework. The framework comprises questions posed to a report accompanied by explanations to clarify central elements.

A.2 Implementation

Given our set of 58 indicators, we aim to create an LLM-based tool that can automate the analyses. For this, we make use of a method called Retrieval Augmented Generation (RAG). RAG bases the answers of an LLM on provided sources. For running this method, we need to proceed in two steps. First, we prepare the reports and store them in a vector database. Second, we search for question-relevant text from the report and base our answer on this. An overview is presented in Figure 6.

For our first step, we aim to obtain the sources for the answers. The sources we provide to the

LLM in this study stem from the sustainability reports of a corresponding company. Thus, we need to prepare these reports as input. For this purpose, we use LlamaParse[10]. Llamaparse is a software package that uses generative AI models to analyze the structure of documents and output the content in a standardized format. We choose Llamaparse because it is equally strong in processing texts and tables of complex PDFs like sustainability reports. Furthermore, we use LlamaIndex[11] to implement the RAG system. We chunk the parsed reports into equally large text parts with a chunksize of 400 words and a chunk overlap of 50 words using the SentenceSplitter() function.[12] This procedure minimizes the loss of context and maintains the input to the model in full-sentence form, if possible. Using LlamaIndex and OpenAI's embedding model "text-embedding-3-large", we create a vector database for each report. This means we have a numerical representation of each chunk, which represents the semantic information about the text.

For our second step, we use the vector database to search for question-relevant information and base our answer on it. For this, we transform a question posed to a report into a numerical representation with the same embedding model. Then, we search for the most similar vectors in our database. This means that we compare the similarity of every vector representing a text chunk of the report to the vector of the question. The most similar vectors are the most relevant text chunks. We use the top 10 most similar text chunks in the report as a basis for our answer. We plug both question and sources into our prompt template. Additionally, the prompt template incorporates the question explanation. Besides, the prompt template enforces that the model only answers on the provided sources and strictly adheres to the given output format. See Figure 9 for the prompt template.

To obtain a final answer to the question, we hand the prompt to "gpt-4o-2024-08-06", OpenAI's most powerful model at the time of the creation of the scores. As shown in the prompt template (Figure 9), we obtain a "Yes" or "No" followed by a short justification of the answer. This allows us to trace both the judgment and reasoning of the model. Besides these two data points, we also obtain a confidence score of the model in predicting "Yes" or "No". For this, we make use of the

[10]See details on LlamaParse here: `https://docs.llamaindex.ai/en/stable/llama_cloud/llama_parse/`

[11]This is the starting point of their documentation: `https://docs.llamaindex.ai/en/stable/understanding/rag/`

[12]For implementation details, see `https://docs.llamaindex.ai/en/stable/api_reference/node_parsers/sentence_splitter/`

inner workings of LLMs. Very simply put, LLMs perform a next-word prediction. This means the LLM calculates word after word what the highest probability for the next word is. Prior research has found that this probability for words can signal the (un-)certainty of a model [see e.g., Liang et al., 2023, Ni et al., 2024]. We make use of the probability of the prediction of the "Yes" or "No" in our answer to quantify the confidence of the model in this answer. This means, we obtain an signal whether the model was very sure in answering "Yes" or "No".

```
You are a senior sustainability analyst with expertise in climate science evaluating a
    company's climate-related reporting.

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. Start your answer with a "[[YES]]" or "[[NO]]" depending on whether you would answer the
    question with a yes or no. Always complement your judgment 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):
```

Figure 9: Prompt for the RAG system. *sources* is replaced by the 10 most relevant text excerpts of the report; *question* is replaced by the question for the report; *explanation* is additional context that makes the question understanding of an expert explicit for the model; *answer_length* is set to 200 to allow for a concise but valuable answer justification.

A.3 Development and Test Set

While RAG systems themselves are well researched [e.g., see Gao et al., 2024], we want to verify how well our system works on our task. We split these efforts into two steps. First, we want to

develop our questions and explanations with a development set. Second, we want to verify the performance on an independent test set.

In our first step, we create a development set. The development set contains correct answer of for all our indicators of the six sustainability reports. To obtain these correct answers but also to develop our RAG system, we use an iterative procedure. We first create a baseline RAG system that creates the answers for all indicators and reports. Then, an expert human annotator reviews the answers and marks the incorrect choices. All insights during the answer correction process are discussed in the author team and serve to refine explanations, indicators, and RAG setup. Finally, the generation of answers is rerun, and the answers are checked again. This process is repeated until we deem the system to run sufficiently.

As a preliminary indication of the functionality of the system, we calculate the accuracy of correct "Yes" and "No" answers of the system. We find that our system answers are around 93% accurate (see Table 13). Besides the sheer accuracy, we can also investigate whether the certainty of the models' "Yes"/"No" answers is decision-useful. We find that correct answer have an average confidence of 97% while incorrect answers have an average confidence of 80%. This indicates that confidence can indeed be decision-useful in determining whether the model is correct. Using the development dataset, we also investigate a second aspect of LLMs. API-based LLMs like ours are prone to nondeterministic behaviour. Given the large scale of the models and some randomized initialization steps when using API-based LLMs, it is possible that the answer varies. This is problematic if the behaviour is very strong because it makes the final system unreliable. In order to check this behavior, we run the answering process five times on the development dataset. We find a standard deviation in accuracy of 0.3%. In other words, across 5 runs, answers for 8 question-answer pairs did alternate across all 1910 question-answer pairs. We conclude that the problem is present for our study but in a negligible magnitude.

In our second step, we want to develop a test set. Although our development set gave us a good indication of the performance of the system, these insights may be subject to overfitting. We adjusted the model to accommodate errors that we saw in the development set. Thus, we run the final RAG system on another four reports, and an expert human annotator checks each answer by hand. On this test set, the model achieves an accuracy of 91% (see Table 14). This reaffirms the

Number of Runs	Mean Accuracy	Std. Accuracy	Min Accuracy	Max Accuracy
5	0.9314	0.0034	0.9267	0.9346

Table 13: Average accuracy of the RAG system when predicting the correct "Yes" or "No" on the development set over five runs.

Accuracy	F1-Score	Precision	Recall
0.9119	0.9333	0.9103	0.9575

Table 14: Accuracy, F1-Score, Precision and Recall of the RAG system when predicting the correct "Yes" or "No" on the test set.

strong performance of the model. Besides, incorrect answers have an average confidence of 85% and correct answers of 96%. This confirms the decision-usefullness of the confidence score.

B Appendix

Tables

Figures

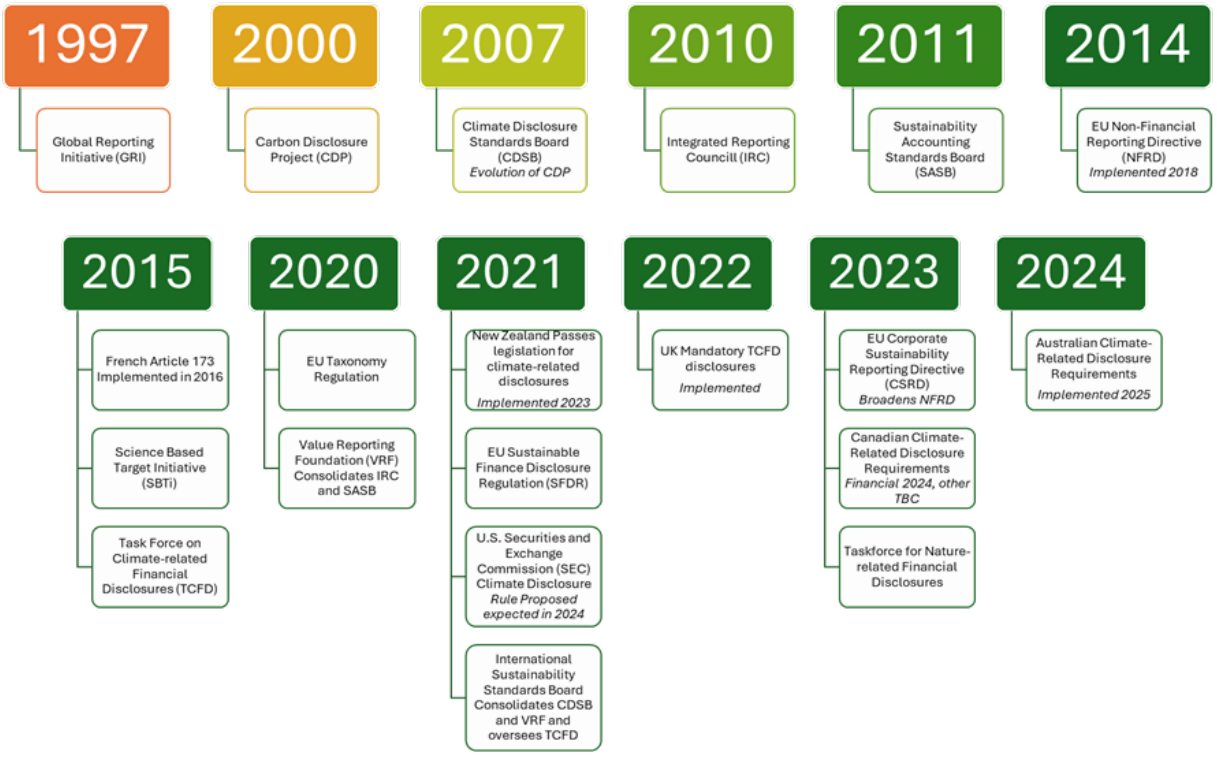


Figure 10: Timeline of Non-financial Reporting Frameworks: This Figure presents a summarizing timeline of the major global voluntary and mandatory non-financial reporting standards and frameworks. Green boxes indicate voluntary standards/frameworks, while the orange boxes indicate mandatory standards. The arrows indicate when a standard/framework has been merged or subsumed

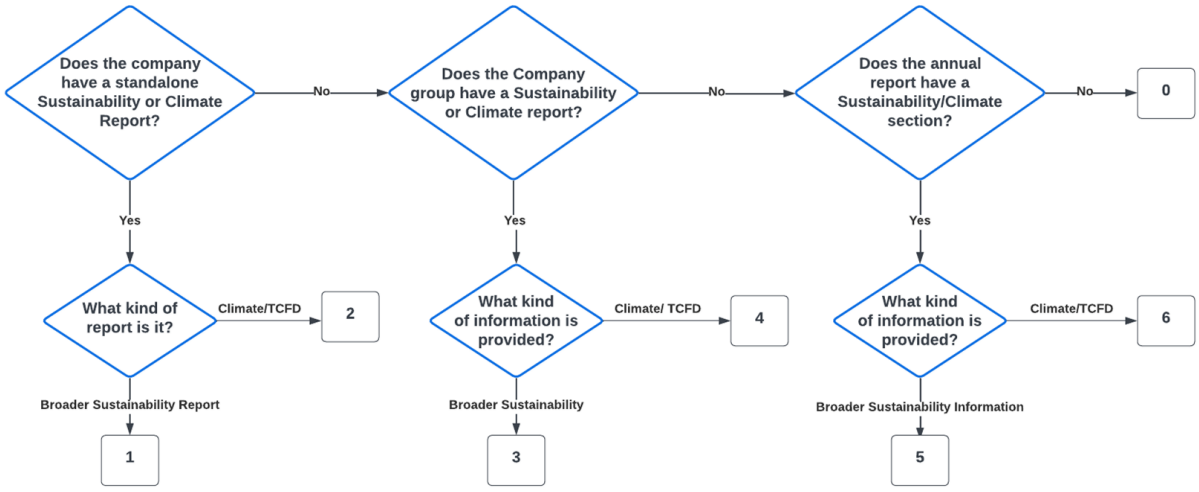


Figure 11: Non-financial disclosure collection and classification logic: