



# *Predicting Real Decarbonization Rates from Corporate Climate Change Disclosure*

*An analysis of the relationship between corporate  
climate change disclosure and real  
decarbonization rates*

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Corporate Climate Change Disclosure*

ABSTRACT

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Thesis advisor: George Serafeim and Kevin Rader      Fabrizio Serafini

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THIS THESIS IS DEDICATED TO MY DAD, WHO TAUGHT ME THE  
VALUE OF HARD WORK.



# Acknowledgments

Thank you so much to my Dad because he's the best.

*This is a quote.*

Author

# 1

## Introduction

### 1.1 MOTIVATION

#### QUESTIONS

Can quantitative forecasting play a central role in enhancing our understanding of global emissions? Will it allow us to make strategic decisions when decarbonizing? Can we build a more sustainable future with a targeted approach that uses data to identify potential for improvement? What other data do we need to increase our prediction accuracy and understand the impact of business strategies on decarbonization? Can we predict future decarbonization rates and, if so, what is the best way to do it?

## WHY IS THIS IMPORTANT? AND THE INTERSECTION OF ACADEMIC AND BUSINESS INTEREST

Those are only a few of the very important and interesting questions that drew me to research decarbonization and to focus on the role of corporate emission-level data in the process. I believe that research in this area is crucial to advance our ability to build a more sustainable future. Furthermore, the answers to these questions can help us make better decisions and build a more sustainable future while also creating value for businesses. Additionally, the call for more data in decarbonization comes not only from the academic world but also from the fact that many business opportunities arise from the climate transition that inevitably require good and valid information to determine which companies and sectors are winners and losers, which are the champions in the decarbonization process, which are the laggards, and which are the companies that are greenwashing. I believe that studying specifically corporate emissions and forecasting decarbonization rates as I am doing in this thesis can be useful to three key stakeholders:

### THE KEY STAKEHOLDERS

1. **Investors** who are increasingly interested in understanding the climate risk of their portfolios and in identifying the companies that are best positioned to succeed in the transition to a low-carbon economy. For examples, companies such as BlackRock [insert quotation here] are enhancing their sustainable investing strategies and offering more sustainable investment products to their clients.
2. **Companies** who are increasingly interested in understanding their climate risk and in identifying the best strategies to reduce their emissions and to succeed in the transition to a low-carbon

economy. Additionally, companies might be interested in benchmarking against their peers in the sector to understand how they are performing relative to their competitors and to identify the best practices.

3. **Policy makers** who are increasingly interested in understanding the climate risk of their countries and in identifying the best strategies to reduce their emissions and to succeed in the transition to a low-carbon economy. A sector and company level analysis can be useful in determining optimal targets for new policies, identifying the best practices, and understanding the impact of new policies on the sector and on the economy.

#### CONNECTION BETWEEN COMPUTER SCIENCE AND DECARBONIZATION

Finally, I believe that the use of data and modeling techniques can help us build a more sustainable future in a practical, nonpolitical, and unbiased way. Estimating emissions is an amazing example of how Computer Science and Statistical models can help us achieve real impact driving strategic decisions. I argue furthermore that it is only through a quantitative driven approach that we can diminish the climate debate and make progress in the climate transition. I am confident that work in the modeling decarbonization has an incredible potential to create value for business and society and especially with increasing data availability and computational power, the time is ripe to make progress in this area. As I will explain in the next sections, this thesis is only possible thanks to increased data availability and to the willingness of corporates to disclose their emissions.

### 1.1.1 EMISSION SCOPES

The thesis will assume familiarity with the concept of Scopes 1, 2, and 3 emissions which I am going to explain in this section. In carbon-accounting and emissions reporting, it is very important to distinguish between three types of emissions: Scope 1, Scope 2, and Scope 3 emissions. Each category represents a different level of emissions associated with an organization's activities.

- **Scope 1** emissions are direct emissions from owned or controlled sources. This includes emissions from company vehicles, and emissions from chemical processes or combustion in owned or controlled boilers, furnaces, etc.
- **Scope 2** emissions are indirect emissions from the generation of purchased electricity, steam, heating, and cooling consumed by the reporting company. These emissions occur at the facility where the energy is generated, not at the point of consumption.
- **Scope 3** emissions are all indirect emissions (not included in Scope 2) that occur in the value chain of the reporting company. This includes both upstream and downstream emissions, encompassing a wide range of activities such as the extraction and production of purchased materials, transportation of purchased fuels, and use of sold products and services.

Understanding these scopes is critical for organizations aiming to fully assess and manage their carbon footprint.



**Figure 1.1.1:** Caption of Scopes 1, 2, and 3 Emissions. Adapted from [5].

### 1.1.2 A BUSINESS ORIENTED FRAMEWORK TO JUSTIFY DECARBONIZATION

The Paris Agreement sets forth ambitious objectives to combat climate change, aiming to cap the increase in global temperatures to 2°C, with an aspirational target of 1.5°C, above pre-industrial levels. This is to be achieved through a series of significant measures, including reaching net-zero greenhouse gas emissions by 2085 and a reduction of these emissions by 10% by 2030 [18]. These goals require substantial transformations in global economic structures, especially in the realms of energy consumption and the development of renewable energy sources. For instance, in the United States, attaining deep decarbonization necessitates a national overhaul in the way energy is produced and used, with implications for urban planning and land management [13]. Similarly, in the European Union, deep decarbonization could be pursued via either a demand-driven system or a centralized approach to manage carbon emissions. However, achieving more ambitious targets will require a broader mix of technologies and greater intersectoral synergy [14]. Numerous policy instruments, particularly carbon taxation, are

progressively being implemented in major developed economies. Some experts advocate for a global carbon tax as a potent mechanism to expedite decarbonization in the energy sector. However, this approach encounters several hurdles, including substantial capital investment needs, competition between different sectors, varying environmental policies across regions, and the challenge of securing public acceptance for changes in energy consumption habits [17].

In my opinion, regardless of the specific outcomes of a global carbon tax, the transition to a low-carbon economy is inevitable and will have a profound impact on the business world. This is because, despite the decrease in 2020 due to the COVID-19 pandemic, global energy-related CO<sub>2</sub> emissions remained at 31.5 Gt, contributing to CO<sub>2</sub> reaching its highest ever average annual concentration in the atmosphere of 412.5 parts per million in 2020 – roughly 50% higher than when the industrial revolution began. Global energy-related CO<sub>2</sub> emissions are expected to rebound and continue increasing, as demand for coal, oil, and gas recovers along with the economy [6]. It seems like carbon emissions are arguably the greatest negative externality that is currently affecting global markets, we don't yet have a single global policy to regulate emissions, that is not game theory optimal for a country to commit to lowering emissions before others, but chances are that if the decarbonization strategy is not implemented, the world will face a climate crisis that will have a profound impact on the economy. Interestingly, the more we wait to implement a decarbonization strategy, the more likely it will be that the transition will need to be more abrupt, and in this case firms that are not prepared will face significant risks, while firms that are prepared will have a competitive advantage. As Professor Serafeim argues, such transition should not be seen as an inefficiency, but rather as a demand for innovation and a source of new business opportunities [15]. Indeed, by transitioning to a low-carbon economy,

companies can create value for their shareholders, employees, and society at large. Therefore, if a company is to succeed in a modern business landscape, it must do so by aligning its profit strategy with a concrete purpose strategy, which includes a commitment to lowering carbon emissions. When it comes to sustainability, the transition will require significant changes in the way companies operate, and it will create both risks and opportunities [15]. For instance, companies that are able to reduce their emissions will be better positioned to succeed in the transition, while companies that are unable to do so will face significant risks. The transition will also create opportunities for new business models and technologies, and it will require companies to adapt to new regulations and policies. In this context, it is crucial for companies to understand their climate risk and to identify the best strategies to reduce their emissions and to succeed in the transition to a low-carbon economy. This is where the role of data and modeling techniques becomes crucial. Not only can these techniques help companies understand their climate risk, but they can also help companies identify the best strategies to reduce their emissions and to succeed in the transition to a low-carbon economy. Under this framework, it is therefore not surprising to see that companies are increasingly interested in understanding their climate risk and in identifying the best strategies to reduce their emissions and to succeed in the transition to a low-carbon economy and are increasingly more willing to disclose them.

## 1.2 CARBON DISCLOSURE PROJECT DATA

The primary data source for this thesis is the Carbon Disclosure Project (CDP) Climate Change Questionnaire [9], which was kindly provided to me by the Climate and Sustainability Impact Lab from





**Figure 1.2.1:** Carbon Disclosure Project Logo. Adapted from [8].

the Digital Design Institute at the Harvard Business School [12]. The Carbon Disclosure Project is a not-for-profit charity that runs the global disclosure system for investors, companies, cities, states and regions to manage their environmental impacts [8]. The importance of the CDP is widely recognized by the business and the academic communities. As Ban Ki Moon, former Secretary General of the United Nations, states “The work of CDP is crucial to the success of global business in the 21st century... helping persuade companies throughout the world to measure, manage, disclose and ultimately reduce their greenhouse gas emissions. No other organization is gathering this type of corporate climate change data and providing it to the marketplace” [8]. The Carbon Disclosure Project Sustainability Questionnaire uses the Greenhouse Gas (GHG) Protocol as a reporting model for carbon-related data [4]. It is one of the largest datasets of self-reported GHG emissions and collects a wide range of information on climate change-related topics. The questionnaire provides a globally consistent disclosure standard for GHG emissions and information on a firm’s activities to reduce GHG emissions. The CDP is backed by a large number of institutional investors, including banks, insurance companies, asset management companies, and pension funds holding US\$100 trillion in assets (i.e., CDP signatories),

which act as “norm entrepreneurs” [16]. Currently more than 23,000 companies disclose their emission data through the survey, representing two thirds of global market capitalization [8].

## MOTIVATIONS BEHIND CORPORATE DISCLOSURE TO THE CDP

The Carbon Disclosure Project (CDP) questionnaire has not only gained increasing popularity among companies but has also become a pivotal tool for investors and other stakeholders in evaluating corporate climate risks. It plays a crucial role in identifying effective strategies for emission reduction and in navigating the transition towards a low-carbon economy. The growth in the completion and publication rates of the CDP questionnaire reflects its importance, with institutional investors exerting a notable influence on climate change disclosure through corporate communication channels [11]. Consequently, the annual increase in the number of companies engaging in disclosure highlights a substantial data pool, invaluable for analyzing the decarbonization process and projecting future emission trends. The rationale for companies to disclose varies, encompassing regulatory compliance, investor expectation alignment, reputation enhancement, peer benchmarking, emission reduction opportunity identification, and risk assessment. Furthermore, disclosing to CDP entails two independent steps: the first involves the completion of the questionnaire, while the second involves the publication of the response. The latter step is particularly significant, as it demonstrates a company’s commitment to transparency and accountability, thereby enhancing its reputation and credibility [11].

### 1.2.1 CURRENT METRICS AND LIMITATIONS

The CDP survey assigns a score that ranks the performance of companies when decarbonizing. For reference, 48% of S&P companies

scored high-performance band B ratings and above in their Carbon Disclosure Project (CDP) reports in 2014 [19]. When assigning a score, CDP assesses the level of detail and comprehensiveness in a response, as well as the company's awareness of environmental issues, its management methods and progress towards environmental stewardship [7]. Additionally, specifically for climate-change scores, to receive an A-level grade a company must verify at least 70% of Scope 1, Scope 2 and Scope 3 emissions with a CDP-approved verification standard. Among other criteria, to score an A on Climate Change, companies must have robust governance and oversight of climate issues, rigorous risk management processes, verified scope 1 and 2 emissions and be reducing emissions across their value chain. Most Climate Change A List companies as of 2022 have well established emissions targets that have been approved by the SBTi, and evidence of targets which cover their scope 3 emissions [7].



**Figure 1.2.2:** Caption of CDP Scoring Grades. Adapted from [7].

While the CDP score is a valuable and widely recognized metric, it has several limitations. First, the CDP score is assigned based on adherence to best-practices and does not provide a future outlook on the company-specific ability to reduce emissions. It signals that the company is currently adhering to best practices, but there is no immediate way to know by how much will the company be able to reduce its emissions in the future. Second, the CDP score is based on self-reported data, which can be subject to biases and errors. Third, the score does not provide an estimate of the company's future emissions, which is crucial for investors and policy makers. Thus, the score can be useful as a first metric and this leaves the door open for more sophisticated models to be developed which is the main goal of this thesis, in particular when it comes to forecasting next-year emissions and whether a company will perform better or worse in the future compared to its peers.

### 1.3 RESEARCH QUESTIONS

**Todo :)**

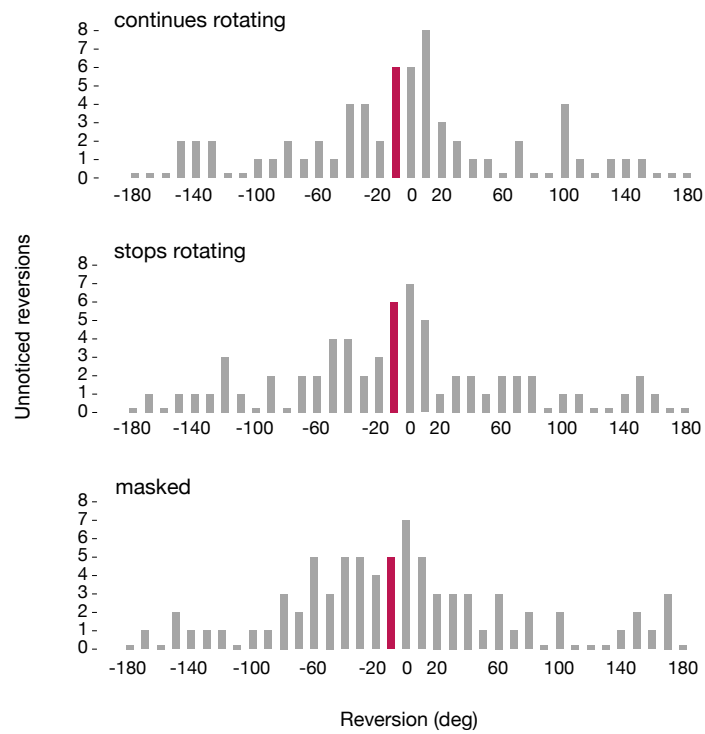
$$\frac{1}{\sqrt{2\pi}} \int_{-\infty}^{\infty} e^{-x^2/2} dx = 1.$$

Three amazing histograms are shown in Figure 2.4.1.

### predictions



### data



**Figure 1.3.1:** Three histograms are shown. Note that...

# 2

## Data

### 2.1 DATA FORMATS

The reports can be requested from the CDP website [8], they are available both in PDF and a structured CSV format. The CSV files encompass the responses submitted to the CDP questionnaire, which form the foundation of the predictor and response variables for this thesis. My work is a continuation of the initial data processing that was executed by Climate and Sustainability Impact Lab [12] and kindly shared with me in the form of various stata files and a repository containing both the raw and processed data, where the multiple sections had been extracted from the survey and aligned across different years. I then imported all the data and further processed it to create the training and test sets for the following models.

## 2.2 CDP REPORT STRUCTURE

The CDP survey has  $X$  primary sections, with each section containing a list of subsections with relevant questions. This is a list of the primary sections as well as a brief introduction to the types of questions present in the section:

- **C0 - Introduction:** General description of the organization, along with information on where the company operates geographically, the currency used to report financial information, and the reporting boundary (whether it is financial or operational control), and the ISIN if the company is public
- **C1 - Governance:** Governance structures and processes related to climate change within the organization. It includes questions about board-level oversight of climate-related issues, the roles and responsibilities of management in addressing climate change, and how climate-related risks and opportunities are integrated into the company's overall governance framework. This section provides insight into the company's commitment to addressing climate change at the highest level of its organizational structure.
- **C2 - Risks and Opportunities:** Identification of processes that the organization uses to identify, assess, and respond to climate-related risks and opportunities. It includes questions regarding the definition of time horizons (short, medium, and long-term) for these risks and opportunities, and specific related details. This section aims to understand how the company perceives and manages potential impacts of climate change on its business, highlighting its approach to mitigating risks and capitalizing on new opportunities arising from the changing climate landscape.

- **C3 - Business Strategy:** This section examines the company's business strategy in relation to climate change. It explores whether the organization's strategy includes a transition plan that aligns with a 1.5°C world scenario, detailing the nature and publicly available aspects of this plan. The focus is on understanding how the company's strategy is designed to adapt to and mitigate climate-related issues, and how it plans to transition towards a lower-carbon, more sustainable business model. This section also looks at how feedback is collected from shareholders on the transition plan, emphasizing the integration of climate considerations into the core business strategy.
- **C4 - Targets and Performance:** This section presents an in-depth analysis of the company's specific emissions targets, including which emissions scopes are covered, targeted reduction percentages, and the current progress towards these goals. It also examines the emissions reduction initiatives that the company had active during the reporting year, detailing associated investments and the expected payback period. This part of the report effectively illustrates both the targets set by the company for reducing emissions and the concrete initiatives underway to achieve these objectives.
- **C5 - Emissions Methodology:** Insights into the company's emissions methodology, including any structural changes that may have occurred. It outlines the base year emissions against which progress is measured and explains the methodology employed to collect and report emission data. Additionally, it highlights the protocols and standards adhered to, ensuring the accuracy, consistency, and comparability of emissions data over time.



- **C6 - Emissions Data:** This section covers both Scope 1 and Scope 2 emissions. It includes relevant details, such as the categorization of Scope 2 emissions as either location-based or market-based. Additionally, the section provides insights into emission intensity per product, allowing for a detailed examination of emissions in relation to the company's products and operations.
- **C7 - Emissions Breakdowns:** This is the section where company emissions (scope 1 and 2) are broken down into various sub-categories based on country/region, business division, and sector production activity. Most importantly, this section also provides a breakdown of changes in gross global emissions (Scope 1 and 2 combined), and for each of them a specification of how your emissions compare to the previous year. **Emissions breakdowns will be further analyzed in the response variable discussion and linked to this section.**
- **C8 - Energy:** A comprehensive description of energy purchases and consumption, with a specification of renewable and non-renewable sources as well as consumption breakdowns by location. This section is useful in understanding whether the company is actively purchasing renewable energy and whether the firm's activity are energy intensive.
- **C9 - Additional metrics:** Description of other sustainability related metrics such as investments in low carbon research and development, transport technologies, and product/services
- **C10 - Verification:** This section provides a comprehensive description of the verification methodologies that the firm implements to verify and audit its emissions scopes. The report

includes the proportion of verified emissions by scopes, verification standards and status.

- **C11 - Carbon Pricing:** Assessment of whether the company is subjected to a carbon tax and, if so, in which geographies and under which regimes along with a description of the percentage of emission scopes covered by the policy and the strategies that the company is implementing to comply with the regulations. Additionally, the section asks whether the company has an internal price of carbon and its related objectives.
- **C12 - Engagement:** Analysis of the company's effort to engage with its value chain to reduce carbon emissions. In particular, the company discloses which agents does the company collaborate with, whether the company requires suppliers to meet certain sustainability criteria, and whether the company engages with customers to drive awareness on climate related issues. Additionally, the company discloses whether it engages with policy makers in a way that could influence climate related policy, law, or regulation
- **Other Sections:** Sections beyond C12 are not relevant for the purpose of the thesis. They include details on biodiversity and signoff details among other metrics.

## 2.3 A CASE STUDY ON TWO CDP REPORTS

To begin the discussion on exploratory data analysis, I must first address the complexities of emission accounting and reporting within the framework of CDP data, highlighting its distinct nature compared to the more standardized field of financial reporting. That is, despite ongoing improvements, emission reporting still falls short of the

robust standards established in financial accounting. I will highlight this by analyzing the 2022 CDP reports from two markedly different companies: General Motors (GM) in the automotive sector and Jet Blue in the airline industry. These reports underscore the highly company-specific nature of emission data, with significant variances stemming from diverse operational practices, especially across different industries. This results in a substantial reliance on text-based and free-form answers within the CDP reports, presenting unique challenges for data analysis. To navigate this complexity, a critical starting point is to analyze the inherent differences in these reports, which will inform and refine our modeling approach. By understanding and accommodating these industry-specific nuances, we aim to develop a more accurate and representative model of emission reporting and reduction strategies as well as identifying potential areas of improvement.

### 2.3.1 GENERAL MOTORS 2022 CDP REPORT

General Motors Company (GM), a global leader in the automotive industry, is headquartered in Detroit, Michigan, USA. Renowned for its ownership and production of the Chevrolet, GMC, Cadillac, and Buick brands, GM was the largest automaker in the United States by sales in 2022. GM's commitment to sustainability is evident in its strategic approach to reducing Scope 1, Scope 2, and Scope 3 greenhouse gas (GHG) emissions, with comprehensive governance and ambitious environmental targets.

#### SCOPE 1 AND SCOPE 2 EMISSIONS

GM has set forth aggressive targets to reduce its Scope 1 and Scope 2 emissions by 71.4% by 2035, relative to its 2018 baseline. In 2018, GM reported Scope 1 emissions of 1,763,555 metric tons CO<sub>2</sub>e and

Scope 2 emissions of 3,924,338 metric tons CO<sub>2</sub>e. By the reporting year 2022, GM achieved a reduction to 1,252,906 metric tons CO<sub>2</sub>e for Scope 1 and 2,150,694 metric tons CO<sub>2</sub>e for Scope 2, marking significant progress towards its goal. This reduction aligns with the 1.5 degrees Celsius strategy set by the Paris Agreement, underscoring GM's commitment to global climate initiatives [10, 21].

GM's strategy includes enhancing energy efficiency across its manufacturing operations and increasing the use of renewable energy. In 2021, GM implemented over 300 energy efficiency improvements, such as upgrading to more efficient equipment and increasing renewable electricity use from 23% to 25%, contributing to GHG reductions in Scope 2 emissions.

### SCOPE 3 EMISSIONS

Addressing Scope 3 emissions, GM has set a target to achieve a 50.4% reduction in its vehicle use emissions, from a baseline of 0.0002466 metric tons of CO<sub>2</sub> per kilometer to 0.0001223136. GM's strategy to meet this target includes transitioning to an all-electric vehicle (EV) future, with plans to introduce 30 new EV models by 2025 and aspirations to be fully electric by 2035. Partnerships to increase renewable energy generation and deploy EV chargers, in collaboration with EvGo, further exemplify GM's holistic approach to reducing its carbon footprint across the value chain.

### KEY TAKEAWAYS

- **Strategic Emissions Reduction:** GM's targeted reductions in Scope 1 and Scope 2 emissions demonstrate a strong commitment to environmental stewardship, leveraging technological advancements and renewable energy.
- **Leadership in Electric Vehicles:** GM's aggressive transition

to an all-EV lineup by 2035 highlights its leadership role in transforming the automotive industry towards sustainability.

- **Comprehensive Approach to Sustainability:** Through its Scope 3 emissions reduction target, GM addresses the broader environmental impact of its products, emphasizing the importance of a comprehensive strategy that extends beyond direct emissions.

GM's sustainability efforts showcase a deep commitment to reducing its environmental impact and leading the automotive industry towards a more sustainable future. By strategically targeting Scope 1, Scope 2, and Scope 3 emissions, GM is not only adhering to global climate agreements but also setting a precedent for corporate responsibility in addressing climate change.

### 2.3.2 JETBLUE AIRWAYS CORPORATION 2022 CDP REPORT

JetBlue Airways Corporation has been steadfast in its commitment to environmental stewardship, focusing on reducing Scope 1, Scope 2, and Scope 3 greenhouse gas (GHG) emissions across its operations. The airline's governance structure emphasizes sustainability, with strategic initiatives overseen by its board and executive team, underscoring a comprehensive approach to addressing climate change.

#### SCOPE 1 AND SCOPE 2 EMISSIONS

In the reporting year 2022, JetBlue's Scope 1 emissions totaled 6,853,927 metric tons CO<sub>2</sub>e, predominantly from jet fuel combustion, a primary challenge within the airline industry. Scope 2 emissions amounted to 25,945 metric tons CO<sub>2</sub>e, reflecting the emissions from electricity consumption. These figures demonstrate JetBlue's

significant environmental footprint, necessitating aggressive measures for reduction.

JetBlue's strategies to mitigate these emissions include modernizing its fleet with more fuel-efficient aircraft, such as the Airbus A220 and A321neo, and investing in sustainable aviation fuel (SAF) to reduce lifecycle GHG emissions associated with jet fuel. Additionally, the airline is transitioning its ground service equipment to electric power, aligning with its commitment to lower Scope 1 and Scope 2 emissions.

### SCOPE 3 EMISSIONS

JetBlue's Scope 3 emissions are a crucial component of its sustainability strategy, addressing emissions from purchased goods and services, capital goods, and fuel-and-energy-related activities not included in Scope 1 or 2. In 2022, the emissions reported were as follows:

- Purchased Goods and Services: 44,922 metric tons CO<sub>2</sub>e, estimated for catered food and onboard product.
- Capital Goods: 485,629 metric tons CO<sub>2</sub>e, associated with aircraft ground equipment and spare parts.
- Fuel-and-Energy-Related Activities: 1,391,126 metric tons CO<sub>2</sub>e, highlighting the broader impact of JetBlue's operational energy use.

These figures were calculated using the Quantis Scope 3 tool, demonstrating JetBlue's reliance on standardized methodologies to quantify and manage its indirect emissions. The airline's commitment to understanding and reducing its Scope 3 emissions is evident through its detailed reporting and targeted reduction strategies, including investments in SAF and efficiency improvements across its value chain.

## KEY TAKEAWAYS

- **Comprehensive Climate Strategy:** JetBlue's efforts to reduce Scope 1, Scope 2, and Scope 3 emissions underscore a holistic approach to sustainability, addressing both direct and indirect sources of GHG emissions.
- **Innovation and Efficiency:** Through fleet modernization, SAF investments, and operational efficiencies, JetBlue is actively working towards reducing its environmental impact, despite the inherent challenges of the airline industry.
- **Scope 3 Emissions Challenge:** JetBlue's detailed reporting on Scope 3 emissions highlights the complexity of addressing indirect emissions. The airline's engagement with its supply chain and investment in sustainable practices exemplify a forward-thinking approach to environmental responsibility.

JetBlue's sustainability efforts reflect a deep commitment to reducing its carbon footprint and contributing to the global fight against climate change. By addressing Scope 1, Scope 2, and Scope 3 emissions with targeted strategies and investments, JetBlue is paving the way for a more sustainable future in aviation.

## 2.4 DATA SOURCES

### 2.4.1 DATA: CLIMATE CHANGE RESPONSE QUESTIONNAIRE

The main data source comes from the CDP Climate Survey, it contains the response surveys from all companies from 2011 to 2022. The data was partially cleaned and processed by the Climate and Sustainability Impact Lab [12] before being shared with me. This comprehensive dataset was provided a repository that includes both raw and processed data in the form of Stata files. Organized by firm-years, each observation in the dataset corresponds to a specific firm in a given year, and is structured in a panel format, having a unique id year pair to uniquely identify each entry. The original dataset contained 34,588 firm-years across 11 years. Since the analysis controls for financial and industry-specific predictors, I decided to focus on public companies, which represent 71% of the firm-years in the dataset. Therefore, 9,785 firm-years were dropped from the analysis because they did not have an ISIN code, which is a unique identifier for public companies.

#### IMPORTANT CONSIDERATIONS ON THE CDP DATA

- **Reporting year lag:** The data from a given year corresponds to the financial and operational data from the previous year. This was an important consideration when merging the CDP data with other data sources, such as the Worldscope financial data.
- **Data processing:** The original data processing entailed the extraction of multiple sections from the survey, which were then systematically aligned across different years, ensuring consistency across times and adjusting the format when the questions on the CDP surveyed changed or were slightly modified. It is important to note that the fact that some



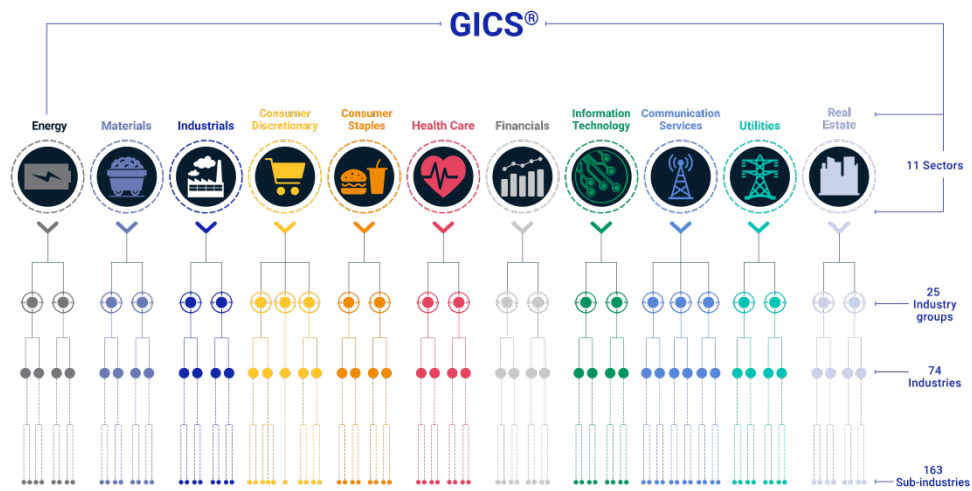
questions were not asked in some years, and that the questions were not always the same across years, is a significant challenge for the analysis which is specifically focused on forecasting emissions.

#### 2.4.2 DATA: WORLDSCOPE FUNDAMENTAL CORE ITEMS

In addition to the CDP Climate Survey data, financial predictors were obtained using the Worldscope database [3] accessed through Wharton Research Data Services (WRDS) [20]. Worldscope offers detailed standardized financials, allowing for comparisons of financial information across companies from various industries worldwide. This database boasts a long history, with over 35 years of data for key developed markets dating back to 1980 and more than 25 years for emerging markets. With its extensive coverage of over 100,000 companies in more than 120 countries, including full standardized coverage of over 30 developed and emerging markets and accounting for 99% of global market capitalization, Worldscope is a comprehensive source for firm-level data. Specifically, I queried the fundamental annuals through Worldscope via WRDS, which provided key global information such as *revenue*, *total assets*, *number of employees*, and *net income*, which I then used as predictors for my analysis [3]. Data was retrieved based on the ISIN code, and resulted in 96% of the firm-years having matching financial data. Of those, 17% had missing values for *at least one* of the selected financial variables, thus the corresponding firm-years were dropped from the data-set. This choice has been made as firms with missing financial data are likely to have total assets less than 1 million, thus I removed them following a similar criteria established by Serafeim et Al. [? ].

### 2.4.3 GICS DATA

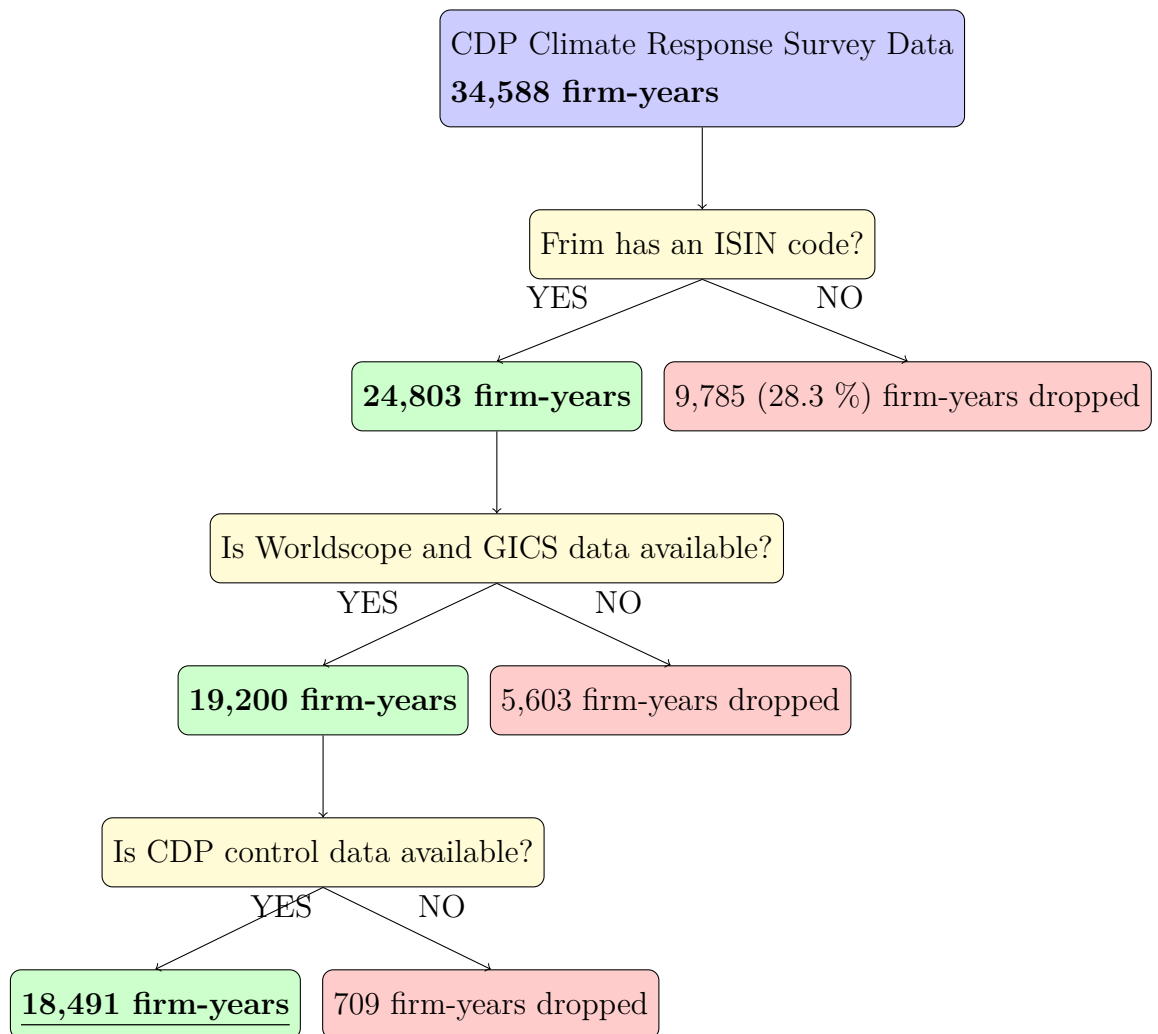
Accessed through WRDS using Capital IQ, the Global Industry Classification Standard (GICS) provides the framework for this study's industry analysis. GICS, a collaborative creation by MSCI and S&P Dow Jones Indices, offers a hierarchical, four-tiered classification system, encompassing Sectors, Industry Groups, Industries, and Sub-Industries. This standard ensures a consistent approach to defining company activities worldwide, crucial for comparative financial analysis. The classification of a company within GICS hinges on its principal business activity, with revenue being a primary determinant. The system also considers earnings and market perception, elements that contribute to the annual refinement of the classifications to mirror evolving market conditions. This research utilizes the 25 industry groups defined within GICS, facilitating a detailed examination of firm-level data against a backdrop of global industry standards [1, 2]. I queried the GICS data only for the firm-years that had matching financial data, resulting in 19,200 firm-years with complete financial and GICS data. GICS data was available for 99% of the firm-years that had matching financial data.



**Figure 2.4.1:** Global Industry Classification Standard (GICS) Structure [2].

#### 2.4.4 DATA CLEANING PROCESS FLOWCHART:

This is a visual representation of the data cleaning process with a specification of the number of firm-years dropped at each step:



- The data Sources and overall stats (such as number of observations, how the data was retrieved)
- The data cleaning process
- The predictor organization with all the EDA done (core, financial, CDP specific data)
- First let's do a variable definition table

#### 2.4.5 RESPONSE VARIABLE

**Table 2.4.1:** Variable Dictionary

Variable	Type	Description	Source
<b>Core Information</b>			
ID	categorical	unique firm identifier	CDP
Year	numerical	reporting year	CDP
Country	categorical	headquarters country	CDP
Continent	categorical	headquarters continent derived from country	CDP
Industry	categorical	Global Industry Classification Standard 25 industry sectors	GICS
<b>Financial Predictors</b>			
log(Revenue)	numerical	natural logarithm of total revenue	Worldscope
log(Assets)	numerical	natural logarithm of total assets	Worldscope
log(Assets 1yr gr.)	numerical	natural logarithm of total assets growth	Worldscope
log(Employees)	numerical	natural logarithm of total employees	Worldscope
log(Empl. 1y gr.)	numerical	natural logarithm of total employees growth	Worldscope
log(Net Income)	numerical	natural logarithm of net income	Worldscope
log(Market Cap)	numerical	market capitalization	Worldscope
log(Roe)	numerical	natural logarithm of return on equity	Worldscope
<b>CDP Predictors</b>			
Variable5	Type5	Description5	Source5

*Continued on next page*

Table 2.4.1 – *Continued from previous page*

Variable	Type	Description	Source
Variable6	Type6	Description6	Source6

## 2.4.6 EMISSIONS BREAKDOWN BY CONTINENT

	Count	Mean	Median	Std
Continent				
Africa	602	-2.81%	-0.9%	5.9%
Asia	4601	-3.13%	-1.0%	6.44%
Europe	7112	-4.94%	-1.9%	8.62%
North America	5259	-3.51%	-1.0%	7.31%
Oceania	472	-3.12%	-0.59%	6.88%
South America	430	-4.01%	0.0%	10.12%

## 2.4.7 EMISSIONS BREAKDOWN BY SECTOR

	Count	Mean	Median	Std
Sector				
Automobiles & Components	615	-3.2%	-1.91%	5.54%
Banks	1021	-5.82%	-2.9%	9.46%
Capital Goods	2350	-3.6%	-1.1%	6.87%
Commercial & Professional Services	602	-3.18%	-0.04%	7.7%
Consumer Durables & Apparel	636	-4.5%	-1.4%	8.28%
Consumer Services	378	-2.67%	-0.96%	6.65%

Continued on next page

Sector	Count	Mean	Median	Std
Consumer Staples Distribution & Retail	397	-3.72%	-1.9%	6.72%
Energy	846	-2.62%	-0.15%	5.66%
Equity Real Estate Investment Trusts	515	-5.53%	-2.33%	8.9%
Financial Services	766	-4.45%	-0.6%	8.98%
Food, Beverage & Tobacco	1019	-3.75%	-1.5%	6.63%
Health Care Equipment & Services	505	-3.6%	-0.9%	7.45%
Household & Personal Products	255	-5.33%	-2.4%	8.09%
Insurance	644	-4.85%	-2.0%	8.39%
Materials	2183	-2.46%	-0.6%	5.78%
Media & Entertainment	302	-4.93%	-0.54%	8.25%
Pharmaceuticals, Biotechnology & Life Sciences	604	-4.23%	-1.8%	7.63%
Real Estate Management & Development	222	-4.99%	-1.1%	8.86%
Retailing	484	-4.93%	-1.3%	9.43%
Semiconductors & Semiconductor Equipment	412	-3.6%	-0.5%	8.15%
Software & Services	555	-6.67%	-2.85%	10.21%
Technology Hardware & Equipment	776	-4.5%	-1.8%	8.76%
Telecommunication Services	488	-5.58%	-2.34%	9.26%
Transportation	780	-3.02%	-1.0%	6.3%
Utilities	1121	-3.54%	-0.1%	8.08%

#### 2.4.8 EMISSIONS BREAKDOWN BY COUNTRY

Country	Count	Mean	Median	Std
Argentina	1	0.0%	0.0%	nan%
Australia	397	-3.31%	-0.96%	6.43%
Austria	120	-5.27%	-1.55%	9.79%
Belgium	145	-4.54%	-2.0%	7.84%
Bermuda	20	0.93%	0.0%	12.78%
Brazil	343	-4.2%	0.0%	10.89%
Cambodia	3	0.0%	0.0%	0.0%
Canada	880	-2.59%	0.0%	6.25%
Cayman Islands	5	-1.62%	0.0%	7.54%
Chile	35	-4.44%	0.0%	7.24%
China	158	-1.76%	0.0%	5.85%
Colombia	40	-2.72%	0.0%	5.57%
Czech Republic	12	-13.85%	-0.15%	20.03%
Denmark	208	-4.23%	-0.7%	9.31%
Egypt	7	-1.46%	0.0%	2.85%
Estonia	2	0.0%	0.0%	0.0%
Finland	343	-5.18%	-2.0%	8.59%
France	826	-5.52%	-2.72%	8.46%
Germany	713	-4.28%	-1.06%	8.07%
Greece	41	-6.2%	-3.6%	9.19%
Guernsey	12	-3.38%	-2.54%	3.49%
Hong Kong	137	-1.7%	-0.27%	7.43%
Hungary	10	-2.11%	-0.85%	3.79%
Iceland	5	-2.21%	0.0%	3.51%
India	454	-3.54%	-0.14%	7.63%
Indonesia	13	-1.53%	0.0%	2.76%

Continued on next page



Country	Count	Mean	Median	Std
Ireland	158	-5.52%	-2.5%	7.99%
Israel	41	-3.33%	-1.8%	4.25%
Italy	365	-5.44%	-2.1%	9.25%
Japan	2964	-3.14%	-1.12%	6.08%
Jersey	3	0.0%	0.0%	0.0%
Kuwait	1	0.0%	0.0%	nan%
Lithuania	3	0.0%	0.0%	0.0%
Luxembourg	33	-1.88%	0.0%	6.23%
Malaysia	29	-1.57%	0.0%	6.19%
Malta	4	-3.28%	-1.55%	4.56%
Marshall Islands	2	0.0%	0.0%	0.0%
Mexico	108	-3.39%	0.0%	7.9%
Mongolia	4	0.0%	0.0%	0.0%
Netherlands	241	-5.34%	-2.71%	7.95%
New Zealand	71	-2.23%	0.0%	9.11%
Nigeria	3	0.0%	0.0%	0.0%
Norway	324	-3.95%	-1.1%	7.65%
Panama	2	0.0%	0.0%	0.0%
Peru	11	-1.67%	0.0%	4.53%
Philippines	27	-1.83%	0.0%	4.57%
Poland	36	-2.15%	0.0%	7.3%
Portugal	100	-6.44%	-3.95%	8.85%
Qatar	2	0.0%	0.0%	0.0%
Russia	48	-3.57%	-0.13%	7.12%
Saudi Arabia	1	-0.6%	-0.6%	nan%
Singapore	48	-3.39%	0.0%	7.28%

Continued on next page

	Count	Mean	Median	Std
Country				
South Africa	592	-2.84%	-0.99%	5.93%
South Korea	260	-3.43%	-1.41%	5.32%
Spain	398	-5.93%	-3.13%	9.49%
Sweden	495	-5.85%	-2.0%	10.44%
Switzerland	510	-5.35%	-2.78%	8.83%
Taiwan	129	-4.35%	-1.5%	6.85%
Thailand	79	-1.85%	0.0%	5.8%
Turkey	249	-3.76%	-1.0%	9.01%
Tuvalu	2	0.0%	0.0%	0.0%
USA	4244	-3.73%	-1.13%	7.45%
United Arab Emirates	2	-3.88%	-3.88%	5.49%
United Kingdom	1957	-4.44%	-1.23%	8.11%

#### 2.4.9 EMISSIONS BREAKDOWN BY YEAR

	Count	Mean	Median	Std
Year				
2011	1109	-2.51%	0.0%	6.09%
2012	1252	-3.04%	0.0%	6.03%
2013	1317	-3.29%	-1.0%	5.85%
2014	1322	-3.31%	-1.3%	6.01%
2015	1388	-3.66%	-1.7%	6.1%
2016	1451	-3.41%	-1.44%	5.97%
2017	1483	-3.59%	-1.5%	6.68%
2018	1374	-4.14%	-1.55%	7.69%

Continued on next page

	Count	Mean	Median	Std
Year				
2019	1530	-4.19%	-1.2%	8.08%
2020	1701	-4.52%	-1.5%	8.59%
2021	2088	-5.2%	-1.2%	9.75%
2022	2461	-4.7%	-0.82%	9.79%

- Number of firms and unique isins
- Number of variables
- Number of firms per sector

## 2.5 RESPONSE VARIABLE ANALYSIS

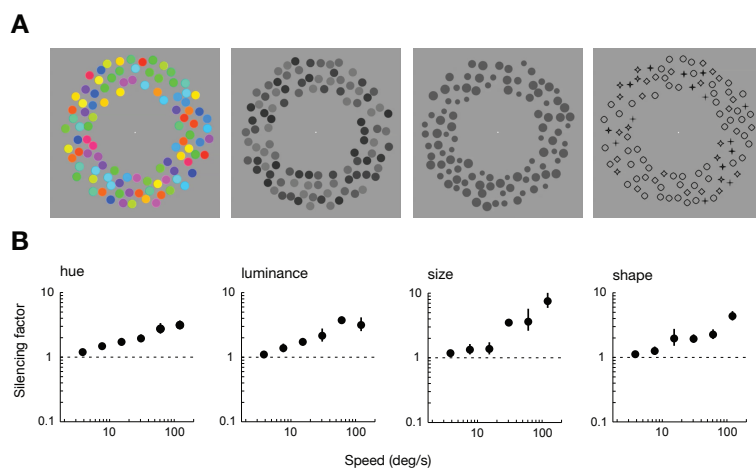
## 2.6 PREDICTOR VARIABLE ANALYSIS

- Here I can put cool visualizations
- Here I can start explainig the data
- Here I can take inspiration from Kaggle
- Here is can do some clustering?

## 2.7 BUILDING THE TRAINING SET

Lorem ipsum dolor sit amet, consectetur adipiscing elit. Morbi commodo, ipsum sed pharetra gravida, orci magna rhoncus neque, id pulvinar odio lorem non turpis. Nullam sit amet enim. Suspendisse id velit vitae ligula volutpat condimentum. Aliquam erat volutpat. Sed quis velit. Nulla facilisi. Nulla libero. Vivamus pharetra posuere sapien.

Some nice graphs are shown in Figure 2.7.1.



**Figure 2.7.1:** Some nice graphs.



Some extra stuff

Here is a useful table of distributions.

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