

Corporate Greenhouse Gas Emissions, Reduction Programs, and Targets
An Analysis of Relationships and Patterns
Anwendungsorientiertes Projektpraktikum – Data Science

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1 Introduction

1.1 Motivation

Climate change presents one of the most significant challenges of our time, with corporate greenhouse gas emissions playing a substantial role in global carbon footprints. As stakeholders increasingly demand corporate climate action, companies worldwide have implemented various emission reduction programs and set targets to demonstrate their commitment to sustainability. Understanding the effectiveness of these initiatives is crucial for both corporate strategy and public policy development.

1.2 Problem Statement

Despite widespread adoption of corporate sustainability initiatives, there remains significant uncertainty regarding which approaches yield meaningful emissions reductions. Companies implement diverse programs and targets, but the relationship between these initiatives and actual emissions outcomes is often unclear. This knowledge gap hinders effective decision-making for both corporate sustainability professionals and policymakers.

1.3 Research Questions

This analysis addresses two primary research questions:

1. What patterns exist in the data regarding corporate greenhouse gas emissions, reduction programs, and targets?
2. What relationships can be derived between corporate greenhouse gas emissions, reduction programs, and targets based on the available data?

2 Fundamentals and Related Research

2.1 Corporate Emissions Measurement Frameworks

Corporate greenhouse gas (GHG) emissions are typically categorized into three scopes according to the Greenhouse Gas Protocol, the most widely used international accounting tool:

- **Scope 1:** Direct emissions from owned or controlled sources (e.g., fuel combustion).
- **Scope 2:** Indirect emissions from purchased energy (electricity, steam, etc.).
- **Scope 3:** All other indirect emissions in the value chain (upstream and downstream).

This framework provides a comprehensive approach, though reporting completeness varies, especially for Scope 3.

2.2 Types of Reduction Programs

Companies implement various emission reduction programs, broadly including:

- **Energy efficiency:** Reducing consumption.
- **Renewable energy:** Transitioning to low-carbon sources.
- **Operational changes:** E.g., transportation optimization, supply chain engagement.
- **Carbon capture:** Technologies to sequester emissions (less common in data).

The specific programs analyzed in this report fall into categories such as Energy Saving, Energy Alternatives, Audits, and Governance structures, based on the available MSCI data.

2.3 Target-Setting Approaches

Common emission reduction target approaches include:

- **Absolute targets:** Reducing total emissions.
- **Intensity targets:** Reducing emissions per unit of output/revenue.
- **Science-based targets (SBTs):** Aligning goals with climate science (often a combination of absolute/intensity).

Key parameters analyzed include scope coverage, target type, time frame, and ambition level (percentage reduction).

3 Methodology

3.1 Data Sources

This analysis utilizes four primary MSCI datasets provided for the project:

- **Company Emissions Data:** Emissions (Scopes 1, 2, limited 3), financial metrics, identifiers.
- **Reduction Targets Data:** Target details (type, scope, ambition, progress).
- **Reduction Programs 1 Data:** High-level strategies (manufacturing, transport, etc.).
- **Reduction Programs 2 Data:** Specific program details (type, year, oversight).

Datasets were linked using the unique company identifier `ISSUERID`.

3.2 Analytical Approach

A multi-stage approach was followed:

1. **Data Preparation:** Integrating datasets, cleaning identifiers and codes, handling missing values (primarily through case-wise deletion for correlations or simple imputation where necessary), and deriving key metrics (e.g., emission trends, target ambition categories).
2. **Exploratory Data Analysis (EDA):** Examining distributions, trends, and patterns using descriptive statistics and visualizations.
3. **Relationship Analysis:** Investigating correlations and associations between emissions, targets, and program variables using statistical tests.
4. **Modeling Exploration (Brief):** Initial exploration using modeling techniques to assess predictive relationships (details reserved for further work).

3.3 Methods Used

The primary methods employed for this internship report include:

- **Descriptive Statistics:** Summarizing central tendencies, distributions, and frequencies.
- **Correlation Analysis:** Using Pearson's r and Spearman's ρ to assess linear and monotonic relationships.
- **Group Comparisons:** Using statistical tests (like t-tests or ANOVA conceptually, though specific tests not detailed here) to compare means (e.g., emission trends across different groups).
- **Visualization:** Using charts (bar charts, scatter plots, maps) to illustrate patterns and relationships.
- *Note:* While pattern mining (association rules) and predictive modeling (ML/DL) were explored, their detailed results are complex and considered beyond the primary scope of this concise internship report, reserved for potential future work (e.g., thesis).

3.4 Evaluation Metrics

Relationships were primarily evaluated using:

- **Correlation coefficients** (r , ρ).
- **Statistical significance** (p-values, conceptually considered).
- **Magnitude of differences** in means or trends between groups.

4 Dataset Creation and Data Preparation

4.1 Dataset Descriptions

The analysis utilized the four MSCI datasets, linked via `ISSUERID`. Key datasets included:

- **Company Emissions:** Approximately 19,000 companies with emissions and financial data. Scope 3 data shows high missingness (over 75%).
- **Reduction Targets:** Around 58,000 target entries covering roughly 7,000 unique companies. High missingness observed for progress (over 65%) and offsets (over 98%).
- **Reduction Programs 1:** About 2,800 companies with high-level strategy information. Most strategy fields have high missingness (over 65%).
- **Reduction Programs 2:** Approximately 52,000 program entries for around 7,000 companies. Oversight information is missing in about 80% of entries.

(Refer to Data Dictionaries for full details).

4.2 Data Cleaning Procedures

Standard cleaning involved harmonizing identifiers, country/industry codes, date formats, and categorical values.

4.3 Missing Data Treatment

Given the high levels of missing data, analyses primarily used pairwise complete observations for correlations and descriptive statistics. Where group comparisons were made (e.g., average trends), they were based on available data for those groups. The prevalence of missing data is a key limitation noted in the Evaluation section.

4.4 Variable Transformations

Key derived variables included:

- **Emissions Trend:** Calculated as the 3-year compound annual growth rate (CAGR) of Scope 1 and 2 intensity (`CARBON_SCOPE_12_INTEN_3Y_GIC_CAGR`). Negative values indicate improvement.
- **Target Ambition Categories:** Derived from `CBN_TARGET_REduc_PCT`, with thresholds defined as follows: Low (below 10%), Medium (10–30%), and High (above 30%).
- **Program Implementation Score (Conceptual):** Based on the number of implemented programs, diversity of program types, and presence of oversight, where available.
- **Benchmarks:** Company-level metrics compared against relevant industry and regional averages.

5 Exploratory Data Analysis

5.1 Emissions Patterns

5.1.1 Geographic Distribution

The dataset covers companies globally, with concentrations in the US, China, Japan, India, and Europe. Significant regional variations in emissions trends were observed:

- Europe showed the strongest average improvement trend (-5.14%).
- North America also showed improvement (-3.20%).
- Asia-Pacific, on average, showed a slight worsening trend (+0.56%).
- Top improving countries included Finland (-9.37%), Denmark (-6.87%), and the UK (-6.45%).

3. Geographic and Industry Context Matters

3.1 Country-Level Target Count vs. Emission Trends Based on 45 Countries with ≥10 Companies

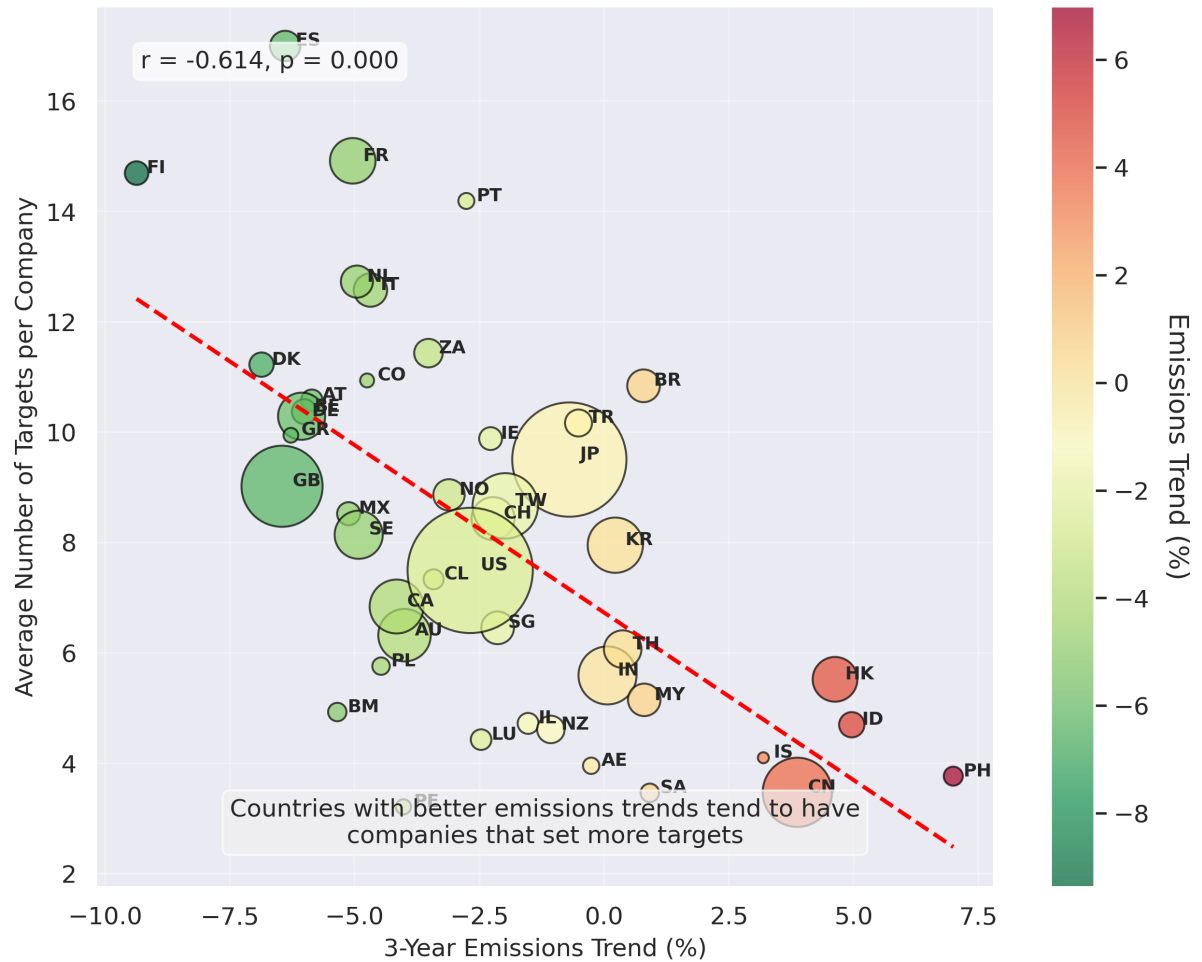


Figure 1: Geographic and Industry Context Matters (Geographic Distribution of Emissions Trends).

5.1.2 Industry Distribution

Emission profiles varied greatly by industry:

- High absolute emissions were concentrated in sectors like Electricity Production, Cement, Refined Petroleum, and Basic Metals.
- Intensity varied, with sectors like Cement showing very high intensity, while Financial Services and Technology were low.
- Some high-emitting sectors like Electricity Distribution (-6.03%) and Basic Metals (-4.49%) showed strong average improvement trends, while others like Lignite Mining (+3.71%) worsened.

5.2 Target-Setting Behavior

- Target setting is widespread among reporting companies, with approximately 7,000 companies having defined targets.
- Absolute targets (53%) are more common than intensity targets (21%).
- A notable share of targets are ambitious, aiming for reductions exceeding 30%.
- Observed relationships include:
 - Companies with higher absolute emissions tend to set more targets but often choose less ambitious percentage reductions.
 - Firms reporting greater Scope 3 emissions are more likely to establish targets.
 - At the country level, a higher prevalence of target-setting is strongly associated with improved emissions trends.



Figure 2: Scale of Emissions and Target-Setting Behavior (Target Count vs. Log Absolute Emissions and Target Ambition vs. Absolute Emissions).

5.3 Program Implementation Trends

- Most companies report multiple programs (avg. 7 per company in Programs 2 dataset).
- Common program categories include Energy Saving, Energy Alternatives, and Responsible Level/Governance.
- Reporting of program implementation peaked around 2020-2022.
- Governance is evolving: Board-level oversight reporting increased significantly over time. Companies reporting executive oversight show better average trends (-1.67%) than those without (+0.67%).

6 Key Relationship Models and Evaluation

This section focuses on evaluating the key relationships identified through statistical analysis and initial modeling explorations, relevant to the research questions. (Detailed predictive modeling results are reserved for future work).

6.1 Impact of Target Characteristics

- **Ambition Level:** Companies with medium-ambition targets (10-30% reduction) showed the best average emission intensity trends (-3.82%), closely followed by high-ambition targets (-3.70%). Both performed significantly better than companies with no reported targets (+1.19%).
- **Target Progress:** Companies reporting substantial progress towards (or exceeding) their targets demonstrated the strongest emission reductions. For instance, those reporting 175-200% progress had an average trend of -8.7%. (Note: High missing data for progress).
- **Target Type:** Companies using absolute targets tended to have lower average intensity than those using intensity targets, though this relationship was weak ($\rho = -0.1$). The analysis indicates that effectiveness is more strongly linked to ambition and progress rather than the target type alone.

6.2 Impact of Program Implementation Elements

- **Audits and Verification:** The presence of formal energy audits correlated strongly with improved trends. External independent audits showed the best average trend (-7.21%), followed by internal audits (-5.33%) and ISO 50001 certification (-3.65%), all outperforming general statements or no evidence.
- **Governance:** As noted in EDA, executive/board oversight was associated with better trends (-1.67%) compared to no evidence (+0.67%).
- **Program Scope/Quality (from Programs 1):** While data is sparse, companies with more comprehensive strategies (e.g., "All or core facilities/products") tended to show better trends than those with "Some" or "General statements", though correlations were generally weak overall.

6.3 Contextual Factors: Industry and Region

- The strength and even direction of relationships between targets/programs and emission trends often varied significantly depending on the industry and region, confirming these as crucial mediating factors.

2. Types of Targets and Their Effectiveness

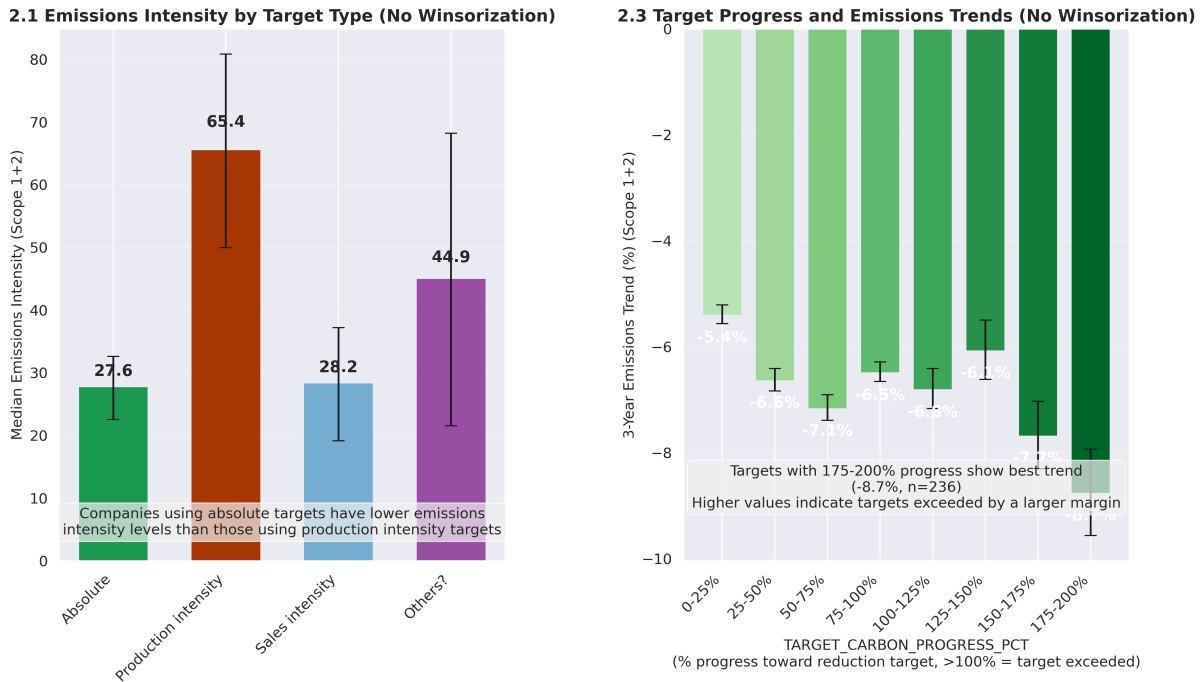


Figure 3: Types of Targets and Their Effectiveness (Emissions by Target Type and Target Progress vs. Emission Trends).

- For example, the correlation between higher emissions and target ambition was positive in some industries but negative in others. Similarly, program effectiveness differed markedly across sectors (e.g., Retail vs. Manufacturing).

6.4 Overall Predictive Power (Brief Note)

Initial modeling explorations (details omitted) suggested that while targets and program elements show correlations with emission trends, their overall power in predicting future trends is modest compared to factors like a company's existing emissions profile, size, industry, and recent historical performance. This implies programs and targets are part of the picture, but not the sole determinants.

6.5 Limitations

These findings are subject to significant limitations:

- **Correlation vs. Causation:** Analyses are correlational; causality cannot be definitively established. Good performance might lead to target setting, or vice-versa, or both could be driven by other factors (e.g., regulation, management quality).
- **Data Gaps:** High levels of missing data for key variables (Scope 3, target progress, program oversight, strategy details) limit the robustness and scope of conclusions.
- **Reporting Quality:** Reliance on self-reported data may introduce bias.
- **Time Lag:** Effects of programs and targets may take time to manifest, potentially longer than the available data window.

7 Discussion

7.1 Interpretation of Key Findings

The analysis indicates that corporate climate targets and sustainability programs are indeed associated with emissions performance. However, these relationships are complex and highly dependent on context. The widespread adoption of targets reflects broad corporate recognition of the climate challenge.

Interestingly, companies with medium-ambition targets tend to show the strongest average improvements. This may suggest that such targets strike a practical balance between ambition, feasibility, and execution.

Governance and verification mechanisms—particularly audits—consistently correlate with better outcomes. This points to the importance of implementation *quality* and *oversight*, rather than just the number of programs in place.

Finally, industry and regional context emerge as critical factors. Emissions reduction is not a one-size-fits-all challenge: sector-specific characteristics (such as technology options, regulatory pressures, and supply chain structures) and regional influences (like energy mix and policy frameworks) play a major role in shaping both emissions patterns and the success of corporate initiatives.

7.2 Business Implications

For companies, the findings tentatively suggest that:

- Setting targets, particularly realistically ambitious ones (e.g., 10-30% initially), is associated with better performance trajectories on average.
- Investing in robust governance (executive oversight) and verification (especially external audits or certifications like ISO 50001) may be crucial for program effectiveness.
- Strategies should be tailored to the specific industry context and regional operating environment.
- Tracking progress diligently is important, as significant progress correlates with strong reductions.

7.3 Policy Considerations

For policymakers, the analysis suggests:

- Policies encouraging credible target-setting and transparent reporting remain important.
- Mechanisms promoting or supporting independent verification and robust governance could enhance the effectiveness of corporate initiatives.
- Sector-specific and regionally-sensitive policies may be more effective than purely universal approaches.
- Addressing data gaps, especially for Scope 3 and program specifics, is crucial for better monitoring and evaluation.

8 Conclusion

8.1 Summary of Findings

This internship report examined patterns and relationships across corporate GHG emissions, reduction targets, and sustainability programs, based on MSCI data. Target-setting is common and generally associated with improved emissions performance—particularly when companies make substantial progress toward their goals.

Medium-ambition targets (10–30% reduction) and programs with strong oversight and third-party verification are most strongly linked to favorable trends. However, these associations are not universal; they are significantly shaped by industry sector and geographic context. Structural characteristics—such as a company’s existing emissions profile and size—remain among the strongest predictors of emissions outcomes.

8.2 Answers to Research Questions

1. **What patterns exist?** The data reveals widespread adoption of absolute emissions targets, notable regional differences in emissions trends (with Europe improving the most and Asia-Pacific the least), strong sector-specific variation in emissions intensity, and growing board-level oversight of climate initiatives.
2. **What relationships can be derived?** Statistical correlations suggest that companies with medium-ambition and high-progress targets tend to achieve better emissions reductions. Similarly, firms with robust governance structures and audit mechanisms perform better on average. However, these findings represent associations rather than causation and are influenced by contextual factors like industry and geography. Early modeling efforts indicate that while targets and programs contribute to outcomes, company fundamentals and historical performance remain stronger predictors.

8.3 Future Research Directions

This internship report provides a foundation for further research that could be developed in a bachelor thesis. Future directions include:

- Developing a more robust metric for program implementation quality, combining program type, governance, and audit mechanisms.
- Investigating causal effects of specific interventions using quasi-experimental designs (e.g., matching, difference-in-differences).
- Incorporating additional public datasets, such as CDP disclosures, national emissions inventories, or sector-specific databases to enrich analysis and improve coverage of Scope 3 and implementation detail.
- Enhancing time-series components of the analysis where more historical data becomes available.
- Leveraging natural language processing to extract insights from qualitative program descriptions (e.g., strategy text fields or sustainability reports).