Decarbonization Priorities: A Sector-Based Analysis of Global Greenhouse Gas Emissions

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Abstract—This paper analyzes global greenhouse gas emissions across major sectors to identify priorities for decarbonization. Using datasets from Our World in Data, the study traces long term emission trends and examines sector and subsector contributions. A structured narrative and a set of refined visualizations guide readers from historical patterns to detailed sources of emissions. The findings show that the energy sector is the largest contributor, that industry and waste emissions are highly concentrated, and that agriculture has a more complex internal structure. An ethics and accessibility review supports the clarity and fairness of the visual design. The results provide a clear foundation for targeted climate mitigation strategies.

I. INTRODUCTION

Understanding which sectors should decarbonize first is a primary question in contemporary climate policy, and answering it requires a clear, data-driven understanding of where greenhouse gas emissions originate. This analysis relies on the comprehensive datasets from Our World in Data (OWID) [2], which integrate global greenhouse gas emission data from leading international statistical bodies, including the Global Carbon Project, the International Energy Agency, and the Intergovernmental Panel on Climate Change. The dataset includes both historical and contemporary emissions, disaggregated by gas type, country, economic sector, and specific subsectoral activities. This level of detail allows for an examination of emissions not only across major sectors, such as energy, industry, agriculture, and waste, but also within the internal processes that drive emissions in each domain. By combining long-term trends with detailed sectoral data, the dataset provides a comprehensive foundation for evaluating decarbonization priorities.

The topic is particularly relevant at a time when global greenhouse gas emissions have reached unprecedented levels, exceeding 50 billion tonnes of CO_2-equivalent annually [4]. Although international climate agreements emphasize economy-wide reductions, effective mitigation requires clarity about which sectors contribute most significantly and which processes within them offer the greatest potential for meaningful, rapid reductions. The urgency of climate action, together with constraints in financial, technological, and political resources, increases the need for clear prioritization. Not all sectors can decarbonize at the same pace, nor do they face the same technical or economic constraints. A sector-based approach therefore enables more strategic interventions, aligning mitigation pathways with the structural realities of global emissions.

This report is intended for an interdisciplinary audience that includes students, policymakers, sustainability analysts, educators, and individuals seeking a clearer understanding of the emissions landscape. The visual and analytical structure supports readers of different expertise levels by pairing accessible explanations with rigorous data interpretation. For policymakers and climate professionals, the sectoral breakdowns offer actionable insights into where policy efforts and investments may yield the highest impact. For students and the broader public, the report offers clarity on the contributions of the energy, industry, agriculture, and waste sectors to the climate crisis and on the reasons decarbonization strategies must differ across these systems.

This work is motivated by the understanding that effective climate mitigation relies on precise analysis and clear communication. By leveraging OWID's rich dataset and presenting the information through a series of thoughtfully designed visualizations, this report seeks to illuminate the structural patterns within global emissions and support informed decision-making. Ultimately, the goal is to demonstrate that prioritizing decarbonization is not merely a technical exercise but a strategic process grounded in understanding where emissions originate and how they can be addressed most effectively.

II. NARRATIVE DESIGN

The narrative design of the report adopts a deliberate top-down structure, leading readers from a broad view of global greenhouse gas emissions to increasingly detailed sectoral and subsectoral perspectives. This structure supports the communicative goal of enabling audiences to first grasp the magnitude of the climate challenge before considering where targeted interventions may be most effective. The storyboard progresses through three sequential stages—historical framing, sectoral comparison, and subsectoral diagnosis—before concluding with a comprehensive synthesis that emphasizes the need to strategically prioritize decarbonization efforts. This staged progression is explicitly reflected in the report's visualization sequence, which transitions from a 170–year emissions trend line to sector-level distributions and then to detailed breakdowns within industry, waste, agriculture, and energy.

The opening stage of the narrative provides the temporal and conceptual groundwork for the analysis. The long-term emissions trajectory from 1850 to 2023, presented through a continuous line chart as shown in Fig. 1, communicates both the sustained escalation of global emissions and the urgency of

identifying the sources of contemporary outputs. By visually emphasizing acceleration in the post–industrial period, this figure positions the audience to understand why sectoral prioritization is essential. The rationale for beginning with this perspective aligns with audience needs: policymakers and students alike require a clear sense of scale before evaluating sector-level dynamics, and the historical overview provides exactly this anchor. As the report notes, the line chart uses perceptually strong encodings to maximize clarity for readers with varying levels of technical proficiency.

The second storyboard stage shifts to a high-level comparison of emissions across major sectors. The sectoral pie chart serves as a bridge between the macro historical context and the subsequent analytical deep dives. Its primary narrative function is to reveal that the energy sector dominates global emissions, contributing 73.2%, while agriculture, industry, and waste comprise comparatively smaller shares (see Fig. 2). For the target audience, this figure helps build an intuition for relative magnitudes before introducing the internal variation within each sector. The rationale for this placement is grounded in audience needs analysis: early-stage learners benefit from simple part-to-whole representations, whereas experts can quickly identify priority domains without yet requiring subsectoral precision.

The third stage of the narrative advances into subsectoral decomposition, employing a series of pie charts to examine industry, waste, and agriculture. These figures reveal distinct structural patterns: industry is concentrated in two dominant processes, waste is split between landfills and wastewater, and agriculture exhibits multifaceted complexity. The storyboard intent is to demonstrate that decarbonization strategies must differ not only across sectors but also within them. This message supports the report's broader claim that effective climate mitigation requires approaches that reflect the structural characteristics of each domain. The choice to use conceptually simple pie charts aligns with the audience analysis: the report is intended for interdisciplinary readers who benefit from accessible conceptual overviews before engaging with technical detail.

The final stage introduces a detailed emissions table for the energy sector. This change in visual format responds to the need for precision in examining the sector responsible for most global emissions. Unlike the concentrated structures of industry and waste, the energy sector displays a diffuse distribution across transportation, buildings, and industrial energy use. The table format was selected precisely because audiences such as policymakers and analysts require accurate values to evaluate tradeoffs and intervention pathways. The narrative intent here is to underscore that energy-sector decarbonization cannot rely on a single technological solution but must address multiple end uses concurrently.

Overall, the narrative design integrates audience needs analysis with a coherent story arc that progresses from global patterns to targeted insights. This structure allows readers from different backgrounds to construct accurate mental models of emission sources while also clarifying the strategic basis for
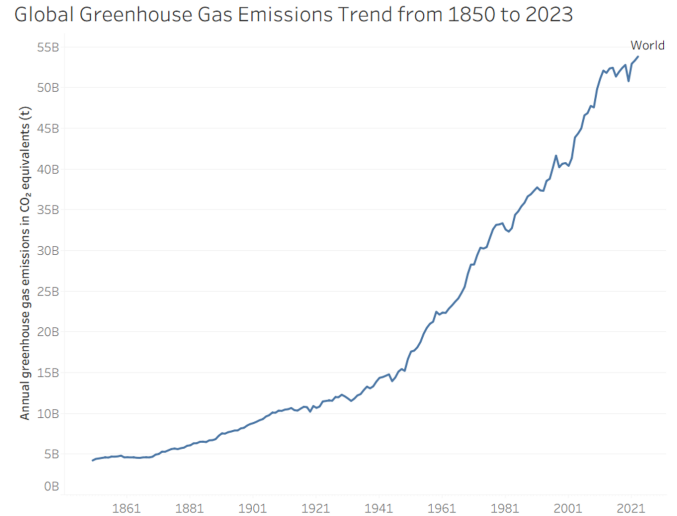

Fig. 1. Long-term trajectory of global annual greenhouse gas emissions from 1850 to 2023, demonstrating a pronounced and continuous growth with steep acceleration after the mid-20th century.

prioritizing specific sectors and subsectors in global decarbonization efforts.

III. Visualization Design & Iteration

The article was designed to guide readers from a macro-level understanding of global greenhouse gas emissions toward increasingly granular insights into how specific sectors and subsectors contribute to the problem. This top-down structure reflects visualization research emphasizing progressive refinement, in which audiences first acquire broad conceptual understanding before examining detailed components (Tufte, 2001) [5]. By initially presenting historical emissions trends, the report grounds the reader in the scale and urgency of the climate challenge, then moves toward contemporary sector distributions and finally into the internal structure of each sector. This ordered progression helps readers form accurate mental models, enabling a narrative shift from "How large is the problem?" to "Where does it come from?" and ultimately "What processes should be prioritized for mitigation?"

A. Long-Term Emissions Trend

The first visualization shown in Fig. 1 is a line chart of annual global greenhouse gas emissions from 1850 to 2023 [3], and it serves as the conceptual foundation of the analysis. Its primary purpose is to establish the long-term context and illustrate the scale and persistence of rising emissions, thus preparing the reader to understand why identifying high-emission sectors is both urgent and necessary. Its encoding choices follow established perceptual principles. Position along a common scale (time on the horizontal axis and emissions on the vertical axis) provides the highest accuracy for quantitative judgment, as demonstrated in Cleveland and McGill's classic hierarchy of graphical perception (1984) [1]. The continuous line mark also reinforces the continuity and
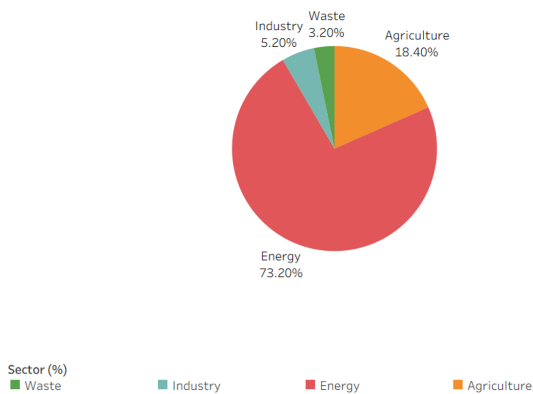
Fig. 2. Proportional contributions of major sectors to global greenhouse gas emissions in 2020, with energy systems accounting for the majority share, followed by agriculture, forestry and land use, industry, and waste.
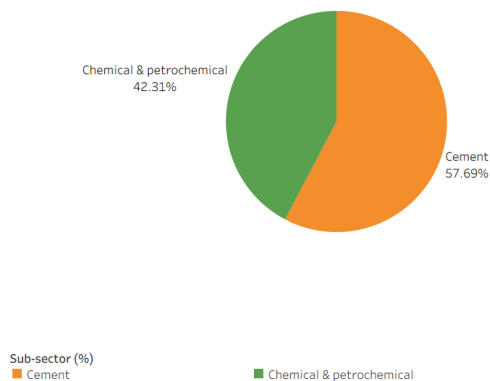

Fig. 3. Composition of industrial greenhouse gas emissions in 2020, showing the relative shares of emissions from cement production and the chemical and petrochemical industries.

long-term nature of emissions growth rather than as isolated points. Although the chart does not include interactive features, this design choice aligns with the report's purpose, as the goal is to convey a clear historical pattern rather than facilitate detailed exploration. Alternative designs, such as bar charts or stacked area graphs, would obscure temporal smoothness and distract from the visualization's purpose of illustrating a clear and accelerating trend. Following Tufte's idea [5] of "data over decoration", the chart's simple design lowers the viewer's mental load and ensures that the historical trend remains the main message and the reason for examining sectors separately.

B. Global Emissions by Sector

As shown in Fig. 2, the second visualization presents a pie chart comparing emissions across global sectors in 2020 and acts as a transitional figure between the historical context and sector-specific insights. It reveals that the energy sector is vastly dominant, contributing 73.2% of emissions, while agriculture (18.4%), industry (5.2%), and waste (3.2%) comprise the remaining share. Although angle encoding is less precise than position or length (Cleveland & McGill, 1984) [1], pie charts remain effective for showing how smaller categories relate to the overall total, particularly when one category is overwhelmingly large. In line with Ware's findings (2013) [7], color is used to distinguish sectors and accelerate categorical identification. A bar chart might offer greater accuracy, but it would reduce the intuitive understanding of how large each category is in relation to the others, which is essential at this point in the discussion.

C. Unified Encoding Rationale for the Pie Charts (Industry, Waste, Agriculture)

Using pie charts for industry, waste, and agriculture visualizations aligns with the shared goal of depicting the internal

distribution of emissions within each sector. This visual form capitalizes on the pie chart's conceptual advantage in showing how components contribute to the total and distinguishing the concentrated pattern from the diverse structural patterns. Although angle and area encoding are perceptually weaker than length (Cleveland & McGill, 1984) [1], they are well suited to datasets with few categories or large differences among them. Color again functions as a categorical channel, aiding perceptual grouping as noted by Ware (2013) [7]. The simplicity of the presentation is consistent with Tufte's principle [5] that visualizations should maximize the data-ink ratio and eliminate unnecessary complexity. Alternative designs such as bar charts or treemaps would increase precision, but risk either emphasizing trivial differences or generating visual clutter, undermining the focus on high-level structural patterns.

D. Industry Sector Emission Sources

Fig. 3 presents a pie chart illustrating the breakdown of industrial greenhouse gas emissions in 2020. Despite contributing less than the energy or agriculture sectors, industry remains central to global decarbonization debates. Its purpose is to highlight the main industrial processes that drive emissions, showing that cement production accounts for 57.69% of sector emissions, followed by chemical and petrochemical processes at 42.31%. By revealing that only two subsectors produce all industrial emissions, the visualization supports calls for targeted technological improvements such as cement substitutes, low-carbon feedstocks, and cleaner industrial heat. While a bar chart would yield more precise values, it could falsely suggest a wider spread of contributors. The pie chart more clearly shows that only two processes dominate the industry sector.
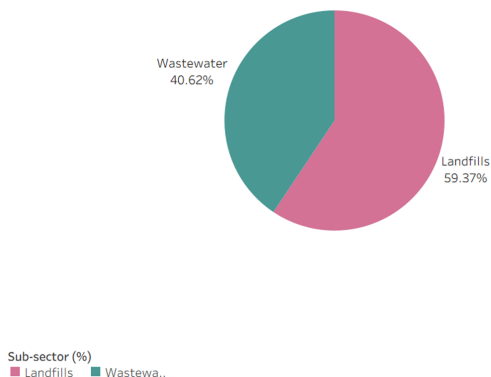
Fig. 4. Breakdown of greenhouse gas emissions from the waste sector in 2020, illustrating the major contributions from landfills and wastewater treatment.
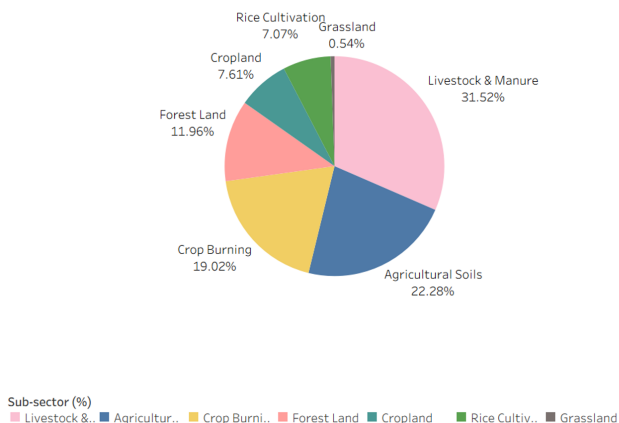

Fig. 5. Distribution of greenhouse gas emissions across agricultural sub-sectors in 2020, highlighting the dominant contributions from livestock and manure, agricultural soils, and crop burning.

E. Waste Sector Emission Sources

Fig. 4 shows a similar concentration pattern in the waste sector in 2020, where landfill emissions (59.37%) exceed wastewater emissions (40.62%). These results provide a basis for targeted mitigation efforts, including the deployment of methane capture technologies and improvements in landfill management practices. Because the visualization includes only two categories, angle encoding poses little difficulty, and the pie chart clearly shows landfill emissions as the larger source.

Through its clarification of emission patterns within the waste sector, the visualization reinforces the broader argument of the report that global emissions are uneven both between sectors and within individual sectors. This provides a foundation for the subsequent analysis of the agricultural sector, which exhibits a more complex and diverse internal structure.

F. Agriculture Sector Emission Sources

Fig. 5 presents a pie chart of agricultural emissions in 2020 and clarifies how emissions grow more complex as the analysis transitions from industrial sectors to land-based systems. Unlike the previous sectors, the agriculture figure presents a wide and diverse set of emission sources. Livestock and manure contribute 31.52%, agricultural soils contribute 22.28%, crop burning contributes 19.02%, along with several smaller sources. Its purpose is to indicate the inherent complexity of agricultural decarbonization, which requires more than a single technological approach. Although options such as stacked bar charts or treemaps might strengthen precise category comparisons, they would weaken the presentation of how each category fits into the total and would risk overstating the importance of minor subsectors.

G. Energy Sector Emission Sources Table

A detailed table of energy subsector emissions in 2020 forms the final visualization displayed in Table. I, which fulfills

a narrative role different from that of the preceding pie charts. Its role is to make it clear that the energy sector is complex and fragmented. Despite contributing the largest share of global greenhouse gas emissions, the sector is not characterized by dominance from only one or two activities. Instead, emissions are distributed across a varied set of end uses, including road transport at 11.90%, residential energy use at 10.90%, other industrial activities at 10.60%, unallocated fuel combustion at 7.80%, and multiple smaller contributors. Through a detailed table, the visualization shows that energy-sector decarbonization must address transportation, buildings, industry, and fuel systems at the same time.

Tables use aligned text and numbers and depend on position on a common scale, the most precise quantitative channel noted by Cleveland and McGill (1984) [1], which supports Tufte's view [5] that tables are superior when accuracy and completeness matter. A bar chart would become difficult to interpret with over twenty subsectors and might introduce misleading visual hierarchies. In contrast, the table preserves clarity and brings attention to the complexity of the sector.

H. Conclusion

Together, the six visualizations construct a cohesive analytic progression. The historical trend establishes urgency; the sector-level pie chart identifies where emissions originate; the subsector pie charts reveal structural concentration or diversity within industry, waste, and agriculture; and the energy table exposes a broad, multifaceted distribution requiring a correspondingly multifaceted mitigation strategy. These visualizations jointly demonstrate that effective decarbonization must be both sector-specific and process-specific, informed by an understanding of the varying structures and drivers behind emissions across the global economy.

Group	Category	Percentage
Energy use in building	Residential	10.90%
	Chemical	3.60%
Transport	Road	11.90%
	Pipeline	0.30%
	Rail	0.40%
	Ship	1.70%
	Aviation	1.90%
Energy use in industry	Other industry	10.60%
	Unallocated fuel combustion	7.80%
	Iron & Steel	7.20%
	Commercial	6.60%
	Livestock & Manure	5.80%
	Agricultural Soils	4.10%
	Oil & Natural Gas	3.90%
	Crop Burning	3.50%
	Cement	3.00%
	Forest Land	2.20%
	Chemical & petrochemical	2.20%
	Landfills	1.90%
	Coal	1.90%
	Energy in Agri & Fishing	1.70%
	Cropland	1.40%
	Wastewater	1.30%
	Rice Cultivation	1.30%
	Food and tobacco	1.00%
	Non-ferrous metals	0.70%
	Paper, pulp & printing	0.60%
	Machinery	0.50%
	Grassland	0.10%

IV. ETHICS & ACCESSIBILITY REFLECTION

This section presents an ethics and accessibility review of the visualizations used in the report. The review focuses on the clarity of information, risks of misinterpretation, and the ability of diverse audiences to understand the data. The goal of this reflection is to ensure that the visualizations communicate information responsibly while remaining accessible to users with different levels of experience and different abilities.

A. Audit Results

The audit identified several strengths in the visualization design. All figures use clear labels, consistent terminology, and transparent data sources. These features help reduce confusion and support accurate interpretation. The narrative structure also follows a logical progression that begins with broad historical context and moves toward sector and subsector detail. This structure reduces cognitive burden for readers because it introduces complexity gradually rather than all at once. The color schemes used in the figures were reviewed for colorblind safety, and most figures remain readable when viewed with common forms of color vision deficiency. The table used to present energy sector emissions performed especially well in the accessibility review because tables allow precise comparisons, are compatible with screen readers, and do not require color to convey meaning.

The audit also noted that the use of multiple formats, including line charts, pie charts, and tables, supports diverse user needs. Readers who prefer visual summaries benefit from charts, while those who require exact numeric values can rely on the table. In addition, the text accompanying each visualization provides clear explanations of the intended message, which further reduces the chance of confusion.

B. Risks Identified and Mitigations Applied.

The audit identified three primary risks. The first risk relates to possible misinterpretation of pie charts. Pie charts depend on angle and area perception, which can be difficult for some viewers to judge accurately. Small categories may appear less important than they actually are, and viewers with low vision may struggle to distinguish slice boundaries. To reduce this risk, labels were placed directly next to each slice, and the number of categories per chart was kept small. The text also clarifies that these charts are intended to show general patterns rather than precise measurements.

The second risk concerns accessibility for users who rely on assistive technologies or who have limited color perception. To address this, the visualizations use color palettes with strong contrast and include text labels so that information is never communicated through color alone. The table uses structured formatting that follows a logical reading order and includes clear column headings, which improves compatibility with screen readers.

The third risk involves possible narrative bias. Visual formats can unintentionally exaggerate the importance of certain categories or hide differences that matter for policy decisions. To reduce this risk, the report explains the reasoning behind choosing each visualization format and acknowledges the limits of each method. This transparency helps prevent overgeneralization and encourages readers to interpret the figures with care.

Overall, the ethics and accessibility review strengthened the report by highlighting areas for improvement and guiding design decisions that support clear, fair, and accessible communication of emissions data for a wide range of audiences.

V. TECHNICAL APPENDIX

A. Data Processing Steps

All data used in this study was obtained from the datasets provided by Our World in Data [2], which compile historical and sector level greenhouse gas emissions from multiple international agencies. The raw data includes annual totals, sector divisions, and subsector categories. Several steps were taken to prepare the data for visualization.

First, the datasets were imported into the analysis environment and checked for missing values. Years with incomplete records were removed in order to ensure consistency across all charts. Second, units were verified and converted into metric tonnes of carbon dioxide equivalent or percentage to allow comparison across sectors. Third, categorical variables were standardized to avoid duplication of subsector names that appeared in slightly different forms in the original source. Fourth, aggregated values were computed where needed, such as total emissions for the agriculture sector or combined totals for industrial processes. These cleaned datasets were then

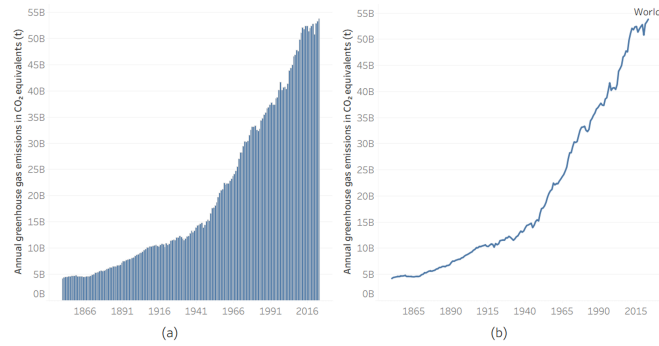Comparison of Historical Emissions Visualizations

Fig. 6. (a) Bar chart showing annual global greenhouse gas emissions over time, highlighting year to year variation and short term fluctuations. (b) Line chart presenting the long term trend of global emissions, emphasizing continuity and the overall acceleration of emissions growth.

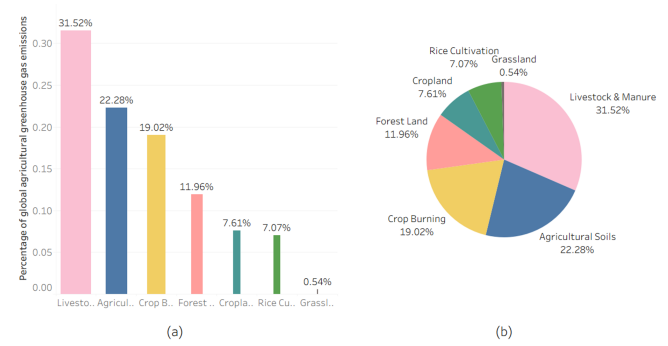Comparison of Agricultural Sector Emission Visualizations

Fig. 7. (a) Bar chart illustrating the percentage contributions of agricultural subsectors, enabling precise comparison across categories. (b) Pie chart presenting the proportional distribution of the same subsectors, offering a high level overview of category shares.

exported into formats suitable for use in both Tableau. These steps ensured that all visualizations were based on reliable, consistent, and validated data.

B. Tool Usage and Versioning

All charts and dashboards were created using Tableau Public 2025.2.4. This tool was selected due to its ability to handle large datasets, create interactive dashboards, and support multiple visualization types. Tableau was also used to apply color palettes that remain readable for viewers with different visual needs. Excel was used for initial data cleaning, preparing datasets such as filtering, grouping, and reshaping data for import into Tableau. Using Python 3.11 to perform file format conversions, such as converting a CSV file into an XLSX file.

LaTeX was used to prepare the written report and to typeset all sections, figures, and references in a consistent academic style. LaTeX provided precise control of formatting, stable handling of citations, and clear integration of figures exported from Tableau. It also supported consistent section structuring across chapters and ensured that the final document followed academic presentation standards.

The KCL Library Search tool was used to locate academic references that informed the visualization design choices. This search platform provided access to peer reviewed literature in data visualization, perception studies, and environmental reporting. Key works, including those by Cleveland and McGill, Tufte, and Ware, were obtained through this tool. Using the KCL Library Search ensured that the report relied on credible and authoritative sources.

C. Dashboard Descriptions and Relation to Visualization Design

The two dashboards included in the appendix each contain a left and right figure. The left figures represent the initial design versions, while the right figures show the improved versions that were ultimately selected for the main report. Presenting these side by side allows readers to understand how design

decisions were made and how each visualization was refined in terms of clarity, precision, and narrative function.

Emissions Trend and Agriculture Sector Dashboard. The dashboards illustrated in Fig. 6 and Fig. 7 compare two sets of visualizations that focus on historical emissions trends and agricultural sector emissions. Fig. 6 (b) presents a line chart, while the Fig. 6 (a) shows a bar chart. The line chart highlights the long term continuity of global emissions growth and helps the viewer see the overall upward pattern. The bar chart provides a clearer view of year to year changes and draws attention to fluctuations in recent decades. As noted in the Visualization Design and Iteration chapter, the bar chart was selected for the final report because it makes annual differences easier to interpret and supports the narrative goal of showing the steady rise in emissions with greater emphasis on short term variation.

Since the report uses several pie charts, the example of agricultural emissions by subsector is used here for illustration. Fig. 7 (b) displays this information in a pie chart, while the Fig. 7 (a) presents it in a bar chart. The pie chart allows quick identification of major categories but makes it difficult to compare categories that are similar in size. The bar chart improves comparison by providing a precise visual scale and a clear ranking of subsector contributions. Because the agricultural sector contains many categories with moderate differences, the bar chart was selected as the final version used in the main report. This choice supports the need for clear comparison and improved analytical accuracy.

Energy Sector Dashboard. Fig. 8 compares visualizations for the energy sector, which contains a large number of subsectors and therefore requires careful attention to readability. The Fig. 8 (a) presents a pie chart of energy sector emissions. While useful for showing general proportions, it becomes visually crowded due to the large number of categories. Small slices become difficult to read, and differences between similar categories are not easy to judge. The Fig. 8 (b) presents a formatted table listing emissions shares for all subsectors. This layout avoids visual clutter, allows accurate reading of

Comparison of Energy Sector Emission Visualizations in 2020

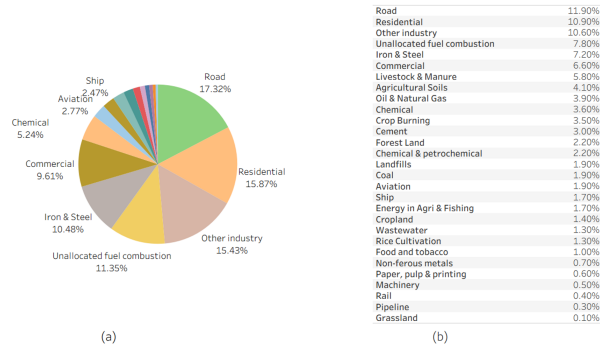|	
Road	11.90%
Residential	10.90%
Other industry	10.60%
Unallocated fuel combustion	7.80%
Iron & Steel	7.20%
Commercial	6.60%
Livestock & Manure	5.80%
Agricultural Soils	4.10%
Oil & Natural Gas	3.90%
Chemical	3.60%
Crop Burning	3.50%
Cement	3.00%
Forest Land	2.20%
Chemical & petrochemical	2.20%
Landfills	1.90%
Coal	1.90%
Aviation	1.90%
Ship	1.70%
Energy in Agri & Fishing	1.70%
Cropland	1.40%
Wastewater	1.30%
Rice Cultivation	1.30%
Food and tobacco	1.00%
Non-ferous metals	0.70%
Paper, pulp & printing	0.60%
Machinery	0.50%
Rail	0.40%
Pipeline	0.30%
Grassland	0.10%

(a) (b)

Fig. 8. (a) Pie chart displaying emissions from energy subsectors, providing an overview of proportional contributions but with limited readability due to numerous small categories. (b) Tabular presentation listing all subsector emission shares, offering complete numerical accuracy and improved clarity for detailed analysis.

each value, and supports users who require detailed and exact information. As described in the Visualization Design and Iteration chapter, the table was chosen as the final version because it provides the highest level of precision and allows all subsectors to be viewed without confusion. This is especially important for the energy sector, where no single subsector dominates and many activities contribute meaningful shares. The table format improves accessibility and supports more careful decision making.

Together, these dashboards reflect the design goals of accessibility, clarity, and progressive detail. They support the narrative flow of the report by guiding viewers from global patterns toward increasingly specific sources of emissions.

D. Links to interactive visualizations

Interactive versions of the visualizations presented in this report are provided to support further exploration of the data and to allow users to engage directly with the figures. A demonstration video showing the structure and functionality of the dashboards is available at the following link: *https://reurl.cc/aMdN83*.

In addition to the video demonstration, selected files used in this study, including the Tableau workbooks, processed datasets, and supplementary scripts, have been uploaded to a public GitHub repository. These materials can be accessed at: *https://github.com/qwe12345113/Telling-Story-Induvidual-Coursework*.

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