

SmogSense

Understand the unseen

PROCESS BOOK

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BACKGROUND

Air quality isn't merely a measure of fresh air; it directly impacts human health, productivity, and ecosystem resilience. Pollution exposure is linked to respiratory diseases, cardiovascular conditions, and cognitive decline, making air pollution a critical public-health challenge across Europe and beyond. While pollution was once treated as a localized problem, advances in monitoring and modeling have revealed its transboundary nature and systemic effects, elevating it to a global concern.

Several web-based tools attempt to bridge this gap by visualizing air quality on interactive maps. Current platforms, however, often lack contextual explanations and educational insights that connect raw measurements to health and environmental implications. These limitations underscore the urgent need for a more intuitive and informative solution – one that not only presents data but also empowers users with actionable insights.

Our project, **SmogSense - Understand the Unseen**, directly addresses these challenges by offering a streamlined, narrative-driven single-page web application.



GOAL

Our narrative-driven interface guides you through Europe's air quality, from a continental AQI map that highlights clean and caution zones to country and city charts revealing fresh breezes or breathing challenges at a glance. Switch to pollutant mode to track O₃, NO₂ and more over time and explore Curiosities for insights, such as how EV adoption often coincides with pollution dips, so you leave with actionable ideas. Embracing "less is more," our minimal design keeps interactions intuitive and focused, grounded in three core values. **Clarity:** straightforward data; **Accessibility:** intuitive for every user; **Empowerment:** insights for informed decisions.

FROM IDEAS

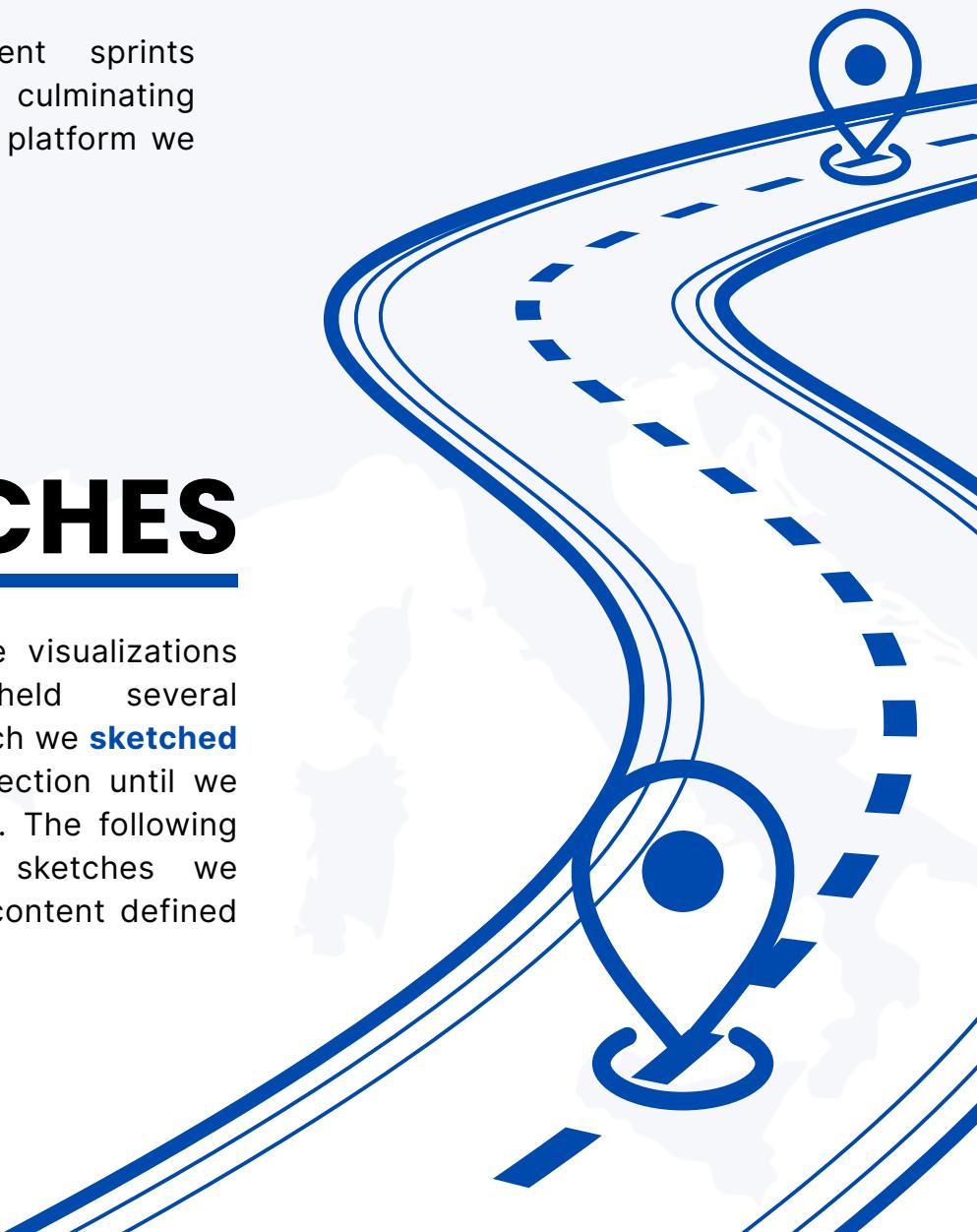
What a journey it's been. We began by exploring existing air-quality visualizations and environmental reports to spark our own ideas. From there, we sketched several rough layouts, experimenting with map styles, color palettes, and simple animations that communicate pollution levels without distraction.

Our **brainstorming sessions** helped us refine each interaction, from country-click navigation to tooltip phrasing, ensuring every detail remained clear and approachable. In parallel, we tackled **performance challenges** by optimizing data handling so our visualizations load smoothly.

Finally, focused development sprints brought these designs to life, culminating in the interactive SmogSense platform we present today.

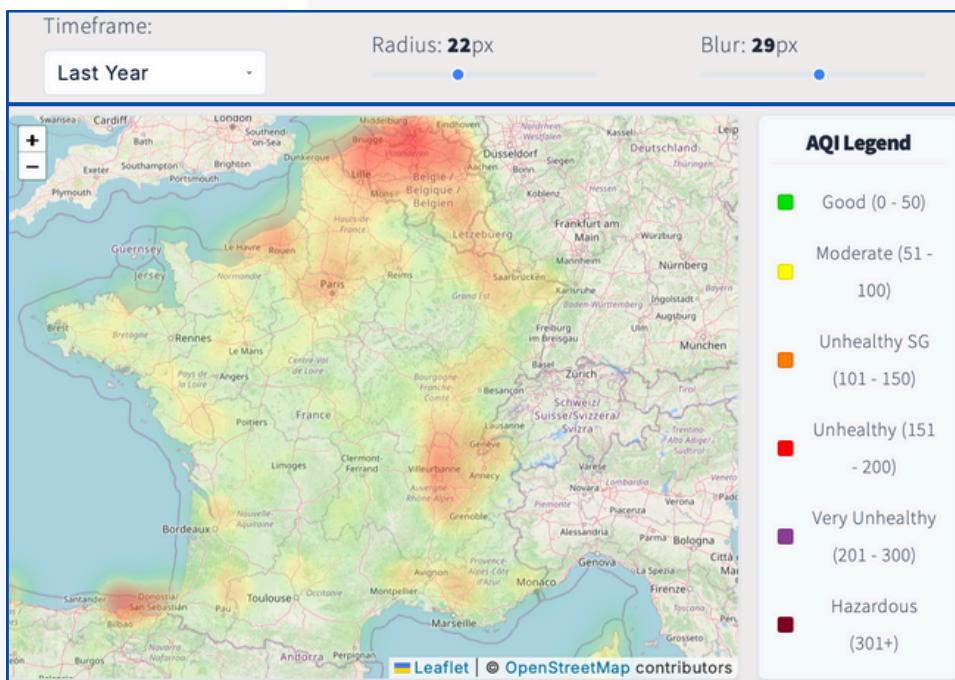
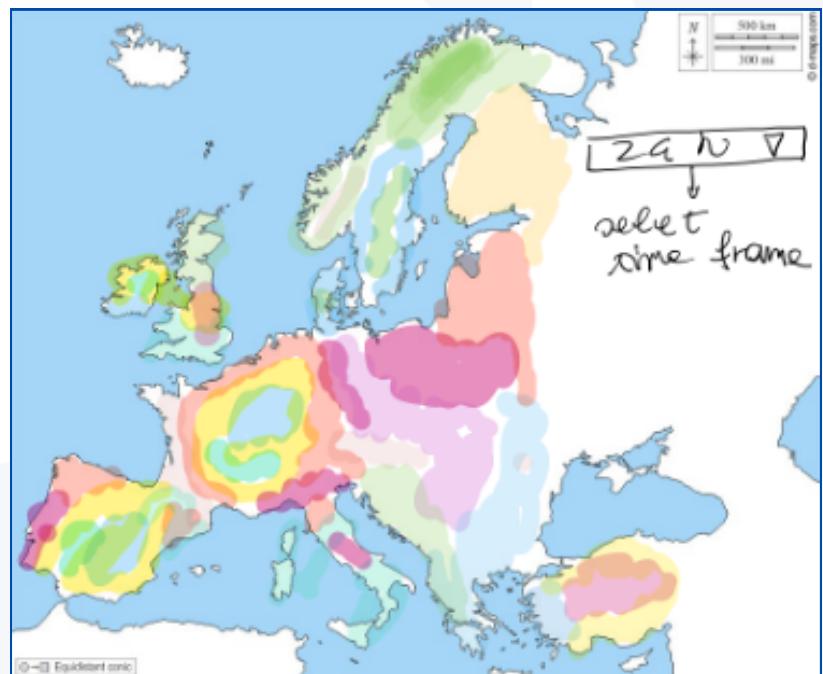
TO SKETCHES

To define the most effective visualizations for SmogSense, we held several brainstorming sessions in which we **sketched paper drafts** of every site section until we arrived at a shared structure. The following pages present the main sketches we developed, aligned with the content defined in the project's Milestone 2.



MAP

In our initial phase, we drafted multiple layouts to identify the clearest way to display Europe's air quality. We chose a **full continent heat map** of the Air Quality Index paired with a drop down menu for selecting timeframes, offering live data from the last 24 hours, the past month, the previous year or any custom range. By fine tuning color gradients, from deep violet reds for severe pollution through yellows to greens for the cleanest air, and experimenting with different map styles, we ensured users can immediately understand pollution patterns across the continent.

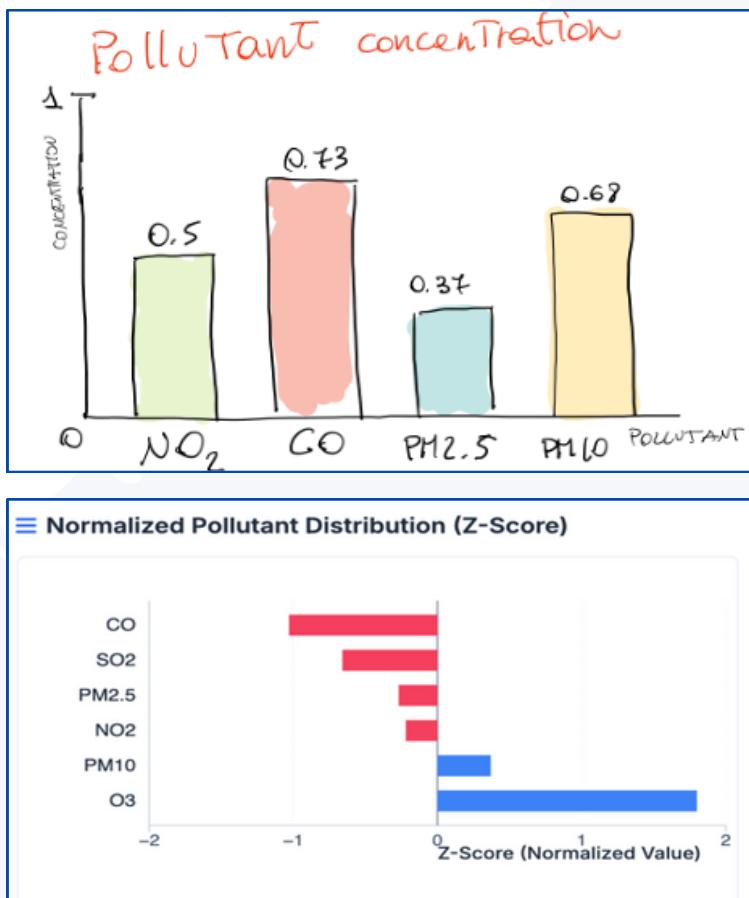


Building on our Milestone 2 prototype, we then added **Radius and Blur sliders** for precise control: upping the radius creates broader "heat blobs" for a high-level overview, while lowering it reveals sharper, localized hotspots, and adjusting the blur softens or sharpens the transitions between these areas. Together, these features turn raw measurements into an engaging, user-driven exploration of Europe's air quality.

As users scroll past the Europe overview, the page shifts to two synced panels: an interactive map on the left and detailed statistics on the right for the chosen country. Users pick a country from a dropdown menu; clicking its region on the map then opens a pop-up card showing key air-quality metrics with units and the last-update timestamp.

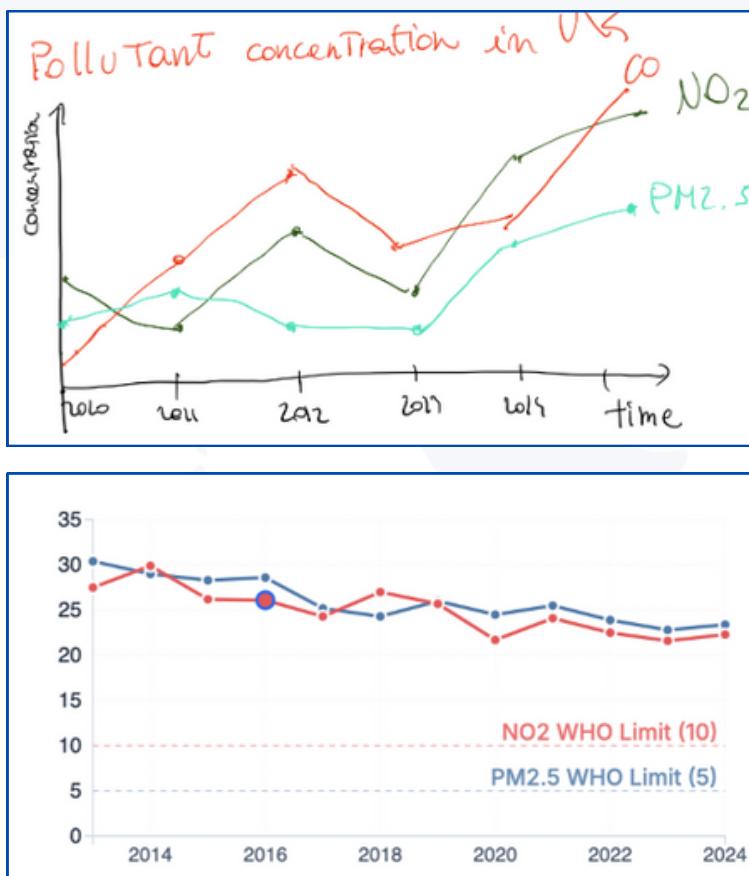
BAR CHART

The first statistical chart is a **horizontal bar chart**. Our earliest paper prototype featured a vertical bar chart of pollutant concentrations normalized via Z scores, but when we moved to implementation we chose horizontal bars instead. This orientation makes positive and negative Z score values immediately intuitive, as bars extend to the right for above average pollution and to the left for below average, and it takes advantage of the screen's natural widescreen aspect, ensuring better readability and a more user friendly experience.



LINE CHART

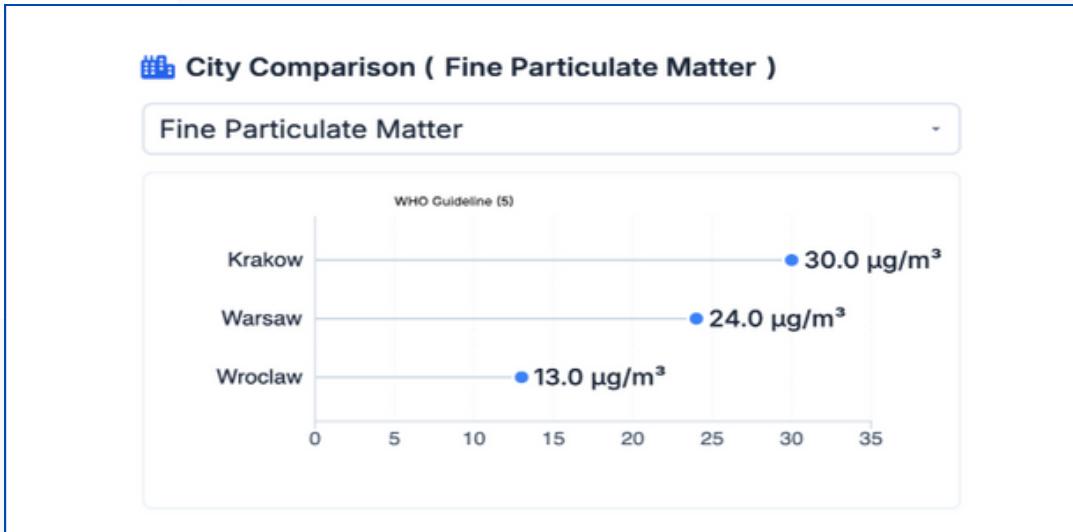
After exploring the Z-score distribution, the next visualization we propose is a **dynamic line chart** that traces pollutant levels over the past year, revealing both long-term trends and seasonal peaks at a glance. Above the plot, simple checkboxes let you show or hide any of the nine key contaminants, so you can layer multiple series for **side-by-side comparison** or focus on a single pollutant at its true scale. Subtle dashed horizontal lines, one for each selected pollutant, mark the WHO's annual guideline, highlighting moments when concentrations cross safe limits. This combination of interactive controls and standardized benchmarks makes it easy to interpret complex data and understand when air quality poses a public-health concern.



This line chart has stayed largely true to our original prototype, preserving its intuitive design while adding a final touch of interactivity. Now, when the user hovers or clicks on any data point on the line chart, a precise concentration value pops up, ensuring you never miss the exact figure, even if it lies outside the chart's typical range. This small enhancement turns a static trend line into a fully interactive exploration, letting the user dig into the details whenever curiosity strikes.

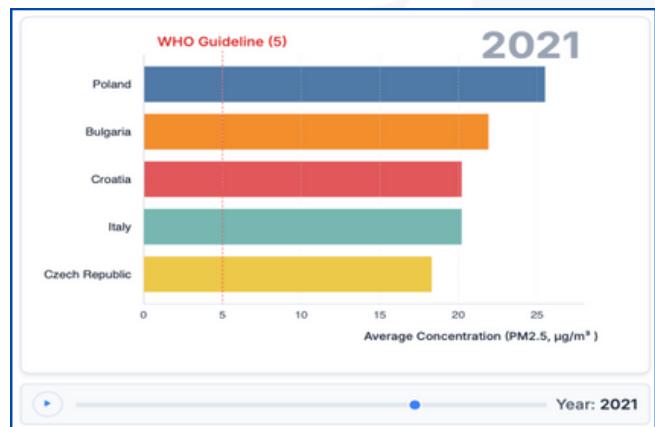
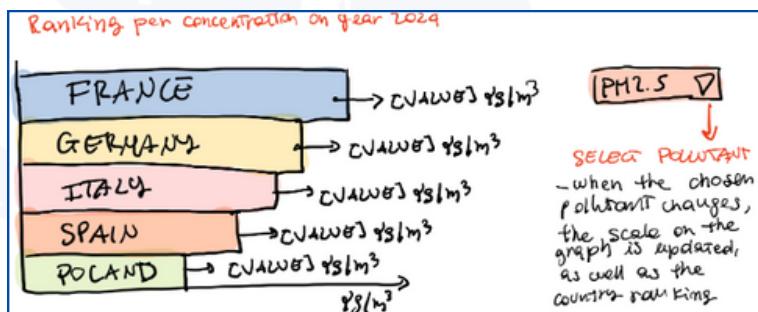
CITY COMPARISON

This final visualization, introduced later in development, follows our Milestone 2 concept by replacing bars with dot markers to lower visual density and add variety after the Z score chart. It embodies our cascading drill down approach from continent to country to city and presents a **horizontal City Comparison chart** that ranks urban areas by their average pollutant concentration.



Each location appears on the vertical axis, with its value plotted along the horizontal axis in $\mu\text{g}/\text{m}^3$, instantly revealing which areas exceed safety thresholds. A subtle guideline indicates the recommended limit, while precise data labels eliminate guesswork and enable quick comparison. By guiding users from a broad overview to specific urban hotspots, this chart highlights regional air-quality disparities and empowers exploration of the most affected areas.

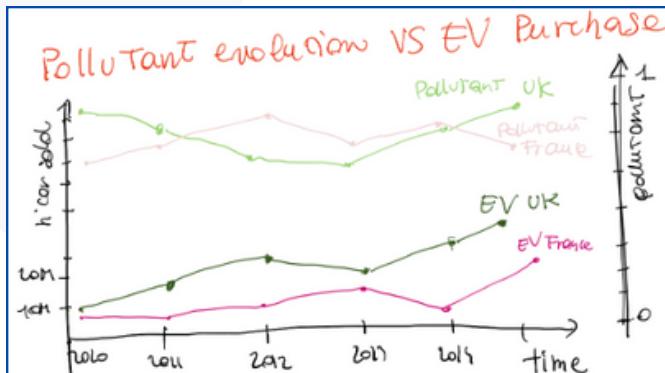
POLLUTANT RANKING



This visualization gives users a new perspective: after navigating from a Europe-wide view to countries and cities, they can dive even deeper by choosing a pollutant rather than a region. A dropdown menu lets users pick the contaminant of interest, which then drives a **dynamic horizontal bar chart** ranking the five most polluted cities each year. Compared to our initial sketchbook idea, a significant enhancement here is the introduction of a dynamic timeline evolution. Users can now actively control the playback of this animation, pausing and restarting it, or directly navigating to any specific year of interest. This added layer of interactivity fundamentally transforms the visualization, enabling a much richer exploration of historical trends.

ELECTRIC VEHICLES

In the final **"Curiosities"** section, users explore the link between clean transport and air quality through a dynamic chart that plots electric vehicle purchases against pollutant levels. One vertical axis shows EV purchase volumes while the other tracks pollutant concentrations, with shaded bands indicating the average over multiple years. By comparing two countries side by side, users can see how increases in EV adoption often align with lower pollution and how slower uptake corresponds with ongoing air quality challenges, underscoring how our transportation choices affect the air we share.



CHALLENGES

Bringing SmogSense to life came with its fair share of challenges. We split responsibilities between D3.js, which handled SVG overlays, and Leaflet, which managed the geographic layers. To keep interactions synchronized, we built a lightweight event system that coordinated tooltips and highlights across both libraries.

To optimize performance, especially on midrange devices, we precomputed heatmap canvases for daily, monthly, and yearly views offscreen, allowing instant updates. We also ensured responsive design across desktops and mobile devices using flexible CSS layouts and debounced resize listeners. Accessibility was a priority: we met WCAG AA standards by using semantic HTML roles, ARIA labels, and full keyboard navigation. Meanwhile, we tackled the massive 20 GB EEA AirBase Parquet dataset by focusing on nine key pollutants, aggregating minute-level data into daily (and soon monthly) summaries, removing invalid entries, and converting the data from Parquet to CSV, then to compact JSON, ultimately reducing it to just a few hundred megabytes for smooth client-side use.

FUTURE PERSPECTIVES

At SmogSense, we chose depth over breadth by focusing on the most vital air quality metrics and guiding users from a continental overview to country-level details, all complemented by rigorous data preprocessing and optimized rendering that delivers instant, interactive charts even on midrange devices. Looking ahead, SmogSense is set to evolve into a richer, more personalized air-quality companion by expanding its pollutant palette to include rarer but health-critical emissions, integrating predictive models that forecast air quality from weather patterns and historical trends, unveiling source-apportionment visualizations to reveal the contributions of traffic, industry or residential heating, and offering custom dashboards that let users tailor their pollutant mix and geographic focus.

PEER ASSESSMENT

SmogSense was the result of a collaborative effort and shared commitment. Each member contributed unique skills across different aspects of the project. **Lorenzo Drudi** led data acquisition, preprocessing, management and integration for SmogSense, sourcing and importing the raw dataset, developing Python scripts to clean and validate the data and integrating the processed data with the platform's interactive visualizations to ensure integrity and usability. **Beatrice Grassano** led visualization development and implementation using HTML, CSS and D3.js, structuring the markup, crafting styles, and engineering complex animations and interactions to transform visual designs into a robust, interactive frontend experience. **Emanuele Rimoldi** led visualization design, detail refinement and Process Book curation, ensuring each chart delivered clarity, usability and visual appeal, polishing visual details to elevate the user experience and meticulously documenting the project's journey and decisions. Our team fostered open communication and strong collaboration through regular brainstorming, code reviews, and shared problem-solving. This synergy helped us overcome even the toughest challenges.