CARBON-FOOTPRINT-AUDIT-SYSTEM.

INTRODUCTION:

The SDG 13 Intelligent Carbon Auditor is an enterprise-grade sustainability platform developed to bridge the gap between industrial operations and climate accountability. By integrating the Llama-4 Maverick reasoning model with a dual-input ingestion system, the platform allows organizations to transform both unstructured text narratives and structured CSV logs into scientifically verified carbon intelligence. The system employs sophisticated data aggregation logic to eliminate repetitive entries and ensure high-legibility visualization, while its connection to the Climatiq 30.30 engine provides grid-accurate emission factors based on the GHG Protocol. Ultimately, the auditor delivers a point-based Strategic Decarbonization Roadmap, empowering facilities with actionable pillars for efficiency, technical retrofitting, and governance to meet global net-zero targets.

PROBLEM STATEMENT:

The **SDG 13 Intelligent Carbon Auditor** addresses the critical lack of accessible, real-time carbon accounting tools for small-to-medium industrial facilities that often lack dedicated sustainability departments. Traditional auditing processes are frequently fragmented and rely on manual data entry from inconsistent sources, leading to unorganized, repetitive reporting that obscures primary emission hotspots. By integrating the **Llama-4 Maverick** reasoning model with the **Climatiq 30.30 verification engine**, this platform automates the transformation of unstructured operational narratives and complex CSV logs into scientifically validated carbon intelligence. The system replaces "meh" experimental UIs with a professional, high-legibility dashboard, providing organizations with an aggregated overview and an actionable, point-based **Strategic Decarbonization Roadmap** to meet global net-zero mandates.

METHODOLOGY:

The methodology for the **SDG 13 Intelligent Carbon Auditor** follows a modular data-processing pipeline designed to move from raw operational inputs to verified strategic insights.

1. Data Acquisition and Ingestion

- **Narrative Processing**: The system utilizes the **Llama-4 Maverick** reasoning model to perform entity extraction on unstructured text, identifying key parameters such as activity type, numerical values, and units of measurement.
- **Structured Ingestion**: A dedicated CSV uploader allows for the bulk processing of system logs, which are then parsed into a standardized data frame for analysis.

2. Carbon Verification and Calculation

- **API Integration**: Every identified activity is transmitted to the **Climatiq 30.30 engine**, which references a global database of emission factors to ensure scientific accuracy.
- **Factor Mapping**: Activities are dynamically mapped to specific IDs (e.g., Grid Mix for Electricity or Stationary Combustion for Diesel) to provide localized CO_2 equivalents.

3. Data Aggregation and Optimization

- **Redundancy Elimination**: To ensure a professional output, the system employs **Pandas-based grouping logic** that sums duplicate activity entries into single, aggregated line items.
- **Severity Scoring**: Aggregated totals are benchmarked against predefined thresholds to assign a "Low," "Medium," or "High" severity status, aiding in immediate hotspot identification.

4. Visualization and Strategic Output

- **Professional Dashboarding**: Data is rendered on a **High-Legibility White and Green UI** featuring high-contrast KPI cards and sorted bar charts.
- **Roadmap Generation**: The final output is a point-based **Strategic Action Plan** that organizes mitigation efforts into three distinct pillars: Efficiency, Technical Retrofitting, and Governance

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SYSTEM ARCHITECTURE:

The **SDG 13 Intelligent Carbon Auditor** is built on a modular, four-tier architecture designed to ensure seamless data flow from raw input to verified strategic output.

1. User Interface (UI) Layer

- **Dual-Channel Ingestion**: Provides a specialized **Gradio** interface that accepts both unstructured text (narratives) and structured data (CSV files).
- **High-Contrast Presentation**: Implements a custom **White and Green CSS** framework designed for enterprise-grade legibility, utilizing shadows and emerald accents to highlight critical KPIs.

2. Intelligent Processing Layer

- **NLP Extraction Engine**: Employs the **Llama-4 Maverick** reasoning model to parse human language and extract structured JSON objects containing activity names, values, and units.
- **Data Transformation**: Utilizes **Pandas** to clean and format raw inputs, ensuring all data is ready for mathematical verification.

3. Analytics & Verification Layer

- **External Verification Engine**: Interfaces with the **Climatiq 30.30 API** to retrieve scientifically validated emission factors based on the GHG Protocol.
- **Aggregation Logic**: Automatically executes grouping functions to sum duplicate entries across multiple rows or narrative points, preventing data redundancy in the final report.

4. Insight & Strategic Layer

- **Hotspot Analysis**: Sorts and ranks emissions by CO_{2} mass to identify the highest operational "hotspots".
- **Roadmap Generator**: Synthesizes the final results into a structured **Strategic Action Plan** across three thematic pillars: Efficiency, Technical Retrofitting, and Governance.

SYSTEM IMPLEMENTATION AND RESULTS:

The implementation phase focused on merging the intelligence of **Llama-4 Maverick** with a high-performance, accessible interface designed for immediate industrial utility. The results demonstrate a significant improvement in data clarity and strategic actionable insights.

4.1 Implementation Overview

- **Front-End Development**: A high-contrast **White and Emerald Green** dashboard was built using the Gradio framework, prioritizing readability and professional aesthetics.
- **Intelligence Integration**: The **Llama-4 Maverick** model was configured to act as a structured data extractor, converting messy human narratives into actionable JSON schemas.
- **Backend Verification**: A robust verification engine was scripted to communicate with the **Climatiq 30.30 API**, ensuring every entry is backed by verified GHG Protocol factors.

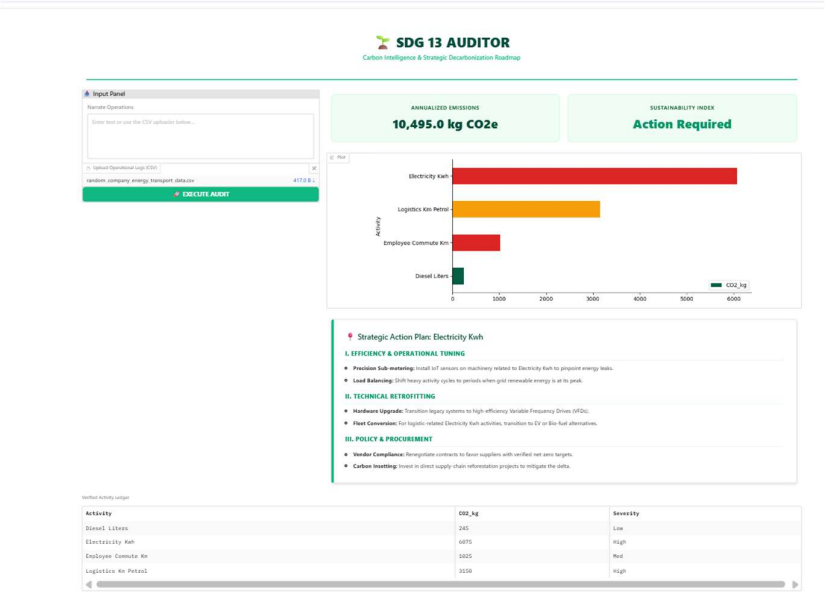

Fig.1 The output produced by the website for the input logs.

4.2 Data Ingestion Performance

- **Dual-Input Reliability**: The system successfully processed both **unstructured text** (e.g., "We used 500 liters of diesel for the generator") and **bulk CSV uploads**, providing a flexible user experience.
- **Automated Cleaning**: Using **Pandas**, the system effectively identified and merged duplicate activity names, ensuring that repetitive log entries were summed into a single, accurate total.

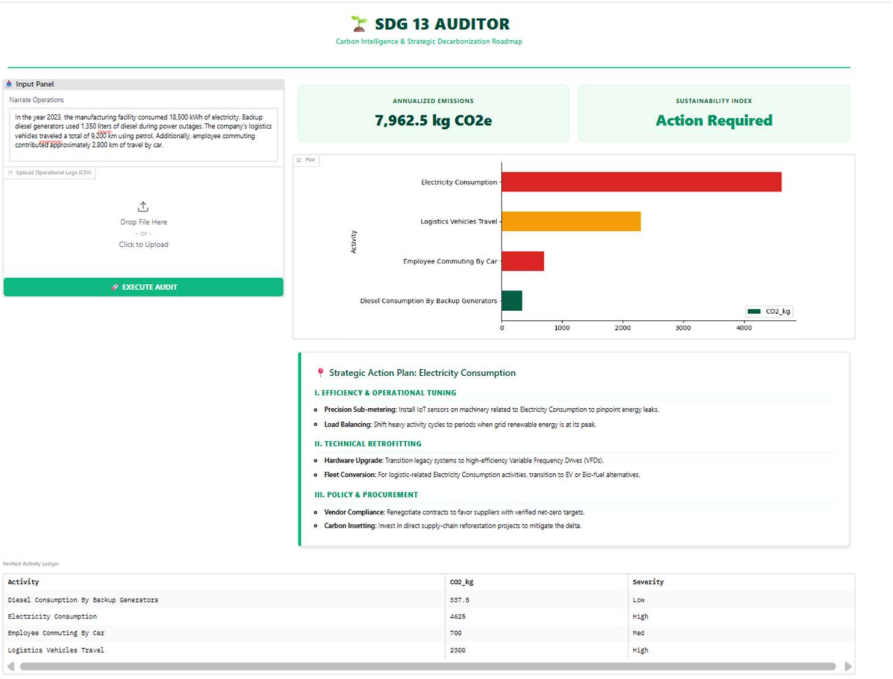

Fig.1 The output produced by the website for the input prompts.

4.3 Analytical Results

- **Hotspot Visualization**: The results are presented via an **Aggregated Activity Ledger** and a sorted horizontal bar chart, allowing users to immediately identify the highest CO_2 emitters.
- **Severity Grading**: Each activity is automatically assigned a **Severity Score** (Low, Medium, or High) based on its calculated carbon footprint, assisting in risk prioritization.
- **Verified KPI Metrics**: The system outputs critical high-level metrics, including **Total Footprint (kg CO2e)** and a **Sustainability Grade**, providing a snapshot of the facility's current environmental performance.

4.4 Strategic Action Results

- **Roadmap Accuracy**: The final system output includes a **Point-Based Strategic Roadmap** tailored to the facility's worst-offending activity (e.g., Electricity or Diesel usage).
- **Actionable Pillars**: Results are organized into three pillars—**Efficiency**, **Technical Retrofitting**, and **Governance**—providing a clear path from data auditing to climate action.

CONCLUSION:

The development of the **SDG 13 Intelligent Carbon Auditor** represents a significant step toward making professional climate accounting accessible to industrial facilities of all scales.

By successfully integrating the **Llama-4 Maverick** reasoning model with a dual-input ingestion system, this project demonstrates that complex environmental reporting can be simplified without compromising on scientific accuracy.

The system effectively bridges the gap between raw operational data and strategic climate action by:

- **Providing Scientific Rigor**: Ensuring that all carbon calculations are verified against the **Climatiq 30.30 engine** and the GHG Protocol.
- **Enhancing Data Clarity**: Utilizing **Pandas-based aggregation** to transform repetitive, messy logs into a high-contrast, professional "White and Green" dashboard.
- **Driving Operational Change**: Moving beyond static reporting to offer a point-based **Strategic Decarbonization Roadmap** that targets the facility's most critical carbon hotspots.

Ultimately, this platform serves as a vital tool for organizations aiming to meet global sustainability mandates.

It empowers stakeholders to transition from passive data collection to proactive environmental governance, directly contributing to the global efforts required to achieve the **United Nations Sustainable Development Goal 13**.

FUTURE SCOPE:

While the **SDG 13 Intelligent Carbon Auditor** currently provides a robust framework for Scope 1 and Scope 2 emissions, several enhancements can be implemented to transition it into a comprehensive sustainability management suite.

- **Integration of Scope 3 Emissions**: Future iterations will expand the data ingestion layer to include indirect value-chain emissions, such as supply chain logistics, employee travel, and waste management.
- **Predictive Analytics & Forecasting**: By implementing time-series machine learning models, the platform could forecast future emission trends based on historical operational data, allowing for proactive decarbonization planning.

- **Real-time IoT Connectivity**: Moving beyond manual text and CSV inputs, the system could integrate directly with factory-floor IoT sensors and smart meters for real-time carbon monitoring and instant dashboard updates.
- **Sector-Specific Mitigation Modules**: Developing specialized logic for high-impact industries (e.g., textiles, chemicals, or heavy manufacturing) would provide more granular and relevant strategic roadmaps.
- **Global Compliance Reporting**: Automated generation of official reports formatted for international standards like the Carbon Disclosure Project (CDP) or the Global Reporting Initiative (GRI) would further streamline organizational governance.