

TrashTechAI: AI-Powered Landfill Management Dashboard

Introduction

The expansion of urban centers and increasing consumption have significantly accelerated the growth of landfills across the United States. Effective landfill management is vital to reduce environmental degradation, safeguard public health, and optimize resource usage.

This project presents a cutting-edge, AI-powered dashboard that consolidates and analyzes nationwide landfill data to deliver intelligent, policy-ready insights tailored for regional planning and waste management optimization.

Problem Statement

Current landfill monitoring systems are often fragmented, lack advanced analytics, and do not offer localized, predictive insights. The absence of real-time intelligence leads to inefficient landfill operations, underutilization of methane as a renewable energy source, and increased environmental and health risks.

Objective

To develop an interactive, AI-enhanced dashboard that:

- Aggregates landfill data from across the U.S.
- Performs intelligent analysis and visualization
- Provides region-specific recommendations using Large Language Models (LLMs)

- Supports smart policy design through contextual, data-driven decision-making
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Relevance to Prompt

The challenge — *"Imagine your city empowered by AI — what would you build to make it safer, smarter, and more inclusive?"* — is directly addressed by:

- Smarter cities through AI-driven waste infrastructure planning.
 - Safer cities by reducing landfill-based emissions and hazards.
 - More inclusive cities by making data insights accessible to policymakers, researchers, and citizens.
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Inspiration

The inspiration for this project came from the pressing need to make urban environments safer, cleaner, and more efficient. Witnessing the adverse environmental impacts caused by inefficient landfill management motivated us to leverage AI to create a centralized, intelligent platform that can provide insights and recommendations for improving landfill operations.

What We Learned

Through this project, we learned how to:

- Aggregate and preprocess large datasets effectively.

- Build and deploy interactive dashboards using Streamlit.
 - Integrate advanced AI models like Google's Gemini API for analysis and policy recommendations.
 - Implement Retrieval-Augmented Generation (RAG) using FAISS to improve the quality of AI-generated insights.
 - Visualize data to support clear, evidence-based decision-making.
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How We Built the Project

Data Collection

We utilized open-source landfill datasets from the U.S. Environmental Protection Agency (EPA):

- EPA LMOP Landfill Database: This includes landfill locations, methane emissions, energy capacities, project types, and operating status across all U.S. states.

Methodology

1. Data Compilation & Preprocessing:
 - Merged state-wise landfill datasets into a unified national database.
 - Cleaned and normalized key fields (State, County, City, Zip Code, Methane Flow, Rated Capacity).
2. AI-Driven Analysis using Gemini API:
 - Integrated Google's Gemini LLM to analyze filtered data dynamically.

- Designed structured prompt templates to deliver region-specific recommendations.
- Incorporated intelligent alerting based on methane thresholds.

3. Retrieval-Augmented Generation (RAG):

- Used FAISS + Sentence Transformers to index and retrieve the most relevant landfill metadata.
- Dynamically injected retrieved chunks into Gemini's prompt for enhanced policy suggestions.
- Enabled context-aware reasoning for improved insight generation.

4. Exploratory Data Visualization:

- Created rich EDA visualizations (statewise trends, methane distributions, capacity outliers).
- Visuals support both national and region-specific perspectives.
- Integrated `matplotlib` and `seaborn` for effective statistical storytelling.

5. Dashboard Development using Streamlit:

- Built an intuitive, responsive frontend with filter controls (state, county, city, zip).
 - Displays both raw data and AI-powered policy guidance.
 - Embedded Gemini responses in real-time upon user selection.
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Features of the Dashboard

- Filterable landfill data by state, county, city, and zip code.
 - Region-specific insights with Gemini LLM recommendations.
 - Context-aware AI using RAG-based memory injection from FAISS.
 - Interactive visualizations for methane flow, MW capacity, and landfill distribution.
 - Real-time alerting for high-methane or underutilized regions.
 - Policy strategy suggestions aligned with SDG and ESG goals.
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Challenges We Faced

- Data Cleaning: Ensuring consistency across various datasets and handling missing values.
 - API Integration: Efficiently connecting the Gemini API to the Streamlit dashboard for real-time insights.
 - Handling Large Datasets: Merging multiple datasets into a unified framework required optimization for performance.
 - Fine-tuning Prompts: Ensuring that the Gemini API provided relevant, contextual recommendations using structured prompt templates.
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Potential Impact

This platform provides:

- Smarter planning for government agencies and environmental researchers.
 - Cleaner operations through AI-led emissions control and optimization.
 - Greater transparency by making landfill intelligence accessible and explainable.
 - Better ROI for energy recovery from methane and infrastructure funding.
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Conclusion

The AI-Powered Landfill Management Dashboard combines generative AI, vector search (RAG), and rich analytics to deliver a next-gen environmental decision-support system. It empowers policymakers with actionable insights to create smarter, safer, and more sustainable cities — where waste becomes opportunity, and data drives change.