Sustainable Smart City using IBM Granite LLM

Welcome to the documentation for the **Sustainable Smart City Assistant**, an advanced solution powered by **IBM Granite LLM**. This project aims to revolutionize urban management by leveraging Artificial Intelligence to enhance sustainability, optimize resource usage, and improve decision-making for smarter, greener cities. It focuses on streamlining city operations, enabling data-driven governance, and fostering collaboration between citizens and municipal authorities.

Team ID

NM2025TMID03719

Team Size

4 Members

Team Leader

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Team Members

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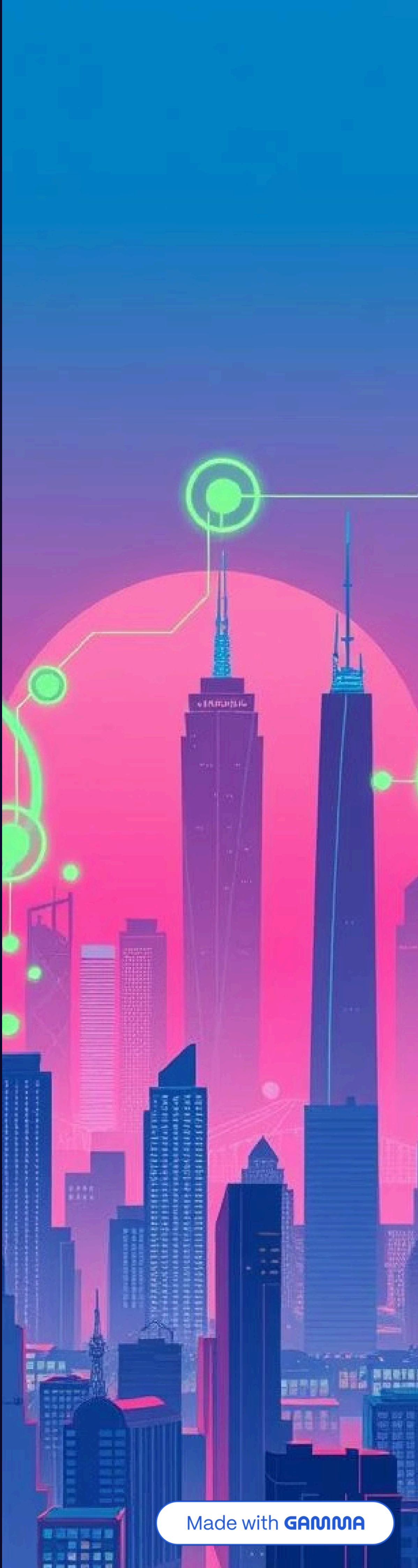
Project Overview: Empowering Sustainable Cities

The core purpose of the Sustainable Smart City Assistant is to help cities and their residents build a more eco-friendly and connected urban environment. By using AI and real-time data, this assistant optimizes crucial resources like energy, water, and waste. It also encourages sustainable habits among citizens by providing personalized tips and services.

For city officials, it acts as a valuable partner, offering clear insights, tools to predict future trends, and simple summaries of complex policies to support strategic planning. Ultimately, this assistant connects technology, government, and community involvement to create greener, more efficient, inclusive, and resilient cities.



Key Features: Smart Interaction & Policy Insights

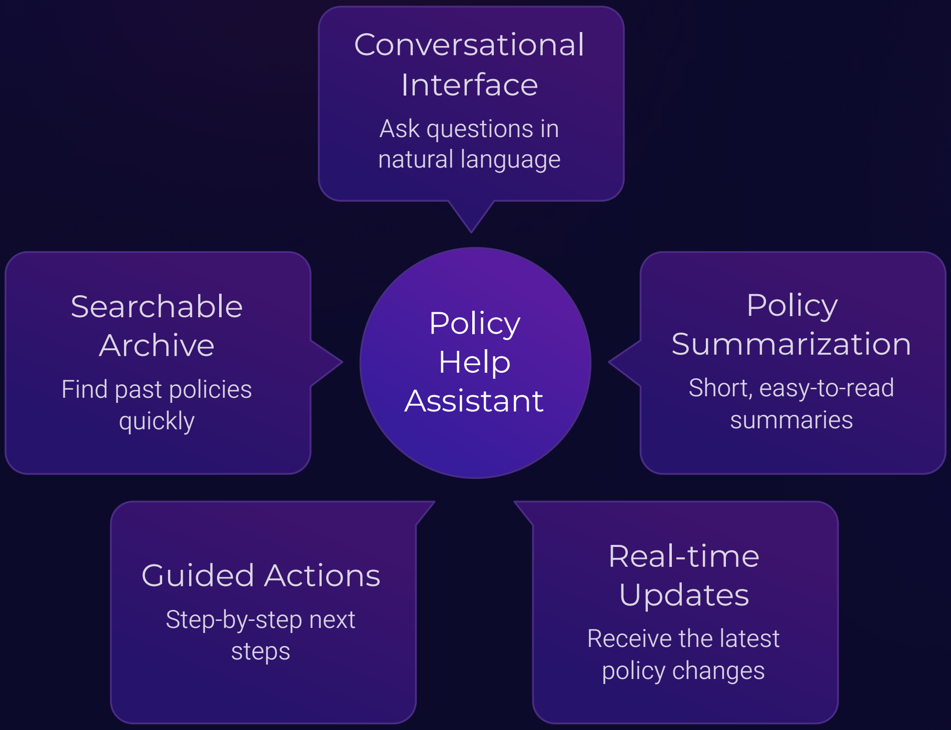
Our Smart City Assistant offers intuitive ways for both citizens and officials to interact and understand complex information. These features are designed to make communication easy and policy comprehension straightforward.

Conversational Interface

Allows users to ask questions, get updates, and receive guidance using everyday language, making interaction natural and easy.

Policy Summarization

Transforms long government documents into short, easy-to-understand summaries, helping users quickly grasp key policies and actions.



Conversational Interface

Ask questions in natural language

Searchable Archive

Find past policies quickly

Policy Help Assistant

Policy Summarization

Short, easy-to-read summaries

Guided Actions

Step-by-step next steps

Real-time Updates

Receive the latest policy changes

Key Features: Predictive Power & Green Living

The assistant provides powerful tools for predicting future resource needs and guiding individuals towards more sustainable daily actions, fostering a greener urban lifestyle.

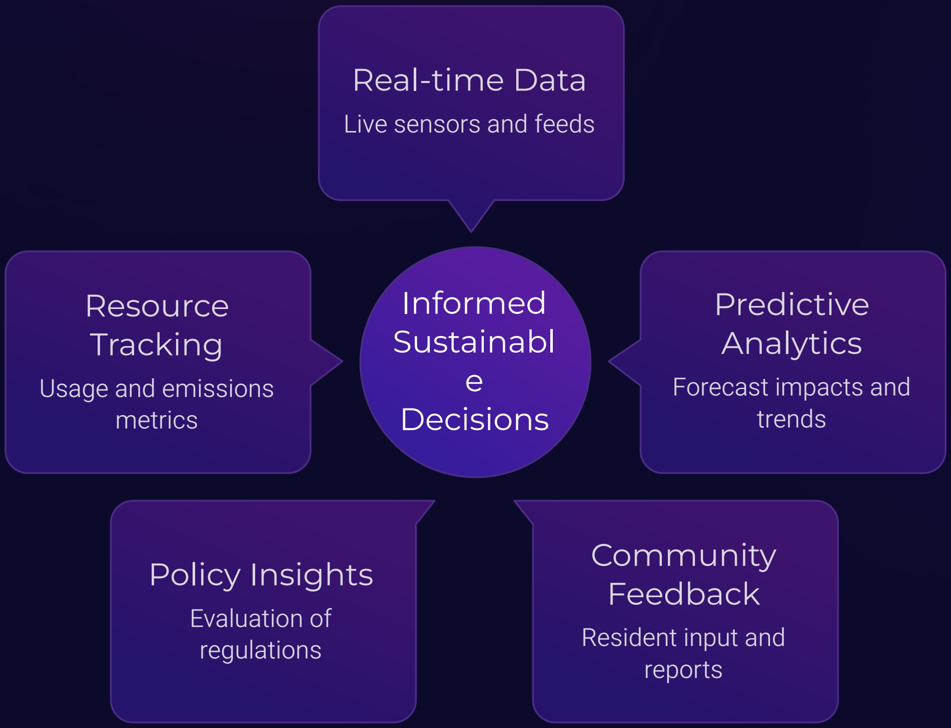
Resource Forecasting

Estimates future energy, water, and waste usage by analyzing past and current data, helping cities plan more effectively.

Eco-Tip Generator

Suggests personalized daily actions to reduce environmental impact, tailored to individual user behavior and preferences.

These features empower both city planners and residents to make informed decisions that contribute to a more sustainable future.



Real-time Data

Live sensors and feeds

Resource Tracking

Usage and emissions metrics

Informed Sustainabl e Decisions

Predictive Analytics

Forecast impacts and trends

Policy Insights

Evaluation of regulations

Community Feedback

Resident input and reports

Key Features: Community Voice & Strategic Vision

Engaging citizens and providing strategic planning support are vital for a thriving smart city. Our assistant includes features specifically designed for these purposes.

Citizen Feedback Loop

Gathers and analyzes public opinions and suggestions, using this valuable input to improve city planning and services.

KPI Forecasting

Projects key performance indicators to help city officials track progress, set goals, and plan strategically for the future.

Key Features: Data Intelligence & User Experience

The Smart City Assistant is equipped with advanced data analysis capabilities and a user-friendly interface to ensure smooth operation and easy access for everyone.

Anomaly Detection

Identifies unusual patterns in sensor or usage data, acting as an early warning system for potential problems or inefficiencies.

Multimodal Input Support

Accepts various data formats like text, PDFs, and CSVs, allowing for flexible document analysis and accurate forecasting.

Streamlit or Gradio UI

Provides an easy-to-use dashboard for both citizens and city officials to interact with the assistant seamlessly.

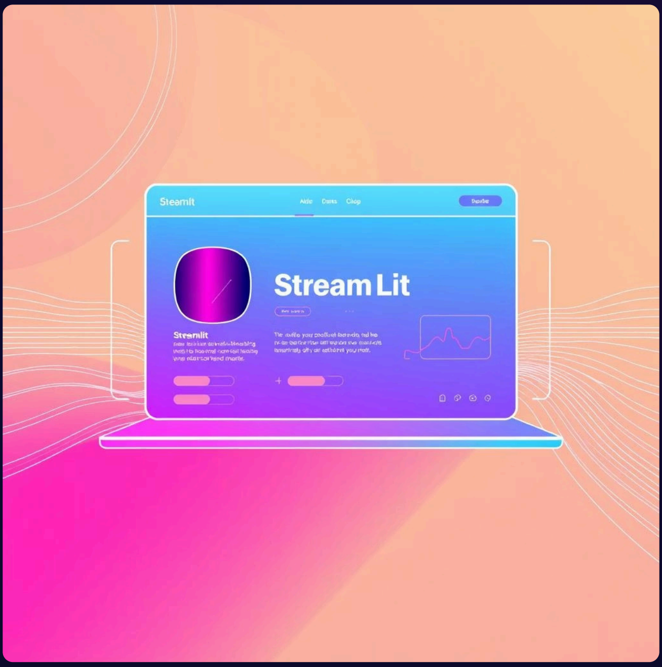
Anomaly Detection
Citizen Access
Multimodal Input
Streamlit UI

System Architecture: Building Blocks

The Smart City Assistant is built on a robust and scalable architecture, combining powerful frontend, backend, and AI components to deliver its intelligent features.

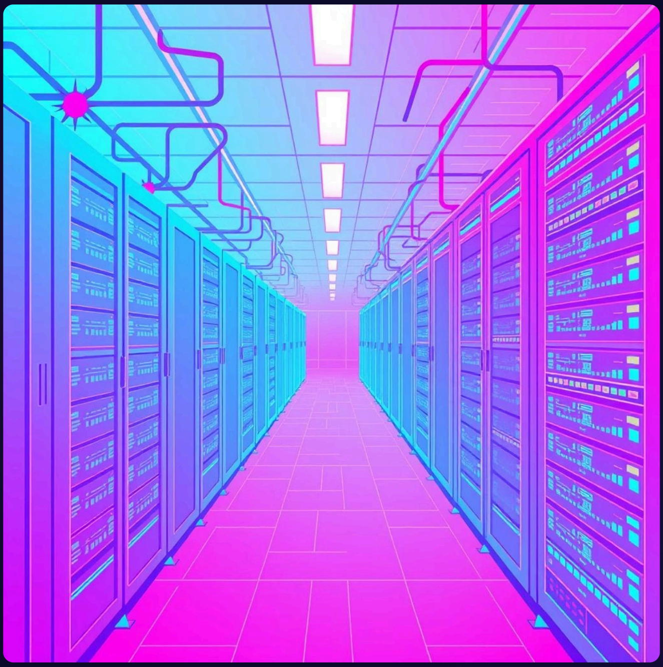
Frontend (Streamlit)

The user interface is built with Streamlit, offering an interactive web experience. It includes dashboards, file upload options, a chat interface, feedback forms, and report viewers. Navigation is simple, making it easy for users to find what they need.



Backend (FastAPI)

FastAPI powers the backend, providing the necessary connections for document processing, chat interactions, eco-tip generation, report creation, and data embedding. It's designed for speed and easy integration with other tools.



LLM Integration (IBM Watsonx Granite)

We use Granite Large Language Models from IBM Watsonx for understanding and generating natural language. These models are carefully prompted to create summaries, sustainability tips, and detailed reports.

System Architecture: Intelligent Processing

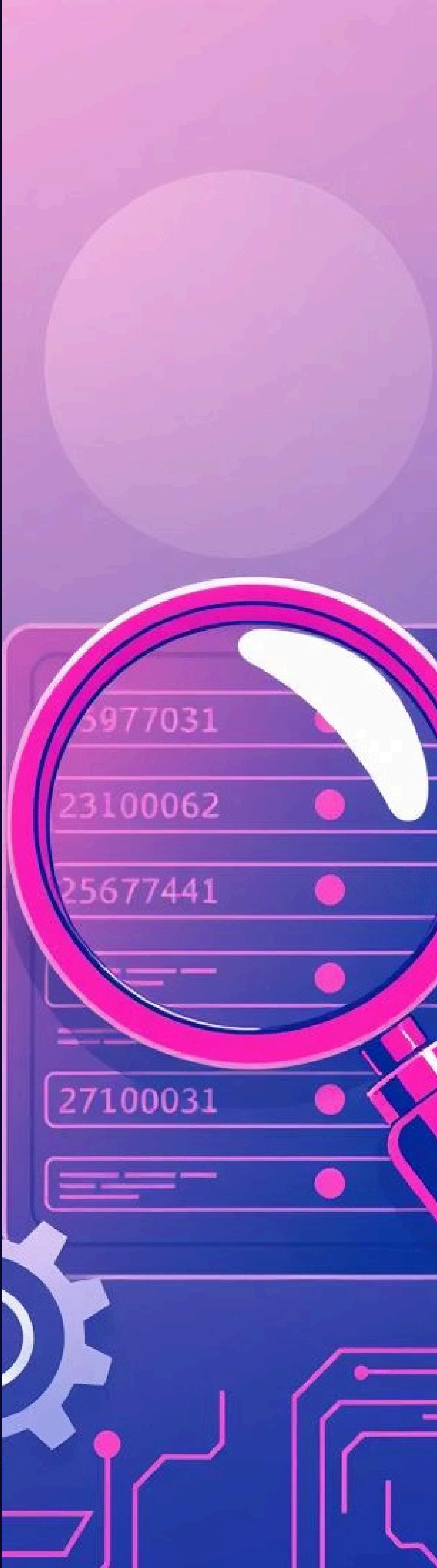
Beyond the core components, the architecture includes specialized modules for advanced data handling and machine learning, enabling the assistant to perform intelligent tasks.

Vector Search (Pinecone)

Uploaded policy documents are converted into numerical representations (embeddings) using Sentence Transformers and stored in Pinecone. This allows users to search documents using natural language queries, finding relevant information quickly.

ML Modules (Forecasting & Anomaly Detection)

Lightweight machine learning models, built with Scikit-learn, handle forecasting and anomaly detection. They analyze time-series data to predict trends and flag unusual values, providing crucial insights for city management.

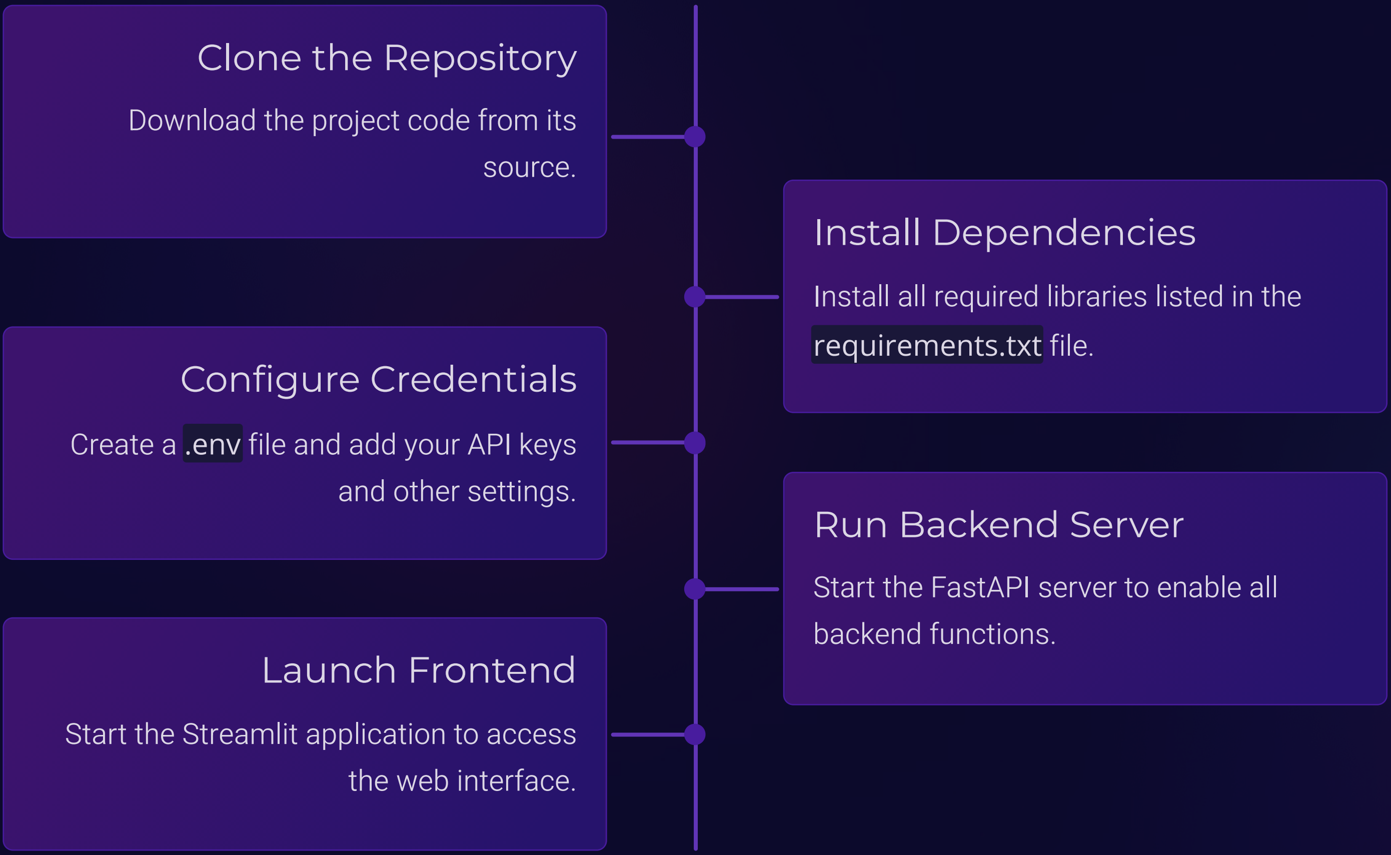


Getting Started: Easy Setup Guide

Setting up and running the Smart City Assistant is a straightforward process. Follow these steps to get the application up and running on your system.

Prerequisites

- Python 3.9 or newer
- pip and virtual environment tools
- API keys for IBM Watsonx and Pinecone
- Internet access for cloud services



Clone the Repository

Download the project code from its source.

Install Dependencies

Install all required libraries listed in the `requirements.txt` file.

Configure Credentials

Create a `.env` file and add your API keys and other settings.

Run Backend Server

Start the FastAPI server to enable all backend functions.

Launch Frontend

Start the Streamlit application to access the web interface.

Running the Application

- Launch the FastAPI server first to make sure backend services are available.
- Run the Streamlit dashboard to open the web interface in your browser.
- Use the sidebar to navigate between different pages and features.
- Upload documents or data, interact with the chat, and view reports or predictions.
- All interactions happen in real-time, with the frontend dynamically updating based on backend responses.

Project Details: APIs, Security & User Experience

This section provides an overview of the available APIs, the approach to authentication, and the design philosophy behind the user interface.

API Documentation

The backend APIs are well-documented and accessible. Key endpoints include:

- `POST /chat/ask`: For user queries and AI responses.
- `POST /upload-doc`: To upload and embed documents.
- `GET /search-docs`: To find similar policies.
- `GET /get-eco-tips`: To receive sustainability advice.
- `POST /submit-feedback`: To store citizen feedback.

Each endpoint is tested and documented in Swagger UI for easy inspection and trial during development.

Authentication

For demonstration purposes, this project runs in an open environment. However, for secure deployments, we plan to integrate:

- Token-based authentication (JWT or API keys).
- OAuth2 with IBM Cloud credentials.
- Role-based access for different user types (admin, citizen, researcher).

Future enhancements will also include user sessions and history tracking for a more personalized experience.

User Interface

The Smart City Assistant's interface is meticulously designed for simplicity and high functionality, ensuring ease of use for all, including non-technical users. It empowers citizens and city officials with intuitive navigation and powerful insights.

A clear, well-structured sidebar provides straightforward access to various modules and functionalities, allowing users to effortlessly switch between different sections of the application. The dashboard prominently features dynamic KPI visualizations, offering real-time insights into city performance and progress towards sustainability goals.

For enhanced usability, the interface incorporates tabbed layouts, making it easy to navigate between core features like the AI chat assistant and personalized eco tips. Users can seamlessly engage with the AI for inquiries and receive actionable environmental advice. Furthermore, the system includes robust PDF report download capabilities, enabling users to easily export and share crucial data and analyses for offline review or stakeholder presentations.

The overall design prioritizes clarity, speed, and comprehensive user guidance. Helpful contextual texts and intuitive workflows are integrated throughout the application, ensuring that users can achieve their objectives efficiently and with minimal effort.

Testing: Ensuring Reliability and Robustness

Comprehensive testing was a critical phase in the development of the Smart City Assistant, conducted through multiple stages to guarantee the system's reliability, accuracy, and performance under various conditions.

1

Unit Testing

Focused on individual components, including prompt engineering functions and utility scripts, to ensure they operate correctly and predictably in isolation.

2

API Testing

Verified the backend endpoints via tools like Swagger UI and Postman, alongside automated test scripts, to ensure robust data exchange and service reliability across all integrations.

3

Manual Testing

Involved hands-on validation of user-facing features such as file uploads, chat responses, and the overall consistency of output, confirming intuitive and correct behavior from an end-user perspective.

4

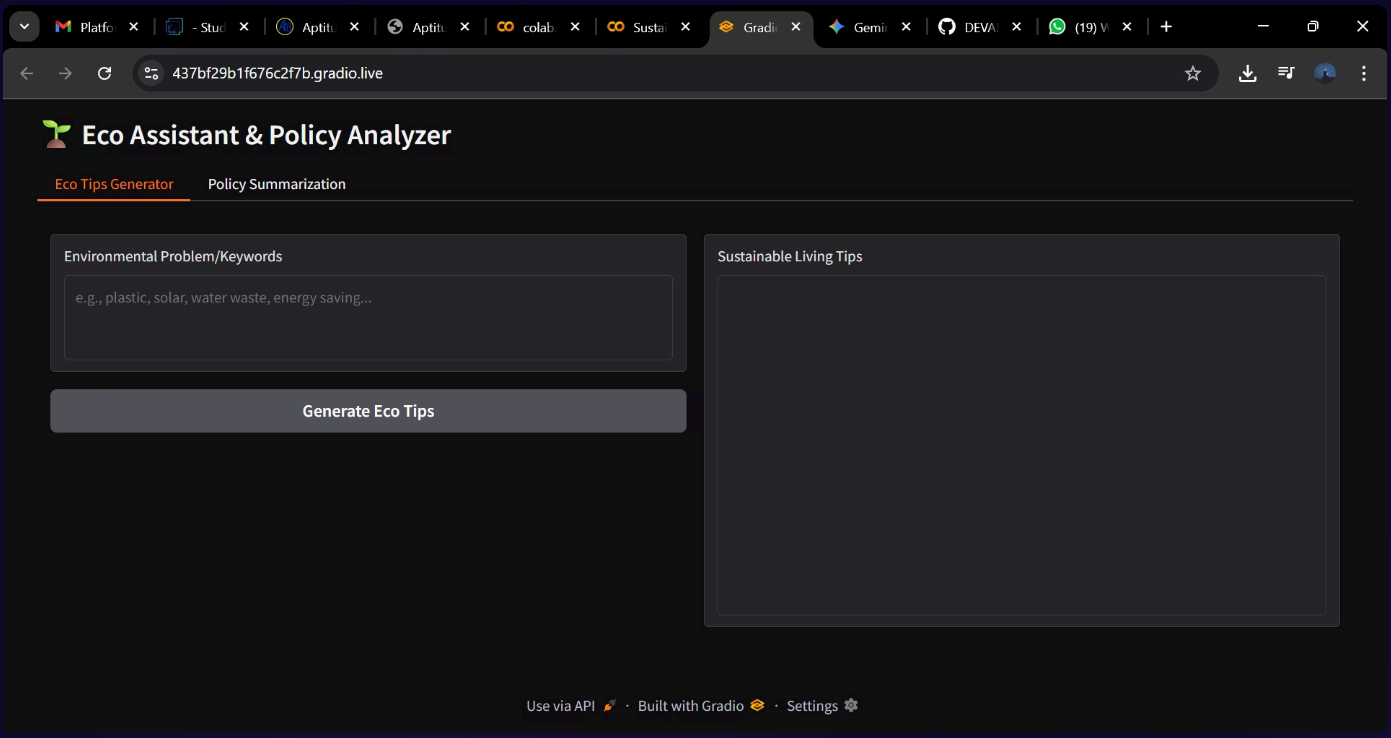
Edge Case Handling

Extensive testing against challenging scenarios including malformed inputs, unusually large files, and invalid API keys was performed to ensure graceful degradation, error recovery, and system stability.

Each function and module was meticulously validated to ensure consistent and reliable operation in both offline environments and when connected to external API services, providing a solid foundation for the assistant's intelligent features.

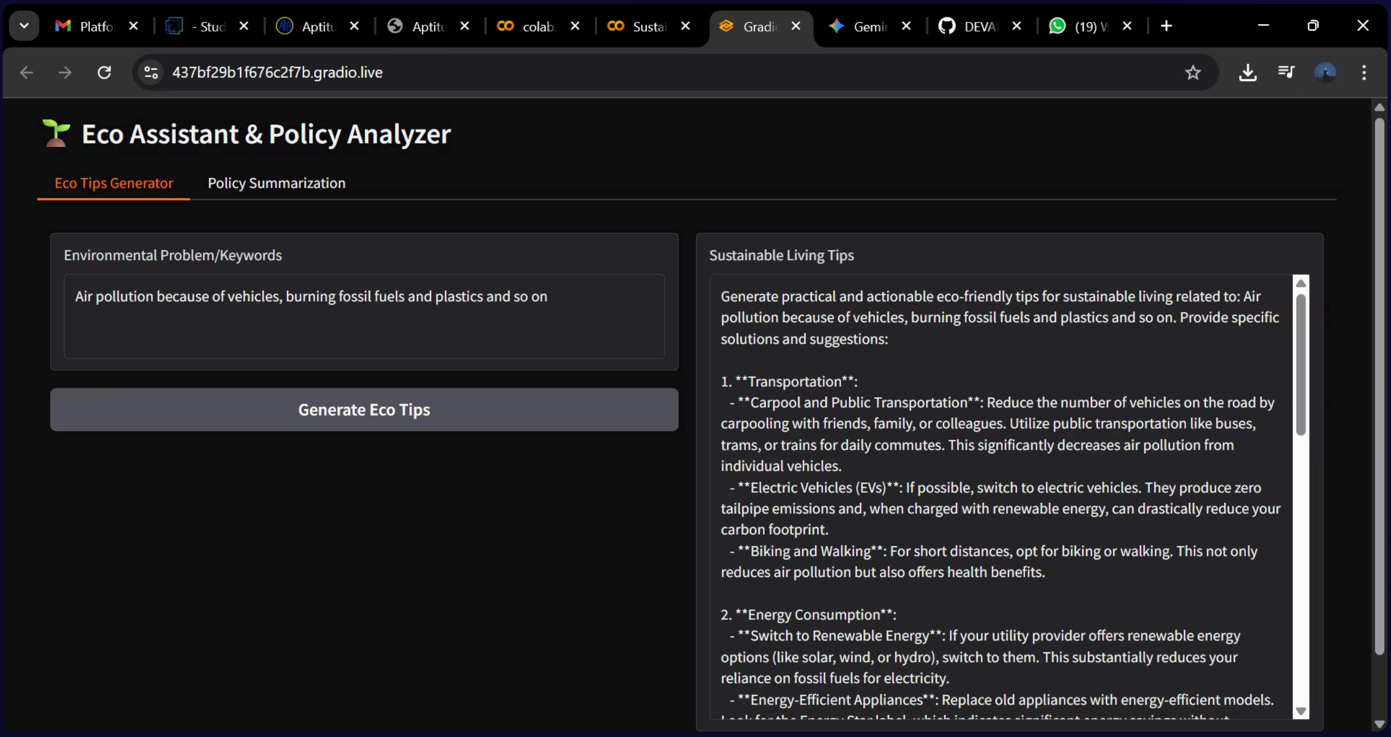
Project Output:

1. Interface of Sustainable **Smart City Assistant using IBM Granite LLM**



Eco Assistant & Policy Analyzer

2. Enter any environmental problems in the **Eco Tips Generator** section ,It provides tips to overcome the problem.



Eco Assistant & Policy Analyzer

Environmental Problem/Keywords: Air pollution because of vehicles, burning fossil fuels and plastics and so on

Sustainable Living Tips

```
Generate practical and actionable eco-friendly tips for sustainable living related to: Air pollution because of vehicles, burning fossil fuels and plastics and so on. Provide specific solutions and suggestions:

1. **Transportation**:
  - **Carpool and Public Transportation**: Reduce the number of vehicles on the road by carpooling with friends, family, or colleagues. Utilize public transportation like buses, trams, or trains for daily commutes. This significantly decreases air pollution from individual vehicles.
  - **Electric Vehicles (EVs)**: If possible, switch to electric vehicles. They produce zero tailpipe emissions and, when charged with renewable energy, can drastically reduce your carbon footprint.
  - **Biking and Walking**: For short distances, opt for biking or walking. This not only reduces air pollution but also offers health benefits.

2. **Energy Consumption**:
  - **Switch to Renewable Energy**: If your utility provider offers renewable energy options (like solar, wind, or hydro), switch to them. This substantially reduces your reliance on fossil fuels for electricity.
  - **Energy-Efficient Appliances**: Replace old appliances with energy-efficient models. Look for the Energy Star label, which indicates significant energy savings without
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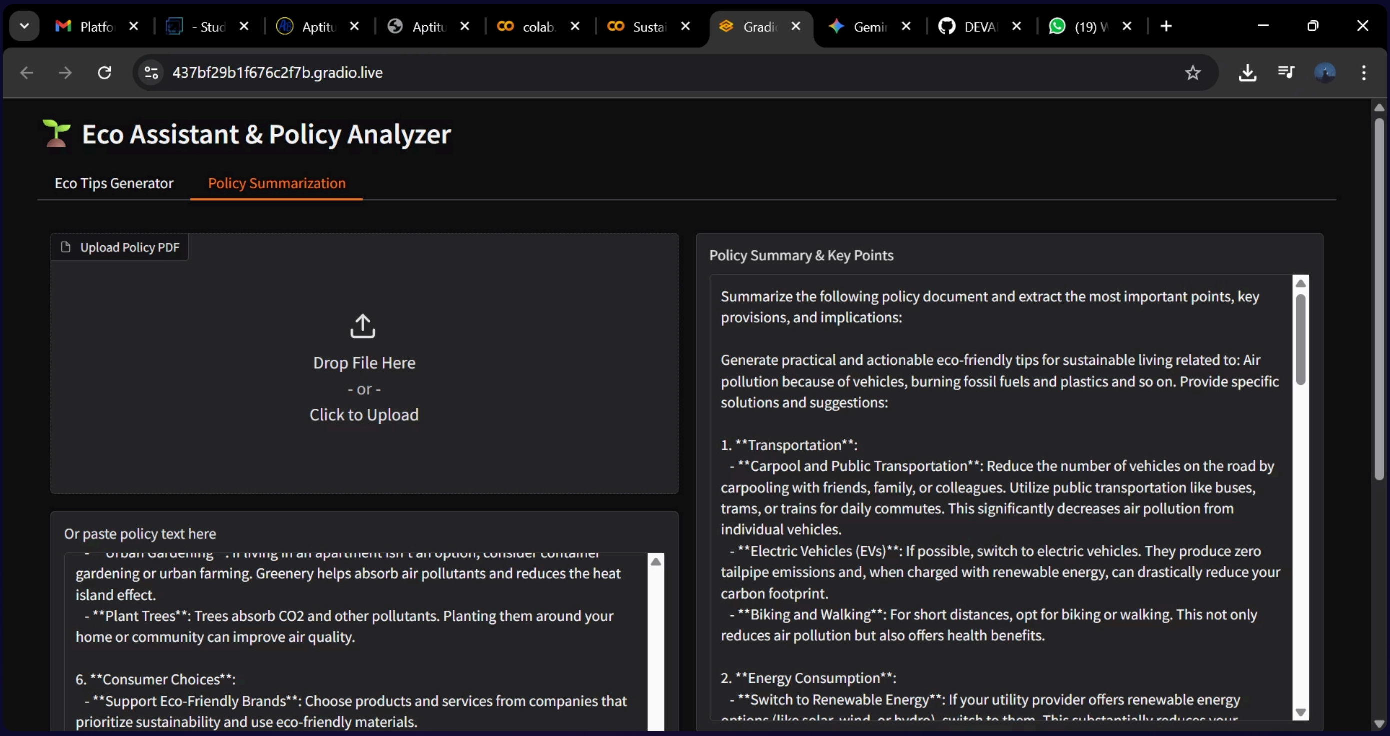
3. Give the policies/tips in **Policy Summarization** section to summarize the points and include key points.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Eco Assistant & Policy Analyzer
Eco Tips Generator
Policy Summarization
Upload Policy PDF
Drop File Here
- or -
Click to Upload
Or paste policy text here
Policy Summary & Key Points

```
  - **Urban Gardening**: If living in an apartment isn't an option, consider container
gardening or urban farming. Greenery helps absorb air pollutants and reduces the heat
island effect.
  - **Plant Trees**: Trees absorb CO2 and other pollutants. Planting them around your
home or community can improve air quality.

6. **Consumer Choices**:
  - **Support Eco-Friendly Brands**: Choose products and services from companies that
prioritize sustainability and use eco-friendly materials.
```

```
Summarize the following policy document and extract the most important points, key
provisions, and implications:

Generate practical and actionable eco-friendly tips for sustainable living related to: Air
pollution because of vehicles, burning fossil fuels and plastics and so on. Provide specific
solutions and suggestions:

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```

Known Issues:

- **Context Limitations** – May give incomplete or vague responses for complex scenarios.
- **Ambiguous Queries** – Struggles with unclear or vague user inputs.
- **Data Freshness** – Delays in real-time data updates (traffic, energy).
- **Scalability** – Performance slows with many concurrent users.
- **Language Support** – Mainly supports English; limited regional language support.
- **Domain Knowledge Gaps** – Generic responses in specialized areas (e.g., waste management).
- **PDF Extraction Errors** – Text extraction issues from poorly formatted PDFs.
- **Privacy Risks** – Potential exposure of sensitive user data.
- **Inconsistent Energy Advice** – Recommendations may not align with policies.
- **No Offline Mode** – Requires internet to function.

🚀 Future Enhancements

1. **Advanced Context Awareness**
   Improve the model's ability to understand and retain long-term context for more accurate recommendations.
2. **Multilingual Support**
   Add support for regional languages to better serve diverse city populations.
3. **Real-Time Data Integration**
   Implement faster, more reliable real-time data pipelines for traffic, energy usage, pollution, etc.
4. **Scalable Infrastructure**
   Optimize backend for better performance under high user load using microservices or serverless architecture.
5. **Enhanced Domain Knowledge**
   Integrate specialized modules for municipal services (e.g., waste management, public transport).
6. **Secure Data Privacy**
   Implement strict data privacy protocols, including anonymization and encrypted storage of sensitive data.
7. **Improved PDF Processing**
   Add smarter preprocessing to handle complex or poorly formatted documents.
8. **Offline Mode Support**
   Enable limited offline functionality for essential services using cached data.
9. **Energy Optimization Algorithms**
   Incorporate advanced algorithms aligned with local policies for energy-saving recommendations.
10. **User Feedback Loop**
    Allow users to provide feedback to continuously improve response accuracy over time.

Conclusion: Empowering Sustainable Smart Cities

The Smart City Assistant, powered by the robust IBM Granite LLM, represents a significant step forward in urban sustainability and governance. This project successfully integrates cutting-edge AI with practical civic needs, delivering a platform designed to enhance citizen engagement, streamline administrative processes, and drive eco-conscious decision-making. Through its intuitive user interface, predictive analytics, and comprehensive data insights, the assistant provides a powerful tool for building truly smart and sustainable communities.

Enhanced Engagement

Facilitating seamless interaction between citizens and city services, fostering community participation.

Data-Driven Decisions

Providing real-time insights and predictive analytics for informed policy-making and resource allocation.

Operational Efficiency

Automating tasks and providing quick access to information, saving time and resources for city administration.

Sustainable Impact

Promoting eco-friendly practices and resource optimization to achieve long-term environmental goals.

While acknowledging known issues such as context limitations and scalability, the foundation laid by this project is robust. Future enhancements, including advanced context awareness, multilingual support, and real-time data integration, will further solidify its role as an indispensable asset for urban centers committed to sustainability and innovation. This assistant is more than just a tool; it's a partner in creating smarter, healthier, and more livable cities for everyone.