Sustainable Smart City

Assistant Using IBM Granite

LLM

Project Documentation

- **Introduction**
- Project title :Sustainable Smart City Assistant Using IBM Granite LLB
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Project overview

Purpose :

A Sustainable Smart City aims to create a livable, efficient, and environmentally friendly urban environment by leveraging technology, innovation, and sustainable practices. The purpose is to:

1. Improve Quality of Life: Enhance the well-being and

quality
of life for citizens through better services, infrastructure, and amenities.

2. Reduce Environmental Impact: Minimize waste, pollution,

and carbon footprint through sustainable practices, renewable energy, and efficient resource management.

3. Promote Economic Growth: Foster innovation,

entrepreneurship, and economic growth through smart infrastructure, digitalization, and data-driven decision-making.

4. Enhance Governance: Improve transparency,

accountability, and citizen engagement through digital governance, participatory planning, and data-driven policy-making.

Key Features

1. Renewable Energy:

Utilizes solar, wind, and other renewable sources to power homes and businesses

2. Efficient Transportation:

Implements smart traffic management and promotes public transport, cycling, and walking

3. Smart Infrastructure:

Uses IoT sensors and data analytics to optimize resource usage and improve services

4. Green Spaces:

Incorporates parks and green roofs to improve air quality and biodiversity

5. Waste Management:

Implements efficient waste collection and recycling systems

6. Citizen Engagement:

Encourages participation through digital platforms and community initiatives

Benefits

1. Reduced Carbon Footprint:
Lower greenhouse gas emissions and energy consumption
2. Improved Quality of Life:
Enhanced public services, safety, and livability
3. Economic Growth:
Attracts businesses and investments through innovation and sustainability

Examples

1. Barcelona's Smart City Initiatives:
Focus on smart lighting, waste management, and public transportation
2. Singapore's Smart Nation Program:
Integrates technology to improve healthcare, transportation, and public services

Architecture

The architecture consists of three main layers:

1. Frontend (Streamlit)

- Provides a user-friendly interface with various features, including:
- Viewing KPIs (Key Performance Indicators)
- Submitting feedback
- Interacting with a chat assistant
- Searching policy vectors
- Generating reports
- Fetching eco-tips

2. Backend (FastAPI)

- Manages API requests and handles file uploads - Integrates with:
- Machine Learning (ML) models
- Pinecone (vector indexing and semantic search)
- Watsonx Granite LLM (Large Language Model)

3. External Services

- IBM Watsonx: Provides LLM prompts and capabilities
- Pinecone: Offers vector indexing and semantic search functionality
- Local/Hosted Data Stores: Stores data for analytics and reporting

Potential Applications

1. Sustainability Analytics: Analyzing data to provide insights on sustainability and environmental impact.
2. Policy Analysis: Using ML models and semantic search to analyze and understand policy documents.
3. Eco-Friendly Recommendations: Providing eco-tips and recommendations to users based on data analysis and ML models.

- **Setup Instructions**

Prerequisites:

- Python 3.9 or later
- pip and virtual environment tools

- API keys for IBM Watsonx and Pinecone
- Internet access to access cloud services

Installation Process:

- Clone the repository
- Install dependencies from requirements.txt
- Create a .env file and configure credentials
- Run the backend server using Fast API
- Launch the frontend via Stream lit
- Upload data and interact with the modules • **Folder Structure**

app/ – Contains all Fast API backend logic including routers, models, and integration modules.

app/api/ – Subdirectory for modular API routes like chat, feedback, report, and document vectorization.

ui/ – Contains frontend components for Stream lit pages, card layouts, and form UIs.

smart_dashboard.py – Entry script for launching the main Stream lit dashboard.

granite_llm.py – Handles all communication with IBM Watsonx Granite model including summarization and chat.

document_embedder.py – Converts documents to embeddings and stores in Pinecone. kpi_file_forecaster.py – Forecasts future energy/water trends using regression. anomaly_file_checker.py – Flags unusual values in uploaded KPI data.

report_generator.py – Constructs AI-generated sustainability reports.

Required libraries:

streamlit: For building interactive dashboard interfaces

fastapi: Backend API framework for rapid development

uvicorn: ASGI server to run FastAPI

requests: For API communication from frontend

python-dotenv: Manage environment variables

sentence-transformers: Text embedding model

pydantic-settings: Handle configuration management

pinecone-client: For semantic document search

scikit-learn, pandas: For anomaly detection and forecasting

matplotlib: For report visualizations

Project Milestones & Development Flow

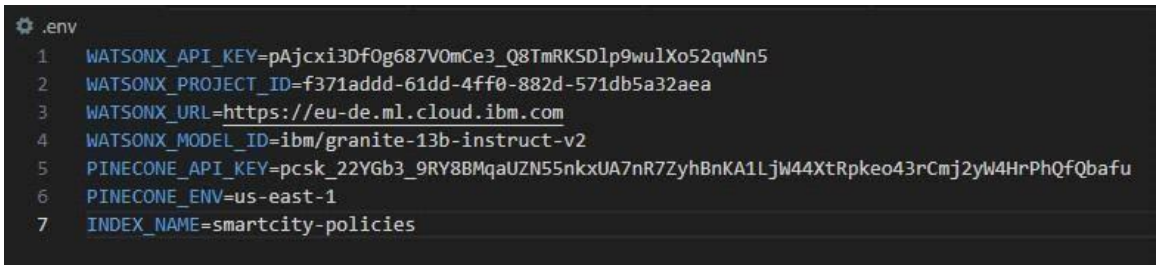
Phase 1 – Project Initialization

Modular Folder Structure Defined: Created separate folders for app/api, services, vectorstore, core, frontend/components, and utils for organized and scalable development.

Environment Setup:

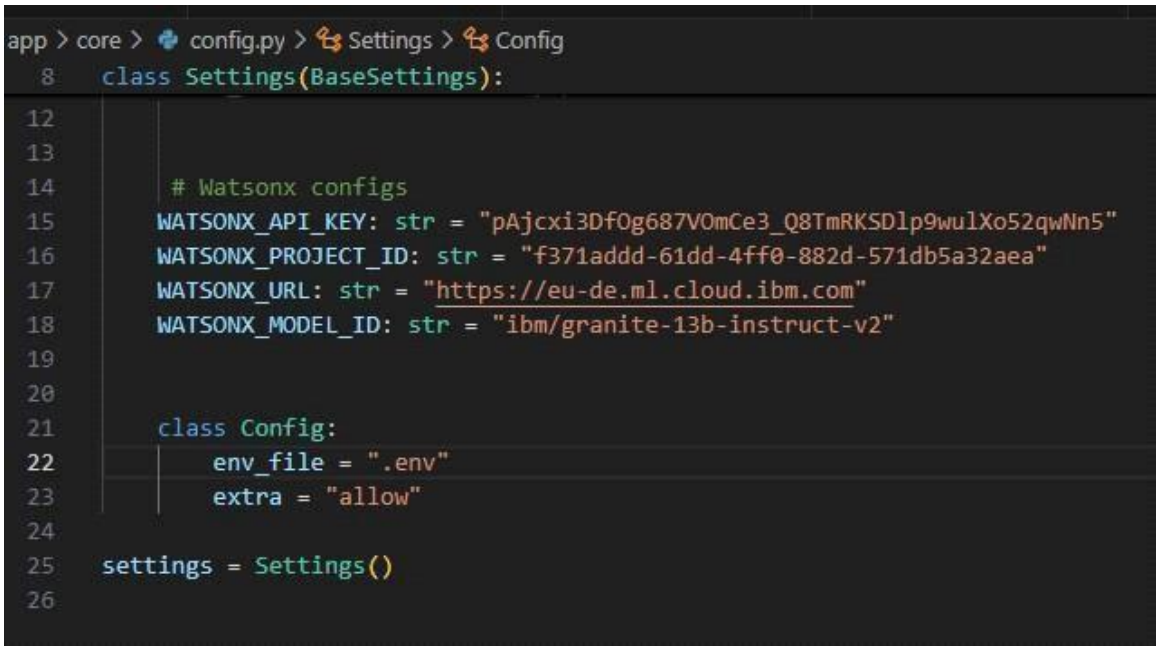
.env file created with keys for Pinecone and Watsonx. config.py loads environment variables securely using pydantic.

.env file



```
.env
WATSONX_API_KEY=pAjcxi3DfOg687VOmCe3_Q8TmRKSDlp9wulXo52qwNn5
WATSONX_PROJECT_ID=f371addd-61dd-4ff0-882d-571db5a32aea
WATSONX_URL=https://eu-de.ml.cloud.ibm.com
WATSONX_MODEL_ID=ibm/granite-13b-instruct-v2
PINECONE_API_KEY=pcsk_22YGb3_9RY8BMqaUZN55nkxUA7nR7ZyhBnKA1LjW44XtRpkeo43rCmj2yW4HrPhQfQbafu
PINECONE_ENV=us-east-1
INDEX_NAME=smartcity-policies
```

Config.py file



```
app > core > config.py > Settings > Config
class Settings(BaseSettings):


    # Watsonx configs
    WATSONX_API_KEY: str = "pAjcxi3DfOg687VOmCe3_Q8TmRKSDlp9wulXo52qwNn5"
    WATSONX_PROJECT_ID: str = "f371addd-61dd-4ff0-882d-571db5a32aea"
    WATSONX_URL: str = "https://eu-de.ml.cloud.ibm.com"
    WATSONX_MODEL_ID: str = "ibm/granite-13b-instruct-v2"


    class Config:
        env_file = ".env"
        extra = "allow"

settings = Settings()
```

Pinecone Initialization:

pinecone_client.py written to initialize the Pinecone vector index (smartcity-policies). Ensured creation with correct dimension=384 matching embedding model.

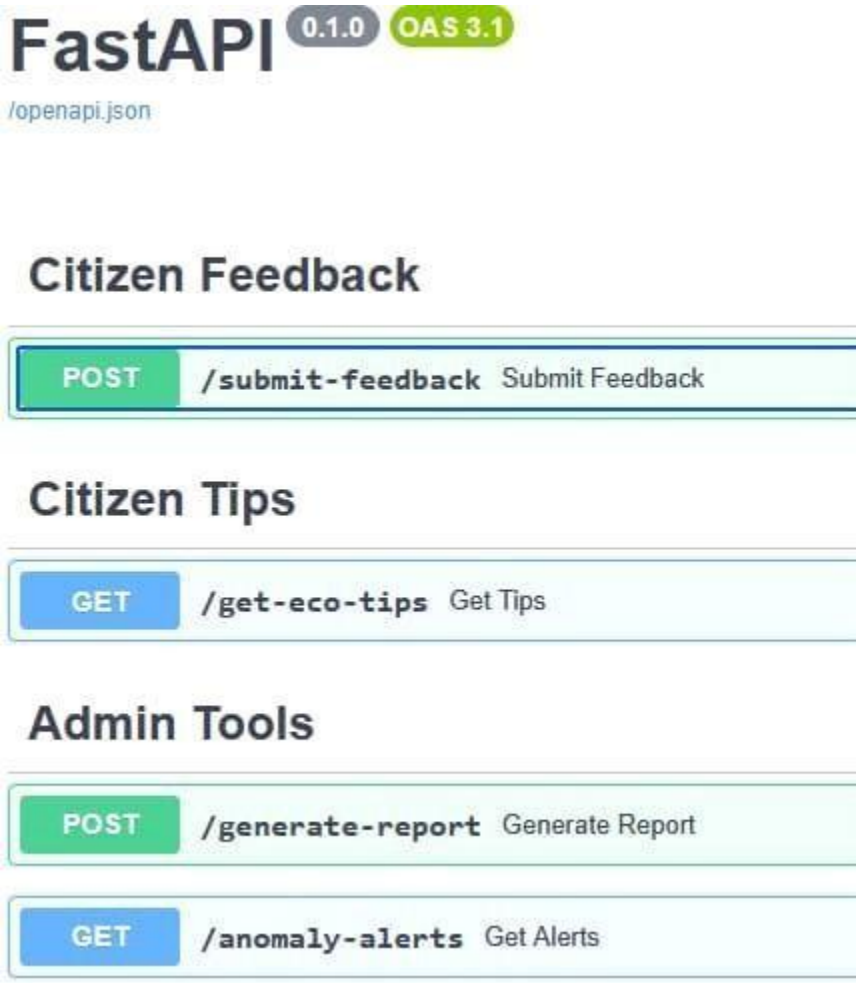
Phase 2 – IBM Watsonx Integration

Watsonx Key & Model Configuration: Set up .env with:

WATSONX_API_KEY, PROJECT_ID, MODEL_ID

Endpoint Testing:

Validated /chat, /policy/summarize, and /get-eco-tips FastAPI routes using Swagger UI.



Phase 3 – Backend API Routers API Routes Implemented:

Developed modular routers:

chat_router.py

feedback_router.py

eco_tips_router.py

kpi_upload_router.py

anomaly_checker.py

vector_router.py, etc.

Testing & Validation:

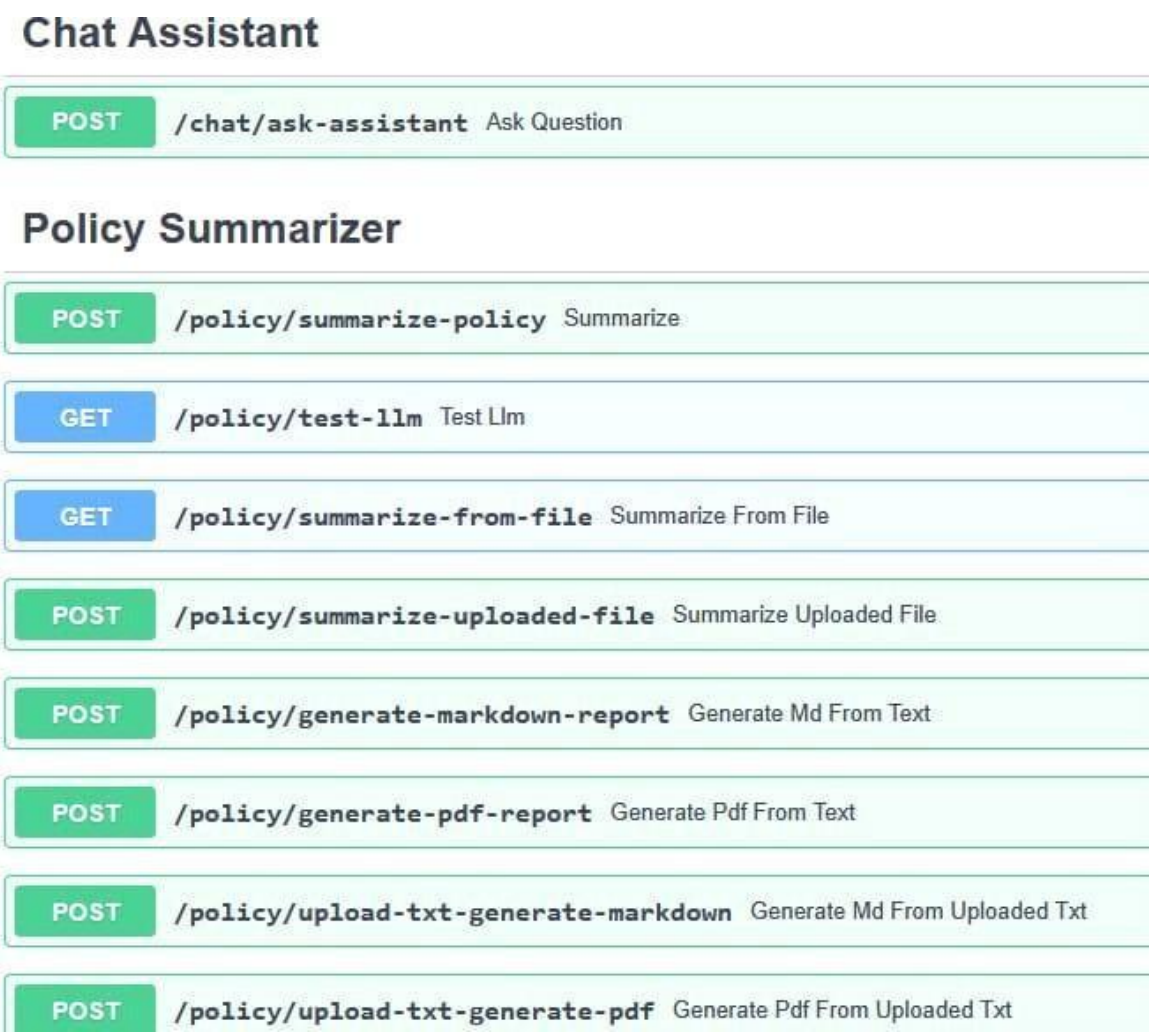
Each route tested for:

JSON payload correctness

File upload parsing

Error handling & logging

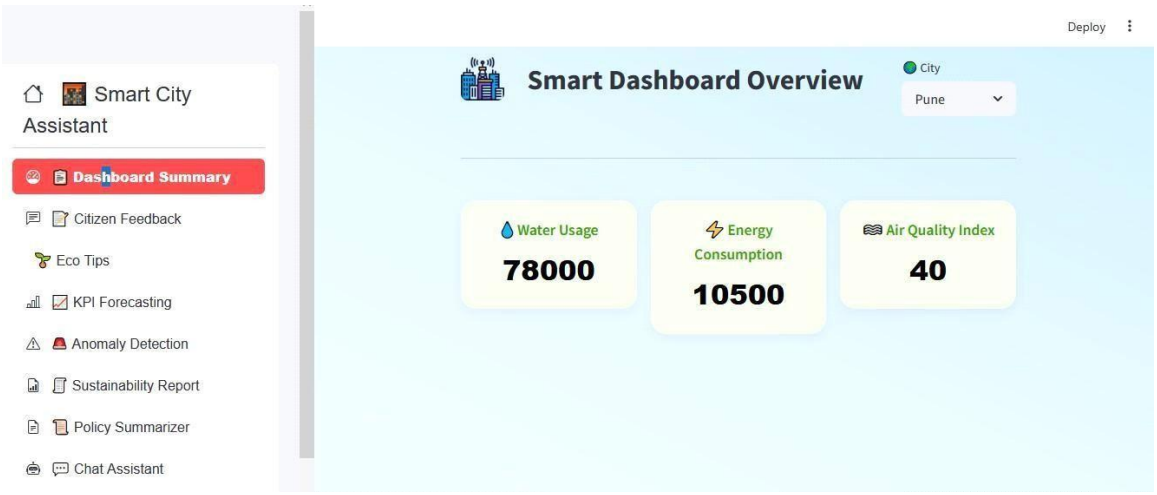
Swagger auto-documentation generation



Phase 4 – Frontend UI Design

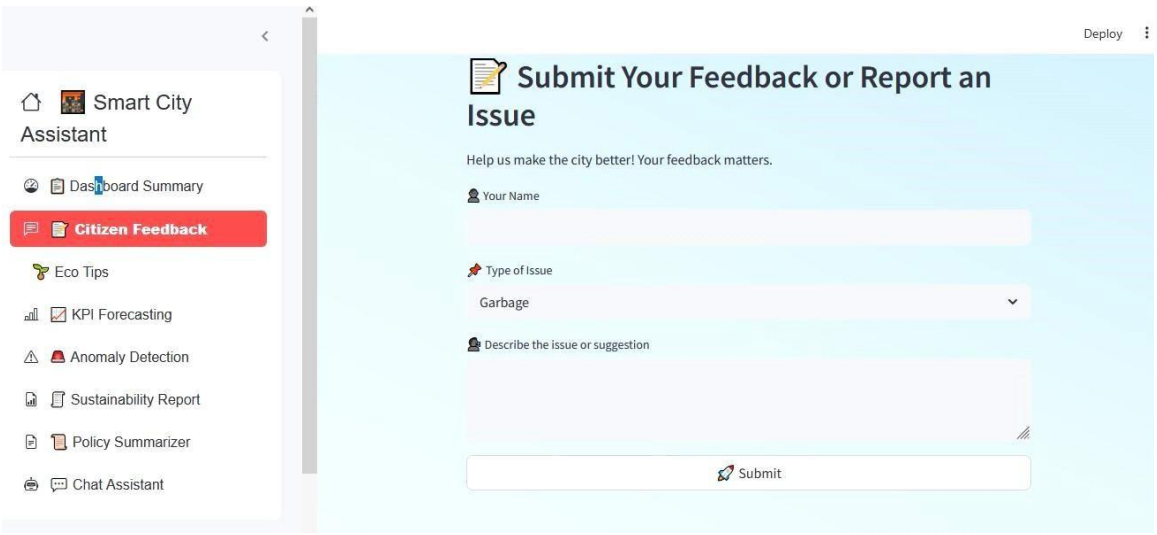
Streamlit UI Structure Implemented:

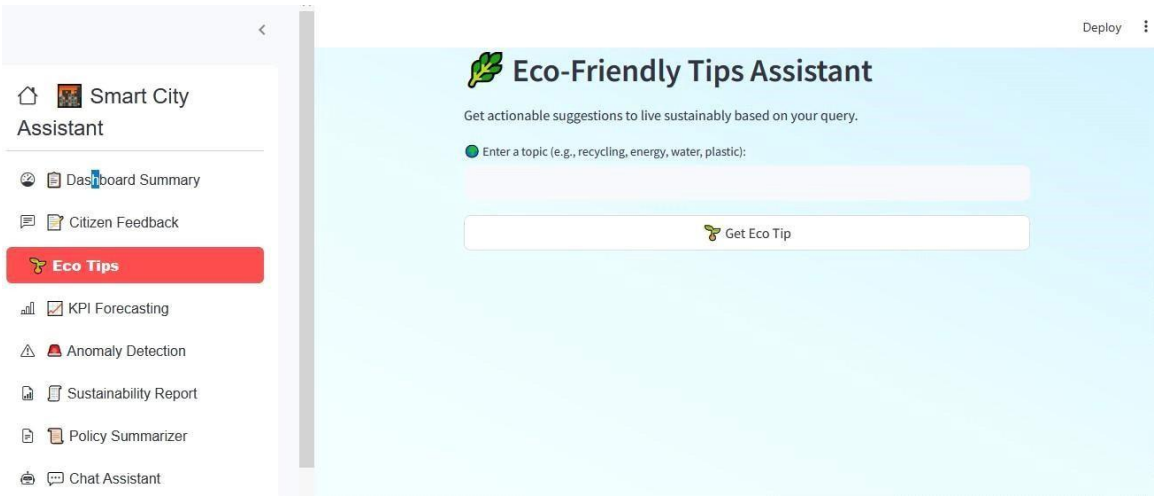
Created central file smart_dashboard.py with conditional rendering for each module using sidebar navigation.



Component Development:

Developed reusable Streamlit components: summary_card.py – Beautiful KPI cards chat_assistant.py – Text prompt and AI reply feedback_form.py, eco_tips.py, report_generator.py, etc.





UI Enhancements Done:

Gradient backgrounds

Icon-rich sidebar using streamlit-option-menu Rounded buttons, font styles, padding fixes

Phase 5 – Pinecone & Document Embedding Embedding

Logic Built:

Created document_embedder.py and document_retriever.py using sentence-transformers.

Phase 6 – Report Generation & Deployment

Granite LLM Report Generator: report_generator.py takes city name and KPI data, generates detailed
city sustainability report using Granite LLM prompts.

Markdown & PDF Support:
Output formatted to text block for copy/paste or PDF download (optional).

End-to-End Integration Testing:
Final dashboard tested on all 8 features: KPI dashboard, feedback form, policy summarization, eco tips, chat, anomaly check, vector search, report generation.