The Energy Access Co-Pilot for City Governments

Polisense.AI – Methodology Whitepaper
AI x City Climate Action Hackathon 2025 Submission

Executive Summary

Cities are at the forefront of the climate crisis, yet many still struggle with energy poverty and limited visibility on where interventions will have the most impact. **Polisense.AI** proposes an AI-driven Energy Access Co-pilot for City Governments, designed to provide actionable insights, prioritize high-impact interventions, and accelerate progress toward universal, reliable, and sustainable energy access.

Our methodology integrates diverse datasets, advanced AI models, and transparent prioritization frameworks into a single decision-support platform. This allows cities to track progress, allocate resources efficiently, and engage stakeholders in evidence-based policy making.

Complementing this mission, **POLISENSE.AI** also functions as an advanced AI-powered policy research platform for sustainable urban development. It leverages a hybrid architecture (custom AI + open-source visualization), integrates multi-modal datasets (satellite imagery, energy infrastructure, demographic data, environmental indicators), and delivers comprehensive policy analysis and recommendations.

Problem Definition & Objectives

Challenge:
Energy poverty disproportionately affects vulnerable urban communities. Many cities lack the data, tools, and processes to identify, prioritize, and implement interventions effectively.

Objectives:

- Build a single source of truth for urban energy access data.

- Prioritize interventions based on **Need, Feasibility, and Impact**.
- Enable faster, evidence-based decisions with transparent justification.
- Provide an AI co-pilot that supports planning, communication, and citizen engagement.
- Extend capabilities toward **policy research, stakeholder mapping, and cost-benefit analysis**.

Conceptual Framework

The solution is designed around three pillars:

1. **Integrated Data Value Chain**
   - Collect and unify data across population, infrastructure, energy usage, and environmental indicators.
   - Provide transparent, standardized metrics for cross-departmental decision-making.
2. **AI-driven Prioritization Methodology**
   - Apply evidence-based scoring models to identify high-impact intervention areas.
   - Enable configurable weighting for alignment with local policy objectives.
3. **Decision Support & Citizen Engagement**
   - Generate actionable insights for policymakers.
   - Provide transparency and feedback loops to citizens to improve alignment.
   - Extend engagement with **automated report generation** and **interactive dashboards**.

Solution & System Architecture

Solution Architecture

- **AI Co-Pilot Layer** – Core engine integrating models, producing rankings, generating insights.
- **Data Value Chain** – Data ingestion, processing, storage, analytics.
- **Communication Interface** – Dashboards, reports, APIs, citizen feedback tools.

System Components

- **Data Ingestion** – Satellite nightlight data, census, grid maps, renewable layers.
- **Processing & Storage** – Normalize, clean, standardize datasets.
- **AI/ML Analysis** – Prioritization scoring, neighborhood ranking.
- **Visualization & Reporting** – Dashboards, open evidence, policy reports.

High-Level Architecture

- **Custom AI Backend (webApi)** – Express.js, TypeScript, PostgreSQL, Redis, Weaviate.
- **ResourceWatch Frontend** – Next.js, React, Mapbox GL, Deck.gl.
- **Web Components (webApp)** – Lit + Material Design 3 for lightweight embedding.

High-Level Architecture

The solution comprises two main components:

1. **Custom AI Backend (webApi)** – A TypeScript-based Express.js API server responsible for AI research, data processing, and real-time analytics. Based on Policy Synth.

2. **ResourceWatch Frontend** – A Next.js application for advanced geospatial visualization and interactive policy dashboards.

This separation enables **independent scaling** of backend processing and frontend rendering, optimizing system performance across diverse urban environments.

System Architecture Diagram

The system architecture integrates multiple external data sources into a unified analytical pipeline, processed by advanced AI models and visualized through an interactive user interface.

External Data Sources Include:

- **MAIIA EI BID Informality Data** – Socioeconomic indicators related to informal settlements.

- **EIA Energy Access Data** – Global and regional energy access datasets.

- **NASA Nightlights Data** – High-resolution satellite imagery for energy poverty detection.

- **ClimateTrace Emissions** – Greenhouse gas emissions data to link energy access with climate impacts.

Software Components:

- **Polisense UI** – A responsive, user-friendly interface for policy exploration.

- **Polisense Backend API** – The core engine orchestrating AI-driven insights.

- **AI RAG Module** – Retrieval-Augmented Generation for intelligent, context-aware decision support.
- **Multi-modal AI** – Processing satellite imagery, energy datasets, and policy documents.
- **ResourceWatch Integration** – Leveraging open-source tools for data transparency and visualization.

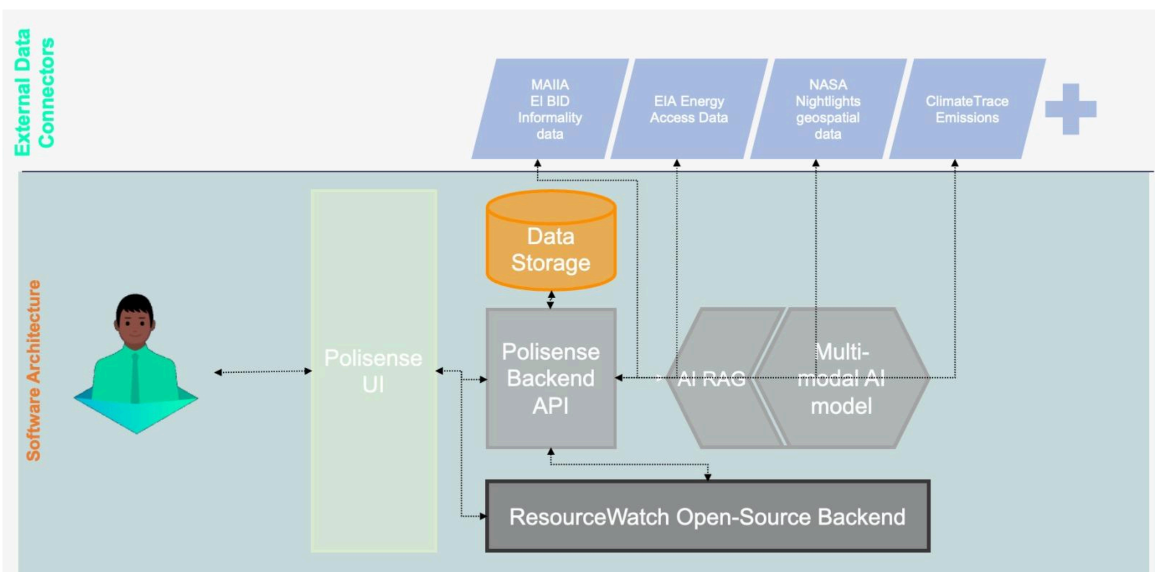

Figure 1: Polisense AI software architecture

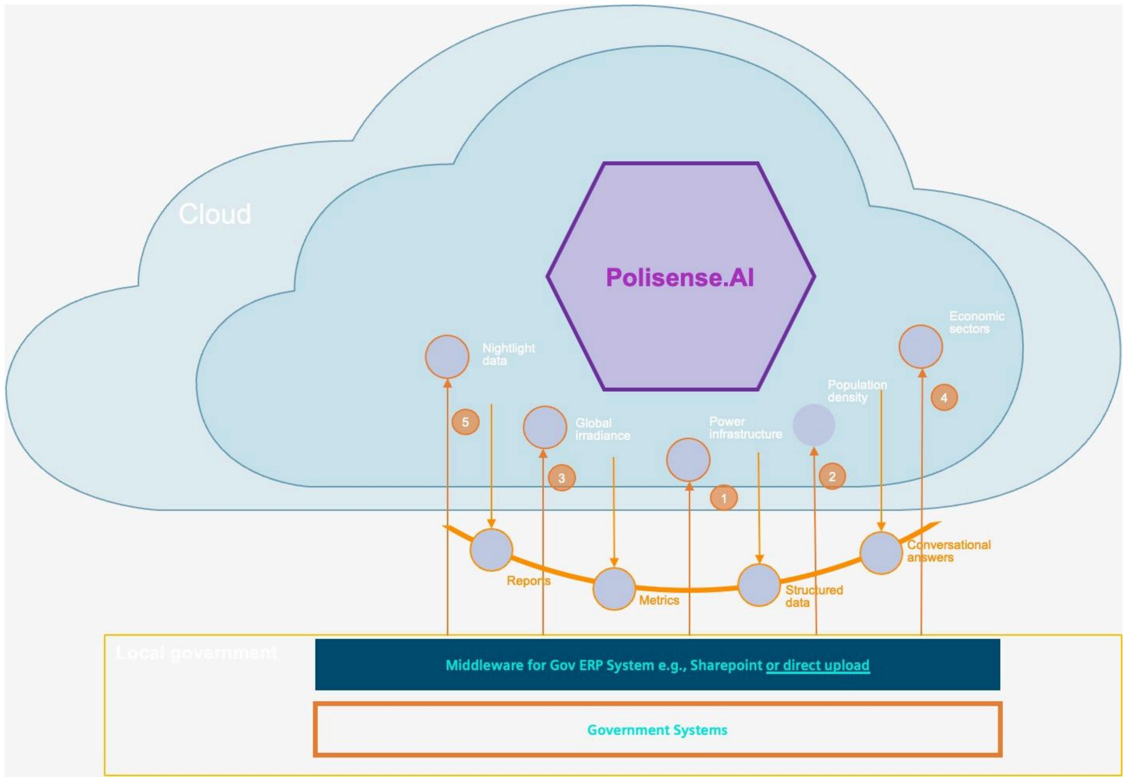

Figure 2: Middleware and cloud system for Polisense AI

Cloud-Based Deployment

Polisense.AI is deployed on a **cloud-native infrastructure** to ensure **scalability, security, and global accessibility**. The cloud-based architecture enables real-time analytics for city governments while maintaining robust data governance.

Key Features of the Deployment:

- Multi-region support for global cities.
- Integration with **government ERP systems** through secure middleware.
- High availability via **Kubernetes orchestration**.
- Scalable storage for large geospatial datasets and AI models.

The system processes data streams from multiple sources, transforms them through AI pipelines, and delivers actionable insights through interactive dashboards and API endpoints.

Backend Architecture (webApi)

The backend serves as the **AI-driven brain of the platform**, managing data ingestion, analysis, and orchestration of research tasks.

Core Technologies:

- **Express.js** – RESTful API framework for backend services.
- **TypeScript** – Ensures maintainability and type safety.
- **PostgreSQL** – Central relational database for structured datasets.
- **Redis** – In-memory caching for real-time performance.
- **Weaviate** – Vector database supporting RAG-based AI functionalities.

AI Research Pipeline Components:

- **SearchQueriesGenerator** – Generates intelligent search queries for research.
- **SearchQueriesRanker** – Uses LLM-based pairwise comparison for ranking.
- **ResearchWeb** – Interfaces with search APIs for data retrieval.
- **SearchResultsRanker** – Scores relevance using GPT-based models.
- **WebPageScanner** – Extracts structured insights from unstructured web content.

Real-Time Processing Features:

- WebSocket-based streaming for **live updates** to city dashboards.
- Continuous token usage monitoring for cost optimization.

- Session persistence via Redis.

Frontend Architecture (ResourceWatch)

The frontend ensures **intuitive interaction with complex data layers**, enabling decision-makers to visualize energy poverty patterns and prioritize interventions effectively.

Key Technologies:

- **Next.js & React** – Modern, fast rendering for dashboards.
- **Redux** – State management for real-time interactivity.
- **Mapbox GL + Deck.gl** – High-performance geospatial visualization.
- **Material-UI & Tailwind CSS** – Consistent, responsive design system.

Core Capabilities:

- Layered visualization of energy access indicators.
- Real-time dashboards integrating AI recommendations.
- Interactive policy simulation tools for scenario testing.
- Widget-based UI for easy customization by city officials.

Data Flow & Integration

The system follows a structured **data pipeline** that ensures integrity and transparency.

Stages:

1. **Data Ingestion** – Aggregates satellite imagery, demographic data, and infrastructure maps.

2. **AI Processing** – Normalizes and scores neighborhoods based on Need, Feasibility, and Impact.
3. **Visualization** – Presents insights via dynamic maps and interactive dashboards.

Integration with External Systems:

- ResourceWatch API for dataset management.
- Google Earth Engine for satellite analysis.
- Secure government ERP middleware for seamless adoption.

Security, Performance & Scalability

Polisense.AI employs **enterprise-grade security practices** and **performance optimizations** to support large-scale deployments.

Security Features:

- API key authentication and role-based access control.
- Comprehensive **CORS** and **input validation** mechanisms.
- Secure environment variable management.

Performance Optimizations:

- Redis caching for frequent queries.
- Load balancing and **horizontal scaling** through Kubernetes.
- Code-splitting and lazy loading for optimized frontend performance.

Scalability Considerations:

- Agent pool management for AI tasks.

- Distributed data storage for high-volume datasets.
- Event-driven architecture for real-time alerts.

Methodology: Prioritizing Areas for Energy Access

The methodology evaluates **Need, Feasibility, and Impact** using measurable indicators.

Indicators:

- **Need:** Population density > 5,000 people/km², Night-lights < 50 lux per capita, Household energy spend > 10% of income, Grid access < 50% of households.
- **Feasibility:** Distance to grid < 2 km, Infrastructure coverage > 50%, Presence of formal addresses, Security score > 0.7 (0–1 scale).
- **Impact:** Potential to reach > 500 households, Solar PV potential > 100 kWh/m²/year, Co-benefits: reduced indoor pollution, improved air quality.

Scoring Formula:

accessPriority = w_1 × normalize(Need) + w_2 × normalize(Feasibility) + w_3 × normalize(Impact)

(Default weights: $w_1 = 0.5$, $w_2 = 0.3$, $w_3 = 0.2$)

Use Cases & User Workflow

Workflow

1. **Data Collection**
   Gather satellite, infrastructure, and socioeconomic datasets to provide a comprehensive view of urban energy needs.
2. **Request & Analysis**
   City officials request a prioritized list of areas for intervention, ensuring data-driven decisions.
3. **AI Processing**
   The AI co-pilot applies a scoring methodology to generate actionable

recommendations for targeted energy access initiatives.

4. **Policy Review & Engagement**
    - AI reviews current policies to identify gaps and opportunities.
    - Officials refine policies and collaborate across departments to ensure alignment.
    - Citizen feedback loops enhance accountability, transparency, and trust in decision-making.

Use Cases

- Expansion of last-mile energy access to underserved communities.
- Targeted solar PV deployment for optimized energy coverage.
- Transparent reporting of investment impacts to stakeholders.
- AI-assisted policy review and iterative improvements for continuous learning.

Features

- **Integrated AI Energy Access Co-pilot** – Provides unified insights and serves as a single source of truth for energy access planning.
- **Efficient Decision-Making** – Enables rapid reporting and fosters cross-department communication.
- **Transparent & Analytical** – Offers explainable AI, evidence-based prioritization, and open access for city stakeholders.

Alignment with Global Frameworks

- Mayors for Climate & Energy (GCoM), the world's largest alliance of cities committed to sustainable and resilient urban futures. By providing actionable insights on energy access, emissions, and policy trade-offs, the platform supports GCoM's objectives of data-driven climate action, transparent monitoring, and shared learning across municipalities worldwide.
- This alignment ensures that local interventions contribute not only to SDG 7 (Affordable & Clean Energy) but also to the broader global climate agenda, reinforcing trust between cities, citizens, and international partners.

Outputs & Deliverables

- **Comprehensive Policy Reports** (with executive summaries, cost-benefit analysis, stakeholder mapping, references).
- **Interactive Dashboards** (multi-layer visualization, scenario testing).
- **Structured Data Outputs** (JSON APIs, CSV exports).
- **Real-time Analytics** (token usage, research progress, cost monitoring).

Security, Performance & Scalability

- **Security**: Role-based access, API key authentication, audit logging.
- **Performance**: Redis caching, Kubernetes scaling, WebSocket streaming.
- **Scalability**: Microservices roadmap, distributed storage, event-driven alerts.

Future Enhancements

- Full microservices migration.
- Edge computing for local processing.
- Citizen participation platforms.
- Predictive analytics for forecasting.
- Mobile + voice-enabled interfaces.
- Academic partnerships and open-source contributions.

Strategy & Outlook

- **Pilots**: Launch in Latin America (e.g., Arequipa, Peru).
- **Partnerships**: Secure hackathon funding and government integration.
- **Scaling**: Expand scope to clean cooking and broader climate action.
- **Long-Term**: Support SDG 7, build climate resilience.

Conclusion

Polisense.AI equips cities with an AI-powered methodology for prioritizing energy access interventions with speed, transparency, and measurable impact. Its dual role as an **Energy Access Co-pilot** and **Policy Research Platform** makes it a transformative solution for governments navigating climate and development challenges.

By combining advanced AI, transparent scoring frameworks, and participatory policy engagement, Polisense.AI strengthens cities' capacity to achieve **reliable, affordable, and sustainable energy access**, while driving broader **sustainable urban development**.

References

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