🌱 EcoPackAI – Project Documentation

1. Architecture Overview

EcoPackAI is designed using a **modular and scalable architecture** that separates concerns across multiple layers to ensure flexibility, maintainability, and future expansion.

Architecture Layers:

- **User Interface Layer**
  Web-based interface for collecting product requirements and displaying recommendations and insights.
- **Data Ingestion Layer**
  Handles structured datasets containing material properties, environmental metrics, and product constraints.
- **Data Processing Layer**
  Performs data cleaning, normalization, feature scaling, and transformation for ML models.
- **Machine Learning Layer**
  Trained predictive and recommendation models for cost, carbon footprint, and sustainability scoring.
- **Recommendation Engine**
  Combines model outputs and rule-based constraints to generate ranked eco-friendly packaging options.
- **Visualization & BI Layer**
  Dashboards and charts to communicate insights such as cost comparison and carbon reduction.
- **Deployment Layer**
  Containerized services deployed to cloud infrastructure with monitoring and CI/CD support.

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2. Dataset Description

EcoPackAI uses **structured and semi-structured datasets** combining packaging material properties and sustainability indicators.

Key Dataset Attributes:

- Material name and category
- Strength and durability metrics
- Weight capacity
- Cost per unit
- Carbon footprint score
- Recyclability percentage
- Biodegradability score
- Regulatory and compliance indicators

The dataset supports **multi-objective optimization**, enabling the system to balance cost efficiency, sustainability, and performance requirements.

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3. Machine Learning Model Explanation

EcoPackAI employs a **hybrid recommendation approach**:

a) Predictive Models

- **Random Forest Regressor**
  Used to predict material cost and environmental impact due to its robustness and interpretability.
- **XGBoost Regressor**
  Applied for higher accuracy in sustainability and carbon footprint prediction.

b) Recommendation Logic

- **Content-based filtering** ranks materials based on similarity to user requirements.
- Model predictions are combined with sustainability rules to produce final ranked recommendations.

This hybrid approach ensures **accurate, explainable, and context-aware recommendations**.

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4. Evaluation Metrics

EcoPackAI is evaluated using both **machine learning performance metrics** and **business-impact metrics**.

Model Evaluation Metrics:

- Precision@K
- Recall@K
- NDCG (Normalized Discounted Cumulative Gain)

Sustainability & Business Metrics:

- Cost savings percentage
- Average carbon footprint reduction
- Sustainability score improvement
- Recommendation relevance score

These metrics ensure the system performs well both technically and environmentally.

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5. BI Dashboard Explanation

The EcoPackAI dashboard provides **interactive and real-time insights** for decision-makers.

Dashboard Features:

- Recommended packaging materials with ranking
- Carbon footprint comparison charts
- Cost analysis across alternative materials
- Sustainability KPIs (recyclability, biodegradability)
- Feature importance and model insights

The dashboard enables **data-driven sustainable packaging decisions** with clear visual explanations.

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6. Deployment Steps

EcoPackAI follows a structured deployment workflow:

1. Environment setup and dependency installation
2. Dataset preprocessing and feature engineering
3. Machine learning model training and evaluation
4. Backend API development for recommendations
5. Frontend and dashboard integration
6. Docker containerization
7. Cloud deployment
8. CI/CD pipeline setup for automated updates
9. Monitoring and logging for performance tracking

This ensures a **production-ready and scalable system**.

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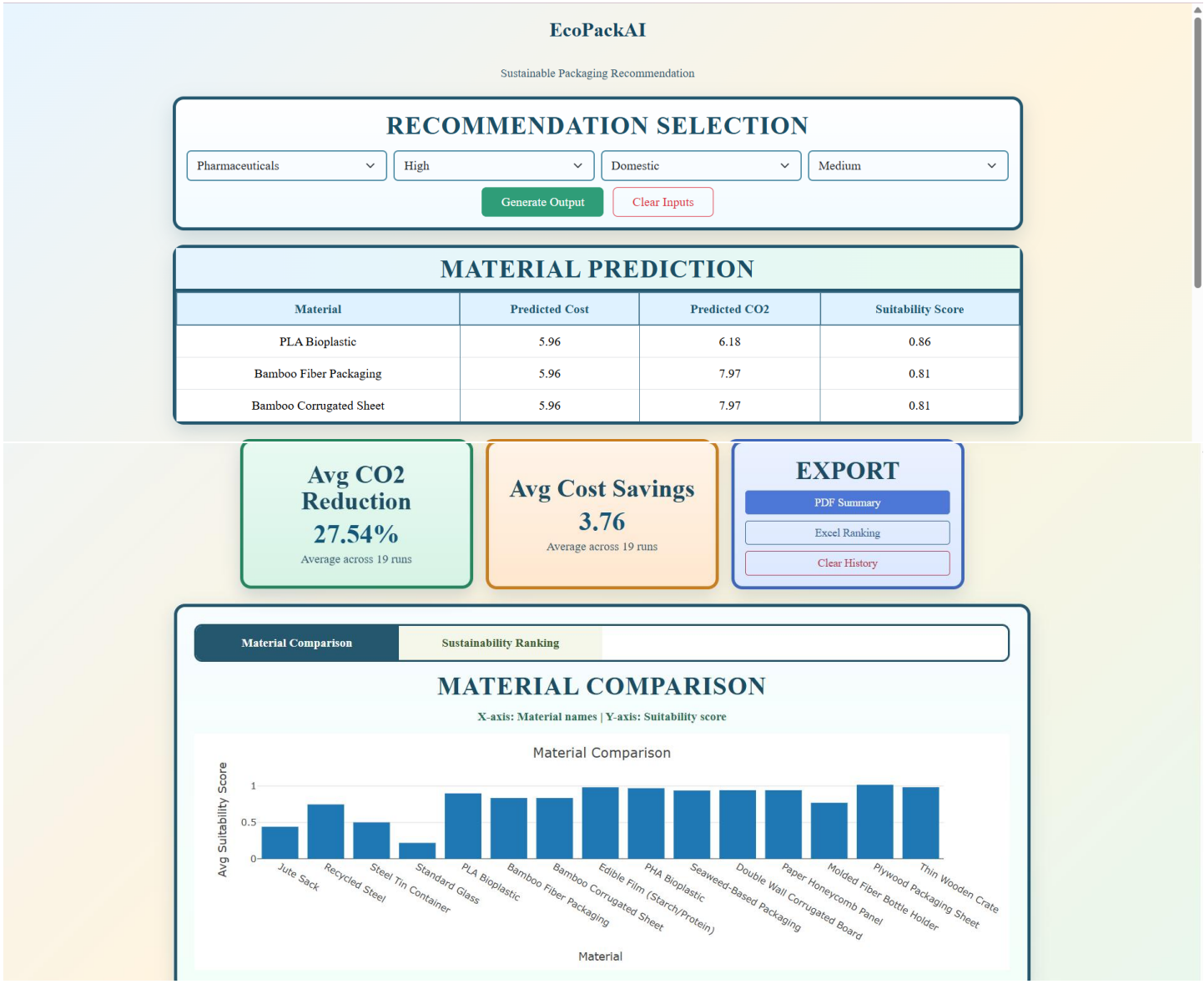
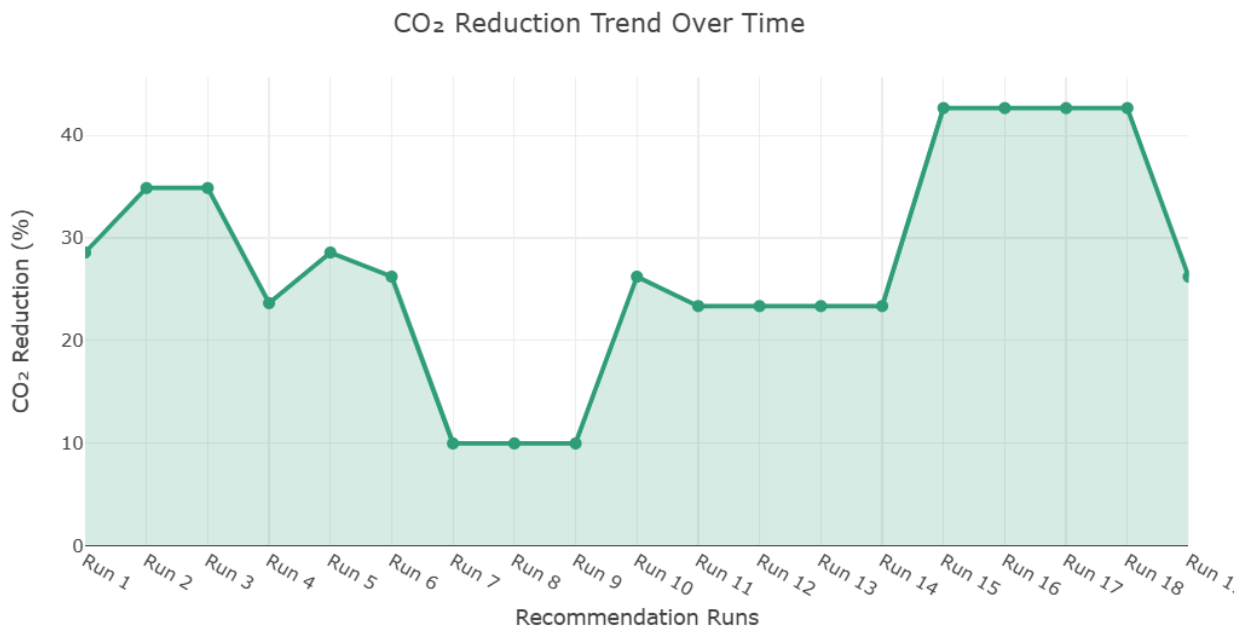
7. Screenshots



CO2 Reduction Analysis



Cost Savings Analysis