EcoPackAI – AI-Powered Sustainable Packaging Recommendation System

Project Statement:

Traditional packaging used in industries and e-commerce heavily relies on non-biodegradable and costly materials, causing increasing environmental damage and financial inefficiency. Businesses lack intelligent decision-support systems that can help them evaluate and adopt eco-friendly alternative packaging materials without compromising durability, product safety, or cost-efficiency.

EcoPackAI is an AI-powered full-stack web platform designed to solve this challenge by recommending optimal packaging materials based on product attributes, sustainability parameters, and industry standards. The system uses machine learning models to assess material suitability and predict both environmental impact (carbon footprint) and cost efficiency. The platform integrates a **Business Intelligence (BI) dashboard** to provide actionable sustainability insights and report measurable reductions in environmental impact, helping organizations make data-driven decisions towards greener supply chains.

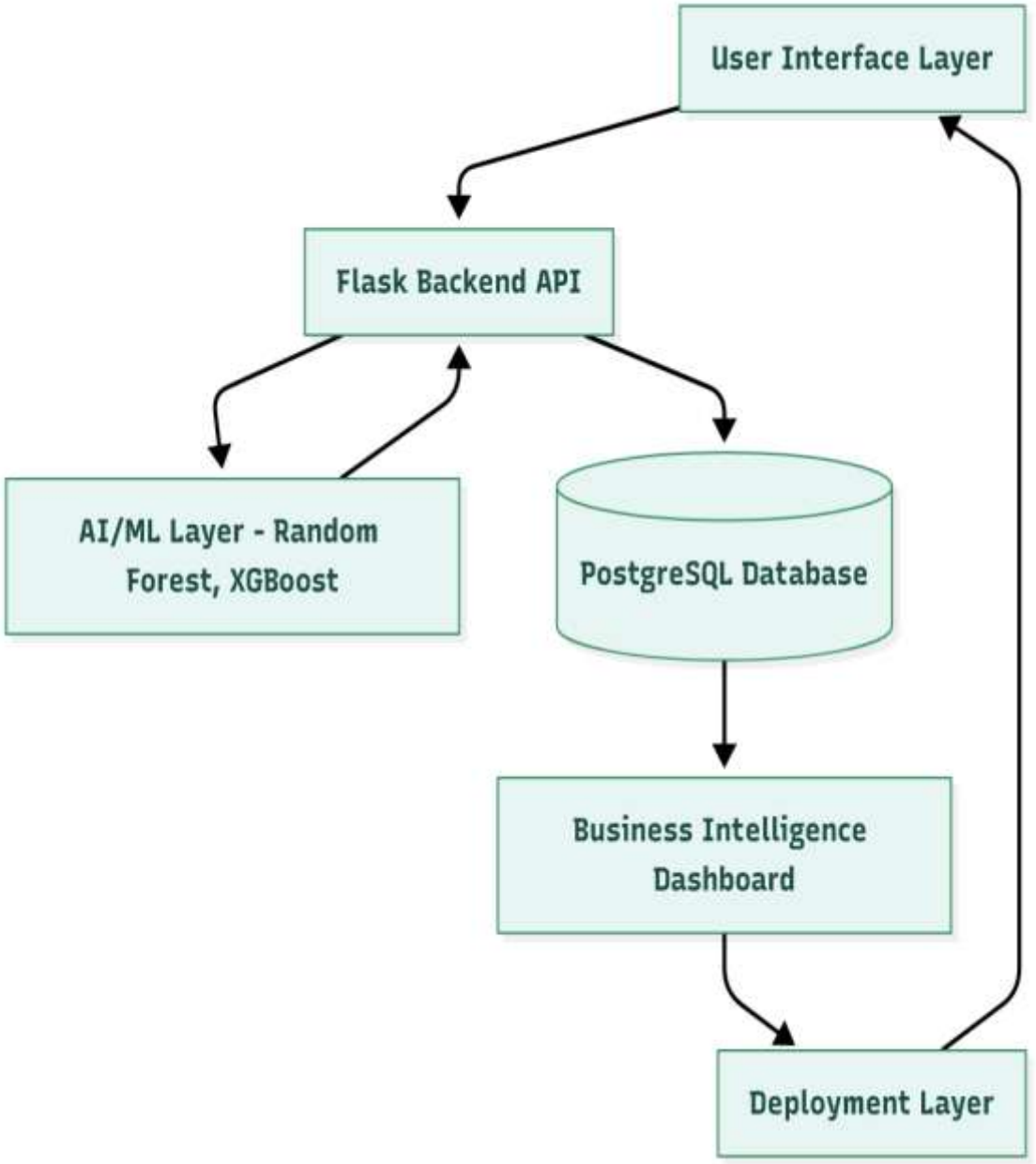
Outcomes:

- Develop a deployable AI-powered recommendation system for eco-friendly packaging materials.
- Analyze and compare packaging materials based on cost, durability, biodegradability, and CO_2 footprint.
- Predict environmental and financial impact using machine learning models.
- Provide ranked recommendations tailored to specific product profiles.
- Enable sustainability reporting through BI dashboards.
- Reduce packaging costs while improving environmental compliance.
- Support industry adoption of green packaging with a scalable intelligent platform.
- Provide documentation and modular architecture for future expansion.

Modules to be implemented

1. Data Collection & Management (Material Database + Product Attributes)
2. Data Cleaning & Feature Engineering
3. Machine Learning Dataset Preparation
4. AI Recommendation Model (ML-based)
5. Flask Backend API Integration
6. Frontend UI (Bootstrap + HTML + JavaScript)
7. BI Dashboard (CO_2 & Cost Analytics)
8. Deployment & Documentation

System Architecture of EcoPackAI – AI-Powered Sustainable Packaging Recommendation System



Week-wise module implementation and high-level requirements with output screenshots

Milestone 1: Week 1-2

Module 1: Data Collection and Management

- Gather eco-friendly material dataset with attributes:
- Material type, strength, weight capacity, biodegradability score, CO_2 emission score, recyclability %
- Collect industry product categories: electronics, food, cosmetics, etc.
- Create PostgreSQL database structure for materials and product data.
- Integrate CSV/Excel material data and validate schema.

Module 2: Data Cleaning and Feature Engineering

- Handle missing values and normalize numerical features.
- Encode categorical material properties.
- Feature engineering for:
- CO_2 Impact Index
- Cost Efficiency Index
- Material Suitability Score
- Validate data quality using summary statistics.

Milestone 2: Week 3–4

Module 3: Machine Learning Dataset Preparation

- Split data into training and testing sets.
- Select ML features for prediction (material safety, strength, shipping category).
- Generate target values for:
- Cost Prediction
- CO_2 Impact Prediction
- Prepare data pipelines and scaling.

Module 4: AI Recommendation Model (ML – Based)

- Train ML models:
- Random Forest Regressor (Cost Prediction)
- XGBoost Regressor (CO_2 Footprint Prediction)
- Model evaluation metrics:
- RMSE, MAE, R^2 Score
- Create material ranking system based on ML predictions.

Milestone 3: Week 5–6

Module 5: Flask Backend API

- Create REST APIs for:
- Product input handling
- AI material recommendation
- Environmental score computation
- Connect Flask backend to PostgreSQL database.
- Secure endpoints and implement JSON response structure.

Module 6: Frontend UI Development

- Build user interface using:
- HTML, CSS, Bootstrap
- Input forms for product parameters
- Display AI material recommendations
- Show ranking table and comparison metrics

Milestone 4: Week 7–8

Module 7: Business Intelligence Dashboard

- Build analytics dashboard showing:
- CO_2 reduction %
- Cost savings
- Material usage trends
- Use matplotlib/plotly charts
- Export sustainability reports in PDF/Excel

Module 8: Deployment & Documentation

- Deploy on Render/Heroku
- Connect with PostgreSQL cloud instance
- Write technical documentation + README
- Project report and video demo

Evaluation Criteria

Milestone 1 Evaluation (Week 1–2):

- The evaluation for Milestone 1 will focus on the successful completion of data foundation and preprocessing tasks for the EcoPackAI system. The following criteria will be assessed:
- Successful collection and organization of eco-friendly packaging material datasets.
- Proper creation and setup of PostgreSQL database with appropriate schema.
- Completion of basic data cleaning operations including handling missing values and removal of duplicates.
- Implementation of feature engineering techniques to derive meaningful sustainability metrics such as CO_2 Impact Index and Cost Efficiency Score.
- Initial documentation of data schema and data dictionary.

Milestone 2 Evaluation (Week 3–4):

Milestone 2 will be evaluated based on correct dataset preparation and AI model development. The assessment will cover:

- Preparation of training and testing datasets with appropriate feature selection.
- Successful implementation of data pipelines including scaling and encoding.
- Development of machine learning models for cost prediction and CO_2 footprint estimation using algorithms like Random Forest and XGBoost.
- Evaluation of model performance using RMSE, MAE, and R^2 metrics.
- Initial material recommendation ranking based on model outputs.

Milestone 3 Evaluation (Week 5–6):

This milestone focuses on the integration of the AI models with the backend logic of the application. Evaluation points include:

- Flask backend API development and integration with ML models.
- Successful connection between Flask application and PostgreSQL database.
- REST API endpoints created for handling product input and returning packaging recommendations.
- JSON response structure implemented correctly and tested.
- Initial integration of the backend with basic frontend UI components.

Milestone 4 Evaluation (Week 7–8):

The final milestone will be evaluated based on application refinement, analytics insights, deployment, and documentation quality. Criteria include:

- Development of BI Dashboard with CO_2 savings visualization and cost analysis charts.
- Ability to generate sustainability reports in PDF or Excel formats.
- Complete integration of frontend, backend, and recommendation system.
- Deployment of EcoPackAI application on Render/Heroku with database connection.