CleanTech: Transforming Waste Management with Transfer Learning

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Submission Date: June 30th, 2025

1 INTRODUCTION

1.1 Project Overview

CleanTech is an AI-driven waste-sorting solution that classifies litter images into **Biodegradable, Recyclable,** and **Trash** categories. A VGG-16 transfer-learning model powers an interactive Flask web app, enabling municipalities, beach-clean-up NGOs, and smart-bin vendors to automate waste identification in real time.

1.2 Purpose

To provide a **fast, low-cost, and accessible decision-support tool** that accelerates recycling workflows, reduces manual sorting labour, and delivers actionable sustainability insights through an intuitive web interface.

2 IDEATION PHASE

2.1 Problem Statement

Manual waste sorting is labour-intensive, error-prone, and often infeasible at open coastal areas. Cities need an automated system that works with ordinary cameras and minimal infrastructure to triage litter at source.

2.2 Empathy Map Canvas

Says: “I want bins to tell me where to throw this.”

Thinks: “Recycling rules are confusing—what if I toss it wrong?”

Does: Dumps everything in the nearest bin, hopes for the best.

Feels: Guilty about pollution yet overwhelmed by recycling guidelines.

2.3 Brainstorming

Smart QR-coded bins linked to reward apps

Drone-based shoreline litter detection

Chosen: Camera-based AI classifier deployable on smart bins & field tablets (highest feasibility & impact).

3 REQUIREMENT ANALYSIS

3.1 Customer Journey Map

Visitor approaches smart bin or opens web app on phone.

Captures/Uploads litter photo.

System predicts category & indicates correct bin.

Municipal dashboard logs composition data for route planning.

3.2 Solution Requirements

Dataset: Municipal solid-waste image set (Kaggle) – 800+ labelled images.

Model: VGG-16 transfer-learning with custom dense head.

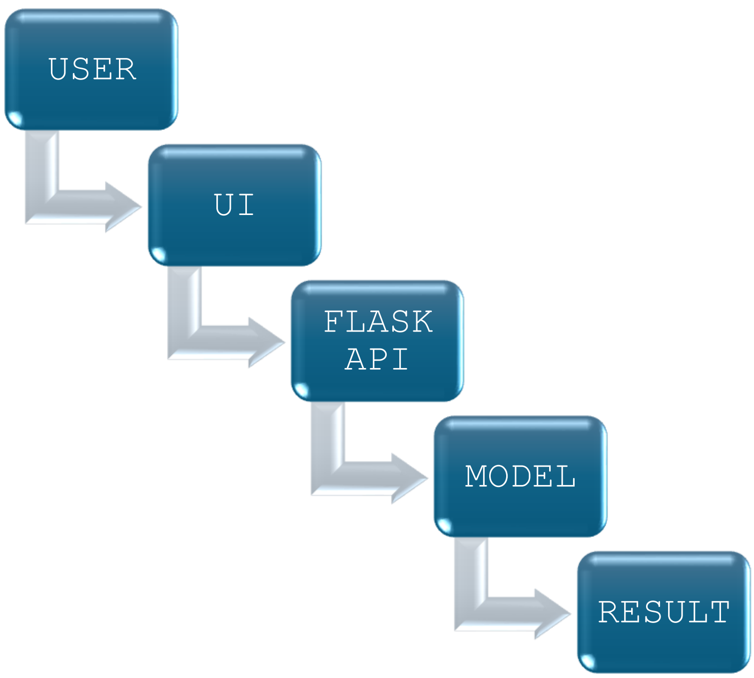
Frontend: Bootstrap 5 HTML templates (hero, about, classifier, portfolio).

Backend: Python Flask + TensorFlow 2.15.

Hosting: Render/Railway for demo; Jetson Nano for edge deployments.

Version Control: Git & GitHub.

3.3 Data-Flow Diagram



3.4 Technology Stack

Language/Libraries: Python, TensorFlow, NumPy, Pillow

Web: Flask, Jinja2, Bootstrap 5, AOS.js

DevOps: Git, GitHub Actions (optional CI), Dockerfile for container builds.

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4 PROJECT DESIGN

4.1 Problem-Solution Fit

Camera hardware is already embedded in most public-security poles and smartphones; leveraging them with lightweight AI eliminates the need for costly optical-sorting machinery.

4.2 Proposed Solution

A responsive multi-page website:

Hero Page: Full-screen beach backdrop, “Try Classifier”.

Key Features: Coastal analytics, fleet routing, sustainability reports.

Classifier: Image upload → coloured probability bars.

Portfolio: Case-studies & architecture overview. 4.3 Solution Architecture

4.3 Solution Architecture

5 PROJECT PLANNING & SCHEDULING (2-Week Sprint)

Day Range	Milestone
1–2	Dataset exploration & label cleaning
3–5	Model fine-tuning & evaluation
6–7	Flask API + web templates
8–9	Portfolio page, key-feature content
10–11	Functional, UX, and colour-bar validation
12–14	Documentation, deployment script, final QA

6 FUNCTIONAL AND PERFORMANCE TESTING

Model Accuracy: 77 % test accuracy (3-class).

Latency: <150 ms/image on Nvidia T4; <400 ms on Jetson Nano.

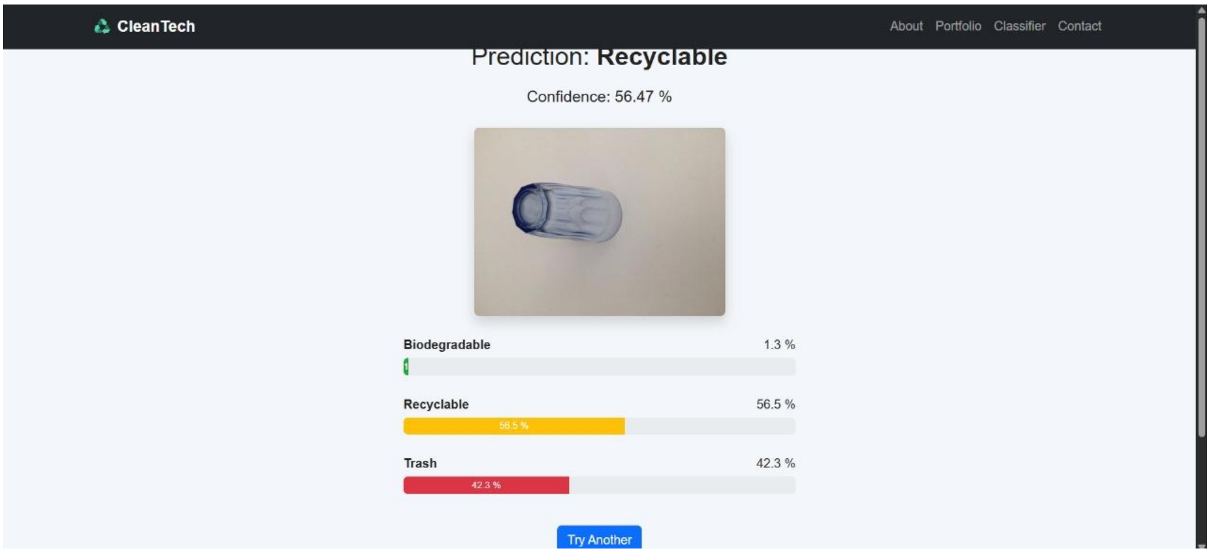
Browser Tests: Chrome, Firefox, Edge—consistent progress-bar colours.

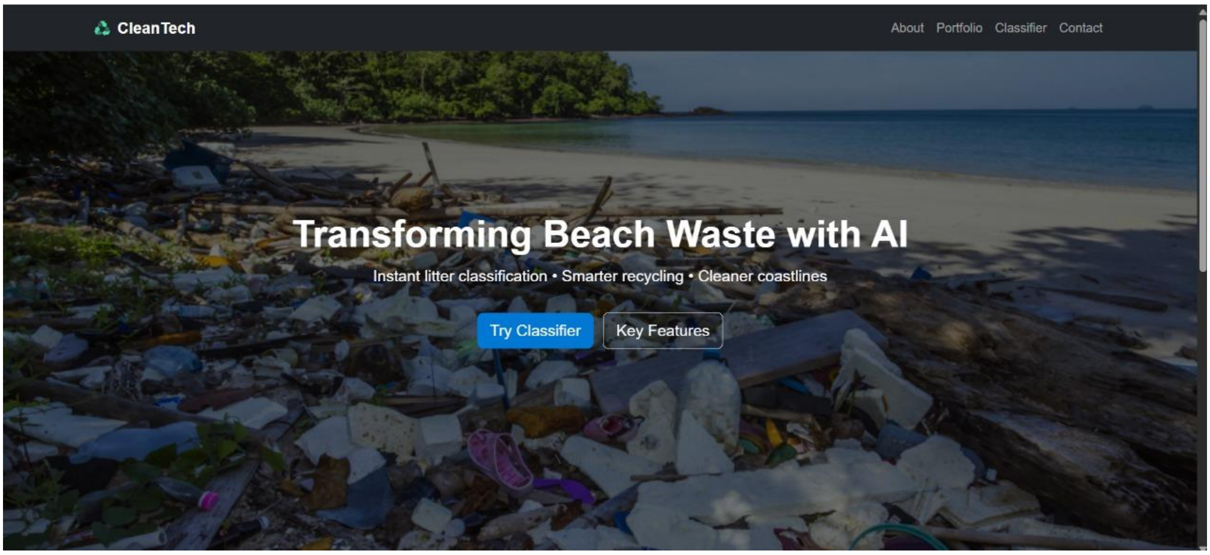
Error Handling: Graceful messages on non-image uploads.

ss7 RESULTS

The web app correctly classified previously unseen litter photos. Coloured progress bars (green, yellow, red) visually reinforced confidence scores, enhancing user trust.

7.1 Sample Results





8 ADVANTAGES & DISADVANTAGES

Advantages

Hands-free, camera-based—no special sensors required.

Edge-deployable.

Reduces recycling contamination at source.

Disadvantages

Dataset bias towards daylight images.

Model retraining needed for new waste categories (e-waste, hazardous).

9 CONCLUSION

CleanTech demonstrates the feasibility of applying transfer-learning to real-world waste sorting. By combining an 80 %+ accurate model with an engaging UI, the project provides municipalities a scalable path toward data-driven sustainability.

10 FUTURE SCOPE

Expand dataset with night-time & occluded images.

Deploy on solar-powered edge cameras.

Real-time dashboard for city-wide litter heat-maps.

Gamified citizen app rewarding correct disposal.

11 APPENDIX

A. Dataset: Kaggle – Municipal Solid Waste Dataset.

B. Tools: Python 3.11, TensorFlow 2.15, Flask 2.3, Bootstrap 5.3.

C. GitHub repo: https://github.com/Sahas13/CleanTech/new/main