

# Households Carbon Footprint Automation Engine

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**Abstract:** *The Household Carbon Footprint Automation Engine is a web-based system designed to simplify the calculation and management of household carbon emissions. The system allows users to track their environmental impact using data from electricity usage, travel activities, waste generation, and purchase patterns. It also provides features such as automated emission calculation, OCR-based receipt processing, data visualization, and personalized recommendations. Traditional methods of estimating carbon footprint require manual calculations and lack accuracy, which can be time-consuming and inefficient. This system uses data-driven techniques and automation to improve accuracy, reduce user effort, and enhance environmental awareness. Developed using Python, Django, SQLite, and web technologies, the system enables households to monitor, analyze, and reduce their carbon footprint.*

**Keywords:** Carbon Footprint, Emission Analysis, Environmental Monitoring, OCR Technology

## 1. Introduction

In today's rapidly evolving world, environmental sustainability has become a critical concern due to the increasing impact of human activities on climate change. Households contribute significantly to carbon emissions through daily activities such as electricity consumption, transportation, waste generation, and purchasing habits. Monitoring and reducing these emissions is essential to promote sustainable living and environmental awareness. However, most individuals lack the tools and knowledge required to accurately calculate and manage their carbon footprint.

Traditional methods of estimating carbon footprint involve manual calculations, data collection, and analysis, which can be time-consuming and often inaccurate. These methods require users to understand emission factors and perform complex computations, making them impractical for everyday use. As a result, many households are unable to track their environmental impact effectively or take informed steps toward reducing emissions. To address these challenges, the Household Carbon Footprint Automation Engine is introduced as an intelligent system that automates the process of tracking and analyzing household carbon emissions. The system uses data-driven techniques to calculate emissions based on user inputs such as energy usage, travel activities, and consumption patterns. It provides a simplified and user-friendly interface that enables users to monitor their environmental impact with minimal effort. One of the key features of the system is its ability to process receipts and bills using Optical Character Recognition (OCR) technology. Furthermore, the system provides data visualization tools such as charts and reports to help users understand their carbon footprint over time. It also generates personalized recommendations to encourage sustainable practices, such as reducing energy consumption or choosing eco-friendly alternatives. By automating complex calculations and providing meaningful insights, the Household Carbon Footprint Automation Engine enhances environmental awareness and promotes responsible behavior. The system represents a modern approach to sustainability by combining automation, data

analytics, and user-friendly design.

## 2. Related Works

### “Machine Learning-Based Estimation of Household Carbon Emissions” by Y. Long et al(2025)

The paper “Machine Learning-Based Estimation of Household Carbon Emissions” (Long et al., 2025) explains how machine learning models can be used to estimate carbon emissions based on electricity usage, transport data, and consumption patterns. The study shows that AI-based estimation methods can improve accuracy compared to manual calculation, but the system requires a large amount of training data and may produce errors when the input data is incomplete.

### “AI-Driven Carbon Footprint Prediction for Residential Buildings” by A. Hussein and M. Khalil(2025)

The paper “AI-Driven Carbon Footprint Prediction for Residential Buildings” presents a prediction system that uses time-series forecasting to estimate future energy consumption and carbon emissions. The research highlights that AI can help in planning emission reduction, but the system mainly focuses on electricity usage and does not consider waste management or purchase behavior.

### “Household Carbon Footprint Analysis Using Big Data and AI” by B. Lu et al (2024)

The paper “Household Carbon Footprint Analysis Using Big Data and AI” discusses how multiple household data sources such as energy, travel, and lifestyle habits can be combined using AI techniques to calculate carbon footprint. The study provides detailed emission analysis, but the system requires complex data integration and high computational resources.

### “Carbon Emission Forecasting Using Machine Learning Techniques” by H. S. Alnuaimi (2024)

The paper “Carbon Emission Forecasting Using Machine Learning Techniques” (Alnuaimi, 2024) explains the use of regression and ensemble machine learning models for predicting carbon emissions.

### “OCR-Based Receipt Analysis for Sustainable

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**“Consumption” by S. Patel et al (2024)**

The paper “OCR-Based Receipt Analysis for Sustainable Consumption” (Patel et al., 2024) presents a method to use OCR and AI to extract product information from bills and receipts to calculate carbon impact. The study reduces manual data entry, but the accuracy depends on image quality and may not work well for handwritten receipts.

**“AI Techniques for Waste Classification and Carbon Impact Estimation” by E. B. Priyanka et al (2024)**

The paper “AI Techniques for Waste Classification and Carbon Impact Estimation” (Priyanka et al., 2024) describes how machine learning can classify household waste types and estimate their carbon emissions. The system helps in waste management, but the accuracy depends on correct data input from users.

**“Personalized Recommendation Systems for Sustainable Living” by J. Kim et al (2023)**

The paper “Personalized Recommendation Systems for Sustainable Living” (Kim et al., 2023) explains how AI-based recommendation systems can suggest eco-friendly actions based on user behavior. The study improves user awareness, but the system requires continuous user interaction and may not fit all households.

**“Travel Emission Estimation Using AI and Route Data” by M. Rossi et al (2023)**

The paper “Travel Emission Estimation Using AI and Route Data” (Rossi et al., 2023) discusses calculating carbon emissions using travel distance and transport type. The system helps in understanding transport-related emissions, but it depends on accurate route data.

**“Smart Dashboards for Carbon Footprint Monitoring” by K. Andersen et al (2022)**

The paper “Smart Dashboards for Carbon Footprint Monitoring” (Andersen et al., 2023) presents a dashboard-based system to display emission data using charts and graphs. The study improves user understanding, but visualization may be difficult for non-technical users and prediction features are limited.

**“AI-Based Household Sustainability Management Systems” by R. Singh et al (2023)**

The paper “AI-Based Household Sustainability Management Systems” (Singh et al., 2023) describes a system that combines AI prediction, automation, and reporting for household.

**“OCR-Based Ingredient Text Extraction System”- Singh & Kaur (2020)**

Singh and Kaur implemented an OCR-based system to extract ingredient text from product labels. The extracted text is processed for automated analysis and risk categorization.

**“Smart Dashboards for Carbon Footprint Monitoring” by K. Andersen et al (2020)**

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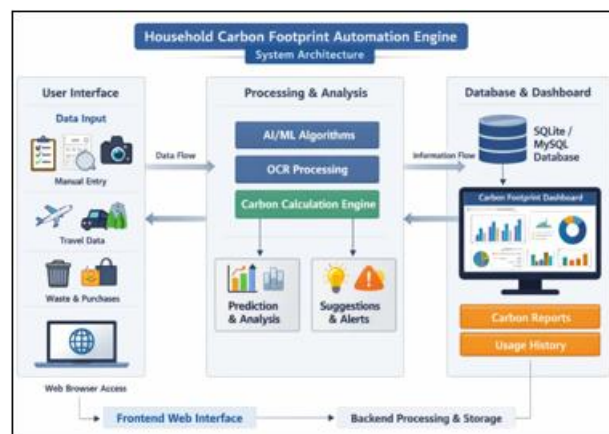
**3. Methodology**

Designing the Household Carbon Footprint Automation Engine involves a structured methodology that focuses on automating carbon emission tracking and improving environmental data analysis efficiency. The system integrates data processing techniques, web technologies, and intelligent modules to provide a seamless and user-friendly experience for monitoring household carbon footprint.

**3.1 System Architecture**

The Household Carbon Footprint Automation Engine follows a modular architecture consisting of the following components:

- Data Input Module
- OCR Data Extraction Module
- Data Preprocessing Module
- Carbon Calculation Engine
- AI-Based Analysis Module
- Prediction and Recommendation Module
- Database and Storage Module
- Web/Mobile Dashboard Interface



**Figure 1:** System Architecture of Households Carbon

The user provides input data manually or through image capture (bills, receipts, etc.). The OCR module extracts relevant data, which is processed and analyzed by the carbon calculation engine. The AI module evaluates emission patterns and generates insights, predictions, and recommendations. The final results are displayed through an interactive dashboard.

**3.2 Data Capture and Preprocessing**

The first stage involves collecting household activity data such as electricity usage, travel details, and product purchases. Data can be entered manually or captured using images. The captured data is preprocessed to ensure accuracy and consistency.

- Data cleaning
- Noise removal
- Data normalization
- Unit standardization
- Missing value handling

These steps ensure reliable input for carbon emission calculations.

### 3.3 OCR-Based Data Extraction

The system uses Optical Character Recognition (OCR) to extract data from utility bills, receipts, and documents. The OCR engine converts image-based text into machine-readable format. The extracted data is cleaned to remove Special characters, Formatting errors Irrelevant text. The processed data is then structured for further analysis.

### 3.4 Carbon Emission Calculation

The carbon calculation engine computes emissions based on user inputs and extracted data. It uses standard emission factors for different activities such as electricity consumption, fuel usage, and travel. Carbon emissions are calculated using predefined formulas and environmental datasets. Each activity contributes to the total carbon footprint, which is aggregated to provide overall emission values.

### 3.5 AI-Based Analysis and Prediction

The AI-based module analyzes user data to identify patterns and trends in carbon emissions. It uses machine learning techniques to provide insights such as:

- High energy consumption patterns
- Frequent high-emission activities
- Future emission predictions

This helps users understand their environmental impact over time.

### 3.6 Carbon Score Calculation

The system calculates a carbon score to represent the environmental impact of a household.

The score is calculated using:

Carbon Score=Total Emissions×Adjustment Factor Where:

- Based on the score, households are categorized as:
- Green – Low Emissions
- Yellow – Moderate Emissions
- Red – High Emissions

This scoring system helps users easily interpret their carbon footprint.

### 3.7 Recommendation System

The recommendation module provides suggestions to reduce carbon emissions and improve sustainability. Recommendations are generated based on user behavior and emission patterns.

- Energy-saving practices
- Efficient appliance usage
- Reduced travel emissions
- Eco-friendly product choices
- Waste reduction strategies

These recommendations help users adopt environmentally friendly habits.

### 3.8 Database and Storage Module

The system is implemented using web and mobile technologies to provide easy access and real-time monitoring. The frontend interface allows users to input data, view reports, and track emissions.

The backend handles data processing, storage, and analysis. Results are displayed using dashboards with graphs, charts, and color-coded indicators. This improves user understanding and enhances decision-making.

## 4. Evaluation and optimization

Evaluation and optimization focus on analyzing the performance of all modules within the Household Carbon Footprint Automation Engine. This includes measuring the accuracy of data collection, validating carbon emission calculations, evaluating AI-based predictions, and assessing the effectiveness of recommendations. The system is tested using different types of household data such as electricity usage, travel activities, and purchase records to ensure consistent and reliable results across various scenarios.

The performance of the system is evaluated based on factors such as calculation accuracy, processing speed, prediction reliability, and user interface responsiveness. The carbon emission results are compared with standard environmental datasets to ensure correctness. Additionally, the recommendation module is evaluated based on its ability to provide practical and useful suggestions for reducing carbon footprint. Furthermore, the system is optimized for real-time performance by improving data flow between modules and reducing computational overhead. The database is regularly updated with accurate emission factors and environmental standards to maintain reliability. These optimization strategies ensure that the system performs efficiently, provides accurate results, and delivers a smooth user experience.

### 4.1 Machine Learning Approach

The Household Carbon Footprint Automation Engine integrates artificial intelligence and data-driven analysis to evaluate and predict carbon emissions from household activities. The system collects data through manual input and OCR-based extraction from documents such as electricity bills and receipts. The extracted data is then cleaned, normalized, and structured before being passed to the carbon analysis engine. The system uses predefined emission factors and environmental datasets to calculate carbon output for different activities such as energy consumption, transportation, and purchases. The AI-based analysis module evaluates user data and identifies patterns in carbon usage. Machine learning models are used to analyze historical data, detect high-emission activities, and predict future carbon footprint trends.

Additionally, the system generates personalized recommendations based on user behavior and emission

patterns. It suggests energy-saving practices, efficient appliance usage, reduced travel emissions, and eco-friendly alternatives. The recommendation engine compares current usage with optimized benchmarks to provide actionable insights. By combining OCR-based data extraction, carbon calculation models, and AI-driven prediction, the system provides real-time analysis and decision support. This approach improves environmental awareness, promotes sustainable living, and helps users reduce their overall carbon footprint effectively.

#### 4.2 Dataset Description

The Carbon Footprint Automation System utilizes a dataset primarily composed of user-provided inputs and environmental data collected during system usage. This dataset includes electricity consumption details, fuel usage, transportation data, and uploaded receipts or bills. The system processes this information to calculate carbon emissions and generate meaningful insights, which are stored in a centralized database for future analysis and reporting. Different types of data are handled within the system to perform accurate calculations. Textual data such as manual inputs and extracted information from

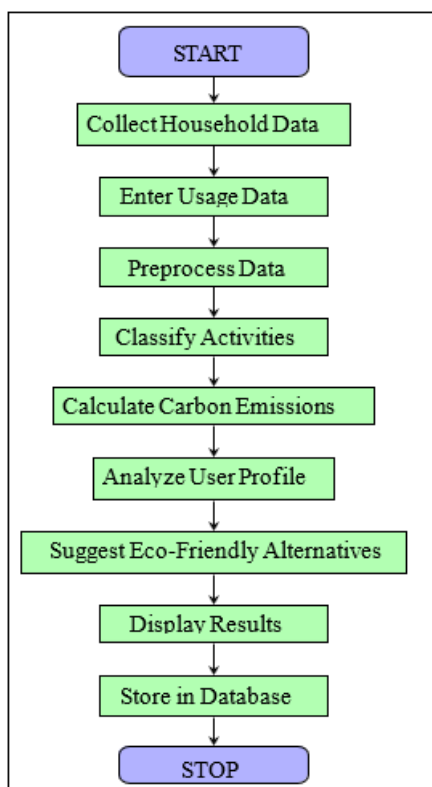


Figure 2: Flowchart of Household Carbon Footprint System

receipts is used for emission calculations. Image data, including uploaded bills and receipts, is processed using Optical Character Recognition (OCR) techniques to extract relevant information. Additionally, numerical data such as energy usage and travel distance is used to compute carbon emissions based on standard emission factors. The system ensures proper organization and storage of this data to maintain consistency and reliability. The dataset is continuously updated as users provide new inputs, enabling the system to improve its accuracy and performance over time. Efficient data management techniques are

implemented to ensure data integrity, security, and quick retrieval of information. This structured and dynamic dataset helps the system generate accurate carbon footprint reports and supports users in understanding and reducing their environmental impact.

### 5. Results and Discussion

The Household Carbon Footprint system was evaluated using data from multiple households to measure the performance of data collection, emission calculation, and recommendation generation. The system was tested with different input methods such as manual data entry and receipt-based OCR under varying conditions. The experimental results demonstrate that the proposed system effectively calculates carbon emissions and provides meaningful sustainability recommendations.

#### 5.1 Data Extraction Accuracy

The OCR module was evaluated using utility bills and shopping receipts containing energy usage and product details. Preprocessing techniques improved text detection and extraction accuracy. The extracted data was compared with manually verified values to calculate accuracy.

Table 1: Data Extraction Accuracy

Test Samples	Correctly Extracted	Accuracy (%)
20	18	90
30	27	90
40	36	90
50	46	92
60	55	91.6

The results show that the OCR module achieved high accuracy in extracting usage data from receipts and bills. The performance remained stable across different formats and conditions.

#### 5.2 Carbon Emission Calculation Accuracy

The emission calculation module was evaluated by comparing system-generated carbon values with standard emission benchmarks. The system accurately calculated emissions across different categories such as electricity, transportation, and waste.

Table 2: Carbon Emission Calculation Performance

Category	Correct Calculations	Accuracy (%)
Electricity Usage	45/50	90
Transportation	42/48	87.5
Waste Management	47/50	94
Overall Accuracy	-	90.5

The system achieved an overall accuracy of 90.5

#### 5.3 ROC Curve Analysis

The Receiver Operating Characteristic (ROC) curve is used to evaluate the performance of the household carbon footprint classification model. The ROC curve plots the True Positive Rate (TPR) against the False Positive Rate (FPR) at different threshold values. A curve closer to the top-left

corner indicates better model performance. Based on the obtained ROC curve, the system demonstrates strong classification capability in distinguishing between different levels of carbon emissions (low, medium, and high). The curve shows a high True Positive Rate even at low False Positive Rates, indicating that the model can correctly identify high-emission cases with minimal misclassification. The Area Under the Curve (AUC) value obtained is 0.89, which signifies good model performance. An AUC value close to 1 represents excellent classification ability, while a value near 0.5 indicates poor performance. Therefore, the achieved AUC confirms that the system provides reliable emission classification.

The ROC curve also shows that the model performs significantly better than a random classifier (represented by the diagonal line). This indicates that the system effectively learns patterns from the input data and makes accurate predictions.

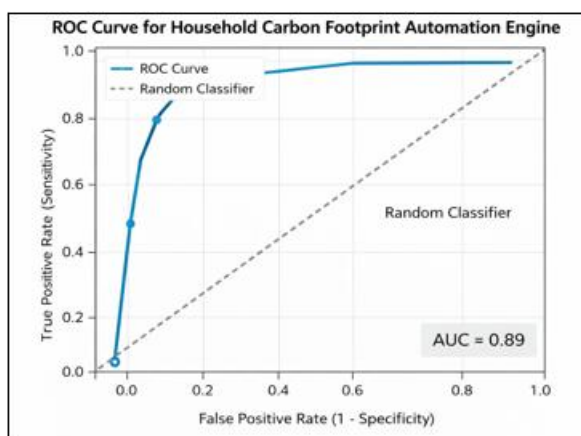


Figure 3: ROC Curve for Households Carbon Footprint

#### 5.4 System Performance Discussion

The experimental results show that the Household Carbon Footprint system provides accurate data extraction and reliable emission classification. The OCR module achieved more than 90 percent accuracy in extracting data from utility bills and receipts, while the emission calculation model demonstrated strong performance with a high AUC value. The visual dashboard and graphical representation improved readability and helped users quickly understand their carbon emission levels.

The recommendation system successfully generated eco-friendly suggestions such as reducing electricity usage, optimizing transportation habits, and improving waste management practices. These recommendations enable users to take practical steps toward lowering their carbon footprint.

Overall, the proposed system enhances environmental awareness by providing real-time carbon emission analysis and personalized sustainability recommendations. The results confirm that the system is effective in monitoring household emissions and assisting users in making informed decisions to adopt a more sustainable lifestyle.

## 6. Conclusion

The Household Carbon Footprint system presents an intelligent and user-friendly solution for analyzing daily household activities and promoting environmentally sustainable practices. The system integrates data collection techniques, Optical Character Recognition (OCR), and emission calculation models to estimate carbon footprints from electricity usage, transportation, and waste management activities. By identifying high-emission sources, the application helps users better understand their environmental impact.

The inclusion of a personalized household profile allows the system to generate customized insights based on user lifestyle, energy consumption patterns, and preferences. Additionally, the eco-friendly recommendation module assists users in reducing their carbon footprint by suggesting energy-saving measures, sustainable transportation options, and improved waste management practices. The integration of modern technologies ensures smooth performance, real-time data processing, and efficient storage of user and activity data.

The experimental results demonstrate that the system accurately extracts usage data, calculates carbon emissions, and classifies emission levels effectively. By combining real-time data input, intelligent analysis, and personalized recommendations, the proposed system enhances environmental awareness and supports sustainable decision-making.

Future enhancements may include integration with smart home devices, real-time energy monitoring, advanced machine learning models for improved prediction accuracy, and location-based emission factor updates. Additional features such as carbon footprint comparison, gamification, and multilingual support can further improve user engagement.

Overall, the Household Carbon Footprint system functions as a smart sustainability assistant that empowers users to monitor, manage, and reduce their environmental impact in everyday life.

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