Sustainable electronic goods Recommendation based on Carbon Footprint Insights

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***Abstract*— Carbon footprint refers to the total amount of carbon dioxide(CO2) gas emitted directly or indirectly over the life cycle of a product. Carbon footprint is the measure of whether an organization is environment-friendly. Various approaches have been proposed to measure the carbon footprint of products. Most of these approaches prescribe using an LCA-based framework to assess the carbon footprint. LCA refers to Life Cycle Assessment and involves calculating the emissions due to processes of the product over its entire lifecycle. Electronic products contribute significantly to global carbon emissions. The contribution to the carbon emissions is about 4% which is comparable to that of the airline industry having a contribution of 2-4%. The different components that are used for sustainability recommendation system are Database, Recommendation and optimization model, Chatbot and Website. Since different modules are integrated, object-oriented methodology will be used. SQL Database is used, as the data about the product should be stored in a Structured Database. Proximal Policy Optimization (PPO) is efficient in learning and optimization stuff and therefore we will be using it to build our recommendation and optimization model. Llama 2 LLM is a free LLM that has a good performance. So, Llama 2 will be used to train the chatbot. Streamlit is used for the front-end. This project is a comparison tool to help choose products with lower carbon impact and cost, both optimised. The user will be provided, by this project, tips for reducing emissions through smarter energy use, disposal, and production choices. He/she will be encouraged to adopt eco-friendly practices.**

Keywords*— *Carbon Footprint, Life Cycle Assessment (LCA), Sustainability, Electronic Products, Proximal Policy Optimization (PPO), Reinforcement Learning, Recommendation System, Optimization Model

I. INTRODUCTION

Sustainability-focused decision-making is crucial as industries and consumers seek to reduce their carbon footprint. However, identifying eco-friendly products and making sustainable choices can be complex. This project develops an AI-powered Sustainability Recommender System, integrating Reinforcement Learning (PPO), LLama-based chatbot interactions, and carbon footprint analysis using LCA datasets to help users make informed, sustainable purchasing decisions. By leveraging AI and reinforcement learning, this project aims to empower users to make more eco-conscious purchasing decisions, contributing to a greener future.

II. LITERATURE SURVEY

[1] outlines methodologies for integrating digital wins into lifecycle assessments to achieve a lower carbon footprint, specifically in manufacturing and product lifecycle management. [2] compares various standards for carbon footprint assessments, analyzing quantification methods and emission treatment approaches. [3] reviews existing carbon footprint estimation methods, focusing on the lifecycle approach. It identifies gaps in current methodologies and suggests improvements for greater precision. [4] explores global research trends in carbon footprint tracking. Emphasizes using technology like AI and blockchain for tracking carbon footprint in complex supply chains. [5] analyzes the environmental impacts of integrated circuit (IC) production, emphasizing carbon footprint and energy demand, and advocates for standardized methodologies to reduce the ecological footprint. [6] contains the LCA of 2 electronic devices- smart watch and a TV remote, and this paper contains the different electronic components these devices have. [7] contains the methodology of LCA of a smartphone, also the data of individual components are given. [8] conducts a Life Cycle Assessment (LCA) comparing a smartwatch and a TV remote by examining their electronic components and evaluating their environmental impacts throughout their lifecycle. [9] presents the life cycle assessment (LCA) methodology for smartphones, detailing the environmental impact of individual components. It aims to inform consumers about the ecological footprint of their devices. [10] analyzes the environmental impacts of integrated circuit (IC) production, emphasizing carbon footprint and energy demand, and advocates for standardized methodologies to reduce the ecological footprint.[11] discusses the prevailing methods used by organizations to estimate the CF of their electronics products and identifies the challenges faced by the electronics industry when adopting these methods in an environment of decreasing product development cycles with complex and diffuse supply chains. [12] describes an LCA method for a Chinese personal computer. [13] provides an original calculation of the LCI data for each electronic components industry. [14] compares LCA variation for 3 electronic products. [15] focuses on embodied carbon emissions of user devices associated with accessing networks, hence tablets, smartphones and feature phones, laptop and desktop PCs, PC displays and customer premises equipment (CPEs). [16] is a study that analyses and compares which electronic product contributes more to the global warming, by analysing the carbon footprint of electronic products. [17] compares the GHG emission of 11 electronic products. [18] proposes a Product Carbon Footprint(PCF) of a Printed Circuit Board(PCB). [19] estimates the carbon footprint (CF) of smartphones and life cycle costs (LCC) for consumers in scenarios where different material efficiency strategies are implemented in Europe. [20] analyses the carbon footprint of gaming console like PlayStation3.

III. OBJECTIVES

The authors of this paper aim to fulfil the below objectives.

- Analyse the data from suppliers, logistics, disposal etc. to extract the carbon footprint of electronic products across their lifecycles
- Optimise cost and carbon footprint of electronic products.
- Develop a system the recommends sustainable electronic goods

IV. METHODOLOGY

This project aims to develop a sustainability tracker that recommends electronic products to users based on the carbon footprint. Traditional recommendation algorithms do not take into account sustainability metrics. We'll be employing a reinforcement-learning based recommendation system using proximal policy optimization for personalized product suggestion while also considering environmental impact.

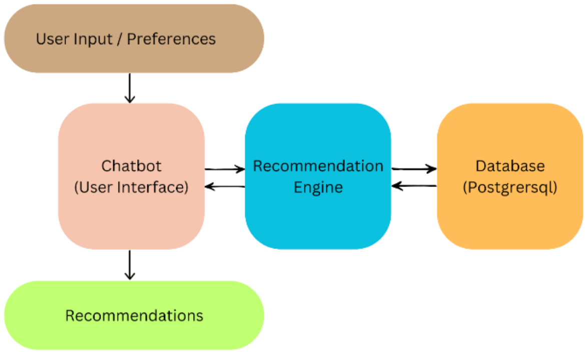

Figure 1: Architectural diagram of the project

A. *Module specification*

1. *User Input:* The user inputs the preferences of the product he/she wishes to buy. It contains specification and category of the product. They can also input their preferred carbon footprint.

2. *Chatbot:* It is the user interface using which the user interacts. Developed using Llama, an open source Llm developed by Meta. The chatbot is trained by specifying user intents and gradually updating the knowledge base.

3. *Recommendation Engine:* This module consists of the ML model which is used to predict the recommendations. It takes in input from the Chatbot and fetches the user history from the database. All these parameters are combined together to make personalized recommendations. The model utilizes the Proximal Policy Optimization(PPO) algorithm, a reinforcement learning algorithm.

4. *Database:* It consists of all the data about all the recommendable products. The user authentication/identification data is also present. Postgresql is used to develop the database.

5. *Recommendations:* The output that the user gets from the chatbot. It consists of the products in the range of the user input optimized with sustainability metrics like carbon footprint.

V. RESULTS AND DISCUSSION

The model asks for a product category, and it gives product recommendation optimizing carbon footprint and cost of the electronic products. Fig 2 and 3 show the working of the model.

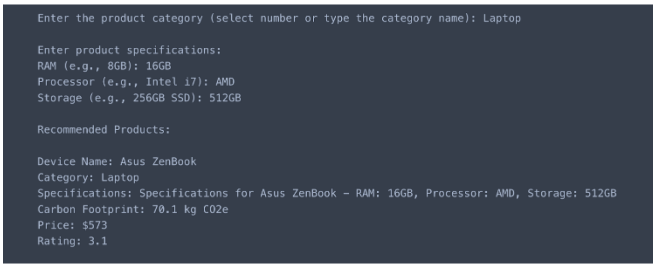

Figure 2: Working of the model

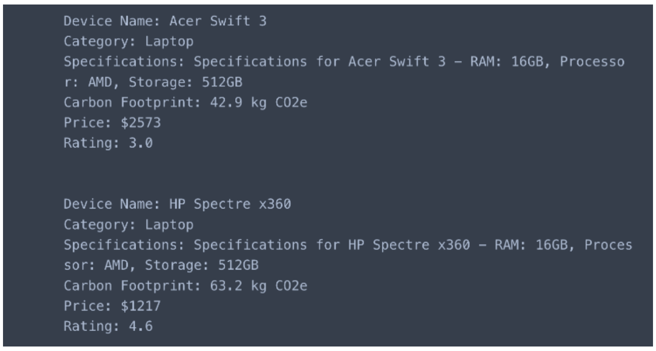

Figure 3: Working of the model

The chatbot developed allows the user to ask questions in natural language, and gives output if the sentence contains valid category.

Figure 4: Chatbot if there is a valid category given

If there is an invalid output given, the chatbot tells the user that the product category is invalid.

Figure 5: Chatbot if there is an invalid category

VI. CONCLUSION AND FUTURE WORKS

The sustainability recommendation system suggests sustainable electronic products based on carbon footprint, optimising both carbon footprint and cost. The system built using PostgresSQL database, PPO reinforcement learning algorithm, Llama API and streamlit has fulfilled all the objectives.

To further enhance the Sustainability Recommender System, several key improvements can be implemented:

- Exploring more advanced reinforcement learning techniques, such as Twin Delayed Deep Deterministic Policy Gradient (TD3) or Soft Actor-Critic (SAC), could improve policy optimization and stability.
- Preventing input data drift by expanding LCA data of various new electronic products.
- Enhancing the performance of PPO, so as to give real-time responses.
- Enhancing the UI, to add interactive visualisations.

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