EcoPulse: A digital solution for Sustainability

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***Abstract*— EcoPulse is an innovative app that promotes sustainability by facilitating users to track sustainable activity and make well-informed, eco-friendly decisions. With a minimalist, user-friendly interface, it enables users to log recycling activities, recognize types of wastes, and show graphs and reports designed to track progress easily. The app further has a locator of recycling facilities in proximity and an education module consisting of tutorials and articles regarding green activities like composting. In addition, EcoPulse features a carbon footprint calculator, which approximates emissions in relation to modes of travel and provides more sustainable alternatives. Gamification is provided whereby the user gets badges and is able to exchange points for prizes for their green action. As there is greater awareness of environmental degradation and climate change, now it is the need of the hour that we incorporate sustainable ways of life into our lives, but nobody lacks responsible means to measure and maximize their environmental impact, and thereby EcoPulse becomes a necessary instrument to empower improved habits.**

Keywords—sustainability, carbon footprint, recycling, green living, mobile application

I. INTRODUCTION

We see waste being carelessly dumped on empty land plots and water bodies like streams, canals, rivers, lakes, etc. everyday. Land and water pollution is growing at an alarming rate. Oceans are being contaminated with huge quantities of plastic waste and other materials. The growing concerns and problems due to climate change and environmental degradation necessitate the adoption of sustainable practices in our day-to-day life. However, many individuals lack access to reliable tools that help them measure and improve their ecological as well as environmental impact[1]. A lot of people, especially the younger generation who have the ability to be the harbingers of change[2], with a basic knowledge about sustainability would like to contribute to eco-friendly causes but have no idea where to start from. EcoPulse is an app which is designed to bridge this gap by providing users with a comprehensive mobile application that empowers them to make informed and great eco-friendly decisions. The app utilises technology to facilitate behavioral changes by offering real-time data, personalized recommendations to users, and

community engagement features. Aligned with the United Nations Sustainable Development Goal 12 (Responsible Consumption and Production)[3], the app helps users adopt habits that minimize waste, optimize resource use, and reduce their overall environmental footprint. Figure 1 illustrates how through a mobile app we can contribute to the environment using the metaphor of a planting and growing a tree.

Figure 1 - Eco-friendly App

This paper provides a detailed description about the app including its design, implementation and functionality. By ensuring a user-friendly interface, the app ensures user retention and allows the user to devote their time to contribute and participate in activities that bring about positive change.

II. AWARENESS

Although adopting a sustainable lifestyle is gaining popularity around the world, knowledge about these eco-friendly practices is still limited. Most people do not know how their daily life and actions impact the environment[4] and how to adopt solutions available for reducing their carbon footprint and other metrics. EcoPulse acts as a guide for users to learn about sustainability and promotes active environment friendly participation. The app combines personalised suggestions, graphical representations of user actions, and challenges to encourage sustainable practices. Through digital tools for imparting environmental awareness and knowledge[5] , the app aims at improving sustainable knowledge among the current generation. Government institutions, environment conservation groups and communities, schools can use this app to support eco-friendly campaigns. The data insights generated from each user can be used to view trends in sustainability and adopt required initiatives. By focusing on education, community feedback, and tips for improvement , EcoPulse strives to create long-term sustainable awareness and leave a positive impact on the environment.

A survey conducted on how people deal with their household waste showed the following results[6].

Figure 2 - Handling of Biodegradable Waste in Kochi Municipal Corporation[6]

From Figure 2, we can understand that 132 families gave their bio waste to Haritha Karma Sena, 79 families disposed of their waste in their own house. 14 families gave the waste to community level waste handlers and other methods were used by 17 families.

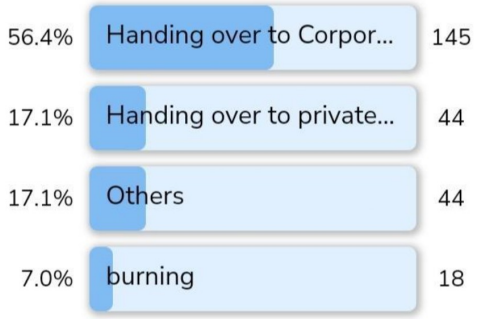

Figure 3 - Handling of Non-Biodegradable Waste in Kochi Municipal Corporation[6]

Similarly from Figure 3, we can understand that 144 gave their non-bio waste to Haritha Karma Sena, 44 families gave their waste to private agencies, 44 used other methods of waste disposal and 18 of the families burned the waste.

III. LITERATURE REVIEW

The intersection of digital technology and sustainability has inspired the creation of green behavior-enhancing mobile apps. The apps utilize

real-time data monitoring, gamification, and artificial intelligence-driven insights to encourage green behavior. AWorld and Oroeco are good instances that utilize gamification to encourage carbon footprint reduction and waste reduction [5]. AWorld, in conjunction with the United Nations' ACTNOW campaign, has learning challenges as a theme, while Oroeco tracks carbon footprints according to information shared by the users. They do have their limitations, however. AWorld adopts a mainly educative strategy without offering tailored-up recommendations for sustainability, and Oroeco relies on user-supplied data, which is subjective for calculating the footprint. As per scholarly research, most of the apps suffer from long-term user engagement due to the effectiveness of gamification declining in the long run [2]. In addition to behavioral participation, waste management apps promote civic participation[1], whereas carbon footprint calculators with AI assist people in making environmentally friendly decisions[7]. Geolocation services, including Google Maps API, facilitate easier access to recycling facilities [8]. Few apps, however, offer real-time tracking and goal-setting, which is critical for habit formation[4]. EcoPulse addresses these problems by combining personalized sustainability goals, real-time recommendations, AI-driven insights, and game-like interactions, encouraging prolonged user engagement and measurable outcomes. By integrating these elements, EcoPulse bridges the knowledge-action gap, producing a more usable, accessible sustainability platform.

IV. PROPOSED SYSTEM

A. Waste Recycled Log

Records the amount of waste recycled by the user through providing the waste to local government organizations or by the user themselves directly. The waste recycled periodically is recorded along with attributes like waste type, recycled amount, and recycled date. The values recorded are then displayed on a graph for better understanding of the user. The user can set certain targets to reach, for example to recycle 10 kg of plastic within the next month. The app analyses the waste recycled and suggests ideas for decreasing the amount of waste generated and effective recycling methods.

B. Carbon Footprint Calculator

It is used to analyse and read user behaviour and provides actionable insights based on that. The daily carbon footprint tracker can help the user to understand their carbon footprint each day and generate comparative reports based on the data from other days. The app provides recommendations to reduce the carbon footprint to the user.

C. Eco-Friendly Tips and Challenges

Encourages users to adopt sustainable habits through gamification and badges. The app provides a learning platform that includes guides and tutorials on waste management practices, managing carbon footprint and other sustainable practices.

D. Recycling Centres Location

Uses GPS-based mapping module to guide users to the nearest recycling facilities. People having an idea about recycling centres closest to them can help in frequent use of these centres by them. The app provides directions and details about nearby recycling centres so that users can choose a recycling centre according to their convenience.

SYSTEM DESIGN AND IMPLEMENTATION

A. Architecture

*E*coPulse follows a architecture comprising of Flutter as the framework for developing the frontend of the app which provides cross-platform compatibility. The backend is developed using Node.js framework and a MongoDB database for storing the data. The app uses Google Maps API for location services, and Gemini API for eco-friendly recommendations.

B. User Characteristics

EcoPulse is designed for all individuals from beginners seeking simple sustainability tips to eco-enthusiasts who want to track their every impact in detail. The interface ensures usability for all demographic users. The application is tailored for students and educators who are provided with educational resources as well as knowledge and sustainability challenges to foster

eco-consciousness in academic environments[8]. It can also be used by businesses and organizations as it offers sustainability tracking tools to help companies manage and reduce their environmental footprint[9]. Most importantly the app is also focused on families and communities by encouraging collective participation in green ecological initiatives through shared challenges and group tracking features.

C. Constraints and Dependencies

The hardware limitations includes GPS-enabled devices for location-based services. The app depends on external third-party APIs for data accuracy. The app also needs to deal with privacy considerations.

D. Security and Data Protection

EcoPulse ensures a high level of security and data protection to safeguard user information and data. The application implements encryption protocols to secure user data both in transit and at rest.

E. Activity Diagram

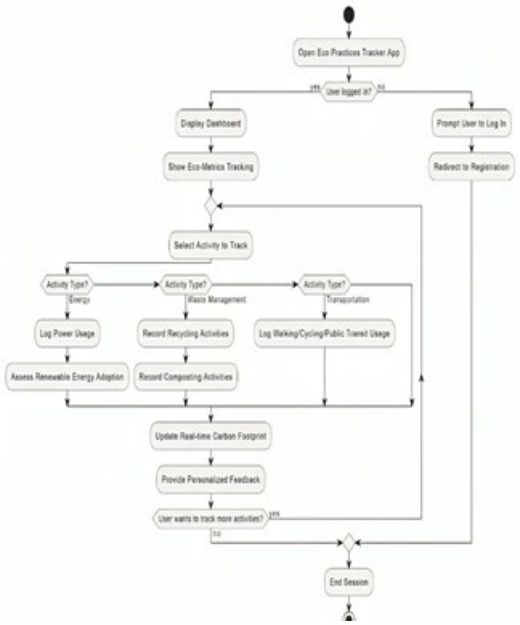

Figure 4 - EcoPulse Activity Diagram

As seen in Figure 4, once the user logs in to the app , it displays the user dashboard specifying the activities done by the user and the overall progress. The user can select which activity to track, whether it be waste recycled logging or carbon footprint calculation. Based on the user inputs, the carbon footprint is calculated and recommendations for reducing the carbon footprint emissions are provided. Personalized feedback based on the metrics recorded by the user is provided.

V. METHODOLOGY

To check the usability and efficiency of the app, a user study was conducted. Users were given the task to use essential features like waste tracking, carbon footprint calculator and gamified challenges. User surveys provided feedback mainly highlighting usage simplicity, level of engagement and general effectiveness of features. Performance standards with respect to response time, application stability, and accuracy in real-time data tracking were also assessed. User engagement was also examined by monitoring how many times users uploaded activities and correctly used the app's features. The results showcased the need for interface improvements and feature enhancements to ensure a more efficient user experience.

Data security and protection are crucial in EcoPulse because the app works with user activity logs and user preferences. The app collects data about various aspects of the user's daily life to calculate the carbon footprint. User authentication is handled by a token-based mechanism currently in which user sessions are saved by token matching against the database. To secure the data, all user authentication data stored are encrypted to provide confidentiality in case of unauthorized access. Also, EcoPulse has the standard GDPR-compliant basics in place, empowering users by giving them control of their data by obtaining consent to store it and providing a mechanism to ask for deletion of the data. We can make upgrades to the current token-based authentication in the future by including OAuth 2.0 and MFA(Multi-Factor Authentication) for enhanced security layers. Through combination of usability testing with solid security protocols, EcoPulse offers a trusted, easy-to-use and privacy-aware environment for sustainable lifestyles.

VI. PROTOYPE

EcoPulse incorporates a range of features designed to enhance user engagement and provide meaningful sustainability tips and insights. The application is built with a user-centric approach, ensuring that individuals can effortlessly integrate eco-friendly habits into their day-to-day routines. Below are the key functionalities that define the EcoPulse experience.

A. Waste Recycle Logs

Recording and tracking the user's waste disposal and recycling habits is an important aspect of the app. This allows the user to log the amount of waste recycled and the type of waste they recycle - plastic, metal, glass, paper, cardboard etc. Users can track the cumulative amount recycled for each type of waste. By updating their waste logs whenever they recycle, users can visualize their progress and trends in their recycling habits. Based on the type of waste recycled, the app provides insights to reduce the effects of the waste and instructions on disposal methods.

B. Carbon Footprint Tracker

By combining technological data and AI-driven insights, this feature enables users to log their daily activities and assess their carbon emissions. The system provides improved recommendations to reduce energy consumption, improve transportation choices, and adopt sustainable habits in the user's choice. Users can set personal sustainability goals and track their progress over time through interactive visualization modules. The app records daily activities related to transportation and uses a formula to estimate CO2 emissions. The app uses AI-insights to provide personalized reduction goals and progress visualization.

C. Recycling Centre Locator

The app uses geolocation services to display nearby recycling centres. It provides real-time updates on centre operational hours and accepted materials. The app also includes user-generated reviews and feedback on the facilities available. The available recycling centres are added to the database including all the details like type of waste primarily accepted, operational hours, and others. It is implemented by using the reliable and widely-used Google Maps API.

D. Sustainability Challenges

Ecopulse offers weekly and monthly eco-friendly challenges (e.g., plastic-free week, zero-waste cooking). For enhanced user experience the app gamifies sustainability goals with reward points and badges. These points can be redeemed for eco-friendly products and other items. The app also enables social sharing to encourage community participation.

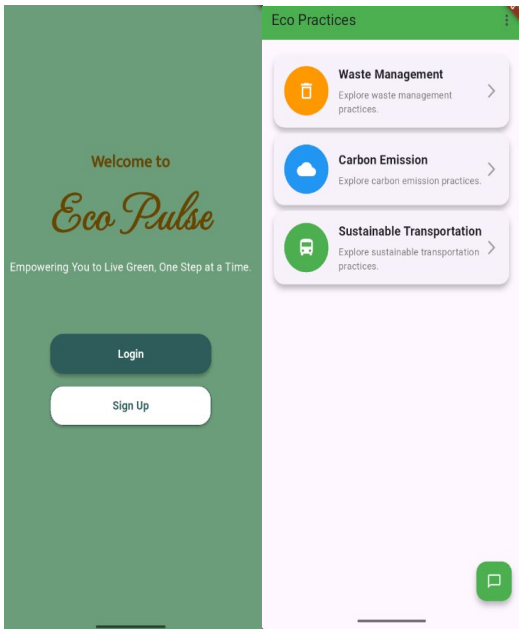

Figure 5 - App Interface

Figure 5 shows the app interface including the landing screen and the home screen of the app. In Figure 6, we can see the waste management module which contains the log waste functionality as shown. Figure 7 shows the carbon footprint module that has the carbon footprint calculator. Figure 8 shows the recycling center locator in the waste management module which is implemented using Google Maps API.

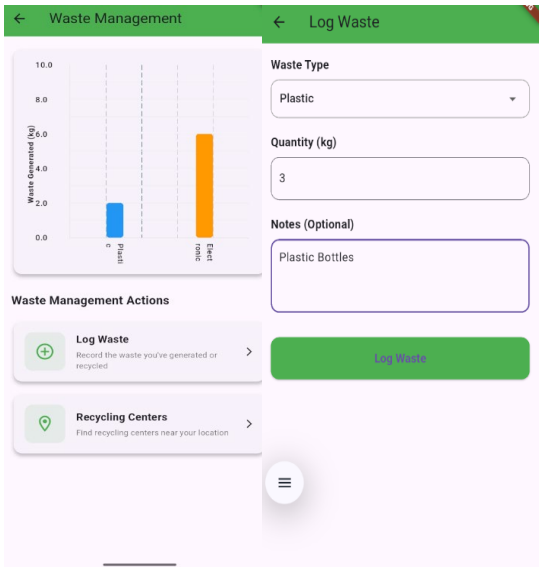

Figure 6 - Waste Management

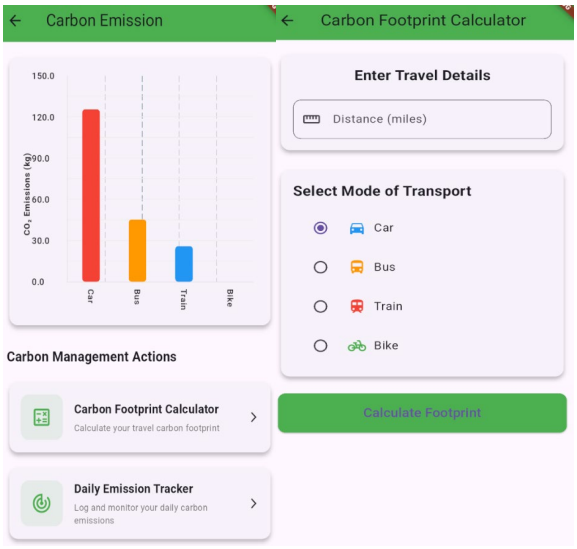

Figure 7 - Carbon Footprint

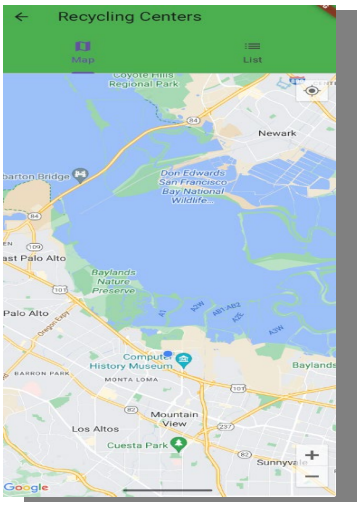

Figure 8 - Recycling Center Locator with Google Maps API

VII. DATABASE DESIGN

EcoPulse employs a relational database model with tables for user profiles, activity logs, challenge participation, and recycling centre locations. Key attributes include a user table which stores personal data, preferences, and progress statistics, an activity table that tracks daily sustainability actions, a recycling centre table which maintains a list of verified locations with real-time updates.

VIII. LIMITATIONS & FUTURE ENHANCEMENTS

While EcoPulse is a robust platform for promoting sustainable behavior, it is not flawless and has a couple of limitations that are to be addressed in future updates. The current system of waste tracking is user report-based, and this can lead to inaccuracies in the data. Future versions will address this limitation by including AI-based waste segregation based on image recognition technology[9], thus making it easier for users to recognize and sort waste correctly. Similarly, while the app offers carbon footprint calculations, it is not complemented by a proper lifestyle-based analysis. Future versions will include behavior-based tracking and personalized feedback based on users' daily habits.

One of the key limitations is the absence of integration with smart home systems, which limits the potential for automating home energy usage tracking and waste management. Future versions will include this integration, thus enabling easy monitoring of sustainability performance indicators within the home environment.

Additionally, although EcoPulse encourages community engagement, its one-language interface can limit access to a multilingual global community. To facilitate greater participation, functionalities like multilingual support and community-based sustainability challenges will be included. In addition to these technological advancements, common challenges are sustaining user retention over the long term and driving user engagement. The majority of sustainability apps are unable to sustain long-term user interest. To overcome this challenge, EcoPulse will continue to develop gamification solutions that integrate more dynamic challenges, social leaderboards, and advanced reward systems. Through continuous refinement of these innovations,

EcoPulse will be an end-to-end and user-focused sustainability platform that encourages green living among various users.

IX. Conclusion

In conclusion, EcoPulse is an essential tool for individuals aiming to reduce their environmental carbon footprint and promote sustainable living. With real-time tracking, community involvement, gamification, and useful tips on sustainability being part of the app, it encourages a culture of eco-friendliness. With updates in the future, its functionality will be further complemented with AI-powered suggestions and home automation integration for automatic monitoring, making it even more effective. While the app might have a minimal impact in the beginning, the small incremental changes that it encourages can have a dramatic impact on community behavior. By enabling users to make substantial changes, EcoPulse sets the stage for a more sustainable world, ultimately leading to a healthier planet for everyone. With ongoing usage and innovation, the app can facilitate lasting, positive environmental change.

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