

Earth Guardian: Your Personal Path to Carbon Neutrality

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I. INTRODUCTION

From the latest assessment report by the Intergovernmental Panel on Climate Change (IPCC), the climate crisis is evident and needs to be addressed. Recent events like rising global temperatures, extreme weather events such as heatwaves, biodiversity losses, and rising sea levels are a cause of the climate crisis. Specifically in the United Kingdom, these impacts include increased flooding, coastal erosions, and disruption to agriculture, thus emphasising the need for immediate mitigation strategies being implemented all around the world to create a more sustainable future.

The main contributor to the climate crisis is due to the greenhouse effect. The emission of gases that cause the greenhouse effect, especially carbon dioxide due to human actions, are an important cause to the climate crisis. These gases trap heat in the atmosphere and this results in higher worldwide temperatures. The increase in heat is also causing severe impacts like extreme weather, increased ocean levels and reduction of various life forms we see today. The main causes for these gases and pollutants in the atmosphere are from human actions such as burning fossil fuels to create energy, industrial activities, cutting down trees (deforestation) as well as specific farming techniques.

Every choice we make, from the food we eat to the way we use transportation has a carbon footprint. This term is a measure of the greenhouse gases that are released into the Earth's atmosphere. The addition of each individual carbon footprint to a global scale has a massive impact on the environment. By understanding this relationship between our daily actions and the impact it has on the environment, we can become more conscious of our carbon footprint and make decisions that contribute to a lower footprint, creating a more sustainable future.

The progress in technology over the last decade, such as mobile applications, has been a great help to mitigate the climate crisis. They have played an important role for users who wish to help the earth by reducing their carbon footprint, through the measure of their emissions. In the past few years, successful apps that track energy usage as well as encouraging users to become greener has been a great way to help users become conscious in how much carbon footprint they consume, making them become more environmentally friendly.

For the Extended Project Qualification (EPQ), I decided to create an IOS app that tracks the user's carbon footprint. It is written primarily in Typescript and React Native, using many other technologies like Expo and Redux. It measures a user's carbon footprint for various things such as food, transport, energy consumption and streaming, using an accurate algorithm I created.

This written report is an analysis on every single step I took to create this app. From the research, learning how to code in Typescript, React Native and using stylesheets, to iterative testing using alpha & beta testers. I will mention the extensive research conducted to create a great user interface (UI) and experience (UX), the challenges encountered while developing the app and how I overcame them. Furthermore, it will also go in depth on how I created a reliable carbon footprint calculator, incorporating emission data, and how I addressed ethical issues about data privacy and security I had to consider throughout the project.

Though this is only an A-Level EPQ, I hope to provide an insight into the real-world challenges of developing a complex mobile application with a purpose like mine. Climate change is a stressing issue that needs to be addressed and dealt with accordingly. By the events that I previously mentioned, we need to change as a species to create a more sustainable future. By creating EarthGuardian, I hope to contribute to the movement of individuals and groups who are taking action to protect our planet.

II. AIMS & OBJECTIVES

Before beginning the EPQ project I had quite a few ambitious objectives in mind. Mentioned below will be reasons why I was not able to create a few functions I wish I developed. The primary aim of this project was to develop a user-friendly iOS mobile application where users can easily and accurately calculate their carbon footprint. By providing a tool that quantifies the impact individual actions have on the environment, EarthGuardian aims to bridge the gap between awareness and action.

The core function of my app:

Carbon Footprint Calculator: An accurate calculator where users can calculate their carbon footprint on different items, such as foods, like high meat meals, low meat meals, fish, and more, transportation, like a flight from Paris to New York, energy usage, and more. It uses an algorithm that gives an estimated measurement of how much carbon dioxide equivalent is produced each time you do that action, like eating, flying etc. This tool lets users track their carbon emissions based on the data they provide. Users can also record information about their carbon footprint on a log to see how much total they produce each month. Additionally, it shows the average annual consumption in different countries, and it allows you to add a target tailored to your country, so you can be conscious if you are below the average emission for your own country. This characteristic tries to bring attention to how each country has different carbon footprints, and whether or not the averages of each country, and the average recommended, is higher or lower than the user's own yearly/monthly carbon footprint. This calculator covers many sections, from what you eat (how much dairy or meat, if its local or not) to transportation methods (car use vs public transport vs air travel), energy use (electric vs gas with renewable sources) and more. This can also help users spot where they can make substantial reductions in their carbon footprint by switching to vegan diet, etc.

As mentioned above, the original ideas of EarthGuardian had many other functions, like community forums for exchanging tips and resources, an individual carbon footprint suggestion engine, as well as game-like elements such as leader boards and challenges to compete against friends. These features were not implemented in the current version of the app due to time and resource constraints. However, they will remain a part of the long-term vision of the app and will be added into future updates to enhance user engagement and further promote sustainable behaviour change. The community forum could create a feeling of being part of a group where users can share ideas and the successes and challenges they've had on this journey towards a greener lifestyle. Furthermore, a personal recommendation engine could use machine-learning (ML) algorithms to provide tailored suggestions for reducing emissions based on the user's data, while game-like elements could make the process of reducing the user's footprint more engaging and rewarding.

It aims to have an effect in the fight against climate change. The app's natural interface, complex calculations, and resources were created to give power to the users and take

ownership of their environmental impact and contribute to a sustainable future. I hope the app influences the users to make informed decisions on their carbon footprint. EarthGuardian wants to help with worldwide efforts to reduce global emissions and create a more sustainable future for us all.

III. INITIAL PLANNING

The initial planning phase of EarthGuardian was very important in order to set up the correct environment needed to make app development successful. It included careful research, project management and making a detailed Gantt chart for managing the time frame of this project, for all tasks to be finished on schedule. The research part was especially significant as it involved learning different carbon footprint calculation methodologies, whether to use APIs, the best user interface (UI) and experience (UX) design principles and analysing case studies of other successful mobile carbon tracking applications. This research was essential in understanding how the calculators worked and identifying areas of greater innovation for EarthGuardian. For example, I explored popular carbon calculators like the WWF Footprint Calculator and the Carbon Footprint Ltd. Calculator, writing down their strengths (e.g. user-friendly interface, many categories) and weaknesses (e.g. lack of personalisation, limited resources). The knowledge obtained from this analysis was then applied into the design and reaction of EarthGuardian, ensuring it had an amazing user-friendly interface and a comprehensive calculator.

GANTT CHART ANALYSIS

I created the Gantt Chart at the beginning of my EPQ journey to structure the different things I had to do to complete my EPQ. The Gantt chart, a visual representation of the project timeline, was divided into distinct phases, each with specific tasks and deadlines. Each phase, like the planning project, primary research, production log, learning, user testing and more, had their own timeline, where I would write 'aim' at the beginning of the phase when it would be begun and completed. This made it very simple for me to track the progress I have made on all the different aspects of my EPQ. The Gantt chart allowed me to have great time-management and allocate more time to difficult phases like the key screens & calculator development.

The design phase involved creating wireframes and mock-ups of the app's interface, ensuring it had a user-friendly and intuitive design that would have a clear navigation layout where users can smoothly navigate through the app. This step involved sketching out how various screens should look like, trying different colour combinations as well as different font types. Furthermore, I considered the entire flow of the user experience (UX) within the app – how they moved from one section or feature to another. The goal was to create an interface that was not only visually appealing, but also easy to use and understand, even for some users with limited technical knowledge.

Next came the app's functionalities and integrating the carbon footprint calculator into my app. This phase was very challenging due to many reasons. I needed to have a deep understanding of core functionalities used in React Native, and many times throughout this development I had to ask questions on Stack Overflow and consult with other more expert developers. I had to learn how to structure the app's main components, manage application states, handle the input from users, and how to allow the data from users to remain on the app once it is closed. This involved many hours of research, coding, debugging and testing to

ensure the app worked as planned. Other functionalities like in the settings screen, the change of metric units was pure maths and as maths is one of my strengths, I was able to easily implement it into my app.

The last part was the testing, where I had many user testers, in-depth in my testing document, and a lot of feedback to collect and implement. The testing process was a great way for me to identify bugs and fit the user's needs into my app while maintaining the interface design. Also, I had to update my Gantt Chart to allow for more testing to be conducted, as I believed it was a lot more important than other parts, so I allocated a lot more time for iterative testing and feedback implementation. Now, I believed I made the right choice as one of my aims was to create an app fit to the user's needs, and I believed as I carried out many tests and implemented a lot of feedback, I achieved my aim. The changes I made on my Gantt Chart show how crucial it was to being flexible and organised, as I had many testing errors and unexpected challenges which I had to spend a lot of time on, therefore having a Gantt Chart allowed me to make this process a lot easier.

RESEARCH ON CARBON FOOTPRINT CALCULATIONS

The research phase for the carbon footprint calculation was very extensive. It included looking into different carbon footprint calculators, reading academic papers and government reports, as well as searching online resources. This was done to examine what factors contribute to make the most accurate carbon footprint calculator, such as transportation emissions, or how much energy is used, among others like what food choices do the users make and waste generation. I investigated the methods employed by different groups, including the Environmental Protection agency (EPA) and the World Wildlife Fund (WWF), for measuring carbon footprints. Additionally, I read scholarly papers about life cycle assessments and carbon accounting to comprehend the fundamental concepts and computations better.

One of the primary challenges encountered in this phase was ensuring the accuracy of the carbon footprint calculations. The data available online had different levels of detail as well as reliability, plus certain emissions categories were harder to measure than others. Below will be a guide on how I was able to calculate the respective carbon footprint for each category:

a. TRANSPORT

Car travel: For car travel, the calculation used this formula:

$$\text{Emissions (kgCO}_2\text{e)} = \text{Distance (km)} * \text{Emission Factor} \left(\frac{\text{kgCO}_2\text{e}}{\text{km}} \right)$$

The emission factor varies depending on the fuel type and vehicle efficiency, with data sourced from the UK's Department for Business, energy & Industrial Strategy (BEIS). For example, Fossil-fuelled cars emit approximately 257 gCO₂eq per km, resulting in about 2.6kg of CO₂ for every 10km driven.

Air Travel: Air travel are estimated based on flight distance and class. Short-, medium- and long-haul flights have different emission factors based on average speeds. EarthGuardian does not consider for the radiative forcing index (RFI) for the warming effect of air travel.

b. FOOD

Food Consumption: Emissions from food consumption are calculated using the formula:

$$Emission (kgCO_2e) = Food Weight (kg) * Emission Factor \left(\frac{kgCO_2e}{kg} \right)$$

Emission factors for various food items are sourced from the database like the Environmental Working Group (EWG) and academic research. The calculator does not consider the production, processing and transportation stages of each food item.

c. ELECTRICITY

Electricity consumption: To calculate emissions from electricity use, the following formula is used:

$$Emissions (kgCO_2e) = Electricity Consumption (kWh) * Carbon Intensity \left(\frac{kgCO_2e}{kWh} \right)$$

The carbon intensity represents the amount of CO₂e emitted per unit of electricity generated and it varies by country and obtained from the Electricity Map.

d. STREAMING

Data Transfer: The emissions from data transfers are very difficult to calculate, though I was able to break it down into different parts. They are estimated using an enhanced version of the 1-byte model developed by The Shift Project. By considering the duration, and type of streaming service (e.g. HD video, music) we can estimate the data volume downloaded. This formula is as follows (variables used are data centre, network transmission, and energy consumption):

$$Total\ GHG = GHG_{dataCentre} + GHG_{network} + GHG_{device}$$

Each component is calculated using data weight, duration of streaming, emission factors, and the carbon intensity of electricity.

Each variable is as follows:

$$GHG_{dataCentre} = dataWeight \times Factor_{DataCentre} \times electricity.world$$

$$GHG_{network} = dataWeight \times Factor_{Network} \times electricity.world$$

$$GHG_{device} = duration \times Factor_{Device} \times electricity(carbonElectricityIntensity)$$

GHG: Greenhouse Gases

To ensure the algorithms were precise and accurate, I cross-referenced data from multiple sources and consulted online with experts in this field. Furthermore, I conducted tests to know how different assumptions and data entries influenced the final estimation of the carbon

footprint. This research and data interpretation was necessary to create a calculator that is dependable. Also, the design of the app allows the user's input to be updated and refined over time, so the carbon calculation will remain as accurate as possible when a user's lifestyle changes.

I also researched an additional function which was to include indirect emissions in the calculator. These are those which are not directly caused by what the user does, such as eating food, but still connected to it. For example, if a user ate meat, then indirect emissions would be the production and the transportation of the meat to the user. These emissions are very difficult to implement into my app, though it would provide a more precise emission number, it is too complex for my current knowledge, though it will be included in future versions of the app.

IV. RESEARCH AND DESIGN

This was quite extensive, as I felt it to be very important. I focused on researching the best methods to create a user-friendly interface, both UI and UX, while also providing the most complex information about their emission. I had to find a balance between being accurate with my scientific calculations, and still being a simple and user-friendly app to the users.

UI/UX DESIGN PRINCIPLES

I considered implementing a few important laws for my UI/UX designing principles.

Hick's Law states that the more stimuli (or choices) users face, the longer it will take them to make a decision¹. This law was used to simplify the app's interface by reducing the cognitive load on users. To do this, I decreased the number of options given to users at one point in time and used understandable language for explaining complicated ideas. As an example, instead of overwhelming users with many input fields, the app presented them with a step-by-step process, guiding them through each category of their carbon footprint one at a time. This method made the application more user-friendly, and helped users concentrate on a single lifestyle at a time, making the task of calculating their carbon footprint less difficult.

Furthermore, Fitts's Law, which states that the time to acquire a target is a function of the distance to and size of the target², was used to optimize the placement and size of elements like buttons in the app. This made sure they were put on spots easy to reach while also having a size which allowed the user to accurately tap even on smaller screens. For instance, we place the 'Add Emission' button close to the bottom of the screen so it is easy for the user's thumb to access it. It was designed so the button could be touched with ease. This care for the user ergonomics not only made the app easier to use but also improved the user experience (UX).

¹ Interaction Design Foundation, "What is Hick's Law?", 2024, <https://www.interaction-design.org/literature/topics/hick-s-law>

² Wikipedia: "Fitt's Law", 2024, https://en.wikipedia.org/wiki/Fitts%27s_law

Gestalt principles, such as proximity, similarity, and closure³, were used to create a visually cohesive and intuitive interface. These help users see elements as belonging together, making the app easier to navigate around without confusion. I grouped related input fields together and used similar visual components for similar functions. This similarity in appearance of the app made it easier for users to comprehend the structure of the app quickly and how functions work, reducing the time needed to learn how to use the application, making it more convenient to a wider range of users.

Throughout the research and design phase, the app's design was also based on concepts such as user-centred design. This is a concept where I focused on providing the user interface the users would like the most, highlighting their preferences and requirements. The testing I used was not only to show the app worked, but also to implement feedback into the design of the app, so users had an intuitive navigation system and a great UI design tailored to their needs.

ADDITIONAL RESEARCH

The project did not just focus on essential research and the best ways to use UI/UX principles. I also investigated how gamification and community building could be useful in encouraging sustainable behaviour change. Gamification is the use of game-design elements and rules in a non-game environment like EarthGuardian. Many studies have indicated that it enhances user engagement and motivation. Gamification methods like rewards, levels, and leader boards are a common way to do this, and these were researched to be integrated with EarthGuardian. This research involved reviewing academic literature on gamification, as well as analysing successful gamification implementations in other applications. For example, I explored how the user of badges and achievements to reward users for reducing their carbon footprint, as well as challenges and competitions to encourage friendly competition among users.

The idea of building a community was also examined to promote social support and inspire group efforts towards sustainability. Studies about online communities and social networks led to the ideas that creating a successful community would bring trust. The potential benefits of integrating a community forum into EarthGuardian were considered, including the opportunity for users to share tips, challenges, and successes in their journey towards a lower carbon footprint. This involved analysing other communities focused on sustainability and identifying the best practices for active engagement and participation, which I would have implemented onto my app.

While these additional features were not implemented to the app's current version due to a knowledge limit, the research conducted during this phase provided a lot of valuable insights into the future updates or expansions of EarthGuardian which might possibly result in an improved tool that is more engaging and useful to the users. In the future, as these functions will be implemented, they will allow users to be motivated to decrease their carbon footprint or be able to connect with each other and share tips and advice. However, this research also made it clear for the need of moderation and the potential for negative social comparison.

In conclusion, the research and design phase of the EarthGuardian project was a thorough and iterative process that went through considerable research, user feedback, and a careful

³ Toptal, 'Exploring the Gestalt Principles of Design', 2024, <https://www.toptal.com/designers/ui/gestalt-principles-of-design>

balance between different needs. By continuing to incorporate user feedback and exploring innovative ideas, EarthGuardian can become a more impactful tool, not only for individuals, but as the app expands, could lead to complex calculations for business's emissions too.

V. APP DEVELOPMENT

ENVIRONMENT

To create EarthGuardian, I used many technologies & software, but the most important ones I will describe below:

1. Expo CLI: The Expo CLI is a command line interface that I used to test and deploy my app on my iOS simulator. For my simulator, I used the Xcode virtual simulator running an iPhone 15 Pro on IOS 17.4. This was a great way for me to test my app for different inputs, and being able to use the logs whenever I tested something.
2. Visual Studio Code: Visual Studio Code (VS Code) is a very popular coding editor I used throughout the development of EarthGuardian. It has many extensions which I used like syntax highlighting (Prettier), git configuration so I could push my commits to my Github repo and debugging tools I used extensively to help me remove bugs. VS Code also included many extensions for Typescript and React Native like ES7+ React Snippets which worked well to provide me the clearest syntax for my code.
3. For my backend environment setup, I used Node.js and NPM. Node.js is a Javascript runtime environment that allowed me to run JS code outside of a web browser. NPM (Node Package Manager) is a package manager for Node.js that allowed me to install, manage and delete packages and Javascript tools. All my packages are found within the package.json file, alongside other commands which I will go in detail below. Both of these technologies were essential for me to develop an app in React native, as they are both used to install and manage all of the projects dependencies.

NODE PACKAGE MANAGER (NPM)

NPM is a great technology which all developers use (or yarn) for their environments, either to build websites or apps. There is a package.json inside my file which has all of my dependencies and their own versions, so to install these, you would have to run:

```
npm install
```

```
If using Yarn, then yarn install.
```

Key packages I have in my app:

@react-navigation/native: It provides many components to set up React navigation within your app. It includes navigators like the Stack, Tab, and Drawer navigator, used for different navigation patterns.

@react-native-community/slider: This is a slider which I implemented throughout the app in order to allow the users to slide it to choose a value to calculate their footprint.

@react-redux: Redux is used for managing EarthGuardian's state. It's a predictable state container designed to help me run easily test JS/TS apps. Also, Redux helps manage the complexity of the app's state and makes it easier to reason about how data flows through the app.

The Redux state management in EarthGuardian is designed with a performance in mind. Reduces are implemented to handle state updates with a time complexity of $O(1)$ whenever possible, ensuring efficient updates even as the state grows.

These are just a few examples of the many packages used in my app. Each package serves as a specific purpose in the app's functionality, UI, or workflow. The version of each package is also listed in the package.json file, ensuring that the project's dependencies are consistent and compatible.

VERSION CONTROL WITH GIT

Git and Github played a crucial role in development. These technologies allow me to track changes to the codebase over time, experiment with new features without the risk of breaking existing functionality and have a history if I need to go back to any other older version history. As writing this, I have made over 16 deployments and over 50 commits in my private repository.

Here are the most important commands I used with Git:

1. `git add .` : This command stages changes for the next commit. I used the '.' To add all changes in the current directory to the next commit, making it easier and more efficient to push many changes.
2. `git commit -m "message"` : This command creates a new commit, and using the -m allowed me to write a commit message describing the changes made in the commit.
3. `git push -u origin main`: This commands uploads my local commits to my private repository on Github using my branch called 'main'.

I used these commands a lot throughout the development of the project, and they have been very helpful whenever I made errors or made a few bugs in the code, to go back to the older version history and keep working from the older version.

SCREEN COMPONENTS

a. BUDGET SCREEN

The budget screen is one of the main components of the app, as a 'central hub' where users can have an overview of their total emissions, comparing it with their pre-determined budget. It also shows recent activity, such as eating meat or fish. There are a few components here, such as the budget percentage and its ring, and monthly budget, with a few sub-texts relating to eating meat or fish recently.

b. EMISSION SCREEN

When there are no emissions in this screen, either when the user first joins the app, or if they delete all their emissions, there are a few subtexts which give a guideline on what the app does and how to add an emission, which is represented with a button below the texts. This emission screen is the main component of the app where users will be able to see all their emissions and if they have been mitigated or not (through action on a button). If it has been mitigated, then it will show a green icon instead of grey and an 'Offset' label next to the (CO₂eq) tag.

c. ADD EMISSION SCREEN

Upon clicking the 'Add' button on the navigation screen at the bottom, the users will be presented with a variety of choices to get an emission from. There is a list of different items/actions, such as transport, streaming, food, electricity. When a user presses on a category, it will display a sub-category, and once users select an item from there, it will present them with the name, how much of that item they have done/used, the total in carbon emissions, and an option to name the emission. Lastly, there is a button 'Add emission'. Once clicked, the emission will show on the Emission Screen and users will be able to click on the emission and mitigate or delete it.

d. SETTINGS SCREEN

This is the last screen of the app, and it is relatively simple. It shows the users the logo of the app, why it was created, and a button which shows whether or not to display metric or imperial units.

VI. SKILLS DEVELOPMENT

The EarthGuardian project was a massive learning experience. In the technical part, I had to study many frameworks. For example, I had to learn the main concepts in Typescripts which differ from JavaScript. To create an iOS app, I decided to use React native due to being able to integrate on the Expo framework with ease, allowing me to have an easy ecosystem of tools to help me develop the app. React Native was a massive learning curve, as I had to learn managing states and navigation patterns in component-based construction. I also needed to learn how to create components such as buttons and title headings, to re-use them throughout the app. Throughout this 9-month project, React Native's ecosystem constantly evolved, so I had to keep up with the latest updates and best practices. I had to keep looking at the React Native docs to understand any new implementations, or why there was no bug in React native v0.70, but there was in v0.74.

I also have enhanced my soft skills. Having researched various carbon footprint calculation strategies, and UI/UX design principles, it honed my ability to critically evaluate information and being able to understand findings from diverse sources. The iterative nature of app development, with the constant cycle of re-testing and feedback implementation, sharpened my problem-solving skills and taught me the importance of being adaptable and flexible.

Furthermore, I have managed to learn how to break down the app development into different section to make it easier for me to implement them. This is called decomposition, and it is a strategy used by the top companies such as Google and Facebook, which makes it easier for

their developers to focus on smaller, more manageable tasks rather than the whole problem at once. I also had to balance schoolwork, extracurricular activities and app development, so it required careful planning and prioritisation. Overall, this approach helped me stay on track and not getting stressed out of the overwhelming tasks I still had not finished.

The lesson that felt the most important to me is relying on myself for learning and perseverance. While I was making EarthGuardian, it was mainly solitary with the odd help in online forums, and I had to depend on my own initiative and resourcefulness to deal with difficult problems and being able to overcome them. Creating project taught me the value of perseverance, staying strong in tough situations, and the willingness to learn from my mistakes. It made me value how I could build anything with self-directed learning, and the huge selection of internet sources ready for anyone who wants to find them.

VII. PROJECT EVALUATION

The evaluation of the EarthGuardian project involved many different approaches, such as user-testing, a critical evaluation of the app's constraints, and a reflection of ethical implications regarding data confidentiality and security.

USER TESTING

A succession of user testing sessions was carried out to evaluate the app's utility and impact. A varied cohort of individuals, spanning different age groups, genders, and technological proficiency, tested the app and provided feedback. The testing approach included gathering both quantitative and qualitative data, such as task completion time, error rates, and user-feedback. These methods provided insights into the user experience, identified areas for enhancements, and improved understanding of the app's impact on users' awareness and behaviour.

The feedback received from user testing was key to refining the app's design and functionality. For example, users suggested simplifying the input process of the carbon calculator, adding more cues to guide navigation, and providing more detailed explanations of the calculation results. These suggestions were carefully considered and incorporated into subsequent iterations of the app, resulting in a more user-friendly and intuitive interface.

I also had Mr Williams, an expert in the field and the Head of Computer Science at Ellesmere College, give feedback and evaluation of my app. His insights were very valuable to EarthGuardian, and he gave feedback including data visualisation, areas where user flow can be reduced, which I was able to implement into my app, and his agreement that the app was fit for purpose.

PROJECT LIMITATIONS

EarthGuardian relies on self-disclosed data for calculating carbon footprints, which introduces limitations. Users must input details about their lifestyle decisions, which can be biased and may lead to discrepancies in carbon footprint calculations. Additionally, the app focuses on personal actions and may not address the need for other measures such as renewable energy alternatives and sustainable agricultural methods needed in order to address the climate crisis. These are also very necessary to reduce the emission of CO₂.

EarthGuardian aims to complement these institutional changes by empowering individuals to make eco-friendly decisions in their daily lives.

ETHICAL CONSIDERATIONS

To protect user data, EarthGuardian implemented protocols such as encryption and the ability for users to delete their data. A clear privacy protocol outlines how user information is acquired, used, and safeguarded. The project also considers the possibility of algorithm bias and used diverse data sources in developing the algorithm, conducting frequent evaluations to ensure impartiality and accuracy.

VIII. CONCLUSION

The EarthGuardian project has been a path for learning, discovery, and innovation. It has shown the power of individual actions to deal with the climate emergency – as well as showing what could be possible through technology when it comes to making these actions happen easily and have a greater impact. The creation of the app is not just about making a working tool to measure carbon footprints or showcase my skills on a project; it also offers significant understanding about difficulties in designing mobile applications that are simple for users while maintaining scientific correctness and moral accountability.

The study done during this project has shown how urgent it is to handle the climate problem and find creative ways to mitigate its impact. The results from testing with users have stressed on focusing the app's design based around the user and finding a good balance between user interface (UI) and experience (UX). The difficulties met while making the carbon footprint calculator have underlined how intricate it is to measure environmental effect, as well as the importance on continuous research and improvement of data.

Despite its limitations, EarthGuardian is an important step towards giving people control over their carbon footprint and knowing how it affects them. Not only does this app increase understanding of personal carbon footprints, but also offers the means and information needed to make real changes in lifestyle decision. By assisting in changing action at the individual level, EarthGuardian strives to aid worldwide effort to mitigate climate change and create a greener planet.

For the future, there are a few possible paths for EarthGuardian to further develop. Features mentioned previously including community forums & recommendation engines customised to the user's interests and elements of gamification may greatly improve engagement and inspiration for users to become greener. Connecting the app with smart city systems could also give useful information for urban planning and sustainability initiatives. Moreover, adding more features to the app like tracking water usage or measuring waste produce might give a better complete picture of a person's total impact on the environment.

In conclusion, the EarthGuardian project has shown how important personal action and technological creativity are for solving the climate change emergency. It created a tool that is easy to use and scientifically correct in calculating carbon footprints. This has given people ability to do something great for our environment. Although there were difficulties on this path, what I have learnt and discovered is very valuable. The climate crisis is getting worse by every year, so it is very important that we keep finding new answers and use technology to give power for people and communities to make our future more sustainable.

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