Bachelor’s thesis

Information and Communications Technology

2024

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Sustainable Living in the Digital Age: Designing and Evaluating an Interactive Mock-up of a Carbon Footprint Tracker App for Personal Environmental Awareness

TURKU AMK
TURKU UNIVERSITY OF APPLIED SCIENCES

Bachelor's Thesis | Abstract

Turku University of Applied Sciences

Information and Communications Technology

2024 | 74 pages

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Designing a high-fidelity prototype of a carbon footprint tracking and reducing application

This thesis presents the design and development of a high-fidelity interactive prototype for a carbon footprint tracking and reduction application, aimed at enhancing personal environmental awareness and behavior change. The study explores digital solutions for carbon reduction and sustainable living, focusing on integrating UI/UX design principles. Employing methodologies like benchmarking, user interviews, competitive analysis, usability testing, and design iteration, the research drew insights from sustainable living principles, consumption patterns, and behavioral aspects to inform development. Methodologies for calculating carbon footprints were explored, addressing challenges associated with quantifying environmental impacts.

The prototype was developed in Figma, emphasizing a user-friendly design integrating sustainable practices. Usability testing was conducted to evaluate navigation, task completion, and overall user experience, leading to iterative design improvements. Through the usability testing, the usability of the application was tested and optimized, making for a more user-friendly and intuitive final product.

The outcome of this research is a high-fidelity, functional, interactive prototype of a carbon tracking and reduction application, successfully containing intended features, enabling a more effective tool to monitor and reduce one's environmental impact.

Keywords:

Sustainability, carbon footprint tracking, user interface design, user experience design

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1 Introduction

The challenges posed by climate change have intensified the urgency for sustainable practices and environmental stewardship. With the increasing recognition of the role that individuals play in reducing carbon footprints, there is a critical need to develop effective tools and technologies that facilitate behavior change towards sustainability. This thesis focuses on addressing this need through the design and development of an interactive prototype for a carbon footprint tracking and reduction application.

The motivation behind this research stems from several considerations. Firstly, existing carbon footprint tracking applications often fall short in terms of user engagement and long-term effectiveness. Many lack intuitive interfaces and fail to provide compelling incentives for sustained usage. Secondly, as societies transition towards low-carbon economies, there is a demand for user-friendly digital solutions that enable individuals to monitor and manage their environmental impact. Thirdly, empirical research is needed to understand how user interface (UI) and user experience (UX) design principles can be harnessed to promote sustainable behaviors effectively.

This thesis seeks to explore how integrating UI/UX design principles into a carbon footprint tracking application can enhance user engagement and behavior change. The research will investigate the key features and functionalities that contribute to user satisfaction and sustained usage of such applications. Additionally, the study will leverage usability testing to inform iterative design improvements, aiming to optimize the effectiveness of the application in promoting sustainable behaviors.

By addressing these research questions, this thesis aims to contribute to the advancement of sustainable technology solutions. The findings will inform the design and development of digital platforms that empower individuals to make informed, environmentally conscious choices. Ultimately, this research endeavors to support the collective effort towards a more sustainable society by leveraging the potential of digital technologies for positive environmental impact.

2 Literature Review

The literature review section of this thesis provides a comprehensive examination of existing research and scholarship related to sustainable living, carbon footprint calculation methodologies, and digital technologies for promoting environmental awareness and behavior change. This review aims to synthesize key theories, concepts, and empirical findings that inform the design and development of the carbon footprint tracking and reduction application. By exploring relevant literature, this research seeks to identify gaps, challenges, and opportunities in the field of sustainable technology, setting the foundation for the subsequent chapters that delve into methodology, application design, and usability testing. The literature review serves as a vital component in contextualizing the research objectives and guiding the development of innovative solutions to address pressing environmental concerns.

2.1 Sustainable Living Principles

The concept of sustainable living extends beyond isolated actions; it encompasses a consistent set of practices that minimize our environmental impact and contribute to the overall health of the planet's ecosystems and resources (Spaargaren, 2011). Sustainable consumption and production are key elements of this approach. This means utilizing services and products that meet our basic needs and enhance our quality of life, while simultaneously minimizing the use of natural resources, toxic materials, and the generation of waste and pollutants throughout the life cycle of those products and services (Chiang et al., 2023). Ultimately, the goal is to ensure that our current consumption patterns do not compromise the ability of future generations to meet their own needs.

The urgency of adopting sustainable practices is underscored by the very real threat of climate change. This global phenomenon has a significant impact on urban environments, leading to rising sea levels, increased frequency, and intensity of extreme weather events (floods, droughts, and storms), and the spread of tropical diseases (Energy Education, 2023). Addressing climate change requires a coordinated global effort, with action at international, regional, national, and local levels (Zeng et al., 2012). Individuals are the common thread connecting these various levels and empowering them to become active participants in the solution is crucial.

While transitioning to a fully sustainable lifestyle can seem daunting, starting small is an effective approach (McVicker, 2022). Even minor adjustments can significantly contribute to reducing one's carbon footprint. The key lies in adopting a set of consistent practices that, when combined, create a positive environmental impact. Regulatory policies, such as carbon caps, taxes, offsets, and trading schemes, are also being implemented globally to incentivize a transition towards a low-carbon economy (UN, n.d.).

Ultimately, sustainable living is not just about individual actions; it's about embracing a holistic approach that minimizes our environmental impact and ensures a healthy planet for future generations. By actively participating in sustainable consumption practices, supporting regulatory initiatives, and advocating for change, the challenges of climate change can collectively be addressed and a more sustainable future for all can be created.

2.1.1 Overview of Sustainable Practices

The ever-growing demand for resources and the associated environmental consequences pose a significant challenge to global sustainability (Mont et al., 2014). While technological innovations have traditionally been the cornerstone of environmental solutions, the critical role of social innovation is gaining recognition. Social innovation encourages collaboration among stakeholders, promotes access-based consumption models, and fosters a participatory approach to sustainability (Mont et al., 2014). This section delves into the multifaced nature of sustainable practices, highlighting the importance of both technological and social advancements in achieving a sustainable future.

Sustainable Practices Across Various Sectors

Sustainable practices encompass a diverse range of strategies designed to minimize environmental impact while fulfilling human needs (Mont et al., 2014). These generations focus on reducing resource consumption, minimizing waste generation, and promoting conservation efforts. Key areas of focus include:

Energy Conservation: Utilizing energy-efficient technologies, adopting energy-saving behaviors, and transitioning to renewable energy sources (Mont et al., 2014).

Waste Reduction: Minimizing waste generation at the outset, prioritizing recycling, and reuse, and implementing sustainable waste management practices (Mont et al., 2014).

Water Conservation: Reducing water usage, preventing water source pollution, and promoting efficient water management techniques (Mont et al., 2014).

Sustainable Transportation: Encouraging practices that minimize environmental impact through reduced emissions and resource utilization (Mont et al., 2014). This can involve promoting alternative transportation modes such as cycling and public transport, as well as carpooling and using fuel-efficient vehicles. Additionally, it emphasizes sustainable infrastructure development that supports these practices.

Sustainable Agriculture: Minimizing chemical inputs, promoting soil health, conserving water resources, and protecting biodiversity in agricultural practices (Mont et al., 2014).

Sustainable living extends beyond these core areas to encompass sustainable building design and construction, responsible purchasing decisions (green procurement), and fostering sustainable communities. By implementing these practices collectively, environmental degradation can be mitigated, greenhouse gas emissions reduced, and long-term environmental sustainability ensured.

A foundational Framework for Sustainable Consumption

The concept of the five Rs - Rethink, Refuse, Reduce, Reuse, Recycle - constitutes a fundamental framework for fostering sustainable living practices and is rooted in the principles of conscious consumption waste reduction, and resource conservation (Mont et al., 2014). This framework was introduced in 2013 by Béa Johnson in her book "Zero waste home: the ultimate guide to simplifying your life and reducing your waste". It underscores the importance of adopting mindful approaches to consumption and waste management, guiding individuals towards more sustainable lifestyle choices.

Firstly, the principle of Rethink urges individuals to critically evaluate their consumption patterns and discern genuine needs from mere wants. By reevaluating their purchasing decisions and reassessing their materialistic desires, individuals can avoid unnecessary acquisitions and curb excessive consumption, thereby minimizing their environmental footprint (Johnson, 2013).

Secondly, Refuse encourages individuals to exercise restraint and resist the temptation of acquiring unnecessary items, particularly those driven by impulse buying tendencies. By consciously declining goods and services that do not align with their essential needs or long-term sustainability goals, individuals can mitigate the generation of superfluous waste and reduce the strain on finite resources (Johnson, 2013).

Thirdly, the principle of Reduce advocates for scaling down overall consumption levels to alleviate environmental pressures and promote ecological balance. By adopting a mindset of moderation and prioritizing quality over quantity, individuals can minimize their environmental impact while still meeting their essential needs and aspirations (Johnson, 2013).

Fourthly, Reuse emphasizes the importance of extending the lifespan of existing products through creative repurposing and responsible utilization. By embracing the practice of reusing items whenever feasible, individuals can circumvent the need for constant replacement and reduce the volume of waste destined for disposal, thereby conserving resources, and reducing environmental degradation (Johnson, 2013).

In essence, the five Rs framework provides a structured approach to sustainable living, guiding individuals towards more mindful consumption habits and responsible waste management practices. By incorporating these principles into their daily lives, individuals can contribute to the preservation of natural resources, the reduction of environmental pollution, and the promotion of a more sustainable and equitable future for all.

2.1.2 Consumption Patterns and Environmental Impacts

The global narrative of unsustainable consumption is primarily driven by rising European material consumption (Mont et al., 2014). Policy strategies have traditionally focused on technological advancements to mitigate environmental impacts, such as improvements in production processes, eco-friendly product design, and the development of infrastructure for shared services (Mont et al., 2014). However, it is increasingly recognized that sustainable living goes beyond technological solutions and requires a simultaneous focus on social innovation.

The past two decades of policy efforts aimed at promoting sustainable consumption have been hampered by factors such as increasing global trade and the emulation of Western consumption patterns by developing nations (Mont et al., 2014). These trends contribute to a rise in environmental pressures associated with consumption, particularly within key household sectors like food, housing, mobility, and tourism. The need to address unsustainable lifestyles gained international recognition in 1992 with the adoption of Agenda 21, a comprehensive program promoting sustainable development (Mont et al., 2014). Subsequent initiatives, such as the UN Johannesburg Plan of Implementation and the Sustainable Consumption and

Production and Sustainable Industrial Policy Action Plan, have further emphasized the importance of improving environmental performance and fostering demand for sustainable products (Mont et al., 2014).

Redefining Consumption Patterns for a Sustainable Future

Modern lifestyles are characterized by excessive consumption and resource depletion, particularly evident in food, transportation, housing, and tourism sectors (Mont et al., 2014). These sectors contribute significantly to environmental concerns through increased material consumption, emissions, and energy use. Efforts to achieve sustainability require a focus on transforming consumption patterns within these key areas.

Social innovation plays a crucial role in complementing technological advancements. It promotes a shift in our understanding of well-being, encourages access-based consumption models (e.g., car sharing), and fosters a collaborative approach to sustainability through community-driven initiatives (Mont et al., 2014). Sustainable living initiatives worldwide showcase promising pathways towards a future characterized by efficient, alternative, and sufficient consumption patterns. These initiatives include collaborative consumption models, community-driven projects, and lifestyle changes that promote health and well-being. However, social innovation initiatives often face funding limitations compared to their technological counterparts. Addressing these funding disparities is essential for scaling up sustainable living practices and achieving global sustainability.

2.1.3 Behavioral Aspects of Sustainability

Understanding human behavior is crucial for promoting sustainable practices. People adopt sustainable behaviors for various reasons, including environmental concern, economic benefits, social influence, and health consciousness. Identifying these motivations is key to crafting effective strategies. Additionally, encouraging repetitive sustainable actions helps form habits, making these behaviors more automatic and long-lasting. (Tsanov, 2023)

Social pressure and the perception of others' behavior significantly influence individual sustainability choices. Promoting sustainable practices within communities can create a positive ripple effect. Human behavior is greatly influenced by internal drives and external circumstances, highlighting the importance of considering different situational contexts for promoting sustainable behavior. (Tsanov, 2023)

Transitioning to sustainable energy requires a shift in mindset and understanding of individual contribution to environmental sustainability, which can be challenging for some individuals. Education plays a vital role in addressing these psychological barriers by providing accurate information about sustainable energy solutions and emphasizing collective actions. Policies and initiatives promoting renewable energy should consider psychological factors, such as perceptions of incentives and social aspects of pro-environmental activities, to enhance effectiveness (Tsanov. 2023). Financial incentives and education are essential tools for encouraging the uptake of sustainable energy solutions and fostering a foundation for sustainable energy practices.

Individuals possessing a comprehensive understanding of environmental issues and the repercussions of their actions are generally predisposed to embracing sustainable behaviors. However, it is imperative to acknowledge instances where individuals engage in sustainable practices for motivations distinct from environmental concern. A notable illustration is the adoption of a plant-based diet, widely recognized for its substantial environmental benefits in mitigating carbon footprints. Figure 1 illustrates survey results highlighting the motivations behind individuals choosing plant-based foods, showing that environmental concerns represent less than 20% of these motivations (Ho, 2020).

Figure 1. Survey results - why shoppers choose plant-based foods.

In response to this discovery, it is crucial to formulate strategies that highlight environmental rationales. Implementing educational campaigns and interventions that highlight multifaceted benefits, including personal health, ethical considerations, and economic advantages, may serve as a comprehensive countermeasure. By broadening the narrative around sustainability to encompass diverse motivations, there exists a potential to enhance the adoption of eco-friendly behaviors across a wider spectrum of individuals. (UNEP, n.d.)

The "zero-waste" movement demonstrates the power of consumer demand in driving sustainable practices. Consumers prioritize quality, safety, and environmental conformity, often willing to pay more for sustainable products. Aware of this, various Carbon Footprint (CF) labeling schemes are utilized globally by retailers. CF labeling aims to provide transparency and empower consumers to make informed purchasing decisions. (UNEP, n.d.)

Decision-makers often make choices on consumption or production without considering the full life cycle perspective or the broader implications on the environment, society, or the economy. By bringing "life cycle thinking" to the mindset of decision makers, we can enhance the sustainability of their decisions and achieve the SDGs faster and more efficiently. (Tsanov, 2023)

2.2 Carbon Footprint Calculation Methodologies

Carbon accounting and labeling methodologies are used to analyze emissions of products throughout their supply chains. This analysis aims to identify emissions hotspots within a product's lifecycle and inform cost-effective actions for reduction (Corporate Finance Institute, n.d.). However, challenges exist. Designers of carbon accounting schemes must balance the need to respond to policy and corporate agendas with addressing knowledge gaps about greenhouse gas emissions, particularly in developing countries. As a result, carbon accounting may not fully capture the environmental impact of products in these regions.

2.2.1 Carbon footprint

The concept of a carbon footprint has become an essential metric in comprehending the profound influence human activities exert on climate change (Corporate Finance Institute, n.d.). It quantifies the total greenhouse gases (GHGs) emitted by individuals, groups, or even products within a defined timeframe (Corporate Finance Institute, n.d.). These potent gases act like a blanket around the Earth, trapping heat in the atmosphere and contributing to the alarming phenomenon of global warming (Corporate Finance Institute, n.d.). The overwhelming scientific consensus points to a critical truth: the current accelerated pace of climate change is primarily driven by the escalating concentration of greenhouse gases in the atmosphere, largely caused by emissions from fossil fuel combustion and industrial processes (Laksmawati et al., 2024).

Evaluating personal carbon footprint empowers individuals to move beyond simply acknowledging climate change to a place of understanding their own contribution to the problem (Laksmawati et al., 2024). By calculating the footprint, valuable insights are gained into the magnitude and composition of the emissions generated by daily activities. Armed with this knowledge, individuals are better equipped to make informed choices and adopt positive behavioral changes that lead to a reduction in the personal footprint. This ultimately contributes to a decrease in the global footprint, bringing humanity closer to achieving a more sustainable future for all.

A personal carbon footprint analysis goes beyond mere calculation; it acts as a roadmap for targeted action (Laksmawati et al., 2024). By identifying "hot spots" – activities that significantly contribute to the overall emissions – individuals can focus efforts on implementing specific reduction strategies. For instance, pinpointing a large carbon footprint associated with transportation might prompt a switch to cleaner options like cycling or public transport. Similarly, identifying high energy consumption within the home could lead to the adoption of energy-saving practices and the use of more efficient appliances.

A comprehensive personal carbon footprint analysis can also reveal potential roadblocks that may hinder significant reductions in emissions (Laksmawati et al., 2024). These barriers can include limitations on individual control over certain aspects of the carbon footprint. For example, some aspects of the footprint may be influenced by broader societal structures or limitations in available infrastructure. Recognizing these limitations allows individuals to focus efforts on areas where they have the most agency and advocate for systemic changes that can create a more sustainable environment for everyone.

Understanding the carbon footprint is the first crucial step towards taking responsibility for the impact on the planet. By acknowledging the role played and identifying areas for improvement, individuals can become active participants in creating a more sustainable future. Armed with this knowledge, informed choices can be made, advocacy for change can occur, and collective efforts can be made towards a future where human activities and a healthy planet can coexist in harmony.

Transportation

Transportation plays a pivotal role in shaping carbon emissions and air quality, making informed lifestyle choices in this realm crucial for reducing environmental impact (United Nations, n.d.). Currently, the transportation sector stands as the leading contributor to global carbon emissions, predominantly fueled by private vehicles from individual households. Notably, aviation constitutes a significant portion of emissions within this sector, accounting for approximately 10% of global transport-related emissions (United Nations, n.d.).

Single long-haul flights alone can contribute up to 2 tons of carbon emissions, representing a third of an individual's annual carbon footprint (United Nations, n.d.). Given the significant emissions associated with air travel, alternatives such as rail or bus transportation are advocated, particularly for shorter distances, as they offer lower carbon-intensive options (United Nations, n.d.).

Walking and biking emerge as the most environmentally friendly modes of transportation, with minimal carbon emissions compared to other forms of travel. Encouraging individuals to incorporate walking or biking into their daily routines, especially for short trips, can significantly reduce carbon emissions and promote sustainability.

Public transportation also presents a viable alternative to personal vehicle use, with the potential to substantially decrease an individual's carbon footprint by up to 2.2 tons annually (United Nations, n.d.). Additionally, the adoption of electric vehicles (EVs) offers considerable benefits in reducing emissions, with the potential to lower an individual's carbon footprint by up to 2 tons per year (United Nations, n.d.).

Despite individual efforts to reduce transportation-related emissions, the global movement of goods presents significant environmental challenges, particularly concerning air pollutants. To address these challenges comprehensively, a broader analysis is needed to identify key factors influencing carbon reduction and inform the development of smart transportation solutions across various modes of transport (Chiang et al., 2023).

In conclusion, adopting sustainable transportation practices is essential for mitigating carbon emissions and promoting environmental stewardship. By making conscious choices in transportation modes and embracing alternatives such as public transit and electric vehicles, individuals can contribute to reducing their carbon footprint and advancing sustainability goals.

Food

The choices made about food have a profound impact on the carbon footprint, with meat consumption emerging as a significant concern (Energy Education, 2023). Livestock rearing generates a substantial share of greenhouse gas (GHG) emissions, with beef production being particularly impactful. Consider this: the environmental cost of just one kilogram of beef is equivalent to driving a car for roughly 160 miles (Energy Education, 2023). While complete elimination of meat from diets may not be necessary, a conscious reduction in meat consumption offers a powerful strategy for lowering one's carbon footprint.

Beyond the direct emissions associated with animal agriculture, a web of indirect factors contributes to the food sector's carbon footprint. The transportation of food products, the use of pesticides in agriculture, and the consumption of out-of-season produce all play a role in elevating emissions. Processed foods, with their complex supply chains involving transportation, factory production, and extensive packaging, tend to carry a larger carbon footprint compared to their fresh counterparts (Energy Education, 2023).

The environmental consequences of food choices extend far beyond individual carbon footprints. The entire food supply chain, encompassing agricultural practices, land-use changes, transportation, and distribution processes, contributes significantly to GHG emissions (Brenton et al., 2010). The Food and Agriculture Organization (FAO) estimates that, to keep pace with population growth and evolving dietary habits, food production will need to increase by a staggering 60% in the coming decades (Brenton et al., 2010). This intensifying demand places a strain on environmental resources, and the specter of climate change further complicates the equation. Climate change disrupts weather patterns and jeopardizes food security, creating a vicious cycle where food production and climate change exacerbate each other's detrimental effects.

Direct emissions from agricultural activities account for roughly 10-12% of global emissions, and this figure climbs to 30% when additional factors are considered (Iakovou et al., 2016). Furthermore, emissions from agriculture, forestry, and fisheries have nearly doubled over the past 50 years and are projected to continue rising. In response to this growing challenge, governments worldwide are emphasizing the need for sustainable food system management practices that comply with international environmental regulations. By making informed dietary choices, minimizing food waste, and supporting sustainable agricultural practices, individuals can collectively work towards a food system that nourishes both people and the planet.

Energy

Global electricity demand is projected to experience a significant surge, surpassing the anticipated demand for fossil fuels (IEA, 2012). This escalating demand stems from a confluence of factors, including population growth, accelerating urbanization, and the ever-increasing reliance on electronic devices (Heshmati et al., 2015). The combustion of fossil fuels releases greenhouse gases, most notably carbon dioxide, a primary contributor to climate change. The catastrophic nuclear accident at Fukushima Daiichi in 2011 further underscored the safety and environmental concerns associated with traditional energy sources. Additionally, the long-term economic viability of renewable energy sources becomes increasingly attractive as the price of fossil fuels, particularly crude oil, continues to rise.

Renewable energy sources, such as solar, wind, geothermal, and hydropower, are gaining widespread traction due to several inherent advantages. First and foremost, renewables are naturally replenished and boast a minimal environmental impact compared to their fossil fuel counterparts (Heshmati et al., 2015). Furthermore, the generation of electricity through renewable sources produces little to no carbon emissions, thereby significantly reducing humanity's contribution to climate change and mitigating its. Finally, unlike nuclear power plants, renewable energy sources generally pose a lower risk of catastrophic accidents, offering an inherent safety advantage (Heshmati et al., 2015).

Fossil fuels currently dominate the global energy consumption landscape, with significant disparities in both reserves and consumption patterns observed across different regions (Heshmati et al., 2015). Population growth, expanding economies, and price fluctuations are identified as key drivers of energy consumption. Non-OECD countries, experiencing more rapid economic development, are projected to witness a steeper rise in energy consumption compared to developed nations. Vehicle ownership per capita and the size of a nation's service sector significantly influence oil consumption patterns. Developed countries tend to have higher vehicle ownership rates and larger service sectors, consequently exhibiting higher oil consumption (Heshmati et al., 2015).

World energy consumption is anticipated to increase by a staggering 53% between 2008 and 2035, primarily driven by the economic boom in developing countries like China and India (Heshmati et al., 2015). The current growth rate of energy consumption, estimated at around 2.5% annually, raises concerns regarding the long-term sustainability of fossil fuel reserves. Studies suggest that global oil supplies may only be able to meet demand until peak production is reached between 2013 and 2020, necessitating a focused exploration of unconventional oil and renewable energy sources to bridge the future energy gap (Heshmati et al., 2015). Coal is projected to remain a significant energy source in the foreseeable future, highlighting the critical urgency of transitioning towards renewable energy sources to ensure environmental sustainability.

2.2.2 Methodological Approach

Carbon footprinting has emerged as a widely adopted methodology for evaluating the environmental impact associated with various sectors. This approach quantifies the totality of greenhouse gas (GHG) emissions generated throughout a product's life cycle.

A personal carbon footprint specifically measures the GHG emissions attributable to an individual (Corporate Finance Institute, n.d.). Variations exist in how a carbon footprint is calculated. Scientists typically define it as the sum of two components: the direct (primary) footprint and the indirect (secondary) footprint (Corporate Finance Institute, n.d.). The direct footprint encompasses emissions primarily associated with household activities like heating, electricity use, and transportation choices (private car, air travel, rail travel, etc.) The indirect footprint captures emissions associated with the life cycle of products and services consumed by an individual, along with emissions from infrastructure utilized by the individual in conjunction with society (Corporate Finance Institute, n.d.).

Methodologies employed in carbon footprinting heavily draw upon life cycle assessment (LCA) methods, but with a focused emphasis on environmental impact assessment (Brenton et al., 2010). LCA offers a versatile tool for analyzing products or processes to determine environmental efficiency. However, LCA results can exhibit variations based on the practitioner's choices regarding datasets and designated system boundaries (Brenton et al., 2010).

To ensure comparability when analyzing products calculated by different practitioners, standardized carbon footprint and accounting methodologies like PAS 2050 have been established (Brenton et al., 2010). To achieve this comparability, carbon footprint practitioners must adhere to specific regulations, boundaries, and datasets. PAS 2050 provides guidelines for calculating product-based carbon footprints, enabling comparisons across different products. This standard encompasses the entire life cycle of a product, including the use phase and emissions stemming from direct land use change (Brenton et al., 2010).

The Supply Chain Environmental Analysis Tool (SCEnAT) offers another approach, functioning as a decision support system for evaluating and decarbonizing food networks (Iakovou et al., 2016). Several standardized carbon footprint (CF) methodologies exist, including PAS 2050, the GHG Protocol, and ISO 14067 (Brenton et al., 2010; Iakovou et al., 2016; GHG Protocol, 2024).

The GHG Protocol offers a suite of tools designed to assist companies, cities, and countries in developing comprehensive and reliable inventories of their GHG emissions (GHG Protocol, 2024). These tools aid in tracking progress towards established climate goals and provide guidance throughout the entire inventory development process. Calculating emissions involves a multi-step process, commencing with meticulous attention to quality control procedures and the collection of activity data, followed by the estimation of emissions. The GHG Protocol's Corporate Accounting and Reporting Standard offers valuable guidance on inventory development. These tools embody best-practice methods vetted by industry experts and encompass downloadable guidance documents offering step-by-step assistance. Companies typically require the application of multiple tools to comprehensively capture their emissions (GHG Protocol, 2024).

Greenhouse gases (GHGs) include carbon dioxide (CO2), methane (CH4), nitrous oxide (N2O), and hydrofluorocarbons (HFCs). For standardization purposes, emissions are typically measured in CO2 equivalents (CO2e) (Corporate Finance Institute, n.d.). CO2e simplifies accounting by acknowledging the varying warming impacts of different GHGs. This universally accepted metric is employed for quantifying emissions and is also utilized within carbon markets for functions such as carbon credits and offsets (Corporate Finance Institute, n.d.).

The concept of scopes categorizes emission levels. Scope 1 covers direct emissions from an entity's own operations. Scope 2 incorporates indirect emissions associated with purchased electricity. Finally, scope 3 encompasses broader indirect emissions such as business travel, investments, the end-of-life treatment of sold products, and purchased goods and services (Corporate Finance Institute, n.d.).

The preparation of a GHG inventory entails understanding scopes and organizational boundaries, collecting activity data, converting this data into carbon emissions using carbon equivalent calculators, determining the chosen framework, calculating emissions, and reporting the results alongside future goals. Common frameworks for carbon accounting include the GHG Protocol, EPA's GHG Inventory Guidance, ISO Standard 14064, and The Climate Registry's General Reporting Protocol (Corporate Finance Institute, n.d.).

Key Methodological Approaches

Life Cycle Assessment (LCA): This comprehensive approach considers the environmental impacts of a product or service throughout its entire lifecycle, from raw material extraction to disposal. LCA can be used to assess the carbon footprint of individual products, companies, or even entire supply chains (Saul et al., 2015).

Process-Based Accounting: This method focuses on the greenhouse gas emissions from energy consumption, transportation, waste generation, and industrial processes (WBCSD, 2013).

Input-Output Analysis: This approach utilizes economic data to estimate the carbon footprint of a product or service based on its production inputs. It leverages pre-existing data on the environmental impact of different sectors within an economy. (Tukker & Huppes, 2005).

Hybrid Methods: Many organizations combine elements from different methodologies to create a more comprehensive picture of their carbon footprint. This can involve using process-based accounting for direct emissions and LCA for specific products or services. (WRI & WBCSD, 2011).

2.2.3 Challenges and Critiques

Despite its widespread adoption, carbon footprinting is not without its challenges and limitations. These limitations can be broadly categorized into issues related to data acquisition, methodological inconsistencies, and a focus on a single environmental impact.

A significant challenge lies in collecting accurate and reliable primary data and emission factors, particularly for food products from less developed countries (Brenton et al., 2010). Limited data availability on food production, processing, and transportation processes in these regions poses a hurdle. Furthermore, the lack of robust regulations often renders the available data unverified and unreliable. Complicating matters further, food production methods exhibit substantial variations across less developed countries, making the development of standardized emission factors that accurately reflect the carbon footprint of different products a formidable task. Resource constraints, stemming from a lack of financial and human resources, can further obstruct efforts to gather comprehensive data on food production processes and associated emission factors in these regions (Brenton et al., 2010).

The inherent subjectivity and potential uncertainties associated with carbon footprint calculators present another challenge in drawing accurate comparisons between different methodologies (Brenton et al., 2010). While some degree of comparability can be achieved when practitioners utilize the same methodology, significant variations between methodologies render meaningful comparisons impossible. This underscores the importance of acknowledging the limitations and inherent risks associated with such comparisons (Brenton et al., 2010).

Inconsistencies in accounting methodologies, characterized by varying rules, boundaries, and datasets employed, can render comparisons of carbon footprint results entirely infeasible. These inconsistencies highlight the potential subjectivity and uncertainties inherent in carbon footprint calculations (Brenton et al., 2010). Researchers have also leveled critiques at methodological flaws identified in past studies. Some argue that such studies relied on methodologies lacking the necessary backing to definitively establish a cause-and-effect relationship between energy consumption, economic growth, and CO_2 emissions (Heshmati et al., 2015).

An oversimplification of the relationship between GDP and CO_2 emissions has also emerged as a point of critique. Researchers now recognize a more complex interplay between factors like technological advancements and environmental regulations that significantly influence this relationship. For instance, a developing nation with stringent environmental regulations might boast lower CO_2 emissions compared to a developed nation with lax regulations, despite having similar GDP per capita (Heshmati et al., 2015). This highlights the need for a broader perspective that incorporates the complex interplay of various factors impacting CO_2 emissions, moving beyond a singular focus on GDP per capita as a determinant.

A Danish study has indicated that mitigating climate change necessitates a shared collective responsibility within society. The study suggests that individuals are more likely to reduce their carbon footprints if they witness a concerted effort towards emissions reduction from societal entities such as governments, organizations, and corporations (Corporate Finance Institute, n.d.). Social practice theory further emphasizes that sustainable lifestyles are not merely individual choices, but rather routine-driven behaviors embedded within social contexts (Shove & Watson, 2017; Reckwitz, 2002).

Beyond the limitations discussed above, challenges also arise in the realm of organizational carbon footprinting (Corporate Finance Institute, n.d.). The existence of multiple corporate entities within an organization necessitates careful consideration of organizational boundaries, as these boundaries can significantly impact reporting and inclusion criteria. Carbon accounting becomes crucial considering evolving regulatory environments that mandate emissions disclosure and climate risk assessment. The ability to compare and benchmark emissions allows stakeholders to gain insights into improvements, declines, and relative performance, ultimately informing due diligence processes conducted by rating agencies (Corporate Finance Institute, n.d.). Access to capital can be influenced by management teams' adherence to regulatory requirements, demonstrable progress in emissions reduction, and contributions towards achieving a "net zero" economy.

3 Methodology

The methodology section of this thesis outlines the systematic approach used to design, develop, and evaluate the carbon footprint tracking and reduction application. This chapter details the research design, data collection methods, and analysis techniques employed to achieve the research objectives. By delineating the methodological framework, this section provides transparency into the process of user research, prototype development, and usability testing.

3.1 User Research

Developing a successful application requires a deep understanding of the target audience (Adobe, n.d.). This section delves into the characteristics and behaviors of the primary users who will benefit most from this sustainability-focused mobile application.

3.1.1 Target Audience

The application caters to a broad audience consisting of various demographics, including generation X, generation Y, and generation Z. This demographic has witnessed a confluence of crucial events, including the significant shifts in environmental awareness and attitudes toward sustainability parallel to alarming escalations in climate-related crises. This has contributed to heightened environmental consciousness, prioritization of sustainable practices, and an inclination towards ways to minimize their environmental impact.

There are more specific and targeted demographic groups. Firstly, there are university and young professionals, they have greater flexibility and control over their daily routines, allowing them to easily integrate sustainable practices like walking or using public transportation. Additionally, targeting higher-ups or professionals in leadership positions leverages the power of "leading by example", potentially influencing others to adopt sustainable habits. Finally, parents play a crucial role in shaping the environmental consciousness of future generations. While the presence of numerous household responsibilities may present challenges, integrating sustainable practices into everyday life can significantly reduce a household's carbon footprint and instill these values in children from a young age.

3.1.2 Digital Skills

The application acknowledges that digital proficiency varies among users. To ensure accessibility, the user interface and user experience will be designed with exceptional user-friendliness in mind. A focus on intuitive navigation will cater to users with below average digital skills. Since the application takes the form of a mobile app, basic knowledge of smartphone functionalities and app usage is assumed. Familiarity with other sustainability-related online tools is not required.

3.1.3 Internet Behaviors and Information Consumption

The target audience actively seeks information related to sustainability. Their preferred online platforms include news forums focused on sustainability and online communities that share sustainable lifestyle tips. This behavior indicates a strong desire to learn more about and engage in sustainable practices.

3.1.4 Sustainability Awareness

The application recognizes that the target audience's awareness of sustainability issues may vary. To cater to this spectrum, the app offers adjustable difficulty levels for assigned sustainable actions. This beginner-friendly approach welcomes users who are new to the concept of a sustainable lifestyle.

3.1.5 User Personas

With the insights gathered in the previous sections, we have successfully identified the overall target audience for the application. To further understand the characteristics, behaviors, and goals of the users, we have developed user personas. These personas encompass various skill levels and sustainability aspirations, providing a comprehensive understanding of the diverse user base the application aims to cater to. Figure 2 and figure 3 depict two user personas developed to understand the application's diverse user base, ranging from different skill levels to sustainability aspirations.

Figure 2. User persona – Maria.

Figure 3. User Persona – Sarah.

3.2 Digital Technologies and Sustainability

Digital technologies play a crucial role in supporting and promoting environmental stewardship principles. The concept of digital sustainability emphasizes the integration of social, economic, and environmental considerations into digital products and services. By defining resource-efficient solutions and utilizing technology to advance sustainability goals, organizations can foster a culture of innovation and responsibility that extends beyond traditional boundaries (Mightybytes, 2023). Digital technologies have become crucial for sustainable development, providing innovative solutions to environmental challenges. From artificial intelligence to blockchain and teleconferencing platforms, these tools are reshaping industries and transforming the way we approach sustainability. AI and machine learning, for instance, analyze extensive datasets to develop sustainable strategies and optimize resource usage, enabling businesses to make data-driven decisions that minimize environmental impact (Sombret, 2024).

Moreover, the Internet of Things (IoT) plays a crucial role in enhancing energy efficiency by enabling real-time monitoring and control of devices. By connecting appliances, equipment, and infrastructure, IoT solutions empower organizations to identify inefficiencies and implement them. Similarly, blockchain technology ensures transparency and traceability in supply chains, facilitating the adoption of eco-friendly practices and enabling consumers to make informed choices about the products they purchase (DTN, 2022).

Furthermore, teleconference platforms have become necessary tools for facilitating remote collaborations and reducing the need for physical travel. These platforms offer a greener alternative to face-to-face meetings, significantly minimizing carbon emissions associated with commuting and travel. By embracing digital transformation, businesses can not only enhance their operational efficiency but also contribute to global environmental goals (Sombret, 2024).

Digital transformation is not only about adopting new technologies; it represents a fundamental shift in the way businesses operate and interact with the environment. By leveraging data and software, companies can reimagine traditional processes, optimize energy usage, and reduce greenhouse gas emissions. For instance, advanced analytics tools enable organizations to monitor energy consumption, track waste production, and identify areas for improvement, empowering them to make informed decisions that drive sustainability (DTN, 2022).

As individuals strive to navigate the complex environmental challenges of the 21st century, the integration of digital technologies offers promising avenues for creating greener, more sustainable societies. By embracing digital transformation and harnessing the power of innovation, we can not only reduce our environmental footprint but also drive positive change on a global scale.

3.2.1 Comparative Analysis

The current climate crisis has instilled a growing desire among individuals to reduce their carbon emissions and adopt sustainable lifestyles. However, there exists a large amount of information on eco-friendly practices and carbon neutral lifestyles. Carbon footprint tracking applications address this issue by mustering information into a single, user-friendly platform.

These applications empower individuals to make environmentally conscious choices in their daily lives by calculating and visualizing their carbon footprint. By pinpointing areas of high carbon consumption (pain points), the application can guide users towards targeted actions for carbon emission reduction. Recognizing this growing demand, the market has witnessed a surge in carbon tracking applications, which promote sustainable and carbon-neutral lifestyles. Several of these applications have gained significant popularity among users, this section will explore some of the most prominent examples.

Joro

Joro uses "The Carbonizer", a powerful emissions data algorithm, to analyze user spending data connected through credit or debit cards. Joro goes beyond simple estimates by incorporating detailed datasets on production, transportation, and end-of-life usage specific to various spending categories. This helps users further by providing personalized insights and localized information based on individual profiles, enabling targeted reduction and offsetting strategies. Figure 4 illustrates the user interface of the Joro application.

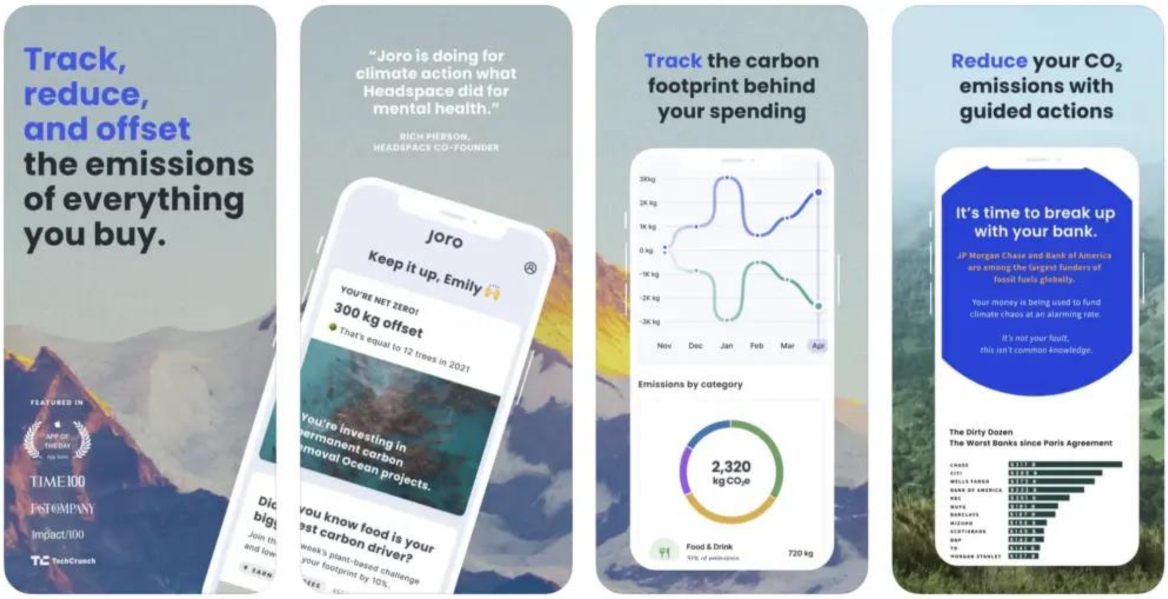

Figure 4. Joro application UI.

Table 1. Positive and negative aspects analysis – Joro.

Positive Aspects	**Negative Aspects**
Seamlessly integrates with credit/debit cards for automatic tracking.	Requires access to users' financial data, raising privacy concerns.
Utilizes a proprietary emissions data algorithm for detailed footprint estimation.	May not capture all carbon emissions accurately, leading to potential inaccuracies in calculations.
Provides insights into carbon emissions across various spending categories.	Reliance on algorithms may lack transparency, making it difficult for users to understand the basis of calculations.
Offers personalized recommendations and localized information based on user profiles.	Limited availability of localized data for accurate estimation in certain regions.
Facilitates identification of top carbon drivers and suggests effective reduction and offsetting strategies.	Lack of transparency in the selection and effectiveness of offsetting projects.

Capture

Focusing on user-friendliness, Capture offers a simple interface and sets personalized carbon reduction targets based on recommendations from the Intergovernmental Panel on Climate Change (IPCC). The app leverages GPS tracking and user-reported dietary information to predict emissions from daily commutes and food choices. Real-time feedback and progress tracking keep users engaged, while automatic offsetting options through verified projects ensure a tangible impact. Capture goes beyond individual action, promoting community engagement through interactive "green challenges" and team leaderboards, making it a valuable tool for collective action. Figure 5 illustrates the user interface of the Capture application

Figure 5. Capture application UI.

Table 2. Positive and negative aspects analysis – Capture.

Positive Aspects	**Negative Aspects**
User-friendly interface with personalized carbon reduction targets.	GPS tracking for emissions prediction may drain device battery and raise privacy concerns.
Predicts emissions from daily journeys and food consumption for comprehensive tracking.	Reliance on user input for food emissions tracking may lead to inaccuracies.
Provides real-time feedback and progress tracking for effective goal monitoring.	Limited selection of carbon offsetting projects may not align with users' preferences.
Offers options for automatic offsetting through verified projects worldwide.	In-app sustainability challenges may lack variety and engagement over time.
Fosters sustainability engagement through interactive 'green challenges' and team leaderboard tracking.	Lack of transparency in the algorithm used to calculate personalized targets.

Earth Hero

Developed by a global team dedicated to climate solutions, Earth Hero offers a customizable approach to carbon reduction. Users take a short survey to identify their carbon sources and set reduction targets aligned with global averages and IPCC recommendations. The app then suggests sustainable actions tailored to user preference and allows customization of difficulty levels. Completing these actions earns "Earth Points", providing a tangible way to track emissions saved. Additionally, the application fosters knowledge sharing and community engagement by offering forums and newsletters on diverse environmental topics. Figure 6 illustrates the user interface of the Earth Hero application

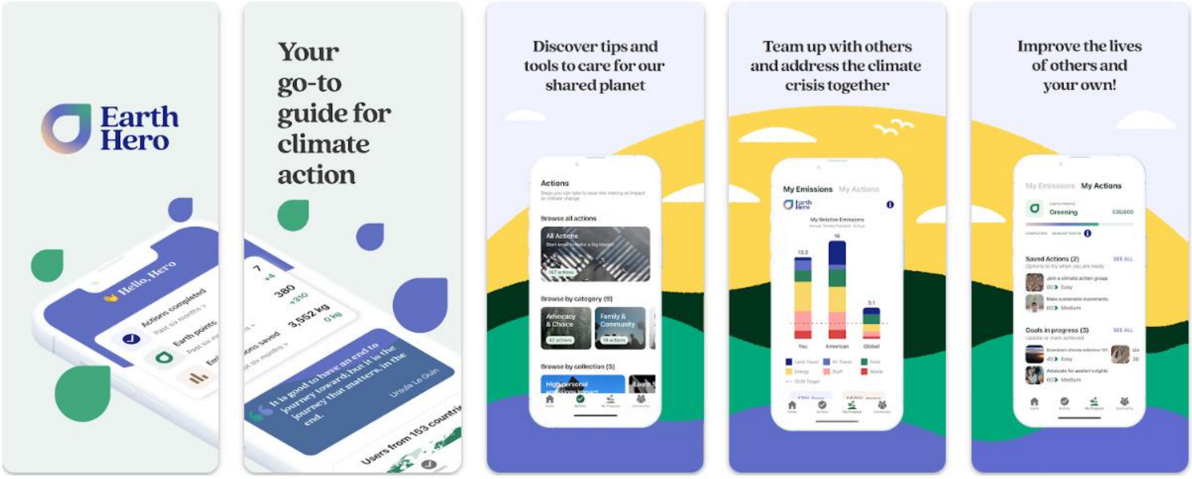

Figure 6. Earth Hero application UI.

Table 3. Positive and negative aspects analysis - Earth Hero.

Positive Aspects	**Negative Aspects**
Customizable approach to carbon reduction based on user preferences.	Relatively basic user interface may lack advanced features found in other apps.
Suggestions for sustainable actions tailored to individual user profiles.	Limited customization options for action difficulty levels.
Allows customization of action difficulty levels for personalized user experience.	Accuracy of carbon emission savings calculation may vary based on user input.
Tracks completed actions and calculates 'Earth Points' for carbon emissions saved.	Reliance on self-reported data may lead to overestimation or underestimation of actual carbon savings.
Provides access to forums and newsletters for community engagement and knowledge sharing.	Lack of real-time feedback on progress may impact user motivation and engagement.

4 App Design and Development

This application's features directly reflect the sustainable living principles explored throughout this thesis. Insights are drawn from the multifaceted nature of sustainable practices, encompassing energy conservation, waste reduction, water conservation, sustainable transportation, and sustainable agriculture (Mont et al., 2014) as outlined in Section 2.1.1. The application encourages mindful consumption and resource conservation by embracing the five Rs framework: Rethink, Refuse, Reduce, Reuse, Recycle (Johnson, 2013) – a concept further detailed in Section 2.1.1.2.

Building upon the analysis of consumption patterns and environmental impacts in Section 2.1.2, the application addresses challenges associated with unsustainable consumption. These considerations include reducing material consumption, minimizing waste generation, and promoting sustainable practices across various sectors (Mont et al., 2014).

Behavioral aspects of sustainability, explored in Section 2.1.3, also inform the application's design. By understanding the motivations behind sustainable behaviors and the influence of social factors, features are tailored to user needs and promote effective behavior change (Tsanov, 2023).

The design philosophy aligns with global initiatives for sustainable living, as discussed throughout the thesis (Mont et al., 2014). Considering the target audience's familiarity with popular digital platforms and operating systems (Section 3.1.2), the interface is crafted to be intuitive and accessible, fostering user engagement and participation.

Drawing inspiration from leading sustainability applications like Joro, Capture, and Earth Hero (analyzed in Section 3.2.1), positive features are synthesized to create a cohesive and engaging user experience. Through interactive tools, personalized insights, and community engagement, the application empowers users to make informed choices about their carbon footprint (Mont et al., 2014).

In essence, the application embodies the principles of sustainable living outlined in this thesis. It integrates environmental strategies, behavioral insights, and user-centered design to promote sustainable behavior change. By leveraging existing research and best practices, the application aims to contribute to a more sustainable future and empower individuals to make a positive environmental impact.

4.1 Overview of the Prototype

The prototype presented in this thesis offers a comprehensive preview of a carbon footprint tracking and reduction application, showcasing the user interface (UI) and user experience (UX) design that will define the application. This prototype serves as a visual representation of the application's look, feel, functionality, and user interactions, providing valuable insights into its design and usability.

The prototype is structured into six primary sections: Home, Tasks, Ranking, Analysis, News, and Profile, each demonstrate key features and functionalities essential for managing carbon footprint. It comprises of approximately 50 screens and explores a range of user interactions and application capabilities.

Designed with a philosophy of simplicity, innovation, and accessibility, the prototype adopts a modern and eco-friendly aesthetic, characterized by a minimalist design approach, harmonious color scheme, and intuitive typography. This design concept aims to enhance user engagement and convey information effectively.

One of the core attributes of the prototype is its interactivity. Users can navigate through different screens, engage with tasks, explore rankings and analysis, stay updated with environmental news, and manage their profiles seamlessly.

It was designed entirely using Figma and demonstrates modern UI/UX practices and leverages innovative features to create a dynamic and responsive application interface.

By presenting this prototype, this thesis aims to provide a tangible representation of the envisioned application, emphasizing its potential impact on carbon footprint reduction and laying the groundwork for further refinement and development.

4.2 UI/UX Design Principles

UI/UX design principles outline the fundamental guidelines and concepts used in the design of digital interfaces. These principles make up the best practices to optimize user experience (UX) and user interface (UI), ensuring intuitive, engaging, and effective designs. Utilizing design principles is crucial for creating user-centric products that prioritize usability and satisfaction. Key principles such as simplicity, consistency, accessibility, and feedback guide designers in crafting interfaces that are easy to navigate, visually coherent, inclusive, and responsive to user actions. By adhering to these principles, designers enhance the overall usability and appeal of digital products, fostering positive interactions and promoting user engagement. Incorporating UX/UI principles into thesis content underscores their importance in driving successful design outcomes and user satisfaction in digital contexts. Standard UI/UX design principles were implemented in the making of this design to enhance usability and ensure consistency within the design and design process.

4.2.1 Style guide

A style guide is an essential document that sets out guidelines and standards for the visual and functional aspects of digital products. This guide acts as a reference tool for designers and developers, ensuring consistency, coherence, and usability across different components the application. The primary importance of a style guide lies in its ability to maintain consistency throughout the design process. By defining design patterns, color schemes, typography rules, and layout principles, the style guide streamlines design processes and facilitates development. Consistent design elements contribute to a seamless user experience, reducing confusion and enhancing usability. Moreover, a well-crafted style guide reinforces the brand's visual identity by specifying colors, fonts, iconography, and other brand elements. This consistency not only maintains brand integrity but also facilitates collaboration among designers, developers, and stakeholders, providing a common reference point for design decisions and ensuring a cohesive and user-friendly digital experience. The following style guide was used in the creation of the prototype, it highlights the color palette and typography used in the design. Figures 7 and 8 depict the typography used in the design of the application and the color palette used in the styling of the application.

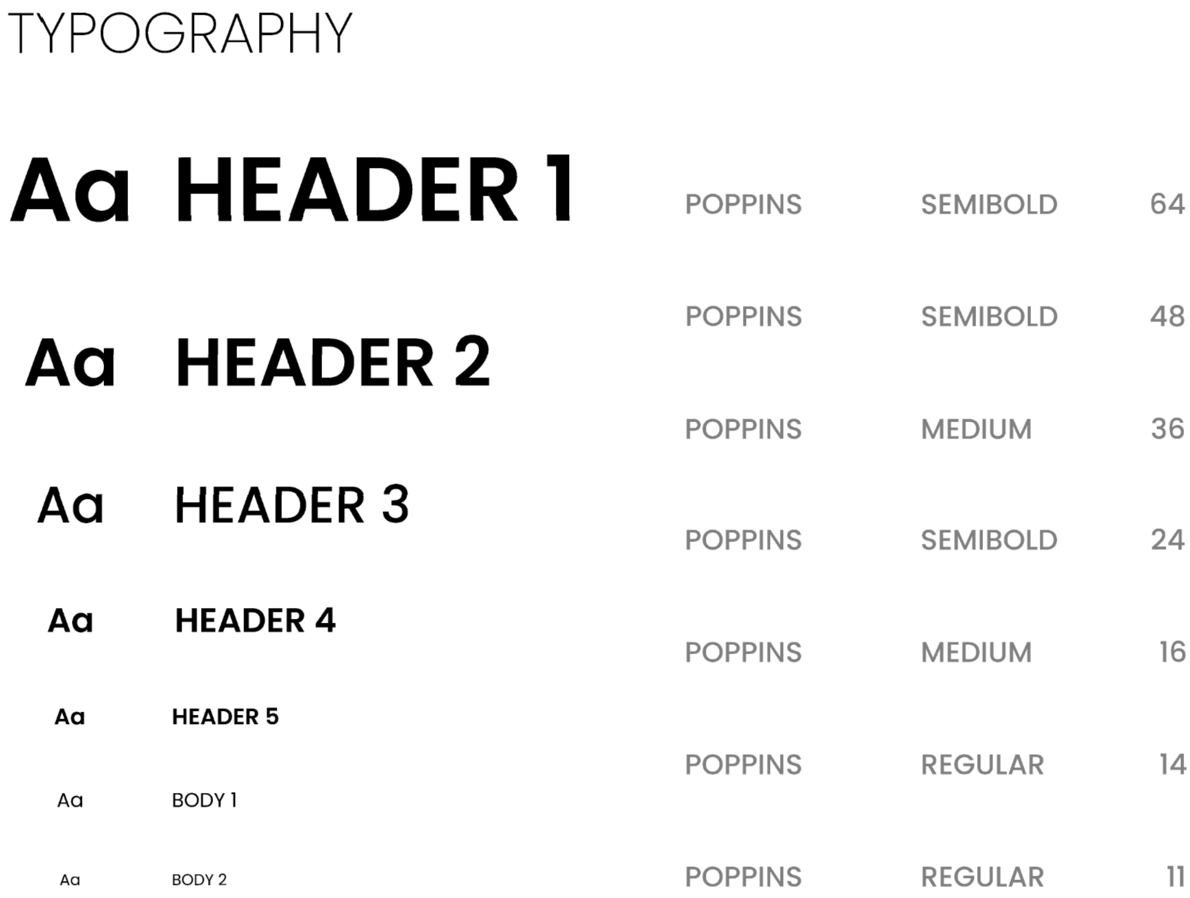

Figure 7. Style guide – Typography.

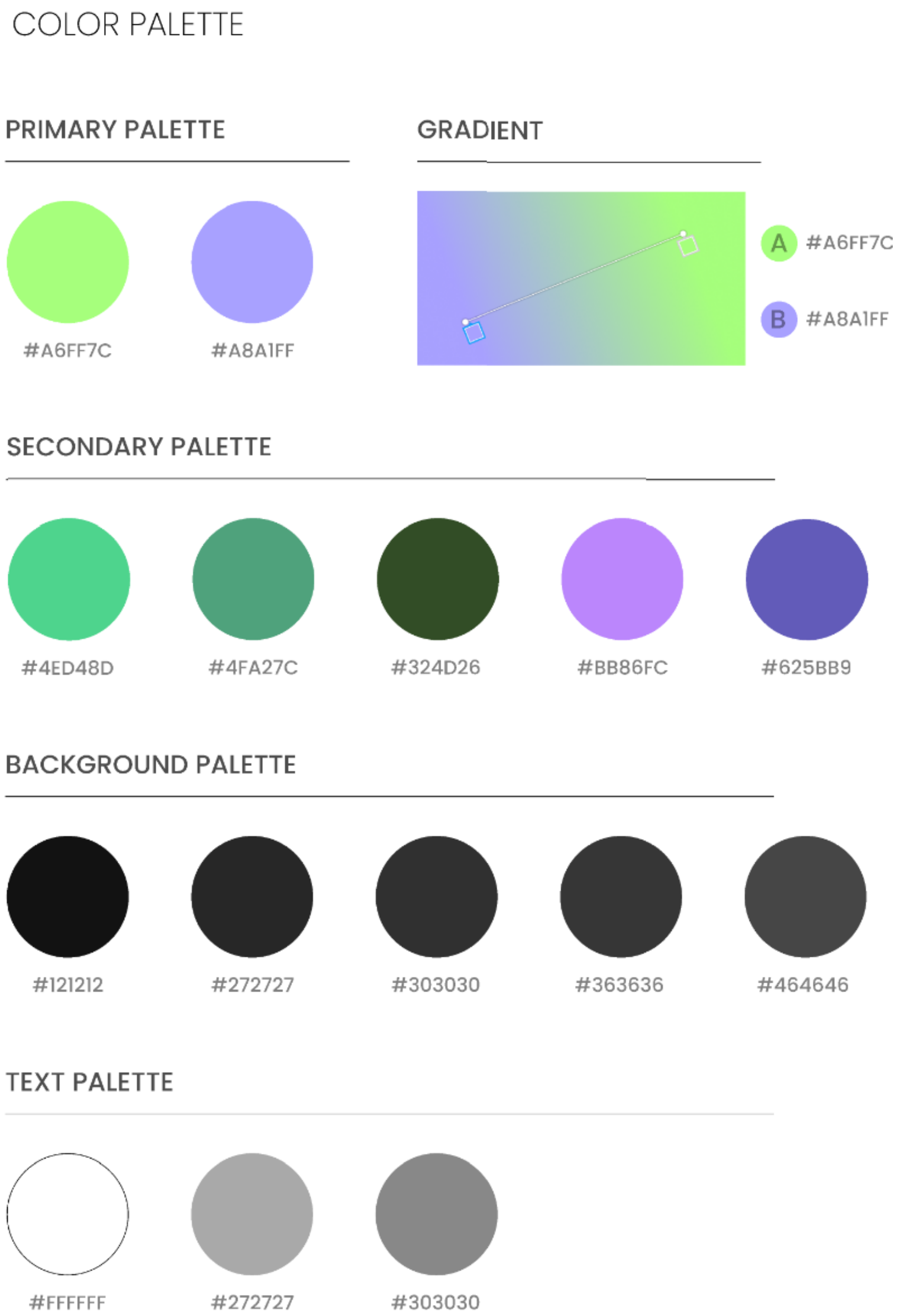

Figure 8. Style guide - Color Palette.

4.2.2 Information architecture

The information Architecture delves into the structural design and organization of the application's content and features. The image below illustrates the information architecture, depicting the hierarchical arrangement of menus, navigation paths, and user flows within the application. Figure 9 highlights the logical flow and organization of information to ensure intuitive user interaction and seamless usability.

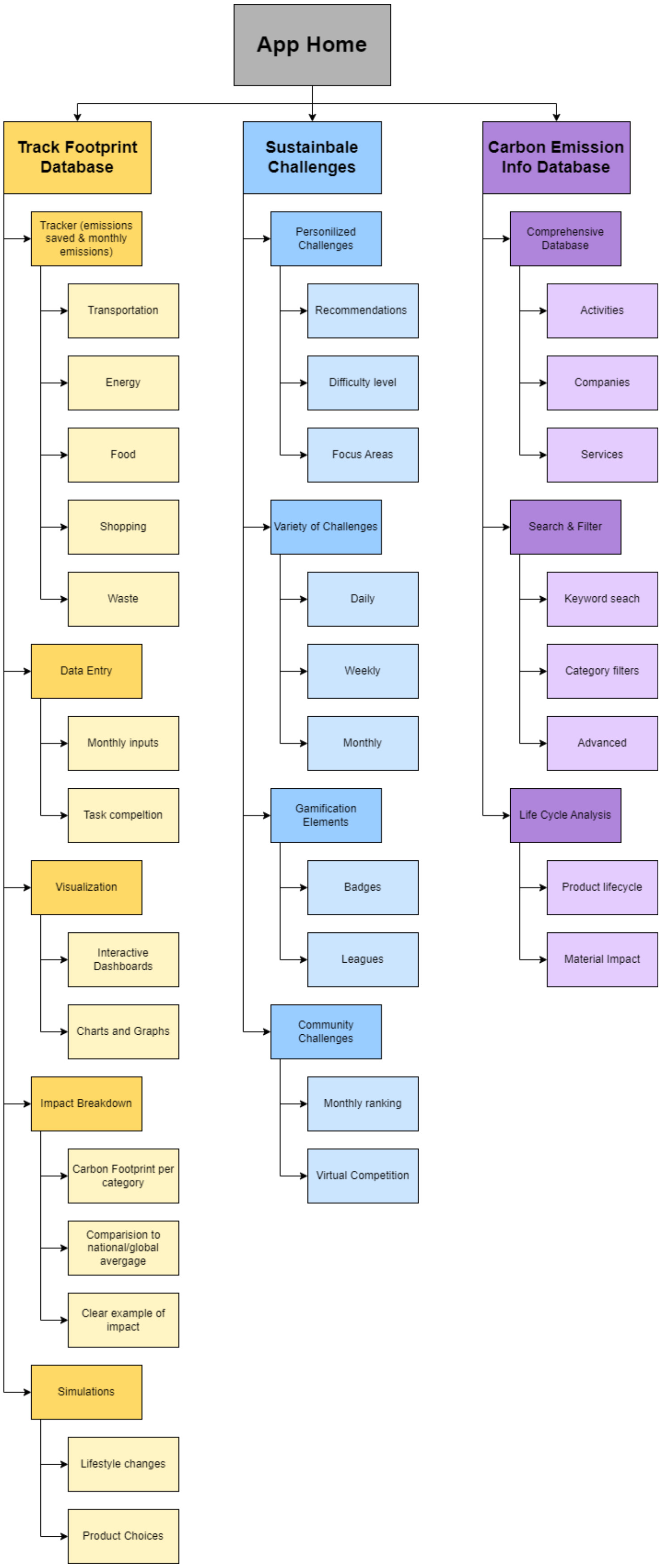

Figure 9. Information Architecture (IA).

4.2.3 Sketch wireframes

Before proceeding to design the application in medium to high fidelity using Figma, I roughly sketched wireframes to visualize my ideas and conceptualize the overall look and implementation of various features. These initial sketches served as foundational building blocks for the main design phase, allowing me to refine and solidify key elements of the application's layout and functionality. This iterative process of wireframing laid the groundwork for developing a cohesive and user-centered design in the subsequent stages. Figure 10 showcases the early wireframe sketches.

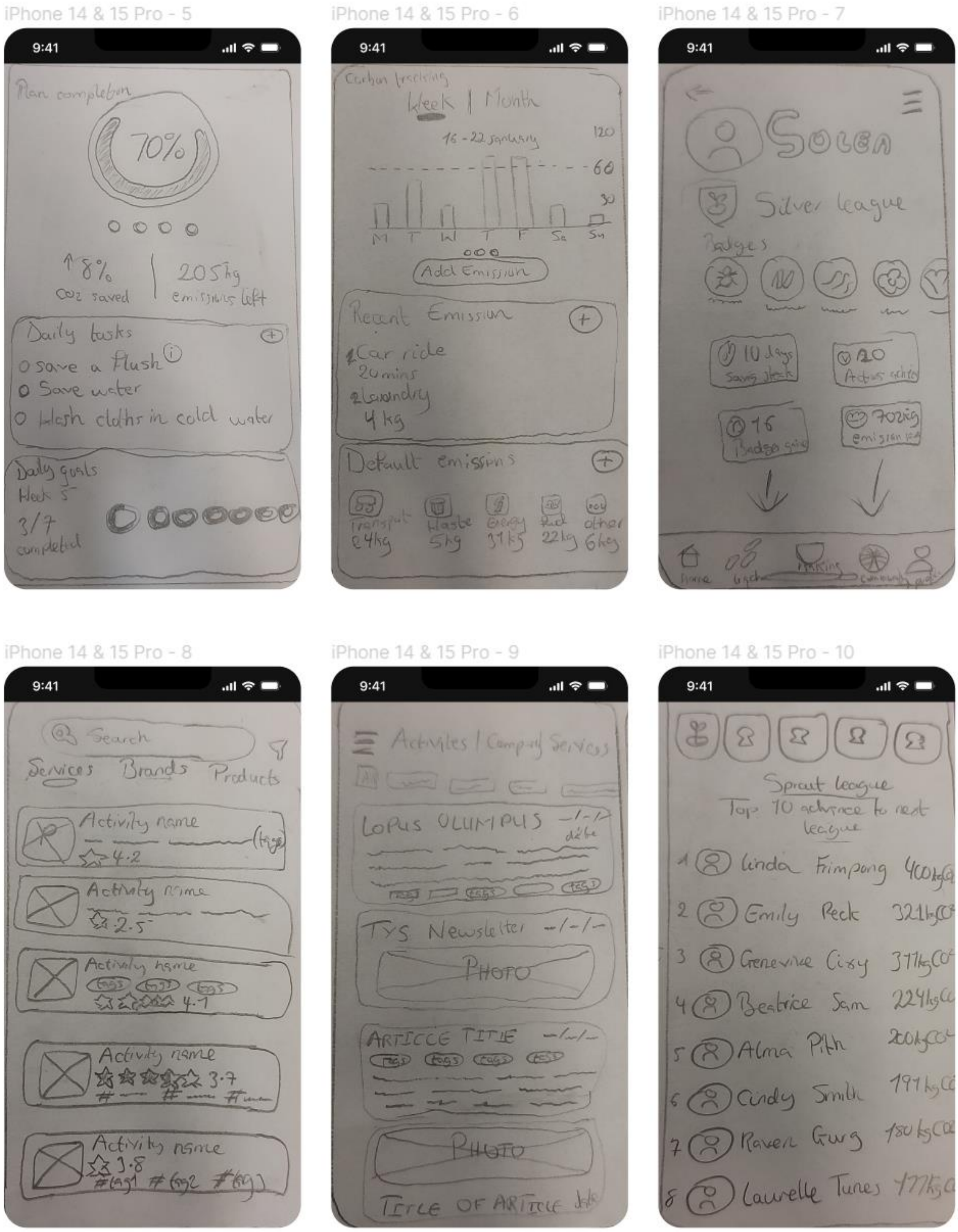

Figure 10. Wireframe sketches.

4.2.4 User Stories

User stories are concise descriptions of features or functionalities from the perspective of an end-user. They express what a user needs or wants to accomplish with a software application or system. Each user story typically follows a specific format that captures the user's goal, the reason behind that goal, and the intended benefit. User stories are used in agile software development to capture requirements and guide designers in building features that align with user needs. The following user stories depict specific user needs and goals within the application.

- As a user, I want to track my carbon footprint across different aspects of my lifestyle, including transportation, energy use, food consumption, and waste generation, to understand my environmental impact over time.
- As a user, I want to enter my data manually into the app for each category of my carbon footprint, allowing me to actively participate in monitoring my progress.
- As a user, I want to visualize my carbon footprint through interactive dashboards, charts, and progress bars, enabling me to easily comprehend the data and track my environmental goals.
- As a user, I want the app to break down my carbon emissions per category, providing insightful comparisons and personalized recommendations to help me reduce my impact.
- As a user, I want to set a monthly target for reducing my carbon footprint, with clear progress charts that motivate and guide me towards achieving my sustainability goals.
- As a user, I want to receive daily tasks and sustainable activities assigned based on my focus areas, encouraging me to adopt greener habits and make conscious choices in my daily life.
- As a user, I want access to personalized sustainable challenges and tasks that match my interests and abilities, providing me with engaging activities to lower my carbon emissions.
- As a user, I want to earn badges and compete on leaderboards through completing sustainable challenges, fostering a sense of achievement and community among like-minded individuals.
- As a user, I want to join community challenges aimed at reducing collective emissions, enabling me to contribute to larger sustainability initiatives and see my impact on a broader scale.

- As a user, I want to explore a comprehensive database of carbon emission information for various brands, products, and services, allowing me to make informed choices and support eco-friendly options.
- As a user, I want to utilize search and filter functionalities within the app to quickly find information about carbon footprints, enabling me to access relevant data and make sustainable decisions efficiently.
- As a user, I want to access life cycle analysis tools integrated into the app, providing detailed insights into the environmental impacts of products and services throughout their lifecycle.
- As a user, I want to access various articles and newsletters on topics of carbon footprint, climate change, sustainability, and so on, enabling me to educate myself, stay updated on current happenings, and gain more insight and knowledge on the topics.

4.2.5 Sustainable Practices in Application Design

In today's digital age, where technology is a part of every aspect of our lives, the environmental impact of software development cannot be understated. With data centers consuming 2% of the world's electricity and the ICT sector potentially responsible for 14% of the global carbon footprint by 2040, the need for sustainable practices in application design is crucial (Beetroot Team, 2023). Sustainable application development is a critical step towards reducing the environmental impact of the IT industry. By adopting efficient development techniques, utilizing renewable energy, and considering the environmental effects of application design and programming, we can pave the way for a greener future.

One key aspect of sustainable application design is ensuring a user-friendly digital experience with efficient accessibility and performance optimization. This includes designing intuitive interfaces, optimizing navigation, and implementing features such as dark mode to reduce energy consumption (Forbes Tech Council, 2023). Designing web applications with responsive layouts and device compatibility further minimizes resource consumption by eliminating the need for multiple versions or separate mobile applications (Forbes Tech Council, 2023).

UX design plays a crucial role in promoting sustainable behaviors and reducing the carbon footprint of digital experiences. Sustainable UX design principles focus on creating intuitive interfaces that reduce cognitive load and encourage energy-efficient user behaviors (UX Collective Bootcamp, 2023). By optimizing information architecture, minimizing unnecessary steps, and balancing aesthetics with functionality, designers can contribute to a more streamlined and sustainable digital landscape (UX Collective Bootcamp, 2023). Additionally, iterative design processes allow for continuous improvement, ensuring that interfaces remain user-centric and environmentally conscious over time (UX Collective Bootcamp, 2023).

In summary, sustainable practices in application design are essential for mitigating the environmental impact of the IT industry. By prioritizing energy efficiency, user experience, and environmental stewardship, designers can create digital experiences that not only meet user needs but also contribute to a more sustainable future for all (UX Collective Bootcamp, 2023; Beetroot Team, 2023; Forbes Tech Council, 2023).

4.3 Application Features

This section provides a comprehensive overview of the key functionalities integrated into the carbon footprint tracking and reduction application. It details the specific components and tools developed to facilitate environmental awareness, behavior change, and sustainable practices among users. By outlining the application features, this section highlights the innovative aspects of the prototype, including carbon footprint tracking, sustainable actions, community engagement tools, and user profile customization.

4.3.1 Carbon Footprint Tracking

Figure 11 illustrates the main pages of the application that serve as a centralized dashboard where users can easily monitor and manage their carbon footprint reduction progress. At the top of the page, users are greeted with essential metrics, including the total amount of carbon emissions saved this month. This information is presented visually using a progress pie chart, providing users with a clear overview of their achievements. Additionally, users can view the percentage growth or reduction compared to the previous month for added context. The home page also displays the remaining carbon emissions in kilograms needed to reach the user's monthly target, motivating users to take further actions.

Integrated within the main page are the daily sustainable tasks that users need to accomplish. Users can mark tasks as completed directly from this section and even add their own tasks to their daily targets for increased customization and engagement. A graph illustrating daily goal progress over the last seven days offers users insights into their task completion trends, aiding in tracking performance and consistency.

A prominent feature on the home page is the weekly target progress bar, which simplifies the monthly target into manageable weekly goals. This bar graphically represents the percentage of the weekly target completed and the remaining amount, facilitating a clearer understanding of progress.

The design of the home page is intentionally user-centric and minimalistic. The primary color scheme uses light green to accentuate key information related to sustainability, complemented by light purple for added visual interest. Adopting a dark mode theme not only aligns with sustainable UI practices but also enhances energy efficiency. The layout prioritizes simplicity and readability, employing larger fonts and ample spacing between elements to enhance accessibility and usability, especially for visually challenged users.

Interactive elements empower users to engage with the application effortlessly. Users can add or remove daily tasks, and clicking on the progress pie chart redirects them to a detailed breakdown of their emissions data. This breakdown section provides insights into the user's carbon footprint, including emissions recorded for the day, monthly emissions split across categories (food, transportation, waste, energy, etc.), and comparative analysis against national and global averages. This holistic view encourages users to track their progress and make informed decisions toward reducing their carbon footprint effectively.

Overall, the home page encapsulates the application's core features and design principles, offering users a comprehensive and intuitive platform to actively participate in sustainable practices and monitor their environmental impact.

Figure 11. Prototype - carbon footprint tracking.

4.3.2 Sustainable Actions

Figure 12 depicts the action pages within the application that offer users a comprehensive platform to discover and engage with sustainable tasks categorized by difficulty levels: easy, medium, and hard. These actions are curated to empower users with actionable steps they can integrate into their daily routines to reduce their carbon footprint. For instance, actions like "take shorter showers" are classified under the easy category, while more complex tasks such as "install a smart thermostat" fall into the medium category, and substantial efforts like "green home renovations" are considered hard tasks.

Each category of actions is presented in a user-friendly layout, allowing for seamless navigation and selection. Within each section, users encounter a range of sustainable tasks accompanied by brief descriptions outlining their impact on reducing the carbon footprint. This concise information aims to enhance user understanding and promote engagement with sustainable practices.

Visual aids, including icons, are purposefully incorporated to complement the text and make the user interface visually appealing and less text heavy. These visual elements contribute to a more engaging and accessible experience for users exploring the various sustainable actions available. Additionally, each action is tagged with an impact level (low, medium, high), providing users with valuable insights into the expected environmental impact of each task.

Users can navigate between the three difficulty levels within the action pages, allowing for effortless exploration and selection of tasks that align with their preferences and lifestyle. Interactive buttons next to each action enable users to add or remove tasks from their daily list directly from the action pages, rationalizing task management and fostering a sense of accomplishment as users progress toward their sustainability goals.

Overall, the design philosophy behind the action pages prioritizes simplicity, user-centricity, and accessibility. By offering a user-friendly interface and thoughtfully categorized tasks, the application empowers users to take meaningful steps towards reducing their environmental impact and embracing sustainable living practices. The action pages serve as a pivotal feature within the carbon footprint tracking and reduction application, facilitating engagement and progress tracking for users committed to sustainable living.

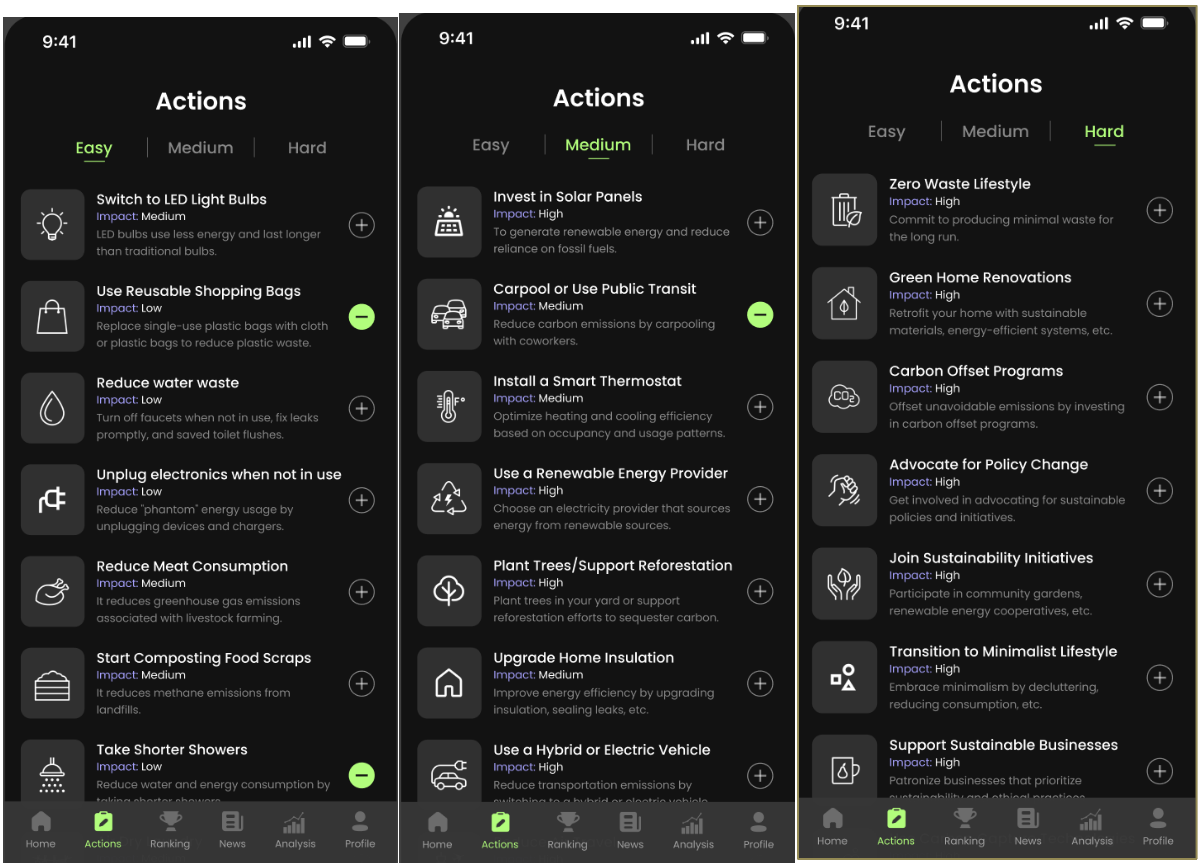

Figure 12. Prototype - sustainable actions.

4.3.3 Carbon Emission Database

Figure 13 shows the news section of the application that comprises two primary pages designed to provide users with curated content and a personalized experience. The first page features a dynamic news feed that integrates external sources to deliver updates and environmental data on topics like sustainability, carbon emissions, climate change, and more. Users can navigate this feed, search for specific topics, and apply filters to refine their content preferences. Tags associated with articles allow users to access news articles specifically related to selected categories of interest.

Upon clicking on an article of interest, users are directed to a dedicated article page where they can read the full text and view accompanying images if available. The article page offers interactive functionalities, enabling users to share articles with others or add them to their favorites for easy access later.

The second page within the news section is the saved articles page, which serves as a repository for all articles saved by the user. Here, users can manage their saved content by removing articles from their collection or sharing them directly from this page. This streamlined interface ensures that users can organize and revisit articles of interest with ease.

Overall, the news section of the application is designed to keep users informed about sustainability-related topics through a user-friendly interface that promotes engagement and customization. By offering personalized news feeds and intuitive article management features, the application enhances the user experience and encourages ongoing exploration of environmental issues and solutions.

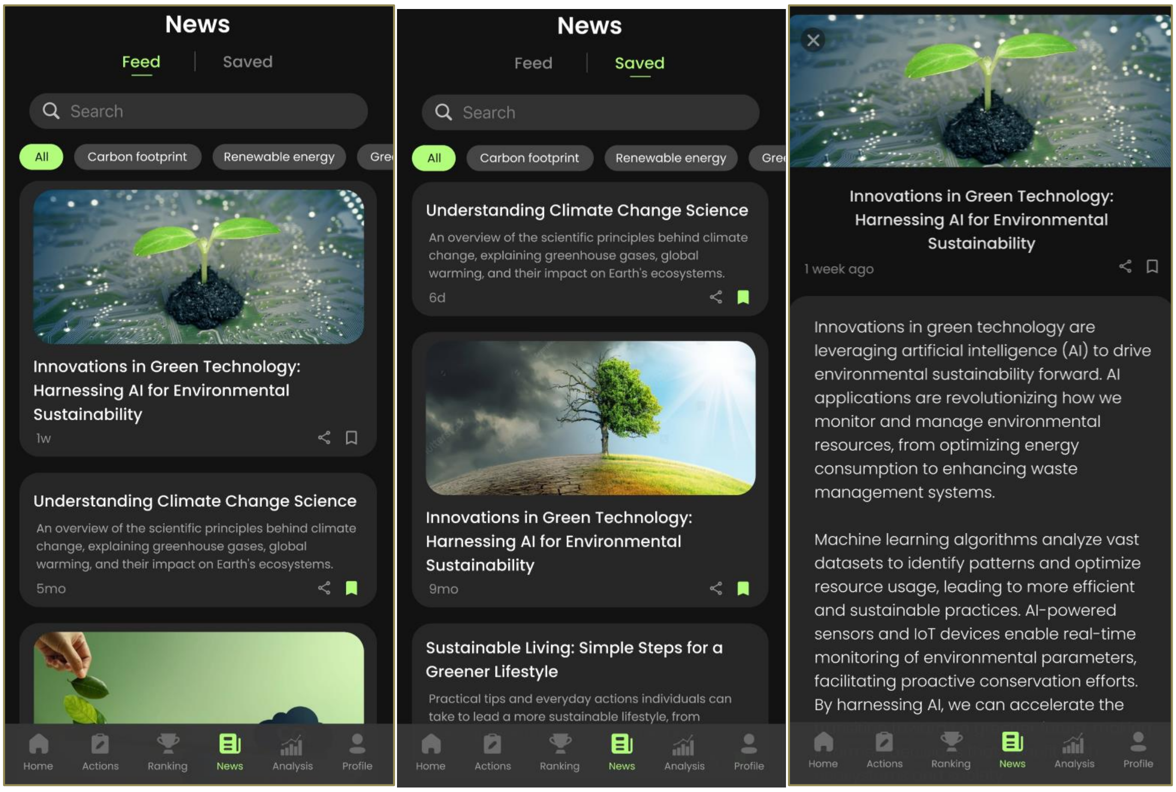

Figure 13. Prototype – News.

Figure 14 is the analysis section of the application that consists of three primary pages, each dedicated to different categories: products, brands, and services. Within each page, users can access a list of items categorized under the respective section, with each item accompanied by an overview of its average carbon footprint. This information serves to inform users about the environmental impact associated with various products, brands, and services.

To facilitate navigation and data accessibility, users have the ability to search and apply filters within each section. This functionality enables users to efficiently browse through items and find specific information based on their preferences and interests.

Clicking on an item within the list opens a pop-up window that provides more detailed information about the environmental impact of the selected item. This detailed view includes a breakdown of various aspects such as the average carbon footprint, environmental impact, sustainability considerations, healthier substitutes (where applicable), transparency (for brands), and sustainable efforts (for brands and services).

By offering comprehensive details and breakdowns for each item, the analysis section empowers users to make informed decisions about their consumption habits. The interactive interface and detailed information enhance user engagement and promote awareness of sustainability considerations related to everyday products, brands, and services. This approach supports the application's overarching goal of encouraging sustainable practices and fostering environmental consciousness among users.

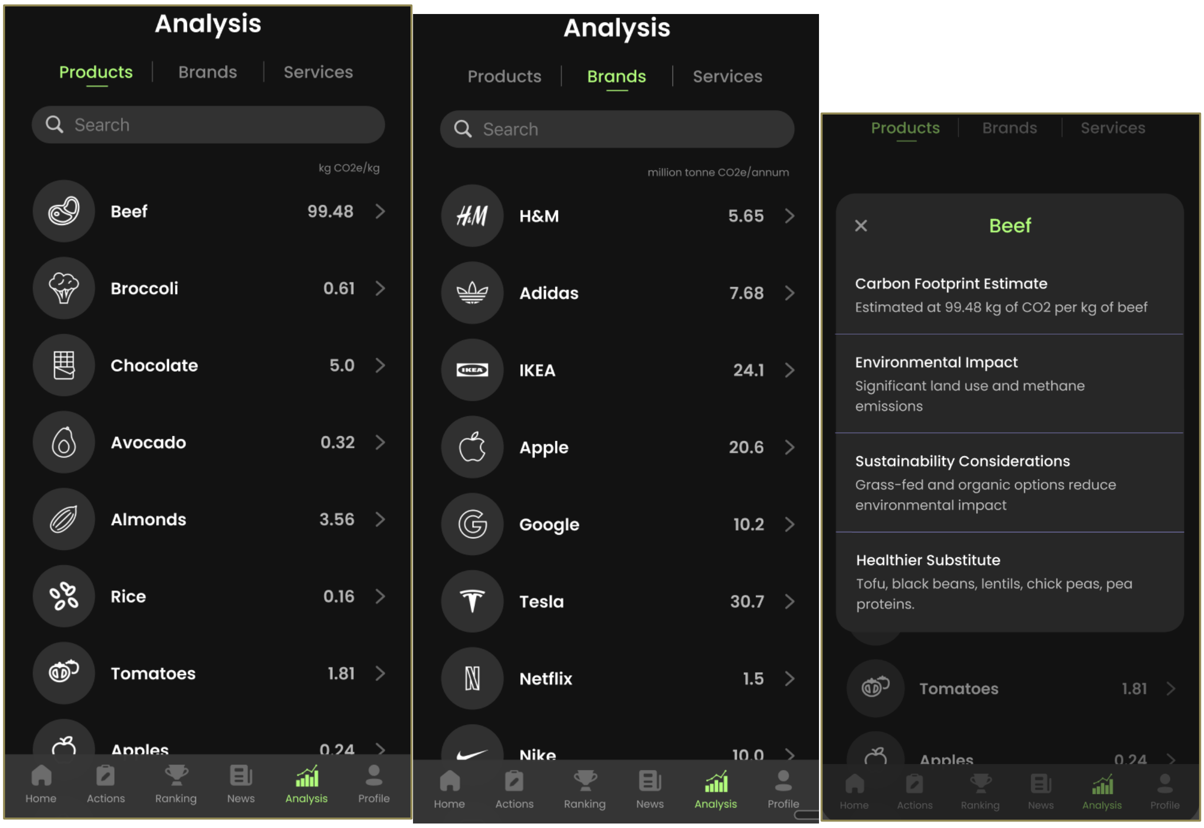

Figure 14. Prototype – Analysis.

4.3.4 Community Competition

Figure 15 shows the pages of the ranking section within the application that serve as a platform for fostering healthy competition among users. It features five distinct leagues that users can participate in based on their monthly emissions savings. Each month, users are ranked according to their savings, and the top 10 users from each league progress to the next league level.

Upon accessing the ranking page, users can easily track their progress by viewing their current rank displayed prominently at the top of the page. This allows users to quickly identify their position without the need to scroll through a lengthy list.

The main content of the ranking page consists of a list displaying user positions within their respective leagues. Each user's position is accompanied by their profile picture, username, and monthly emissions savings. This layout provides a clear overview of the rankings, facilitating user engagement and interaction within the community.

Additionally, users can see how their ranking has changed compared to the previous day, allowing them to monitor their performance over time and providing a sense of daily achievement or progress. This feature encourages continuous engagement and motivates users to strive for greater emissions reductions to climb higher in the rankings.

Overall, the ranking section enhances user engagement by introducing an element of competition while promoting sustainable behaviors and acknowledging users' efforts in reducing carbon emissions. This gamified approach encourages participation and fosters a sense of community among users striving towards common sustainability goals.

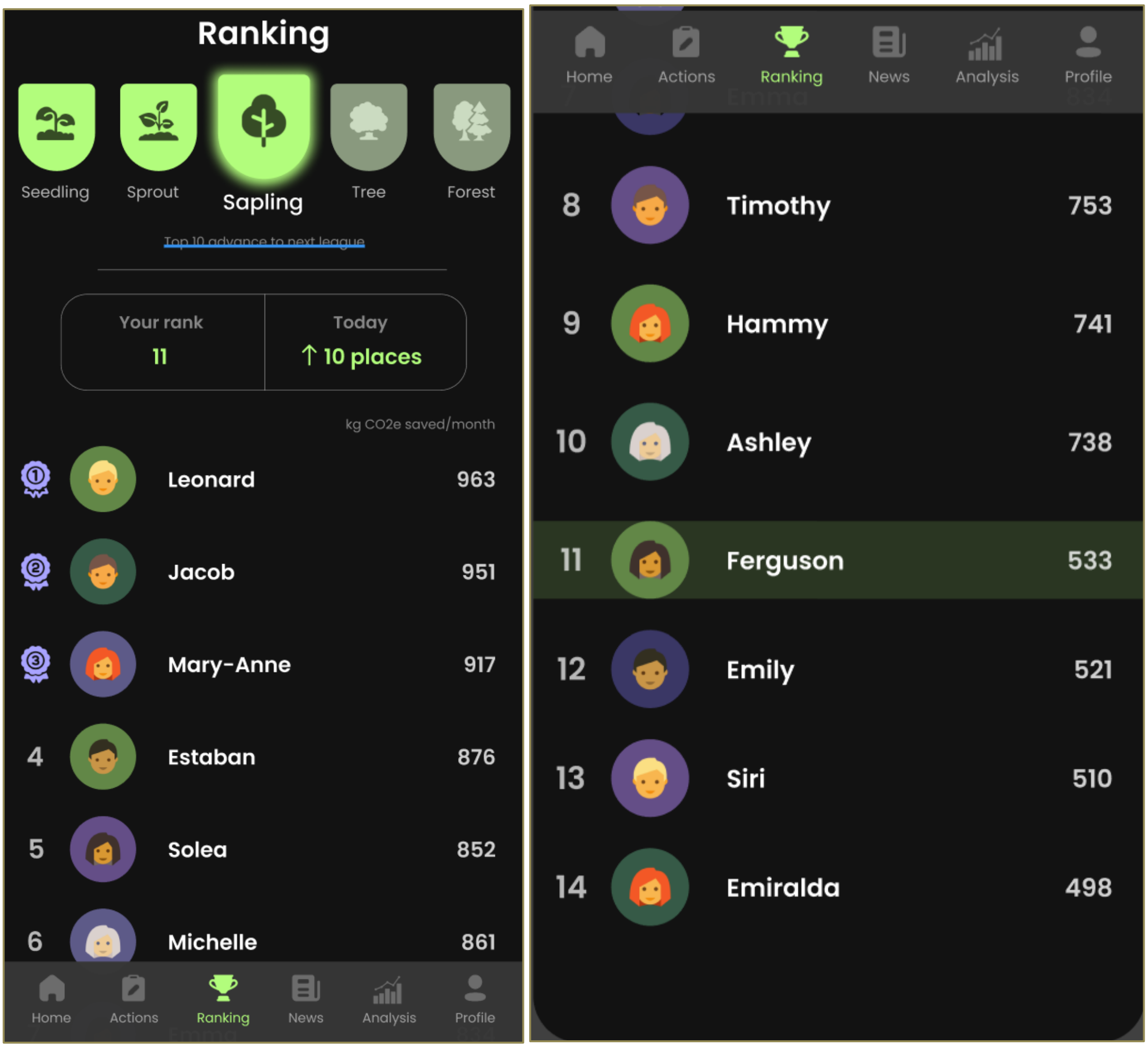

Figure 15. Prototype - community competition.

4.3.5 User Profile

Figure 16 depicts the profile page that serves as a comprehensive dashboard where users can easily manage and understand their personal sustainability data. At the top of the page, users are greeted with their profile picture, username, and the email associated with their application account, ensuring a personalized experience.

One prominent feature of the profile page is the display of badges earned by the user through sustainable activities and emissions savings. These badges symbolize achievements and progress, providing visual recognition for user efforts.

The page also presents key statistics derived from the user's data, including the total emissions saved, the number of actions completed within the week, streak days for sustainable task completion, and the total number of badges accumulated. These metrics offer a snapshot of the user's sustainability performance and progress over time.

A crucial component of the profile page is the ability for users to set their monthly emissions saving target. This is facilitated by a visual scroll bar that allows users to select their desired target in kilograms of emissions saved per month, with options categorized as easy, medium, and hard aids to guide users in setting realistic goals.

Additionally, users can view their assigned focus areas for sustainable actions that change daily. This feature helps users prioritize specific sustainability efforts aligned with their interests and habits.

Lastly, the profile page allows users to set default monthly emissions for transportation, waste, food, and energy. By answering a series of questions, users can provide input that helps calculate their yearly emissions using a preset algorithm. This functionality empowers users to proactively manage and reduce their carbon footprint, promoting awareness and engagement with sustainable practices.

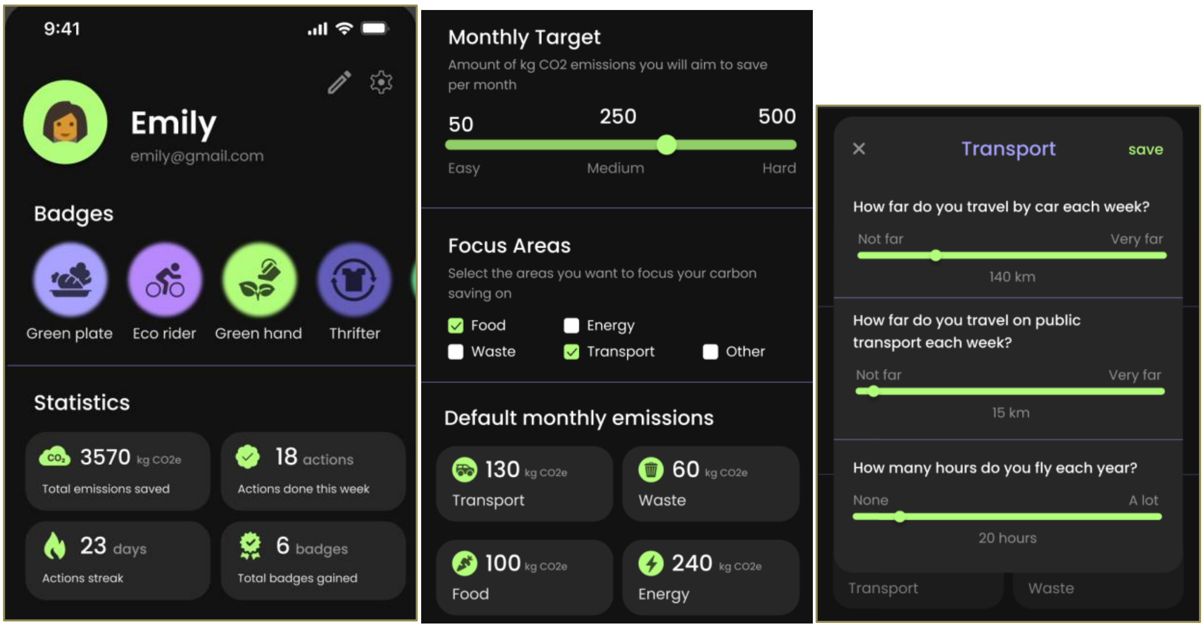

Figure 16. Prototype - user profile.

5 Usability Testing

Usability testing is an essential practice aimed at evaluating the ease of use and effectiveness of a design by observing how representative users interact with it, reflecting the characteristics of the application's target audience. This approach is critical as it uncovers design flaws that may have been overlooked during the design process, providing valuable insights for improvement.

In the context of usability testing, designers assign specific tasks to testers and observe how they navigate and interact with the interface. This observation provides designers with vital insights into the effectiveness of the design, enabling them to make informed improvements that enhance usability and user experience.

The main objectives of usability tests are to determine whether testers can successfully and independently complete assigned tasks. Designers assess testers' performance and mental state during task completion to evaluate the overall usability of the design and gauge user satisfaction. By identifying and prioritizing design problems, usability testing guides designers towards effective solutions that improve the overall look and feel of the application.

To conduct effective usability testing, designers must follow a thorough process. They need to define the scope of testing, decide on the testing approach, and create user tasks that align with the application's objectives. Tasks should be clearly defined with realistic goals, and the testing environment should be conducive to unbiased evaluation. During testing, designers ensure that testers complete tasks independently, observing their interactions and collecting detailed feedback. After testing, designers analyze the results, document findings, and iteratively refine the design based on identified issues.

Analyzing usability test results requires meticulous attention to collected data. Designers must identify patterns and recurrent issues indicating areas for improvement. Quantitative data is used to measure insights, while qualitative data provides deeper understanding of user behaviors and experiences, guiding iterative design refinements to optimize usability and enhance user satisfaction. (Interaction Design Foundation, n.d.)

5.1 Usability test cases

The usability test cases designed to evaluate the carbon footprint tracking and reduction application. Usability testing is instrumental in assessing how effectively users interact with the application, achieve tasks, and navigate its features. Each test case comprises a scenario, objectives, tasks, and observations aimed at capturing user experiences and feedback. By systematically examining user interactions in controlled scenarios, this section aims to identify usability issues, gather insights, and refine the application's design iteratively. The test cases serve as a critical component in ensuring that the application aligns with user expectations, enhances user satisfaction, and fosters meaningful engagement with sustainability initiatives. Through these test cases, the thesis aims to validate the usability and effectiveness of the application's design and functionality.

5.1.1 Navigation

The navigation usability test cases focus on evaluating the ease and efficiency of accessing key features within the carbon footprint tracking and reduction application. By observing user interactions during these navigation tasks, the usability test assesses the intuitiveness and clarity of the application's layout and structure. The following table outlines the navigation usability test cases conducted to evaluate the accessibility and intuitiveness of key features within the application.

Table 4. Usability test cases - Navigation.

Scenario	Objective	Task	Observations
Home Screen Navigation	Evaluate ease of accessing key features from home screen	Navigate to "Home screen" section and locate "Monthly emission Savings" feature.	Tester had some difficulty understanding the phrasing. This indicates the phrasing should be simplified.
Finding Sustainable Challenges	Test clarity of navigation labels and icons	Explore sustainable challenges. Find and access different difficulty levels (easy, medium, hard).	Tester initially had difficulty locating the “impact” feature. This suggests that more saturated colours should be used.
Accessing News Feed	Assess user engagement with external news integration	Locate and browse news feed. Go through the various tags.	Tester thought the animation for an article being removed from saved was to abrupt. This asks for a smoother transition.
Navigating to Profile Settings	Test accessing and modifying user profile picture	Navigate to your user profile and attempt updating you profile info.	Tester quickly located feature from their profile, demonstrating ease of engagement.
Exploring Rankings	Evaluate interaction with user tanking and leaderboard.	Check your current rank among other users. Navigate to the "Ranking" section and describe how you would view monthly emissions savings rankings.	Tester navigated to the ranking page and easily located their rank; this indicates clear information display choices.

5.1.2 Task Completion

The task completion usability test cases assess the application's functionality in facilitating users to achieve specific actions or goals. Through these tests, the thesis evaluates how efficiently users can complete tasks within the application interface. User feedback and observations from task completion tests inform iterative design enhancements to streamline task processes and improve user efficiency. Refer to the table below for a comprehensive overview of the task completion usability test cases.

Table 5. Usability test cases -Tast Completion.

Scenario	Objective	Task	Observations
Adding Daily Task	Test process of adding new sustainable action	Commit to a new sustainability action. Add "Switch to LED bulbs" to daily tasks.	Tester completed task but expressed confusion about how to mark the task as completed. This indicates a need for clearer task management instructions.
Clearing Completed Tasks	Evaluate efficiency of task management features	Clear all completed tasks from list.	Tester efficiently cleared all completed tasks from the list, demonstrating good understanding of task management features.
Sharing News Article	Test user engagement with article sharing functionality	Find an interesting article on sustainable practices. Share article with a friend using app's sharing feature.	Tester easily shared the article using the app's sharing feature. This highlights effective implementation of article sharing functionality.
Setting Monthly Emissions Target	Evaluate user interaction with profile customization	Update monthly emissions target. Navigate to profile settings, access emissions target, and adjust based on sustainability goals.	Both testers had difficulty locating the monthly emissions target. This indicates the phrasing
Exploring Detailed Emissions Breakdown	Assess understanding of carbon footprint breakdown.	Explore detailed emissions breakdown for the month. Navigate to the "Analysis" section and describe how you would access information on transportation, food, energy, waste, and other categories.	Tester located the detailed emissions breakdown for the month easily, this indicates that the feature was well located.

5.1.3 User Experience

The user experience (UX) usability test cases focus on assessing overall user satisfaction and engagement with the carbon footprint tracking and reduction application. By observing user behavior, feedback, and emotional responses during these tasks, the thesis gauges the application's appeal, interactivity, and perceived value. The table below provides details the user experience (UX) usability test cases.

Table 6. Usability test cases -User Experience.

Scenario	Objective	Task	Observations
Engaging with emission recording	Test user interaction with emission recording	Record a recent emission	Tester had difficulty locating the feature in the home page. This shows the feature needs to be moved to a more prominent area.
Browsing Analysis recoded	Assess ease of accessing analysis items	Navigate to “Analysis” and go through the various sections and collect information about a specific product.	Tester browsed through the analysis pages with ease and interacted with easily with the various functionalities.
Checking Progress Bar	Evaluate user interaction with progress indicators	Check weekly progress towards emission reduction goals. Interpret progress bar and understand performance.	Tester interpreted the progress bar accurately and expressed satisfaction with the visual representation
Checking default settings	Assess user interaction with default emissions function	Browse through your default emissions survey to identify if data is accurate.	Testers found their default emissions with ease and successfully interacted with the feature.
Explore data charts	Evaluate user comprehension of displayed graphs	Browse through your user data graphs and describe what you understand.	Tester browsed through emission graphs and easily understood them.

5.2 Design Iteration

After conducting usability testing on the application, several changes were implemented to enhance the overall user experience based on tester feedback:

1. Text Color Adjustments:

Addressed the issue of overly prominent and highlighted text by adjusting the color of certain texts to improve readability and visual balance within the interface. This change aimed to create a more harmonious color scheme throughout the application. Figure 17 presents the visual representation of the iteration done on the design of the prototype.

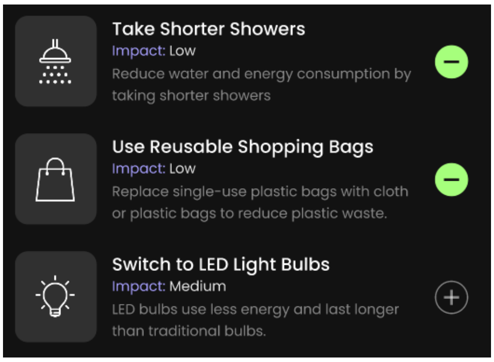

Figure 17. Design iteration - text color adjustment.

2. Task Management Optimization:

Modified the task management layout to ensure that all checked actions are displayed at the top of the list for improved visibility and efficiency. This adjustment facilitates quicker task review and completion for users. Figure 18 presents the visual representation of the iteration done on the design of the prototype.

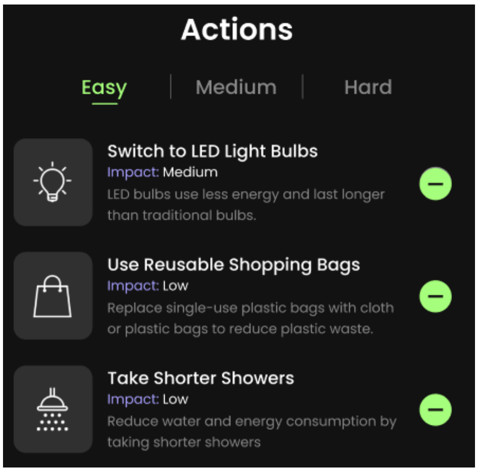

Figure 18. Design iteration - task management.

3. Clear All Checked Actions:

Implemented a clear function to enable users to easily remove all completed or checked actions from their task list. This feature streamlines task management and declutters the user interface. Figure 19 presents the visual representation of the iteration done on the design of the prototype.

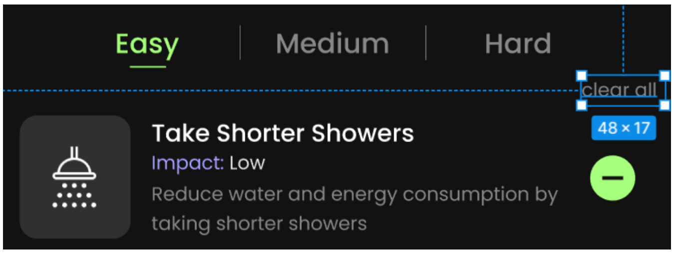

Figure 19. Design Iteration - clear all function.

4. Pop-Up Interaction Enhancement:

Updated the pop-up interaction behavior to allow users to close pop-up windows by clicking outside the dialog box. This change enhances user control and simplifies navigation within the application. Figure 20 presents the visual representation of the iteration done on the design of the prototype.

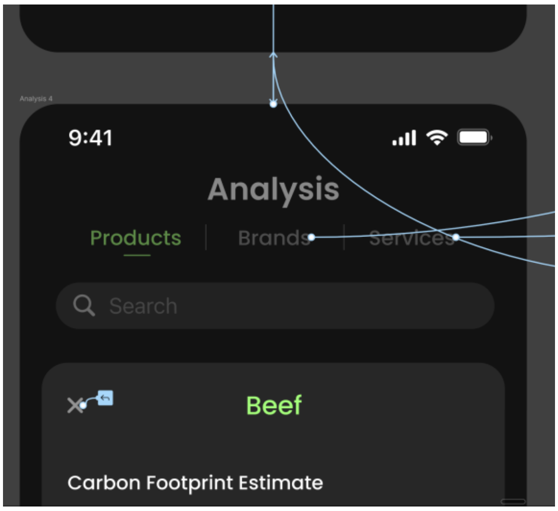

Figure 20. Design iteration - pop-up interaction.

5. Visual Indicator for Monthly Carbon Footprint:

Adjusted the color of numbers indicating an increase in monthly carbon footprint from green to purple. This color change provides a clearer visual cue, signaling negative changes or areas of concern, thereby improving data interpretation for users. Figure 21 presents the visual representation of the iteration done on the design of the prototype.

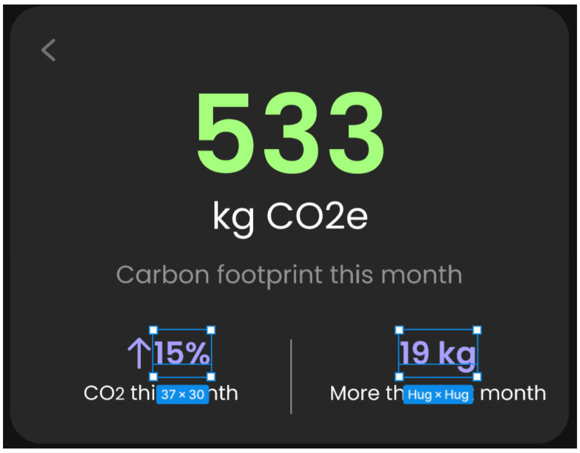

Figure 21. Design iteration - text color enhancement.

6. Main Page Feature Placement:

Moved the "carbon emission recording" feature to the main page for easier access and visibility. This adjustment recognizes the importance of the feature as a primary function within the application, enhancing user convenience and facilitating frequent use. Figure 22 presents the visual representation of the iteration done on the design of the prototype.

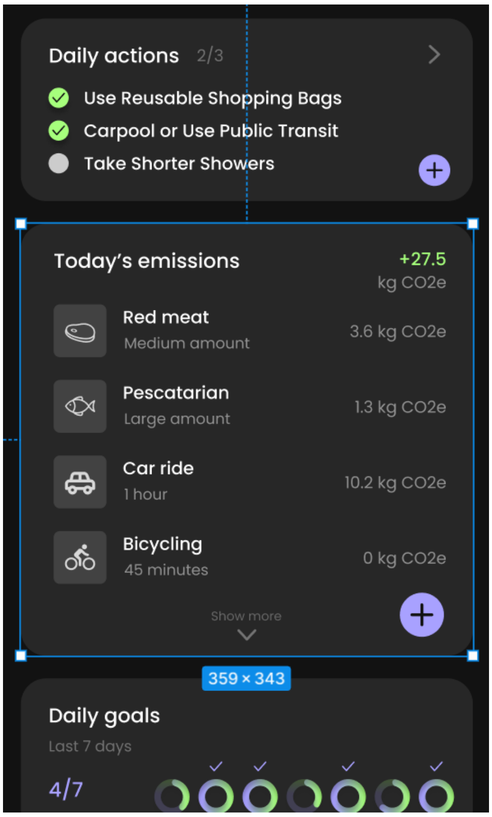

Figure 22. Design iteration - feature placement.

These updates were strategically implemented based on usability test findings to address specific usability issues and enhance user satisfaction with the application. Each change aimed to optimize navigation, task completion, and overall interaction, reflecting a user-centered design approach focused on improving user experience. The iterative nature of these adjustments demonstrates a commitment to continuous improvement and responsiveness to user feedback.

6 Conclusion

In conclusion, with the primary goal of this thesis being to design and develop an interactive prototype for a carbon footprint tracking and reduction application that enables individuals to monitor, manage, and reduce their environmental impact, it analyzed and implemented various aspects and principles of sustainable technology through the design and development of an interactive Figma prototype for a carbon footprint tracking and reduction application. The research began with the exploration of digital solutions for carbon reduction and sustainable living, employing UI and UX design practices to conceive a prototype aimed at fostering personal environmental awareness among users.

The thesis utilized foundational principles of sustainable living, analyzing consumption patterns and behavioral aspects to inform methodologies for calculating carbon footprints and addressing associated challenges. Research methodology centered on understanding target audience segments based on digital skills, internet behaviors, and sustainability awareness, culminating in the creation of user personas that guided the prototype's design.

Pulling insights from existing carbon footprint tracking applications, the design phase prioritized user-centric design principles, integrating sustainable practices to enhance the platform's effectiveness and user appeal. Key features such as carbon footprint tracking, sustainable actions, and community competition were strategically incorporated to engage users and motivate behavior change.

Usability testing played a key role in refining the prototype, focusing on navigation, task completion, and overall user experience. Iterative design improvements based on test outcomes ensured that the application met user needs and expectations, facilitating a seamless and impactful user journey.

Through this thesis, we have demonstrated the potential of digital platforms to empower individuals in monitoring and reducing their environmental impact. By offering a user-friendly and engaging tool for personal environmental awareness, the prototype contributes to advancing eco-friendly digital solutions that promote sustainability and facilitate the transition towards a greener future.

Looking ahead, the insights attained from this research can inform broader efforts in sustainable technology development, emphasizing the importance of user-centered design, accessibility, and sustainability integration. As we navigate the challenges of resource depletion and climate change, the implementation of technology and sustainability will continue to play an essential role in shaping a more environmentally conscious society.

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