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# Rebottle Rewards: An Iot-Integrated System For Incentivized Plastic Waste Management

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***Abstract:*** The Plastic Waste Management and Reward System is designed to promote responsible plastic disposal by leveraging technology to incentivise users for recycling efforts. The system integrates Flask for backend processing, AngularJS, HTML, CSS, and JavaScript for a dynamic frontend, and ImageDB for cloud-based image storage. MySQL is used for secure transaction and user data management, ensuring reliability and efficiency. The platform employs AI-powered image recognition models to classify plastic waste accurately, allowing users to earn rewards based on proper disposal. Rigorous testing methodologies ensure performance, security, and scalability. Future enhancements, including blockchain-based rewards, AI-driven classification improvements, and IoT-enabled smart bins, will further optimize waste tracking and management. This project presents an innovative approach to tackling plastic waste pollution by merging technology with sustainability.

***Index Terms:*** Plastic Waste Management, Reward System, Recycling Incentives, Flask Backend, AngularJS Frontend, ImageDB Cloud Storage, MySQL Database, AI-powered Image Recognition, Waste Classification, Secure Transactions, Performance Testing, Security Testing, Scalability, Blockchain Rewards, IoT Smart Bins, Sustainability, Waste Tracking, Environmental Technology

## I. Introduction

Plastic pollution remains a significant global issue, with improper disposal leading to environmental degradation and health hazards. The Plastic Waste Management and Reward System provides a technological solution by encouraging individuals to recycle plastic waste responsibly through a reward-based model. The system is built on a scalable architecture that utilizes Flask for backend processing, AngularJS for a responsive and dynamic frontend, and ImageDB for cloud-based image storage. MySQL ensures secure management of transactions and user data, making the system reliable and efficient. Users can upload plastic waste images, which are classified using AI-powered models, and receive rewards based on correct disposal.

The development process involves rigorous unit, integration, functional, and security testing to ensure system stability. Cross-platform compatibility and security measures such as encryption and authentication are incorporated to enhance user experience and data protection. By integrating smart waste tracking and incentives, the project fosters eco-friendly habits and contributes to a more sustainable waste management system.

### i. Project Purpose

ReBottle Rewards is an innovative initiative designed to encourage sustainable plastic waste management by integrating IoT technology with an incentivized recycling system. This project enables users to deposit plastic bottles into an intelligent recycling machine, which employs AI-powered image recognition and material analysis to assess the plastic quality and determine its recyclability. Upon successful validation, the system credits reward points to the user's account, which can be redeemed for purchases on an integrated e-commerce platform or supplemented with actual monetary transactions. The project combines both hardware and software components, ensuring a seamless and interactive user experience. The system employs Flask (Python) for backend operations, AngularJS for a responsive frontend, and ImageDB for efficient cloud-based image management, enhancing the overall functionality and user engagement.

**ii. Project Scope**

The scope of the ReBottle Rewards project encompasses the development, deployment, and integration of a smart plastic recycling incentive system. It is designed to facilitate secure user authentication, real-time AI-driven plastic quality verification, and an intuitive reward-based recycling process. Core functionalities include QR code scanning for user identification, automated plastic classification using AI-based image processing, and seamless integration with an e-commerce platform to enable reward redemption. The backend, built using Flask, handles transaction processing and system logic, while the AngularJS-based frontend provides a dynamic and user-friendly interface. AI algorithms enhance the accuracy of plastic quality assessment, reducing human error and improving efficiency. ImageDB supports cloud storage for managing image assets, ensuring reliability and scalability. The platform aims to optimize plastic waste management practices while fostering environmental responsibility through technology-driven incentives.

## II. Related Work

**i. Anna Kremel, "Consumer Behaviour in a Circular System – How Values Promote and Hinder the Participation of Young Adults in the Swedish Deposit-Refund System for Beverage Packaging", 19 December 2023, Springer Nature [1]**

The study explores how young adults in Sweden engage with the deposit-refund system (DRS) for beverage cans and PET bottles using Consumption Value Theory (CVT). Key motivators include convenience, financial incentives, and social influence, while barriers like inconvenience, time constraints, and social stigma hinder participation. Although functional values such as ease of access and rewards encourage recycling, emotional and social factors also play a role, with some feeling guilt or peer pressure. In certain social settings, recycling is stigmatized as a sign of financial need, discouraging participation. The study suggests that financial incentives alone are insufficient, as some individuals donate refunds rather than keeping them. To improve recycling rates, it recommends enhancing convenience, reducing social stigma, and leveraging technology, such as gamification and AI-powered classification, to better engage young users.

**ii. Peter Berks, Molly Sears, Rebecca L.C. Taylor, Carly Trachtman, Sofia B. Villas-Boas," Reduce, reuse, redeem: Deposit-refund recycling Programmes in the presence of alternatives", March 2024, Ecological Economics [2]**

This study examines consumer behaviour in California's Beverage Container Recycling Program, which offers refunds for returning recyclable beverage containers. Using a discrete choice model based on survey data, it evaluates consumer willingness to pay (WTP) for different recycling methods, including kerbside collection, government-subsidized drop-off centres, and non-subsidized centres. While financial incentives boost recycling rates, decisions are also influenced by convenience, social factors, and effort required. Increasing the California Redemption Value (CRV) deposit raises recycling rates but mainly shifts consumers from kerbside collection to drop-off centres rather than increasing overall participation. The study also finds that eliminating government-subsidized drop-off centres has little impact, as consumers adapt by using processing fee centres or kerbside collection. Additionally, demographic factors like income and education shape recycling choices, with higher-income individuals preferring kerbside collection and lower-income households opting for drop-off centres for cash refunds.

**iii. Aggeliki Konstantoglou, Thomas Fotiadis, Dimitris Folinas, Athanasios Falaras and Konstantinos Rotsios," Accessing Consumer Perceptions of the Effectiveness of the Deposit Refund System",12 June 2023, MDPI [3]**

The study examines consumer perceptions of Greece's Deposit Refund System (DRS) and its effectiveness in promoting recycling through a survey across multiple cities. Using Structural Equation Modelling (SEM), it finds that moral and environmental motives significantly influence DRS participation, with a one-unit increase in motivation improving consumer perception by 0.346 units and adoption by 0.296 units. However, barriers such as machine malfunctions, overflowing bins, unclear instructions, limited recycling points, and inadequate support hinder participation. Financial incentives alone are insufficient; consumers stress the need for greater awareness, convenience, and social reinforcement. To enhance DRS effectiveness, the study recommends improving consumer education, expanding collection points, and ensuring better system reliability.

**iv. Comparison with Existing Systems**

The ReBottle Rewards system stands out from conventional recycling platforms by integrating IoT-enabled hardware with a user-centric reward model. While systems like Canada's Return-It Smart allow users to deposit bottles at designated stations, they lack real-time validation and dynamic reward features. Similarly, India's Swachh Bharat Recycle App promotes awareness but relies on manual waste logging without incorporating automated sorting or incentivization mechanisms.

In the Indian context, Dry Waste Collection Centres (DWCCs) established in cities such as Bengaluru serve as decentralized waste hubs. Though some centres are beginning to adopt digital tracking, they remain largely

manual and do not provide user engagement or direct rewards for responsible recycling behaviour. These systems focus more on backend processing rather than encouraging individual participation at the source.

ReBottle Rewards addresses these gaps by using QR-based authentication, ultrasonic sensors for waste detection, and servo-controlled sorting. Unlike traditional models, it also allows users to redeem accumulated points not just through a digital storefront but also for biodegradable products, reinforcing environmentally conscious behaviour. This approach promotes both technological innovation and sustainability, making ReBottle a scalable solution suitable for educational, municipal, and public environments.

Furthermore, the system's modular design enables easy customization and integration across diverse settings without significant infrastructural changes. Its ability to function as a standalone unit with minimal maintenance makes it practical for deployment in urban as well as semi-urban environments. By combining efficient hardware operation with a reward mechanism that emphasizes sustainable consumption, ReBottle Rewards fosters long-term behavioural change, encouraging users to participate actively in plastic waste reduction efforts.

## III. Problem Identification & Statement

### i. Problem Identification

Plastic waste management remains a critical environmental issue due to the large volume of non-recycled plastic that accumulates in landfills and water bodies. A significant challenge in recycling efforts is the lack of automated systems that efficiently evaluate plastic quality and incentivise responsible disposal. Traditional recycling methods rely heavily on manual sorting, leading to inefficiencies, contamination, and a reduced recycling rate. Additionally, the lack of consumer motivation and awareness further exacerbates the issue.

The Rebottle Rewards project addresses these challenges by providing an AI-driven recycling solution that automates plastic quality assessment and integrates a reward-based incentive system. By leveraging AI for plastic classification and IoT for machine automation, this project enhances accuracy and efficiency in plastic waste processing. Users are encouraged to recycle through a transparent, technology-driven approach that tracks their contributions and rewards their participation. The integration of a digital platform allows users to monitor their recycling activities, redeem rewards, and contribute to sustainable practices effortlessly.

### ii. Problem Statement

The ReBottle Rewards system is designed to tackle the challenges associated with plastic waste management, including inefficient sorting mechanisms, lack of user engagement, and limited incentives for responsible recycling. Traditional recycling processes involve extensive manual labour, which is time-consuming, error-prone, and often leads to misclassification of plastic waste. Furthermore, the absence of a structured incentive system discourages individuals from participating in recycling Programmes.

This project aims to provide an efficient and automated solution that employs AI-driven plastic quality assessment to classify recyclables accurately. By integrating IoT-enabled smart machines with a reward-based system, ReBottle Rewards encourages active user participation. The platform offers real-time data insights, seamless reward redemption, and an interactive user experience through its web-based interface. By streamlining the recycling process and incorporating gamified incentives, the system fosters environmental consciousness and promotes responsible waste disposal at a broader scale.

## IV. Goals & Objectives

The ReBottle Rewards system aims to create an intelligent and user-friendly platform that incentivizes plastic recycling through AI-based authentication and IoT-enabled automation. By integrating real-time plastic quality assessment and a structured rewards model, the system enhances recycling participation while promoting environmental sustainability. It ensures a seamless user experience through efficient authentication, transparent reward allocation, and an accessible digital interface.

Key objectives include automating plastic classification using AI for accurate recyclability assessment and enabling quick user interaction through QR-based authentication. A structured points-based incentive system encourages consistent recycling, while multi-device accessibility ensures scalability. The system is designed to foster sustainable waste management practices by making recycling convenient, engaging, and rewarding for users.

## V. System Requirements

### i. Software Requirements

The system is built on a scalable architecture, utilizing Flask for backend processing, AngularJS for a dynamic frontend, and ImageDB for cloud-based image storage. MySQL ensures secure transaction and user data management, while development is conducted using Visual Studio Code for coding and debugging.

### ii. Hardware Requirements

The system is built using an Arduino UNO R3 Clone Microcontroller as the core processing unit, integrated with a Breadboard GL-12800 for circuit layout. An Ultrasonic Sensor HCSR04 detects plastic waste placement, while a SG90 Servo Motor (180 Degrees) enables controlled sorting. The ESP32 CAM Development Board with an OV2640 Camera Module captures images for classification, supported by an Arduino Wi-Fi module for cloud connectivity. Jumper wires facilitate stable data transmission between components. This setup ensures efficient waste identification, processing, and remote monitoring, with scalability for future AI integration and enhanced plastic waste tracking.

## VI. Project Design

### i. Workflow Design

The ReBottle Rewards system provides an efficient recycling process integrated with a rewards-based shopping experience. As shown in Figure 1, the process begins with user registration and login. Once authenticated, upon successful login, they reach the home page, where they can either scan a QR code to connect to a bottle deposit machine, access customer support, or proceed to the "Shop Now" section.

When a user scans the QR code, the system establishes a connection with the deposit machine. The user can then insert a bottle, which undergoes a fraud detection to determine if it is recyclable. If the bottle is not eligible, the user is notified to try again.

If accepted, reward points are credited to the user's account. Users who choose "Shop Now" are redirected to the shopping section, where they can add items to their cart and complete transactions using either their earned reward points or standard payment methods. Customer support is available for assistance, and confirmation emails are sent for key interactions. The system ensures data security through authentication protocols and encrypted transactions, maintaining user privacy and operational efficiency.

### ii. User Authentication and Security

User authentication is secured through login credentials, ensuring only verified users access the platform. Multi-factor authentication (MFA) enhances security, while session management ensures auto-logout for inactive users. Based on authentication, users are redirected to their dashboard, where they can track rewards, manage their profile, and engage with the system. Unauthorized users attempting to access restricted areas are redirected to the login page, maintaining system integrity and security.

## VII. Implementation

### i. Backend – Python (Flask)

The backend of the ReBottle Rewards system is developed using Python, leveraging the Flask framework for efficient transaction handling, API integration, and user authentication. Python's robust data processing capabilities enable seamless communication between the smart recycling machine, the database, and the web application. Flask provides a lightweight yet scalable architecture, allowing smooth interaction between the user interface and the backend while managing reward allocation, user authentication, and transaction records. The integration with MySQL ensures secure data storage, while APIs facilitate real-time plastic quality validation and reward point updates.

### ii. Frontend – HTML, CSS, JavaScript (AngularJS)

The frontend of the ReBottle Rewards system is built using HTML for structuring web pages, CSS for styling and responsive design, and JavaScript, specifically AngularJS, for dynamic interactivity. The user interface includes login and registration pages, a dashboard displaying reward points and recycling history, and navigation options to scan a QR code, access the shopping section, or contact support. CSS ensures a visually appealing and mobile-friendly layout, while JavaScript manages form validation, dynamic content updates, and seamless API communication. The frontend dynamically retrieves and displays user transactions, reward balances, and shopping cart details, ensuring a smooth and engaging user experience.

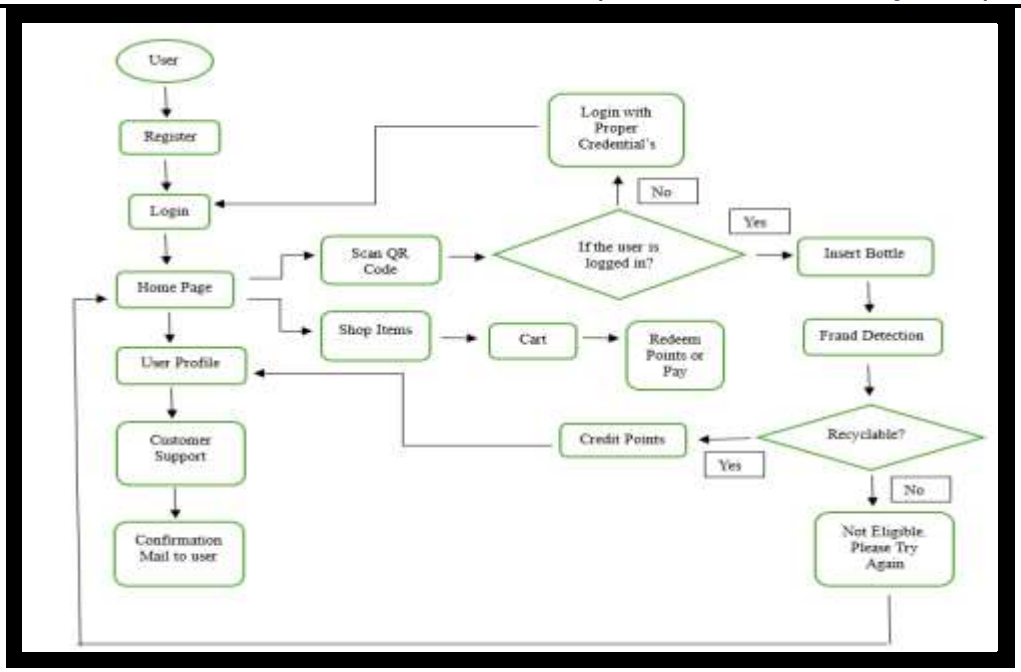


**Figure 1: Workflow of ReBottle Rewards**

## VIII. Adoption Potential

The ReBottle Rewards system holds significant potential for widespread adoption across various public and institutional environments due to its modular design, user-friendly interface, and sustainability-driven incentive model. In municipal settings, the system can be integrated into smart city infrastructure to support local waste management initiatives. By strategically placing ReBottle units in public parks, markets, and transit hubs, municipalities can promote responsible plastic disposal while actively engaging citizens in environmental conservation. The system's ability to log individual contributions and distribute rewards can be tied to local government sustainability campaigns, thereby enhancing public participation and awareness.

Educational institutions such as schools, colleges, and universities present another ideal environment for deployment. ReBottle can serve as both a practical recycling tool and an educational aid, promoting environmental consciousness among students through gamified participation and reward-based motivation. Institutions can incorporate the system into campus sustainability programs, encouraging students to earn points for plastic waste deposits and redeem them for eco-friendly products or campus-based incentives, such as bookstore discounts or cafeteria vouchers.

In the commercial and corporate sector, ReBottle can be implemented in shopping malls, office complexes, and corporate campuses to align with organizational sustainability goals. Businesses adopting green policies can use the system as part of their Corporate Social Responsibility (CSR) initiatives, offering incentives to employees and visitors who engage in recycling. Additionally, its compatibility with digital platforms and low-maintenance design ensures that ReBottle can be deployed with minimal operational overhead, making it a viable solution for long-term use in both high-traffic and community-oriented spaces. Its adaptability, combined with the positive behavioural impact it fosters, positions ReBottle as an effective tool for promoting environmentally responsible habits across multiple sectors.

Moreover, the system's data-driven functionality allows administrators to monitor usage patterns, track recycling volumes, and generate insightful reports for planning and policy-making. This analytical capability not only supports continuous improvement of waste management strategies but also enables measurable impact assessment, making ReBottle a valuable asset for institutions committed to transparency and environmental accountability.

## IX. Results

### i. Website Pages


**Figure 2: Home Page**

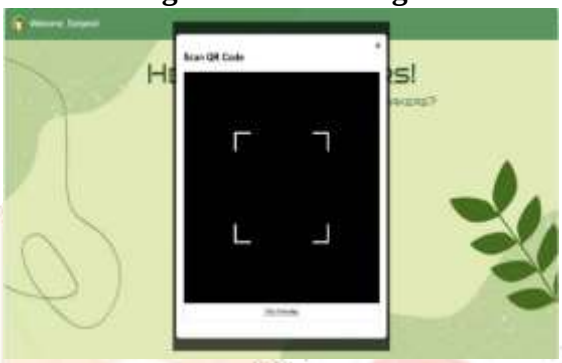


**Figure 3: QR Code Scanner**

**Figure 4: Shop Now Page with Cart and Points Redemption**

**Figure 5: Payment Page**

Figures 2 to 5 illustrate the core interfaces of the ReBottle Rewards platform, emphasizing a user-centric design and seamless navigation. Figure 2 displays the Home Page, which acts as the main dashboard after login. It includes quick navigation options such as Scan Here and Shop Now, along with access to the user's Profile section. The layout is clean and intuitive, designed to ensure ease of access for users of varying age groups and digital literacy levels. Figure 3 presents the QR Code Scanner interface, enabling users to securely link their device with a recycling unit. The scanner initiates a verified session and facilitates real-time tracking of individual recycling activity, compatible across mobile and desktop platforms.

Continuing through the system, Figure 4 highlights the Shop Now Page, where users can browse and redeem their reward points for eco-friendly products or daily-use items. This module includes features like a shopping cart, product listings, and point balance display to simplify the shopping experience. Lastly, Figure 5 showcases the Payment Page, where users complete their redemption using either reward points or a hybrid payment method. The interface employs secure protocols to protect user data and ensure a smooth, trustworthy checkout process, thereby enhancing overall user satisfaction.

### ii. Testing Outcomes

The ReBottle Rewards system was tested over a five-day trial involving 15 users, during which 140 plastic bottles were deposited. Of these, 135 transactions were successfully processed, reflecting a 96.4% success rate. The average response time from QR scan to confirmation was 1.4 seconds, ensuring a quick and efficient user interaction.

User feedback indicated that 88% of participants found the system easy to use and appreciated the clarity in reward tracking. On average, users earned 12–20 points per session, which were successfully redeemed through the integrated reward module, including options for biodegradable product redemption.

Technically, the system maintained 97.5% uptime, and the ESP32-CAM and sensor components performed reliably under continuous operation. Image data captured during testing had a 92% success rate in validation. The system interfaces, shown in Figures 2 to 5, supported a smooth experience across key functions such as login, QR scanning, shopping, and payment processing, demonstrating the platform's readiness for wider deployment.

## X. Testing Methodology

The **ReBottle Rewards system** underwent rigorous testing to ensure its reliability, security, and efficiency across all components. Various testing methodologies were applied to validate both functional and non-functional aspects of the system.

**Unit Testing:** Individual components, including QR-based user authentication, AI-driven plastic classification, and reward point calculations, were tested to confirm their accuracy and reliability.

**Integration Testing:** The interaction between the frontend, backend, and MySQL database was validated to ensure seamless data flow. The QR code scanning module, reward distribution system, and user authentication were tested for smooth integration.

**Functional Testing:** Core features such as user authentication, plastic classification, reward redemption, and transaction tracking were thoroughly tested to ensure correct operation. Edge cases, such as incorrect QR codes or invalid plastic submissions, were also considered.

**Performance Testing:** The system's response time and efficiency were analysed under different workloads using tools like JMeter. High-load scenarios, such as multiple concurrent QR scans and reward redemptions, were tested to ensure stable system performance.

**UI & Usability Testing:** The user interface was evaluated for intuitive navigation, responsiveness across various devices, and accessibility compliance. The system maintained an optimal user experience across mobile and web platforms.

**Security Testing:** Security vulnerabilities such as SQL injection, authentication bypass, and cross-site scripting (XSS) were assessed. Data encryption was implemented for sensitive information, and secure session management was verified.

**Compatibility Testing:** The system was tested on multiple browsers (Chrome, Firefox, Edge, Safari) and devices (Windows, macOS, Android, iOS) to ensure consistent user experience and functionality across all platforms.

**Regression Testing:** Test cases were rerun after feature updates to verify that no existing functionalities were affected. Automated tests ensured system stability after modifications.

**Beta Testing (User Acceptance Testing - UAT):** A beta version of the system was released to a select group of users. Real-world feedback on usability, system responsiveness, and feature effectiveness was collected and analysed. Necessary refinements were made based on user input.

**Final Deployment & Monitoring:** The system was deployed to a staging environment for final validation. Analytics tools were used to monitor system errors, user interactions, and performance metrics post-launch. Continuous improvements were made based on real-time data and user feedback.

## XI. Future Enhancements

• **AI-Driven Plastic Classification Improvements:** Enhance the AI model to Recognise a wider range of plastic types with higher accuracy, improving sorting efficiency and recyclability assessment.

• **Gamification & Leaderboards:** Introduce gamification features such as leaderboards, achievement badges, and reward milestones to encourage user participation and long-term engagement.

• **Mobile App Development:** Expand the platform with a dedicated mobile application for seamless QR code scanning, reward redemption, and recycling tracking on the go.
• **Multi-Language Support:** Integrate multilingual support to cater to diverse users and promote sustainability awareness across different regions.
• **Enhanced Security Measures:** Implement multi-factor authentication (MFA), biometric login, and encrypted storage for safeguarding user data and transactions.
• **Corporate & Institutional Collaborations:** Expand partnerships with businesses, schools, and municipalities to implement large-scale recycling Programmes and reward initiatives.

## Conclusion

The Plastic Waste Management and Reward System successfully integrates Flask, AngularJS, ImageDB, and MySQL to create an efficient and scalable platform for incentivizing responsible waste disposal. The system's AI-driven classification, secure transactions, and intuitive frontend provide a seamless experience for users while encouraging eco-friendly practices. Through comprehensive testing and validation, the platform ensures reliability, security, and cross-platform compatibility. Future developments, such as blockchain-based rewards, IoT-enabled smart bins, and advanced AI classification models, will further enhance the system's functionality. This project not only promotes environmental sustainability but also fosters a community-driven approach to plastic waste reduction, paving the way for a cleaner and more responsible society.

## Author Contributions

i. Prof. Sathya Sheela D: Project supervision, technical mentoring, and evaluation strategy.
ii. Divya T: Hardware module development, including sensor integration and Arduino programming.
iii. Sanjana V: Backend development using Flask, MySQL integration, and AI model training for plastic classification.
iv. Sathya Sai Sri B S: Frontend development using AngularJS, UI/UX design, and responsive layout structuring.

## References

1. Kremel, Anna. "Consumer behaviour in a circular system–how values promote and hinder the participation of young adults in the Swedish deposit-refund system for beverage packaging." *Circular Economy and Sustainability* 4, no. 2 (2024): 1427-1446.
2. Berck, Peter, Molly Sears, Rebecca LC Taylor, Carly Trachtman, and Sofia B. Villas-Boas. "Reduce, reuse, redeem: Deposit-refund recycling Programmes in the presence of alternatives." *Ecological Economics* 217 (2024): 108080.
3. Konstantoglou, Aggeliki, Thomas Fotiadis, Dimitris Folinas, Athanasios Falaras, and Konstantinos Rotsios. "Accessing consumer perceptions of the effectiveness of the deposit refund system." *Sustainability* 15, no. 12 (2023): 9429.