Towards a Green Digital Currency for Smart Communities: An AI-Powered Ecosystem for Citizen Green Stewardship

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Abstract: This paper proposes a new ecosystem vision designed to measure and incentivize citizen and corporate engagement in environmental stewardship through circular economy (CE). The ecosystem uses a gamified platform where participants earn digital points for performing two types of operations: (1) recycling matters and (2) reusing items, within smart communities. We propose to consider these points as a new global digital currency redeemable for rewards and services offered by participating businesses worldwide. The businesses are mainly the polluters that aim to have green advertisement and engagement in the "polluter pays" principle. Consequently, these businesses will benefit simultaneously from green advertising and tax reductions. A suite of digital services and AI-powered tools are used to optimize operations and generate valuable data for improving both urban and rural sustainability initiatives. By making this new currency, we can assess environmental engagement, motivate citizens to adhere into CE, and impose hierarchical participation in sustainable practices. This paper outlines the ecosystem's components, discusses the feasibility of our proposal, and explores its potential benefits and challenges for various stakeholders.

1 INTRODUCTION

The escalating global environmental crisis demands innovative solutions to foster widespread citizen engagement in sustainable practices. Traditional approaches, such as education campaigns and regulatory measures, often fall short in motivating individuals to adopt environmentally friendly behaviors. This paper introduces "Green Points," a novel ecosystem that leverages gamification, digital services, and AI to incentivize sustainable actions.

The new ecosystem operates as a digital platform involving hierarchical participation, where individuals earn points for completing environmentally friendly actions. These points serve as a digital currency that can be redeemed for rewards and services offered by participating businesses, particularly those with a history of environmental impact. By incentivizing sustainable behaviors and fostering a sense of community among different actors, Green Points aims to contribute to the UN Sustainable Development Goals (SDGs) defined for 2030 Agenda, namely:

- SDG 11: Sustainable Cities and Communities,
- SDG 12: Responsible Consumption and Production,
- SDG 13: Climate Action,
- SDG 15: Life on Land,
- SDG 17: Partnerships for the Goals.

The ecosystem integrates digital services and AI-powered tools to optimize operations, track environmental impact, and generate valuable data for improving urban and rural sustainability initiatives. This data-driven approach enables informed decision-making towards achieving a more sustainable and equitable future for all, contributing to the overarching goals of the 17 UN SDGs.

The paper begins by giving a brief literature review in section 2. Then, in section 3, we outline the framework of our proposal and delve inside each component, followed by the ecosystem flow in the 4th section. Section 5 is dedicated to a developed

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prototype called Snowber that serves as a local platform in Algeria. Then we discuss big data analytics, AI tools integration in section 6. The potential and challenges of the proposal are provided respectively in section 7 and 8. We conclude by discussing the findings and exploring opportunities to enhance our approach.

2 LITERATURE REVIEW

The circular economy (CE) is an economic model that aims to eliminate waste and keep resources in use for as long as possible. Unlike the linear economy, which follows a "take-make-dispose" model, the CE emphasizes recycling, reuse, and repair to minimize resource consumption and reduce waste (Hungaro *et al,* 2021). This approach promotes sustainability and resilience by decoupling economic growth from resource depletion and environmental degradation.

Ecological engagement refers to the active involvement of individuals and organizations in environmental protection and sustainability initiatives (Genovese et al.2017; D'Amato et al. 2017; Elia et al. 2017). For citizens, this can include personal actions such as reducing waste, conserving energy, and supporting sustainable businesses. For businesses, ecological engagement involves adopting environmentally friendly practices, reducing their carbon footprint, and contributing to community sustainability initiatives.

Governments play a crucial role in fostering ecological engagement and promoting a circular economy (D'Amato et al. 2017; Elia et al. 2017). They can implement policies and regulations that incentivize sustainable practices, invest in infrastructure for waste management and recycling, and support research and development in CE technologies. Additionally, governments can raise awareness about environmental issues and encourage citizen participation in sustainability initiatives.

Many solutions have been proposed to promote citizen recycling by rewarding them from engaged companies through gamification (Oliveira *et al.* 2021; Santos-Villalba *et al.* 2020), while also considering the potential negative impact of gamification on green consumption behavior (Shahzad, Xu, Rehman, *et al.* 2024). But none has made a central solution where all actors are connected together and use a local digital currency.

On the other hand, the concept of "Smart Community" originated in Silicon Valley, California, in the early 1990s as a response to a severe economic recession (Lindskog, H., 2004). Local leaders, including businesses, community members, government officials, and educators, collaborated to revitalize the region. This collaborative approach to addressing local challenges laid the foundation for the concept of Smart Communities, which has since gained global recognition. While the concept has global applications, its implementation often relies on local initiatives and community-driven solutions.

Numerous studies have investigated Smart Communities and the role of Information Communication Technology (ICT) in advancing sustainability within smart homes and smart manufacturing. For instance, Méndez *et al.* (Méndez, *et al.* 2023) explored methods to encourage sustainable behavior in smart homes by integrating social interaction, personalized gamification, and tailored Human-Machine Interfaces. Their research aimed to enhance user engagement and overcome barriers to adopting smart home technologies within a community setting. Similarly, Sajadieh and Noh (Sajadieh and Noh, 2024) acknowledged the limitations of existing Industry 4.0 maturity models in evaluating the unique aspects of Urban Smart Factories (USFs), such as sustainability, resilience, and human-centricity.

Policy and reform are key elements in Smart Communities, besides smart data and innovation. A Smart Community transcends geographical size. It can encompass a local neighbourhood or extend to a nationwide network, as long as the members share common interests. This collaborative spirit is key. Residents, organizations, and governing bodies all work together to leverage ICT to improve their community's circumstances, transforming their collective reality through technological innovation.

While Smart Cities primarily focus on leveraging technology to improve the efficiency and sustainability of urban environments, Smart Communities emphasize a more holistic approach that prioritizes community well-being, social equity, and environmental sustainability. Although distinct, there's significant overlap between these concepts. Many Smart City initiatives incorporate community engagement and aim to enhance the quality of life for residents.

Blockchain, the foundation of cryptocurrencies, can enhance the CE by improving traceability, transparency, and incentivizing sustainable actions through tokenized rewards (Hakimi *et al.* 2024; Fang, *et al.* 2022). While dedicated "green" digital currencies does not exist yet, blockchain-based platforms offer a promising avenue in Smart Communities.

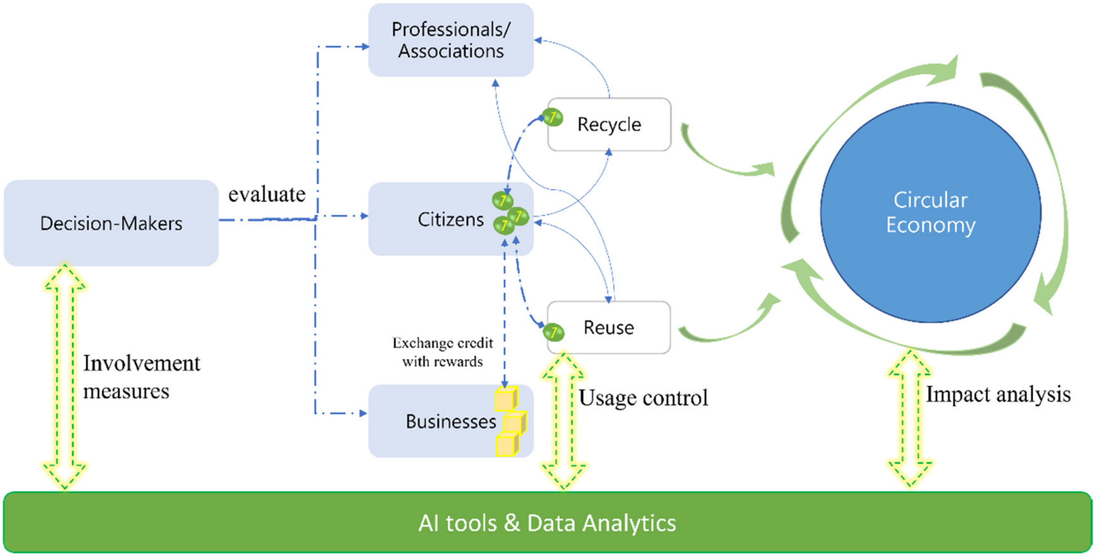

Figure 1: Proposed Ecosystem for Citizen Green Stewardship. The Recycle/Reuse operations performed between citizen, professional and associations empower the CE process, e.g., when a citizen performs a "reuse" operation, he gets green points, which represent a currency exchangeable for rewards. Thus, the operations are rewarded by services and products from the participant businesses. The businesses can also be rewarded by re-evaluating their taxes. AI tools and Data analytics empowers the system at different levels.

In this article, we discuss a new global ecosystem with a digital currency for Smart Communities where all actors can be connected and assessed by governors to encourage ecological actions and eco-responsible advertisement for businesses. A decision support system (Jarke *et al.* 2013; Eboigbe *et al.* 2023) is integrated to provide relevant analytics for decision-makers. AI tools are proposed to optimize and manage related operations.

3 PROPOSAL

To explain our proposal, we illustrate the global ecosystem in Figure 1. This ecosystem focuses on CE enhancement through the collaboration of four key actors composing Smart Communities:

- Decision-Makers: The government actors that evaluate different actors' engagement based on data analytics, and set rules on operations, limits for green points, etc.
- Stakeholders: All direct participating actors in the recycling, collect, transformation or reconditioning. They can be associations, collectors, or supply chain workers.
- Citizens: The core actors. They earn green points for Recycling / Reusing actions.
- Businesses: Any company that offers rewards and services in exchange for Green Points, and receive tax reductions.

The two main operations that are used to empower the circular economy are Recycle and Reuse:

- **Recycle:** this operation is dedicated to matters, and is done between citizens and environmental actors.
- **Reuse:** this operation is dedicated to give a second life for used articles, and it is done between citizen or actors (associations, reconditioners, renovators etc.).

We consider that other operations such as repairing, renting or borrowing can be included under specific Reuse actions.

4 ECOSYSTEM FLOW

The following list outlines the key stages of the Green Points ecosystem flow, illustrating how citizen actions, platform interactions, and digital services work together to create a virtuous cycle of sustainable behavior in a Smart Community. This dynamic interplay of actions and processes drives the ecosystem's effectiveness in achieving its broader sustainability goals:

- Actors' interaction through the digital platform: Citizens and associations/ professionals utilize a digital platform to offer or search offers, or connect with others users. The businesses use the platform to propose rewards in exchange of digital points. Decision-makers analyze the participation of all actors and businesses.

- AI-Powered optimization: AI algorithms (e.g., Genetic algorithms) optimize the collect journey from different users in the neighborhood, recommend the best offers (e.g., Classification), match profiles of users with appropriate partners, and facilitate efficient transactions. Successful transactions are recorded, and the number of Green Points is estimated depending on the offer (e.g., Polynomial regression).
- Data analytics insights & continuous improvement: AI analyzes collected data to provide insights for optimizing system performance, improving efficiency, and informing policy decisions. The system is continuously refined based on data analysis, user feedback, and emerging technologies.

This flow fosters a dynamic cycle of citizen and business engagement, with AI tools, driving sustainable behaviour within the community.

5 PROTOTYPE “SNOWBER”

To prove the applicability of our global ecosystem for Smart Communities, we implemented a digital platform that supports the new proposal. The platform is called ‘Snowber’ - pine trees in Arabic-, and it is designed to handle both recycling and reusing operations (Figure 2). The separation between the two operations is due to the heterogenous types of items and users in each operation. For instance, recycling is dedicated to waste (matters) when reuse is dedicated to goods (second-life items). The other difference is that recycling waste mostly involve matters recyclers, when reusing goods can interest all kinds of users (citizen, reconditioners, renovators etc.).

By doing so, we can partition the platform by theme into two different mobile applications: ‘Snowber Recycle’ and ‘Snowber Reuse’, but yet find almost the same functionalities. Citizens can use the same account in both applications to keep track of their activities. Each user of the mobile applications will get a unique Green Code. This code is used to finalize transactions between users when a collect is achieved. This may avoid fictive accounts or transactions.

A policy of Green Points Credit attribution is set to provide initial credit to associations and professionals to enable making collects and transfer credit to citizen.

Let us now delve into each step of the process as illustrated in Figure 3:

1. User identification: The users can be either citizen, associations or professionals of recycling. A unique Green Code is given to users.
2. Choosing an operation from the main menu: (a) Add an item by filling the form with its details (photos, description, quantity, quantity unit, price, price unit if not free, and location); (b) See pending items of the user on the marketplace; (c) Search for items by checking the marketplace pages or dynamically on Maps; (d) See conversations with other users; (e) Check notifications about conversations, reservations, points and rewards; (f) Edit profile
3. To add an offer or search for offers, the two applications offer different categories depending on whether it is recycled matter or reused item.
4. Choosing an item: The user can directly chat with the owner to make reservation. After reservation, the status of the item is visible to all users as ‘reserved’. The collector can optimize his journey using maps to collect the maximum of items he reserved on the platform. To finalize the collect, the user provides his green code to the owner to be introduced in the platform.
5. Getting points: Introducing the green code of the user allows to finalize the collect, retrieve points from the user to the owner and increment the number of ecological operations for both users.
6. Getting redeemed: The businesses role now is to reward citizen, to their ecological actions and exchange credit with services or production.
7. Reevaluating taxes and stewardship of businesses by decision-makers.
8. Reevaluating stewardship and Green Points metrics are calculated based on historical data.

The platform has been tested over a six-month period to validate the technical operations. However, full validation depends on participating businesses in order to collect real-world data and perform analytics.

Figure 2: Different types of goods considered in Reuse Mobile Application (Up) vs. different types of matters in Recycle Mobile Application (Down).

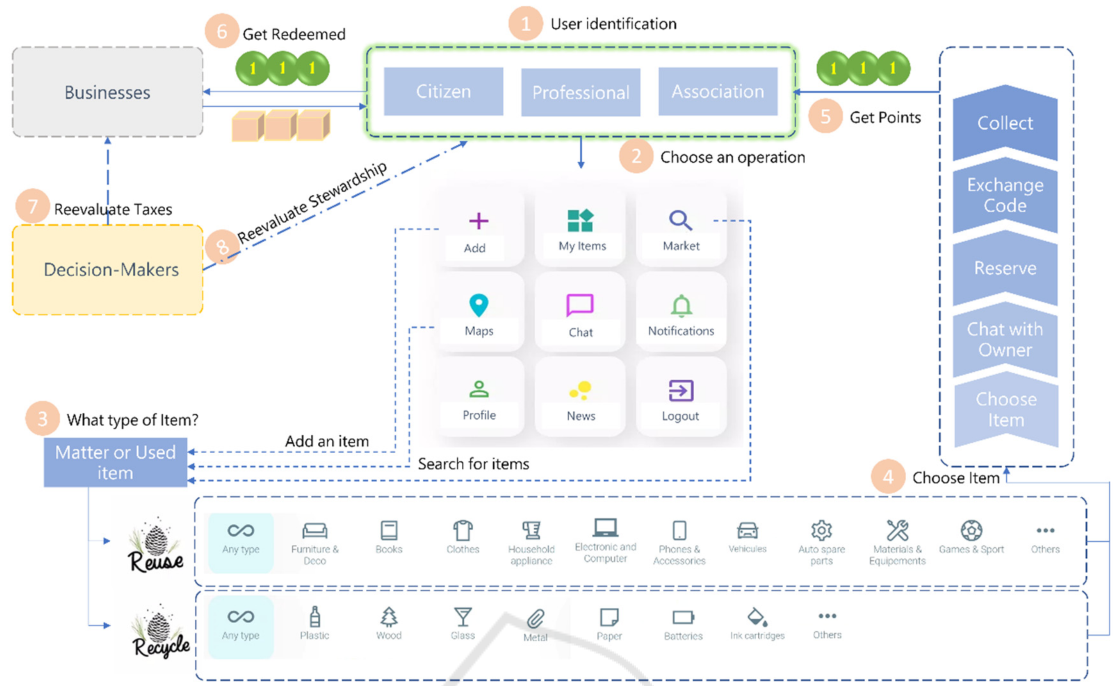

Figure 3: Prototype of Snowber Platform for Recycle/Reuse operations using two mobile applications (Reuse & Recycle) The main actors interact with the platform by either using the marketplace (citizens, professional recycles or associations), redeeming green points (businesses) or evaluating stewardship (decision-makers).

To illustrate the usage of our platform, let's consider a use case centered around Snowber Recycle (Figure 4), our application dedicated to recycling. Note that the process for Snowber Reuse is similar, with the primary difference being the types of items involved.

A visitor can explore the marketplace without logging in. However, to interact with offer or create new offers, they must log in as either a citizen or a professional/association.

The marketplace offers two primary methods for exploration:

- List View: Users can scroll through a list of items sorted by price, distance, or type. This provides a traditional browsing experience.
- Map View: This interactive map visually displays nearby offers, allowing users to easily identify items of interest within their vicinity.

Once a user selects an item, they are presented with detailed information, including its type, price, quantity, and a description. To initiate a transaction, the user can contact the owner through an integrated chat system to discuss reservation details.

If the owner accepts the reservation request, he will update the item's status to "reserved," preventing other users from claiming it. This ensures a smooth and efficient transaction process and avoid unnecessary contacts.

When the user retrieves the item, he exchanges the unique Green Code with the owner. This code serves as a digital token to finalize the transaction and record the exchange on the platform.

Upon successful completion of the transaction, the platform automatically allocates Green Points to the owner based on the type and quantity of the item. These points can be redeemed for various rewards or used to support future recycling initiatives.

6 BIG DATA & AI

Smart data plays a crucial role in enabling Smart Communities. To effectively leverage this data, the integration of AI tools is essential. Furthermore, operating on a large scale necessitates a robust decision-making framework underpinned by powerful analytics and the capacity to process large datasets. This section outlines key analytical requirements and proposes a target schema for a data-warehouse to facilitate informed decision-making. We then explore the potential integration of AI tools within our ecosystem.

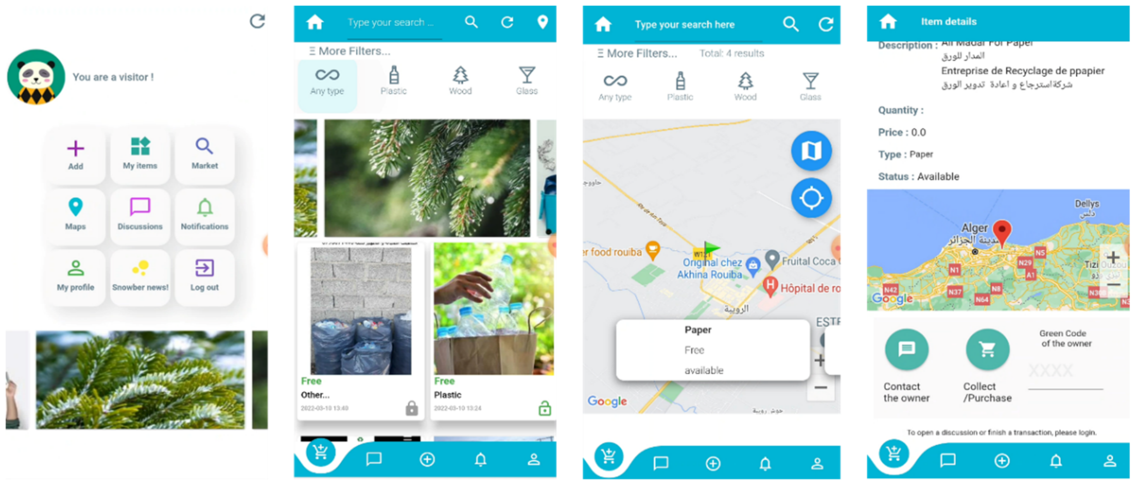

Figure 4: Example of the prototype deployment of Snowber Recycle Application. From left to right, the first image shows the home page for a visitor user. The second image shows the market place dedicated to matter offers. The third image shows the market place on maps. The last image shows details of a selected offer.

6.1 Data Analytics

The analytics to be done by our decision support system are mainly:

- Environmental and social research: The system helps providing valuable data on recycling trends, patterns, and impacts. It also analyzes recycling rates, quantities, and types by region, time, and user category.
- Employment analysis: It allows tracking employment trends in recycling-related fields (e.g., collection, distribution, etc.) and analyzing employment rates by type, region, and time.
- Food waste analysis: Analyzing food waste quantities, types, and locations. And consequently, identifying patterns and trends for food waste reduction strategies.
- Health impact analysis: Analyze potential health problems related to environmental factors (e.g., pollution, waste exposure etc.). Consequently, identify areas of concern and develop targeted interventions.
- Efficiency analysis: Compare the efficiency of traditional waste collection methods with geo-localization-based approaches. Then, evaluate the impact of optimized collection routes on resource utilization and environmental impact.

6.2 Data-Warehouse Design

To support our decision-making process, we design a data-warehouse dedicated to provide the previously listed analytics for decision-makers (e.g., governments, industrials and scientists).

After defining the target analytics, the next step is to select the data sources for integration. For this step, we choose to use the operational databases of our platform. The target schema of the data-warehouse to be designed can be defined as follows:

- Dimensions: The selected dimensions for our decision support system are time (Date, month, year, hour, day of week), type of materials/goods (offer (paper, plastic, electronics, etc.), localization (geographical location e.g., country, region, city), user type (citizen, professional or association) and demographic information (age, gender, income).
- Fact table: The main facts are Recycling/Reusing operations. The corresponding measures are the number of offers and quantity per type.

6.3 AI Tools Integration

AI techniques can be used to regularly re-evaluate the weight of Green Points, transactions efficiency and environmental impacts depending on existing data. The more the platform is used, the more relevant and valuable the data becomes. In the following, we provide some AI tools integration possibilities:

- **Recommendation and optimization:** Machine learning techniques can be used to match the most suitable recyclers or reuse partners based on location, item type, and availability. Meta-heuristics can also be used to optimize collection

routes for recyclers, minimizing travel time and fuel consumption.
- **Predictive analytics:** Forecasting recycling trends, and predict resource needs.
- **Fraud detection and prevention:** Using anomaly detection techniques allows identifying suspicious activities, such as fraudulent point accumulation. Image recognition can be used to verify the authenticity of recycled materials.
- **Enhance user experience:** Chatbots and virtual assistants provide instant support and guide users through the process.

7 POTENTIAL

The proactive engagement of all stakeholders within the ecosystem will strengthen all links in the circular economy chain, laying the foundation for a smart community. This positive impact is anticipated to have significant repercussions across various sectors. Here we outline a non-exhaustive list of some of the expected positive outcomes of our proposal:
- **Ecological impact:** The new ecosystem will significantly impact the environment by enhancing recycling efforts. This includes optimizing collection routes to minimize fuel consumption and emissions, encouraging source separation of waste to improve material quality, and ensuring proper management of toxic waste to prevent environmental contamination. Furthermore, the system will promote sustainable manufacturing practices (repairing, reconditioning, and sustainable production).
- **Social impact:** The new system can significantly enhance social well-being by generating employment opportunities in the CE, including waste collection, processing, and distribution. It promotes improved working conditions for waste collectors, fostering a more dignified and safe working environment. Ultimately, the new system contributes to a higher quality of life by creating a healthier environment.
- **Economic impact:** Improved environmental quality can lead to significant economic benefits. Lower healthcare costs can be realized due to a decrease in illnesses linked to environmental factors, such as respiratory diseases and certain cancers. This translates to lower insurance costs for individuals and businesses as reduced environmental risks diminish the likelihood of health claims. Moreover, by promoting efficient waste management and reducing the need for costly disposal methods, the system can help municipalities significantly lower their spending on recycling and waste treatment programs. For businesses, this system is more advantageous since they use green advertising instead of investing in costly advertising campaigns.

8 CHALLENGES

Realizing the full potential of the Green Points ecosystem will require long-term commitment and collaboration from various stakeholders. The implementation of the new ecosystem will inevitably encounter challenges that require careful consideration and proactive planning to overcome potential obstacles and maximize the positive impact of the system.

This section provides the key challenges facing the successful implementation of the ecosystem:
- **Decision-maker involvement:** Active participation from government agencies and policymakers are crucial for the successful implementation and scaling of the system.
- **Blockchain technology:** Exploring the potential of blockchain technology can enhance transparency, security, and immutability in the management of digital points and transactions. Blockchain's immutable and decentralized nature ensures that all transactions involving Green Points are recorded transparently and publicly verifiable. This eliminates the possibility of data manipulation or fraudulent activities.
- **Cryptocurrency:** Cryptocurrency can facilitate cross-border Green Point exchanges, fostering a global network of sustainable practices and providing financial inclusion for underserved communities. However, volatility and regulatory challenges exist. Utilizing stablecoins and closely monitoring the regulatory landscape are crucial for mitigating these risks and ensuring the long-term success of cryptocurrency integration.
- **Interoperabili**ty: Integrating the system with existing smart city infrastructure, such as public transportation and waste management systems, can enhance efficiency and user experience.
- **Data privacy and security:** Ensuring the secure and ethical handling of user data is paramount. Robust data privacy and security measures must be implemented and regularly audited.
- **Transparency and trust**: Maintaining transparency in all system operations is critical for building and maintaining trust among all stakeholders.

- **Scalability and sustainability:** The system must be designed to accommodate a growing user base and evolving needs while ensuring its long-term sustainability and environmental impact.

While many challenges exist, the potential benefits warrant a concerted effort to address them proactively.

9 CONCLUSIONS

This paper introduces the "Green Points" ecosystem, a novel gamified platform designed to incentivize and measure citizen engagement in sustainable practices within a circular economy framework. By rewarding environmentally friendly actions like recycling and reusing, the system motivates individuals to adopt eco-conscious behaviors. Green Points, functioning as a digital currency, can be redeemed for rewards and services offered by participating businesses.

The proposed ecosystem offers significant benefits to various stakeholders:

- Citizens: Increased motivation for sustainable actions, access to rewards and services, and a sense of community involvement.
- Businesses: Enhanced brand reputation through "green advertising," potential tax reductions, and increased customer loyalty.
- Communities: Sustainable and healthier environment, with more job opportunities within the circular economy sector.

The paper explores the core components of the Green Points ecosystem, including its gamification mechanics, digital currency system, and stakeholder engagement strategies. The feasibility of the system is demonstrated through the development of a prototype platform, "Snowber" composed of two mobile applications. By leveraging big data analytics and AI tools, the system can be continuously optimized to maximize its impact.

To fully realize the potential of the new ecosystem, further research and development are crucial. This includes investigating the integration of emerging technologies such as blockchain and cryptocurrency, exploring its economic viability and policy implications, and developing strategies for large-scale implementation. Future research should also delve into considering other metrics (e.g., carbon credits), the long-term sustainability of the system, and exploring the potential for cross-border collaboration to foster a global network of sustainable practices, ultimately contributing to the emergence of a global, interconnected smart community.

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