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Codesigned Digital Tools for Social Engagement in Climate Change Mitigation

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Abstract: Digital technologies and economies can strengthen participative processes and data- and knowledge-based sustainable urban development. It can also accelerate social integration and the efforts of urban dwellers towards more resilient urban environments. Gap: Most of the tools that strengthen participatory processes were not cocreated with stakeholders. Research shows that codesigned platforms driven by new technological advances and the development of collaborative sharing economy concepts can increase climate change awareness. Still, the rise of participatory innovation technologies does not focus on enabling social engagement in climate change mitigation. Therefore, this paper addresses a research question: can a codesigned community currency stimulate bottom-up initiatives for climate change mitigation, and what is needed for such tools to succeed with the implementation of climate-responsive policies? The aim was to introduce an approach allowing us to codesign an application to encourage pro-environmental behaviors. Hence, the approach of this research was to define the concept of such a tool as a part of a cocreation process with stakeholders in a multidisciplinary and cross-sectoral environment. Method: It uses design thinking enriched with case studies evaluation, workshops, UX design, low fidelity, SUS, and testbeds. Findings and value: The authors introduce the Greencoin concept and argue that the codesigned digital currency operating based on an educational application has the potential to strengthen social engagement in climate change mitigation. Beneficiaries and practical implementation: Such a tool can increase climate awareness by supporting social integration and bottom-up initiatives for climate change mitigation. It can therefore be used by local communities to strengthen their climate-responsive efforts.

Keywords: eco currency; codesign; climate change mitigation

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1. Introduction

While cities cover only 3% of the planet, they use 80% of the energy and are responsible for 75% of the global emissions [1]. The climate impact of cities already has observable effects on the environment. The net cost of damage due to climate change is likely to be significant and to increase over time [2]. Breakthrough technologies may help to respond to the global problem of combating climate change [3]. At the same time, the engagement of urban dwellers in the mitigation processes remains limited, while local urban climate adaptation is characterized to a large extent by public tasks [4]. While local authorities seek to facilitate the engagement of residents, there is still a lack of participatory approaches associated with climate change [5]. The lack of integrated efforts hampers the effectiveness of urban resilience toward climate change [6]. Stimulating climate awareness and enabling community-based mitigation action, which by definition focuses on societal behavior taken to reduce or eliminate emissions [7], can help to build adaptive capacity [8]. However, most of the tools designed with the aim of strengthening bottom-up engagement were not cocreated with stakeholders. Despite the rise of participatory innovation platforms, there is still a limited number of digital tools that strengthen participatory urban planning processes and almost none that facilitate social engagement in climate change mitigation toward strengthening circularity, resilience, and other aspects crucial from the perspective of shaping sustainable and climate-responsive cities. At the same time, the research confirms the need to explore environmental benefits of ICT tools and whether such solutions meet the initial expectations regarding value for sustainability [9].

This article reports on an ongoing research project devoted to developing a codesigned community currency (CC) called Greencoin (GC) aimed at encouraging sustainable everyday practices among city residents. With such a solution, our aim was to introduce a system which is a new type of digital currency operating on the basis of an application to shape climate awareness and strengthen mitigation efforts.

Research shows how the design thinking (DT) methodology is useful for developing such applications that encourage users to be actively involved in shaping a climate-responsive built environment [10,11]. Such a methodological approach focuses on a human-centered design that allows us to find innovative solutions [12–14]; therefore, it was used in the GC project to develop a concept for a community currency application to encourage pro-environmental behaviors.

This article addresses the following research questions:

Q1: Can a codesigned community currency strengthen social engagement in climate change mitigation?
Q2: Can a codesigned community currency stimulate bottom-up initiatives for climate change mitigation?
Q3: What solutions are needed for such a tool to contribute to the implementation of urban climate change policy?

2. Theoretical Background

2.1. Social Engagement and Climate Awareness

There are numerous studies confirming the significant impact of digital technologies on the development and promotion of mitigation actions including circular economy (CE) and climate awareness among different groups [15–17]. New technologies such as big data, the Internet of Things, advanced sensors, blockchain technology, data-based platforms, and prediction tools have an important role in the fight against climate change issues and influencing the attitudes of air polluters, decision makers, and urban dwellers [18]. The visualization of, e.g., footprint results using digital software will be further enhanced with low carbon solutions and behaviors in cities [19] Urban dwellers and climate activists are drawn to these pro-ecological digital mechanisms because of the way they are promoted as well as their accessibility, inclusiveness, and reusability [20]. Pro-environmental technological boosters, such as eco-apps, e-learning platforms, forums, and eco-programs are increasing in popularity due to a reduction in the need for intermediaries, the possibility of almost instant cooperation and coordination, a tendency towards democratization of user groups, and higher chances to be involved in the process of cocreation [21].

As this paper introduces community currency, it is important to emphasize the role of CE in the process of climate change mitigation. It puts emphasis on prolonging the life cycles of goods, reusability, reduction of the carbon footprint of products and services, and sustainable growth based on local value chains and eco-oriented behaviors. While changes in attitudes and behaviors are not easy to achieve, digital technologies have proven to be useful in shaping lifestyles, e.g., in diets, sports, fashion, leisure activities, housing, and even education and social activism [22,23]. Individuals changing their behavior spatially and temporally in response can play a key role when fostering efforts toward climate change mitigation [24]. Changes in attitudes and behaviors are often accelerated by social ties and group affiliations, which can be strengthened by digital technologies. Self-developing and cocreated processes can strengthen such networks. These network effects are based on the persuasion that comes from group membership, which offers more benefits than costs incurred in the process and meanwhile perpetuates activities that aim to upgrade membership, often leading to an increase in expenditure, with the latter subjectively perceived as a "pay-off" [25]. Therefore, digital tools—as platforms and means of network effect formation and strengthening—appear as powerful instruments in the promotion of pro-environmental behaviors.

Research confirms that digital tools (e.g., video games, mobile applications, and social media) are useful for promoting climate change engagement, pro-ecological education, and communication [15,26,27]. Mobile applications are used to promote the principles of CE, e.g., circularity, reusability, recycling, repair, and sharing of services and goods (e.g., e-cargo bikes) in order to reduce the carbon footprint [15,28]. According to Marres and Gerlitz [27], digital social research on climate change on Twitter confirms the robust dynamism and impact of social media on society, providing room for a potentially strong impact of digital methods on groups of users and the promotion of proclimate actions.

Finally, the drawbacks of implementing technological solutions, e.g., due to a lack of stakeholder commitment, too fast and unappealing innovations, mismatched strategy and business models, or apathy due to the unclear impact of pro-ecological actions [15], should be of major concern when developing a CC for climate engagement. To address these issues, GC is designed and modified through a codesign process in collaboration with stakeholders and potential end users to ensure their involvement and essential technological adjustments and to tailor the business strategy to the needs of the local society, local economy, and environment.

2.2. Participatory Approach to Climate Change Mitigation

Studies show a steady increase in efforts from a range of actors to facilitate and support meaningful and effective engagement with communities and stakeholders to mitigate climate changes [29,30]. However, we observe that most of the participatory activities are focused on risk management and rapid disaster response, e.g., [31–33]. Resilience is obviously one of the crucial factors, but other aspects of climate change mitigation should not remain out of scope.

Adaptation of new technologies can increase their accessibility and effectiveness. McKinley et al. [30] identified that successful adaptation for enhancing urban resilience should include a rapid response to change, adoption of a diversity of techniques, broadened participation, and supported social learning and knowledge exchange. Indeed, digital technologies can help civic action, including by mobilizing large communities, sharing resources, and distributing power [34]. Digital social innovation and online platforms for citizen participation in policymaking can help people respond to social challenges and shape healthy urban conditions [35].

The implementation of smart city concepts in urban areas worldwide may contribute to a transition from the "digital divide" to "digital inclusion" [36]. Digital services have the ability to facilitate networking and interaction between stakeholders; hence, they can enhance collaboration towards sustainable development [37]. Innovations in data processing and exchange can strengthen participative processes and online knowledge management in local systems [38]. Strategic intelligence and collaborative innovation occur as important factors in the implementation of successful tools that allow new platform development [37].

However, public participation only leads to more ambitious and transformative local climate governance when it recognizes all actors and provides meaningful engagement at all decision-making stages [4,39]. Therefore, to ensure public engagement and awareness of communities when providing digital tools, justice and equity should be two of the crucial concerns [5]. Such participatory solutions should provide learning and empowerment tools that shape an increased willingness for community cooperation and dialogue [40,41]. Only then is increased individual behavioral change, resulting in stronger and more resilient communities, manageable [42].

Public participation in local decision-making may be seen as a condition of success in transforming societies towards climate resilience and carbon neutrality [4,43]. It is therefore essential to study locality-based person–environment relationships within different contexts [44].

2.3. Role of Digital Tools in Urban Participatory Processes

Social participation in the process of mitigating climate change calls for a stakeholder-centric approach. Research shows that the engagement of stakeholders can be achieved while designing digital practices to promote positive change [45]. However, to keep the attention of urban dwellers, there is a need to involve stakeholders in cocreating value and to introduce solutions illustrating the benefits of applying a stakeholder-centric perspective. Digital solutions can process behavioral data and as a result present the impact that makes it possible to further shape attitudes towards climate change [33,46,47].

Studies of the spatial pattern of behavior of individuals, visualization of social networks, recognition and simulation of individual mobility, and sentiment analysis can be used to design engagement tools that stimulate pro-environmental behaviors. As discussed by Ågerfalk et al. [45], urban dwellers who develop knowledge about socially sustainable behaviors are likely to continue this in the future. Moreover, self-organizing mechanisms can contribute to shaping sustainable behavior [48] and indirect participation [49].

The emergence of technology innovation hubs in cities presents an opportunity for developed and developing countries alike. Connections and communities are key success factors for the growth and sustainability of urban technology innovation ecosystems [50]. Technologies can accelerate efforts towards more sustainable urban environments. It shows that platforms, designed with an aim to enhance, e.g., the sharing economy, can have a positive environmental impact. The development of such codesigned platforms driven by new technological advances and the development of collaborative sharing economy concepts increases climate change awareness [51]. However, to deliver technological innovation, the adoption of new or significantly improved production or delivery methods is required, which will in most cases entail the need to engage human resources [50].

3. Aims of This Research

The aim of this research was to introduce a concept for a codesigned community currency application to educate and encourage pro-environmental behaviors in urban dwellers. This aim was further fulfilled with the following supplementary goals, addressing accordingly our research questions:

G1: Evaluating digital tools for social participation to assess the social engagement and to define the stakeholders.

G2: Codesigning of a concept for a community currency application with stakeholders in a multidisciplinary environment.

G3: Conducting and evaluating an iterative process to develop the concept for the application design to ensure social engagement in climate mitigation processes.

4. Methodological Approach

Design thinking is a methodology that entails the full spectrum of innovation activities with a human-centered design ethos [52]. Moreover, considering both the role and underlying assumptions, DT is scalable and can be applied incrementally to improve existing ideas, or it can be applied radically to create disruptive solutions that meet the needs of people in entirely new ways [12–14].

As described in Figure 1, this research was divided into six stages that relate to the DT methodology. Here, we explain the iterative process of developing the concept. The process enabled the involvement of different actors during the process and established a base for the verification of each decision. The figure explains the deliverables of each stage as well as the tools used during the process. The process includes the evaluation of case studies as a base for further steps, a series of workshops, and the work of experts. A crucial part was the prototyping and testing phase, during which the use of user experience (UX) tools and system modelling allowed us to define the final concept, ending with the production of the GC application.

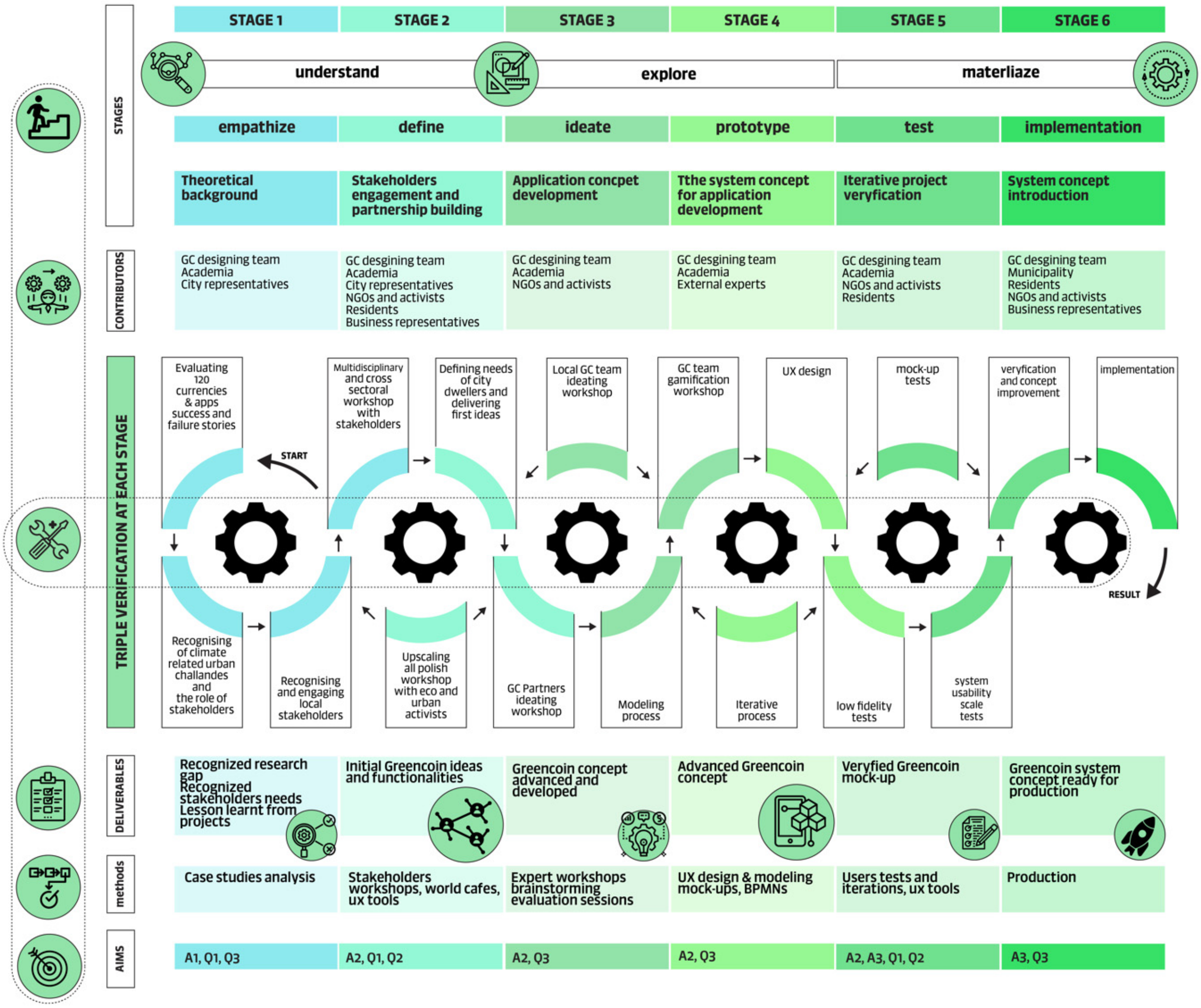

Figure 1. Research design—steps, contributors, methods, aims, and deliverables. Authors' own elaboration.

4.1. Contributors

The overarching goal of the project was to create an application that will serve city residents in developing and reinforcing their pro-environmental behavior. An indispensable part of designing such a solution was to include a variety of stakeholders in the process who will also be future users of the application. In Figure 1, we explain who contributed to the concept-designing process at each step. The contributors were defined at the early stage based on personas drawn by the initiating team and further invited based on the following criteria: (a) representatives of all sectors, (b) a variety of city representatives selected by the authorities after meeting about the initial concept, (c) local activists and residents encouraged by them to join our efforts, (d) academic partners based on competencies required for such a system to be designed, (e) business partners selected within an open call, and (f) other partners and contributors who joined the process when encouraged by those who were already involved as the process was kept open. A multidisciplinary and cross-sectoral environment was cultivated to develop the concept. The roles and inputs from the stakeholders changed and evolved depending on the level of concept advancement. Their input was mainly collected by means of qualitative research and observation of the stakeholders' involvement, the course and results of which are presented in more detail in the next sections of this paper. This included a series of workshops, both face-to-face and online, informal interviews, the development of a stakeholder's involvement strategy, and the creation of a foundation for long-term cooperation with crucial actors. The most important actors were city and private sector representatives, the nongovernmental sector, and residents.

4.2. Deliverables, Methods, and Research Phases

Step 1: Empathize—This step focuses on the identification of the main stakeholders or users and understanding their main needs, perspectives, and experiences [53]. This stage required a systematic literature review [54,55] and an analysis of 120 case studies to understand who the stakeholders are of the existing community currencies and applications that concentrate on pro-ecological actions designed to mitigate climate change. While analyzing the cases using the criteria of basic information, social aspects, operating bases, and technological aspects (findings published in our papers—[56,57]), we also addressed two questions:

- Who are the stakeholders or groups of people for whom the currency or application has been designed, and who is the target user of the proposed solution?
- What were the stakeholders' engagement and participatory mechanisms of the examined projects, with a particular emphasis on the mechanisms that succeeded and that failed?

Step 2: Define—This step focuses on engaging stakeholders in the codesign of climate change mitigation tools. This phase included a series of workshops involving different groups of potential audiences, direct and indirect.

Based on Step 1, we involved the following participants: residents, representatives of city institutions (e.g., city hall, municipal water suppliers, cultural centers), educational institutions (e.g., information and education center, sport center), private business (e.g., Lotos oil company, Olivia Centre), and nongovernmental organizations (NGOs).

The workshops were conducted on-site (local level) and remotely (national level) between October and November 2021 in Gdańsk, Poland. We gathered a total of approx. 50 stakeholders, who were accompanied by members of the project team acting as presenters, moderators, facilitators, or observers.

To facilitate relationships and enhance active engagement and discussion among participants, we created a collaborative learning environment using the World Café [58]. With an emphasis on users and their needs, seeing the problem from different perspectives, and working out a solution through frequent feedback, we also used the DT method [59]. Participants worked in groups to ensure the highest possible diversity of urban representatives in terms of their socio-professional roles. Each workshop was conducted according to the following phases: (1) presentation of the idea of introducing an alternative currency, (2) identification of challenges faced by the city inhabitants, (3) identification of existing good practices that could respond to the diagnosed challenges, (4) proposal of functionalities that could be included in the designed tool to support climate change mitigation, (5) analysis of the strengths and weaknesses of the potential solutions. During the workshops, we also used user experience tools such as "5 why", "jobs to be done", "empathy map", and "value proposition canvas" [60].

Step 3: Ideate—This step included iterative brainstorming and evaluation sessions [61], which lasted 9 months, starting in June 2021. Within this phase, consecutive concept versions of the system were developed in the form of a set of functionalities and evaluated with regard to the CC flow, user interaction methods, technical capabilities, and implementation risk assessment. The brainstorming session process included cooperation in a multidisciplinary and cross-sectoral team [62]. The process iterated on the following steps: obtaining input from stakeholders, designing (based on this input) in the project team (experts in different fields), and testing this design. A total of 11 experts from the disciplines of informatics, sociology, urban planning, economics, education, and user experience were engaged in a series of activities based on the results of Step 1. The working sessions were divided into weekly technical team meetings, biweekly all-teams meetings, three internal workshops, a gamification workshop facilitated by an external expert, and presentations followed by discussions at the end of the ideate stage iterations. During the process, the teams worked on developing the subsequent iterations of the system, beginning with a set of concept maps, and verifying the feasibility of the solutions in terms of the project goals by the end of each iteration.

Step 4: Prototype—We used prototypes during brainstorming sessions, which is an established way of eliciting functional requirements for software systems [63]. Graphical user interface prototypes and mock-ups were used to visualize the system at an early development stage to help explain ideas to nontechnical stakeholders and potential end users [64].

System modelling adds a level of abstraction that helps developers, analysts, and stakeholders better understand the planned functionality of the system [65]. To obtain different perspectives of our system, and to exclude unnecessary details and focus on the most essential elements, we used UML (unified modelling language), which is a standardized way of visualizing the design of systems [66]. We also used Business Process Model and Notation (BPMN) 2.0.2 [67] diagrams, which were used to model the business processes, data flow, and use cases of our system [68].

The BPMN standard introduces many different elements to be used in diagrams. In a BPMN diagram, a pool is used as the graphical representation of a participant of a collaboration. Lanes are used to partition a pool into smaller entities (distinct roles or subsystems of the participant). An event is something that can happen during the process and may change its flow. There are three types of event: start, intermediate, and end. Gateways are used to control the flow of the process, creating branching paths which will change the execution flow depending on a specified condition. A task of a process is an atomic activity to be performed in the process that cannot be broken down into a finer level of detail.

Step 5: Test—This step was for usability testing. It focused on UX research methods including user testing, task-based user interviews, and task-based testing [60]. It was enriched with the thinking-aloud protocol to collect participants' opinions on particular actions in the application [69]. We also used the system usability scale (SUS) survey [70] to pose ten questions, with five responses to each question [71], to measure the usability of the system under development. A total of 15 users participated in this phase to check the usability through the questions asked by us. The process was repeated 3 times in groups of 5 testers.

Step 6: Implementation—This step consisted of the preparation of the system specification, programming requirements, system architecture, and final design mock-ups [72,73].Two information systems researchers and a user experience/user interface specialist prepared the documentation during the process [74,75]. The specification was divided into functional requirements which described the system modules, nonfunctional requirements, description of the user management module, and system delivery requirements [76].

During the process, a technical dialogue with selected companies was applied [77,78]. The final version of the system specification and requirements was analyzed by three IT companies proficient in the delivery of mobile application-based solutions [79,80]. The process included four phases: the companies had two weeks to get acquainted with the presented specification and mock-ups, and each company attended an online meeting with the experts from the GC team to answer the companies' questions and help them understand the requirements. During the third step, the companies presented the written analysis of the specification, and lastly, the specification was adjusted, resulting in the full GC system specification and requirements [80,81].

5. Results

Step 1: Empathize—After analyzing 120 case studies of social or community currencies and applications that are relevant to behavior change toward climate mitigation [56,57,82]), we found that households, local communities, residents, local businesses, tourists, and collectors [83,84] are frequent examples of stakeholders in the examined sample. Less typical stakeholders are small- and medium-sized enterprises (SMEs), artisans, and unemployed residents [85]. The most frequent stakeholders are users/individuals, businesses, and partners [86]. Local institutions and tourists can also be stakeholders depending on the CC or the application aims and implementation methods [87].

We found that the analyzed projects often seek to involve a large number of stakeholders by making the inclusion criteria very broad while putting special emphasis on completing the project mission and goals (e.g., Engelgeld, KannWas, Ovolos) [88,89]. Given this, stakeholders are in general expected to share the main project goals, follow the rules, and support the project objectives (for example, to be pro-ecological, to be community-oriented, or to promote sustainability, etc.—e.g., Aikapankki, Beki, NU-Spaarpass) [83,85,89–91]. In the examined sample, the participants' engagement in the design process is rather limited, while the end users' engagement over time often determines the project's overall resilience, evolution, and final success or failure [92]. On the other hand, evaluation of the project strengths and bottlenecks requires the inclusion of other determinants, such as, e.g., financial aspects, established timeframe, strategy, and project goals [93].

Insofar as the community currencies and applications intend to attract as many users and participants as possible (e.g., Makkie, Brixton Pound, Balaton korona) [94,95], the precise definitions and characteristics of the target social groups are broad, inclusive, and often vague. In the examined sample, we learned that the number of users is typically given within two timespans with no regular examinations of the scale over the operating period. The community-oriented and alternative character of social currencies makes NGOs natural providers of these projects (e.g., Abeille, La Leman) [96,97]. Consortia are often involved in international grants that finance social currency projects [85]. In such a case, the responsibilities are clearly defined in the international grant contract. The majority of the CC providers are not-for-profit organizations, foundations, charities, associations, or limited liability companies [98]. Occasionally, CC providers are local municipalities [99]; however, such examples are less frequent.

Based on these insights, we developed a figure that visualizes the engagement mechanisms and the roles the stakeholders play at each phase of the project's duration (Figure 2).

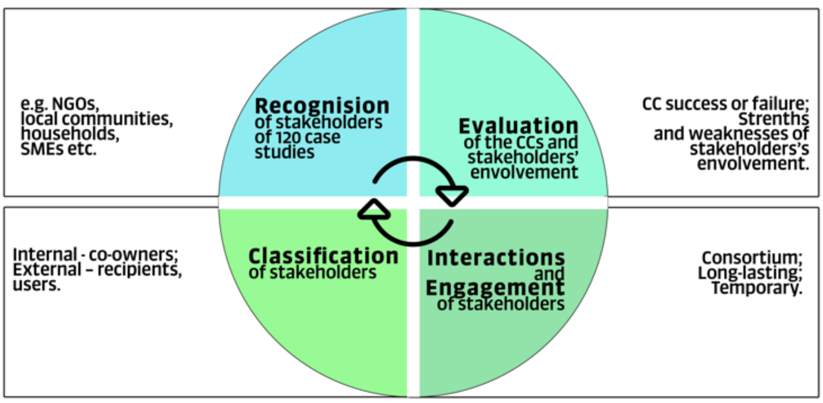

Figure 2. Stakeholders' empathizing. Authors' own elaboration.

CC or application projects where consortia are involved or where an extensive network of partners is apparent generally exhibit more vital and resilient characteristics [91] than CCs or applications that lack those foundations (e.g., Makkie, SoNantes (now Moneko), e-Portemonnee (now Limb-U), Spice Time Credits). When the project evolves over time, it is sometimes problematic to define the main provider (e.g., the initial idea came from academics and the project was initiated by an NGO but finally was transformed from a paper-money concept to a digital one, with the final project owner and developer being a private company). Another limitation could be a lack of information about the project providers and their legal status or limited information available externally [100].

The majority of experiments are local in nature, while the majority of operational community currencies are digital (or digital and paper)—e.g., Bristol Pound, Chiemgauer [86,95]. The majority of the examined currencies and applications are operational systems. The life of the experimental currencies is usually shorter—e.g., Sysmä [89,101]. The support of local authorities and a well-developed network of partners are frequent components of the operational currencies [85]. Cross-country and cross-regional initiatives, English language support for the project in terms of project promotion, a lasting online presence, research, and publications [97]—these premises tend to attract more users, partners, and sponsors to the project and contribute to its liveliness.

To summarize, based on the analysis of the case studies, the inclusion criteria for the users are quite broad, with more emphasis put on the project goals shared among stakeholders. The end users' engagement in the designing process is limited, while their engagement during the implementation phase often determines the overall success of the project. External project evaluation is also often based on the facts and figures presented by the community currency and application providers themselves, with a focus on specific time ranges that are not always systematic, objective, and methodological in nature. Moreover, the measurement of the project impact and the tools for assessing the users' engagement are often unavailable externally, bringing additional limitations to the final evaluation.

Based on the performed analysis, we conclude that active involvement of a broader range of stakeholders, including potential users, local municipalities, and business partners, in the design stage of a CC for climate engagement and its further elaboration and implementation is essential for the project's overall success. The lesson learned from this evaluation allowed us to define a process of defining and engaging stakeholders while designing GC (Figure 3).

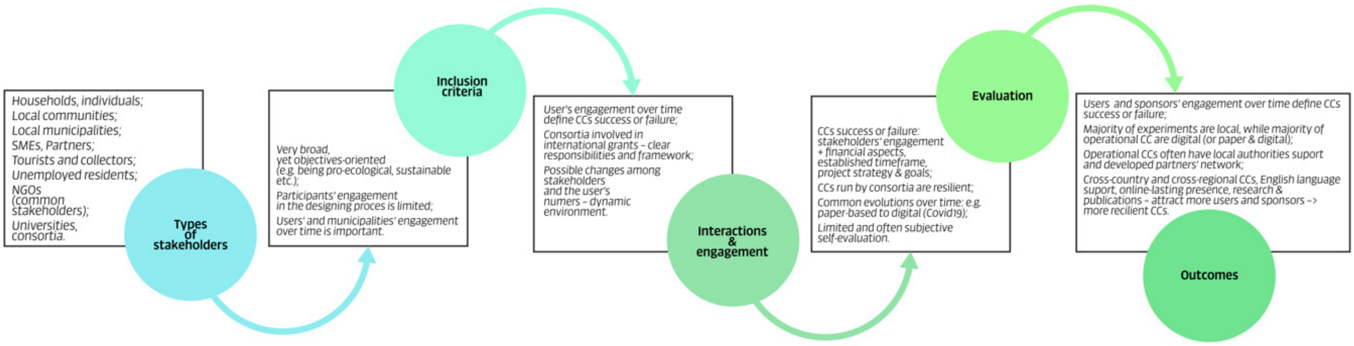

Figure 3. Five steps of stakeholders' involvement in the participatory design. Authors' own elaboration.

Step 2: Define—Workshops, open dialogue sessions, and mock-up tests with potential target groups—including current project consortium members, local Gdańsk municipality representatives, community members, and potential business partners and users—were launched, further shaping our GC participatory design process [102]. These workshops, dialogue sessions, and mock-up tests formed the development directions of GC, including the actions and application features relevant for end users (e.g., elements of gamification, inclusive district-based actions, etc.) as well as the methods of involvement and potential support from the Gdańsk municipality and local businesses.

During this phase, we focused on actively involving potential stakeholders and future users of our tool. We noticed that key actors are very easily and willingly involved in a process that they perceive as socially important and directly affecting them. Although participation in the workshops was voluntary, the number of people that participated and their engagement in the workshop activities indicates that the invited stakeholders were genuinely interested in the topics presented and that they accepted our methodology. The allocation of participants into as-diverse-as-possible subgroups in terms of their profession and position was particularly important for the course of the event. In our opinion, this enhanced the discussion and unleashed creativity among the participants, who were also city residents.

The first part of the workshop was to identify any challenges faced by the city inhabitants and to further group them in order to propose solutions which at the same time help to mitigate climate change. Among the most significant challenges identified were traffic jams in the city, mainly involving access roads from the ring road and satellite districts. This problem is exacerbated by the lack of integration of public transport, which is dispersed among many operators (bus and tram transport, rapid urban rail, metropolitan rail) who find it difficult to agree on a common approach. The public transport is also overcrowded, which discourages people from using it. The strategic services are mostly located in the central districts, so people are forced to drive to the city center where most workplaces, schools, and kindergartens are located.

Another challenge identified by workshop participants related to waste management. It included issues such as insufficient education on waste segregation and a lack of effective solutions for selective waste collection in public spaces; in addition, in companies, institutions, and workplaces, there are numerous practices of wasting food, a lack of publicly available places designated for storing nonstandard waste (e.g., electrowaste), and insufficient knowledge about the functioning of such places. The low environmental awareness of city residents, manifested by the lack of visible results of their actions, was highlighted many times.

The next main challenge was related to issues of water management and urban greenery. Insufficient environmental education and a lack of proper pro-environmental habits result in rainwater not being collected and used for watering greenery, while rainwater drains are often treated as garbage bins. Municipal water reservoirs are polluted. Due to the special location of the city (a coastal city), the challenges of keeping the sea water clean and the beaches clean were also highlighted. City authorities not only refrain from supporting the extension of green areas but also even cover the existing ones with concrete.

The second part of the workshop was focused on identifying existing good practices that could respond to the diagnosed challenges. Among the actions related to waste management which the participants mentioned as the most inspiring and worth implementing in their city were the introduction of food vouchers; food fridges to counteract food waste; waste collection companies running competitions; eco-kayaks (free rentals of water equipment in exchange for collecting litter from the water); actions towards communal cleaning of the world to promote the idea of not littering in the city; allocation of the participatory budget for expanding green areas and creating rain gardens, flower meadows, and green roofs; raising funds for social innovation for the environment; and promotion of drinking tap water.

The next stage, particularly important from the point of view of application development, was the proposal of functionalities that could be included in the designed tool supporting climate change mitigation. From the point of view of reducing urban traffic and, thus, air pollution, participants pointed to the possibility of using the GC app as a common payment method for public transport. This functionality would integrate stakeholders (municipal authorities, municipal and private employers) who would act as sponsors of the solution (transferring funds from paid municipal car parks, subsidizing public transport tickets from financial surpluses) and city residents who would actively engage in pro-environmental activities (using bicycles, shared means of transport encouraged by gamification elements to earn points in the GC application).

From the point of view of supporting waste management, water management, or other challenges, the application could play the role of integrating nonformal education (providing information in the form of messages, news, notifications, and interventions by means of a feedback system and providing quizzes, puzzles, and knowledge competitions) and informal education (shaping pro-environmental behavior through a system of positive reinforcement by means of rewards, incentives, and nudges). This system would be a great support for city officials, employers, and residents who declared that they would like to join actions to improve the environment but often do not know how to do so or lack the motivation to undertake individual actions that seem to be of little importance from a global perspective.

Step 3: Ideate—As presented in Figure 1 in the Methods section, the engagement during the process shifted from more cooperative to more expert-oriented. The brainstorming sessions were organized in a multidisciplinary environment of stakeholders and the project consortium (w.3, see Figure 2). During the brainstorming, several alternative scenarios were developed. At the end of the first stage, 31 potential functionalities and strategies were developed and evaluated along with user interface mock-ups, which enabled fluent communication among team members. The initial findings are presented in Figure 4. The final framework covered different solutions and strategies for a GC system, which can be divided into the following categories: (1) GC transfer methods and models, (2) points granting, (3) points spending, (4) gamification elements, (5) partner cooperation scenarios (Figure 4).

			V.1	w.1	w.2	f.g.	w.3	v.2	w.4	v.3
1	Gamification	Badges		☑		☑	☑	☑		☑
		Challenges		☑		☑	☑	☑	☑	☑
		Achievements	☑		☑	☑	☑	☑	☑	☑
		Statistics						☑	☑	☑
		Groups							☑	☑
		Rankings							☑	☑
		Narration based							☑	
2	Rewards	Users marketplace			☑					
		Partners marketplace		☑	☑	☑	☑	☑	☑	☑
		Partners		☑	☑	☑	☑	☑	☑	☑
		ID						☑	☑	☑
		Wallet				☑	☑	☑	☑	☑
3	Actions Verification	GPS tracking	☑	☑	☑		☑	☑		☑
		Photo Peer Review		☑	☑			☑	☑	☑
		Photo Peer Review + GPS		☑	☑			☑	☑	☑
		Organizer On-Site Verification		☑				☑		☑
		Image Recognition		☑						
4	Social Elements	Notifications			☑	☑	☑			☑
		Users Events Organization		☑					☑	
		Users Created Content		☑						
		Timebank		☑						
		Chat		☑						
		Social Media Integration		☑					☑	
		Top Users		☑					☑	
		Influencers Cooperation		☑						
		City Events Organization		☑	☑	☑	☑		☑	☑
		Volonteering							☑	
5	Education	Quizes	☑	☑				☑	☑	☑
		Educational Paths		☑		☑	☑		☑	
		Nutrition		☑					☑	
		Educational Materials	☑	☑		☑	☑	☑	☑	☑
6	Additional	GC QR Codes						☑		☑
		Map of Partners		☑	☑	☑	☑	☑	☑	☑
		Map of Events		☑	☑	☑	☑	☑	☑	☑
		News		☑	☑					☑
		Calendar Integration		☑						
		CO2 Monitoring							☑	
		Companies Advertisment			☑					
		Partners Systems Integration		☑						

Figure 4. Development of GC system elements. Source: authors' own elaboration. Columns: v.1: initial version of the app functionality; w.1: internal workshop at Gdańsk University of Technology (GUT); w.2: international workshop in Gdańsk + workshop with stakeholders; f.g: focus groups; w.3: internal workshop at GUT; v.2: second version of the app functionality; w.4: gamification workshops at GUT; v.3: final app functionality.

This became a foundation for the further development of mock-ups, functionality development, and evaluation of the selected actions and rewards proposed covering the environmental feasibility of the system. The previously defined items were used during the subsequent steps when we presented the ideas to future users. The final decisions were made regarding the system elements, test and learn process, and user interface. The team members also introduced the foundation of a gamification mechanism, exploring methods of engaging the users in pro-environmental activities. The last iteration resulted in a finished system specification followed by interface mock-ups to be implemented in the GC system.

Step 4: Prototype—The purpose of this phase was to understand how system users can interact with the GC system (Figure 5). To do so, we visualized these using BPMN diagrams and designing mock-ups.

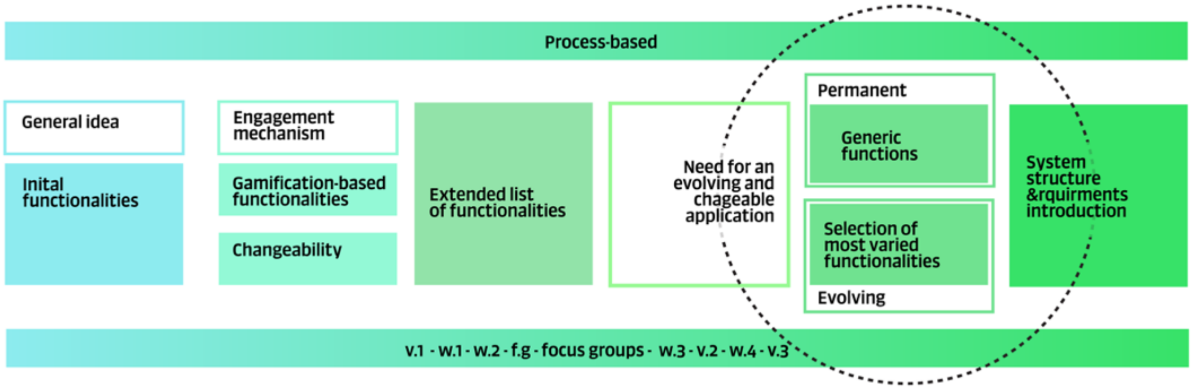

Figure 5. Process-based prototyping phase for GC system development.

For the final phase, we used the following selection criteria: the functionalities that appear most often during the DT process, those that cover the biggest spectrum of climate-related issues, and those that cover all categories (Figure 4). Some of these functionalities would be implemented using very similar graphical user interface (GUI) elements, data flow, and verification methods; therefore, such groups can bring more general functionalities. It can be argued that a larger number of different functionalities ensure user engagement [92]; therefore, the ambition was to build a system which opens the possibility for future administrators to enrich the application with new tasks in the postdevelopment phase of the project.

BPMN diagrams were developed for 15 processes (achievements, alternative transport, calendar, challenges, quiz, GC ID, login, register, map, marketplace, peer review (with location info), peer review (without location info), QR code, statistics, wallet). For some functionalities with trivial user interaction with the application (e.g., the "Home screen" function), diagrams were unnecessary and so were not developed. An example BPMN diagram developed for the GC system function "Peer review (with location info)" is presented in Figure 6.

For processes that require another user (or system administrator) to perform an action, we used two pools to represent both users' interactions with the system separately. In each pool, different lanes were used to categorize activities performed (or initiated) by different actors. By the actor of the process, we mean some entity (a person or a computer system) that can perform some actions and interact with the whole GC system. While modelling, we identified actors who are involved mostly in the processes: a user, a mobile app, an application server. Occasionally, additional actors appear, such as a system administrator or some external web services that the GC system will be integrated with. Every process begins and ends with an event. There is often more than one end event in a diagram, as the process can end with either a success or a failure. Conditional statements are represented by gateways. Every action to be performed by an actor is modelled as a task, and data and control flows (both between actors and from one task to another) are represented as the appropriate types of BPMN connections.

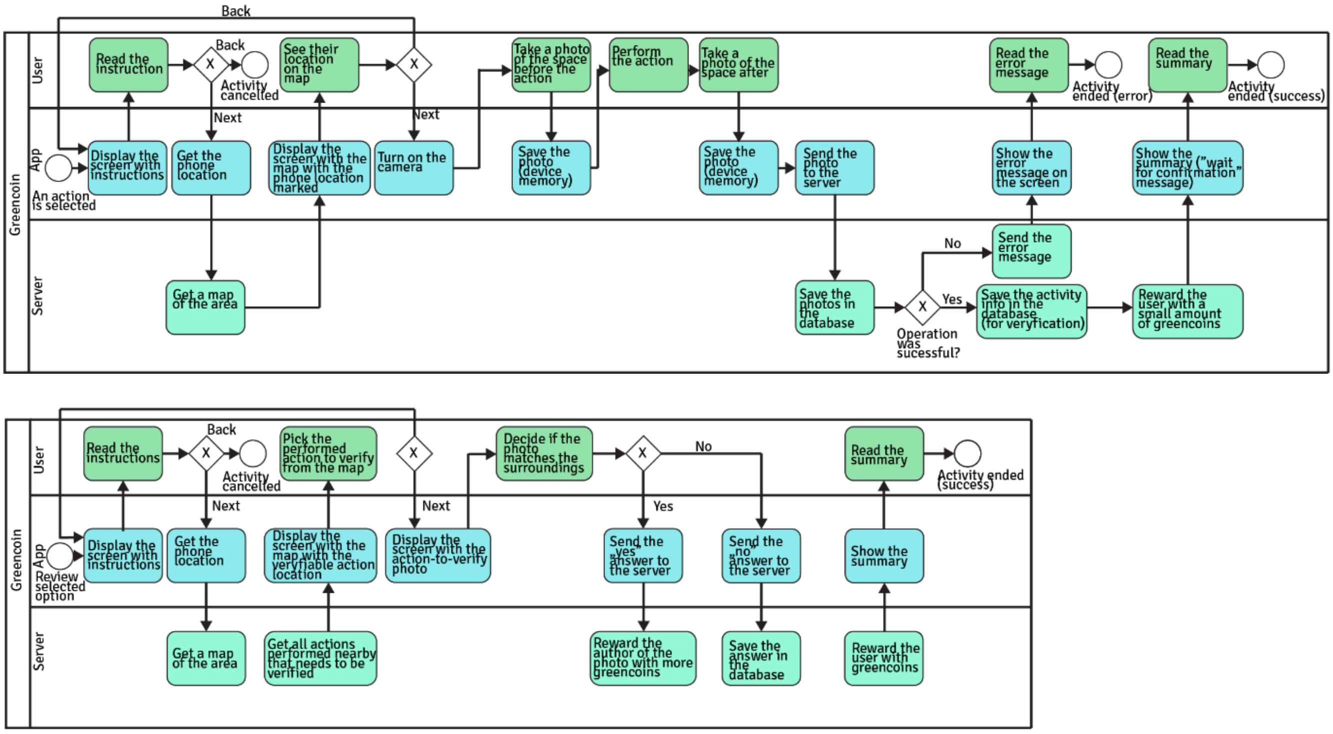

Figure 6. Examples of BPMNs. Authors' own elaboration.

The BPMNs were further transformed into mock-ups that evolved in the next phases. Initially, the wireframes were to present generic functionalities, such as a home page, an "earn/spend it" tab, and functionalities such as alternative transport, statistics, and a calendar. They were extended with examples of different functionalities representing a framework, which is to evolve in the postdevelopment phase. Final mock-ups prepared for the GC project are illustrated in Figure 7.

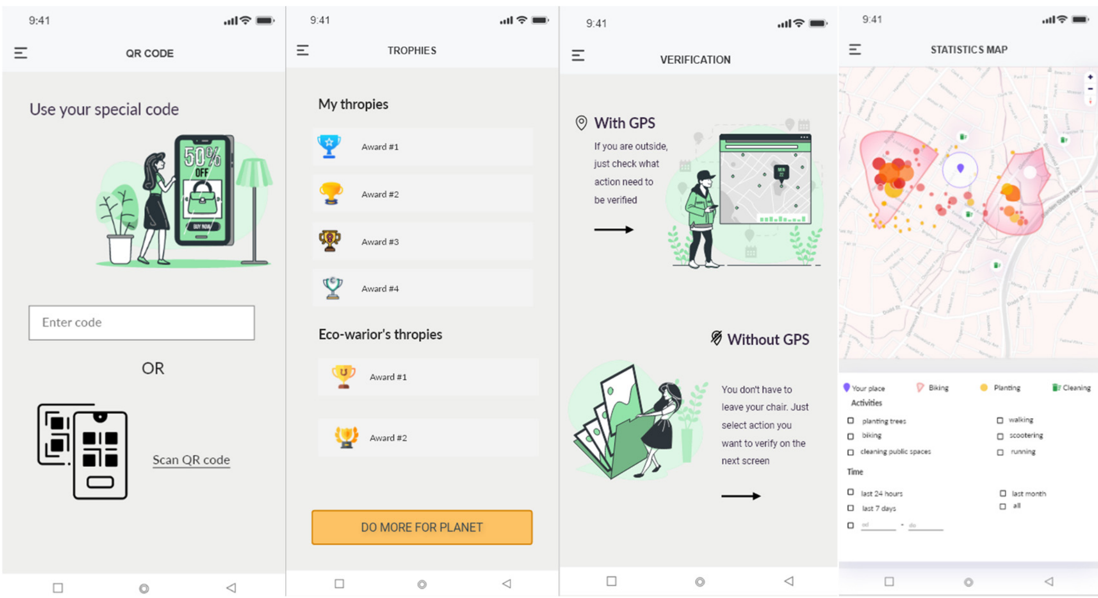

Figure 7. Examples of mock-ups. Authors' own elaboration.

Step 5: Test. The tests were conducted on a low-fidelity (lo-fi) prototype, i.e., a low-detail mock-up. The tests assumed 3 rounds of usability tests (qualitative method) on users aged between 14 and 59. The study involved 12 respondents—6 in each round. The sample size was selected based on Nielsen and Landauer [103].

The users invited to the first round tested the modules and solutions, which were then evaluated using the SUS method [70]. These were earning and spending points (home page), transport, peer review verification, GC ID, and achievements. In the second round, we tested modules and solutions such as calendar, marketplace, map, and QR code scanning. The third was for identifying a way to earn GCs, transport, peer review verification, groups, and statistics.

During the DT process, we defined the idea of self-verification between the GC users, which means that undertaken actions are checked by the GC society before the GCs are awarded. We therefore carefully designed and tested the peer review verification process at this phase.

Examples of tasks to be performed by testers and the expected user path are presented in Table 1.

Table 1. Examples of activities in the GC system. Authors' own elaboration.

Task	Expected User Path
The GC app rewards eco-friendly behavior and allows you to collect GCs that can then be redeemed. You have decided to save the planet. While visiting the shop today, find out how many GCs you can get for this and how you could spend them.	- Selects tile transport. - Selects walking. - Tells you how many GCs you are receiving. - Returns to the home screen and goes to the "spend" tab.
We can do more together, which is why at GC, we work as a group. You also belong to a group. Find the profile of your group.	- Starts from the home screen. - Finds the "groups" tile. - Says that the group has "x" members and you can invite more. - Reads the group's ranking.
To communicate between business partners and users, a QR code is needed. It allows you to get more GCs. Check if the application has this option.	- Searches in "earn". - Selects the "QR scan" tile. - Enters the value of the GCs earned.
GCs can be earned without leaving home by helping us verify other users' activities. Verify that no one is trying to scam the system and that they have actually installed solar panels.	- On the "earn" tab, selects the "verification" tile. - Reads the option description. - Chooses "online".

The process allowed us to draw conclusions and design improvements after each round. One example of a case which occurred was the "peer review" module. Users did not associate the "confirmation" tile with the task of verifying activities undertaken by other users. The problem was solved by changing the text to "verification". During the tests, none of the testers reported any problems with performing this task.

The final version of the prototype scored 81.25 on the system usability scale, which, according to the SUS scale, was an A level.

Step 6: Implementation and proposing final shape of the project. As a result of the implementation phase, the GC system specification was prepared. The document included all the information required by the IT companies to develop the system. It consisted of 20 application functional requirements, 14 admin system functional requirements, 8 nonfunctional requirements, a description of the visual elements, system deployment and support requirements, system website requirements, and, lastly, the system development phase.

Records for every functional requirement consist of identification code of the functional requirement (e.g., FR01-Quiz), name, description of the requirement and application functionalities related to it, lists of sources of the input data, results of the function related to the requirement, entry points to the related function in the app, dependencies for the requirement, and attachments of the requirement (e.g., a graphical user interface mock-up). Along with the mock-ups, the specification presents a full list of requirements.

As a result, the GC system was designed as an evolving mechanism to be constantly updated and enriched with new functionalities. It is built based on partnerships and technological solutions implemented in the application.

The digital currency application framework consists of three main groups:

- Main scored functionalities: gamified and action-oriented, education-oriented, and challenges whose accomplishment is to be verified either by the system itself or the GC community.
- Wallet: including an exchange system from impact measures and achievements to currency to be spent in the marketplace which combines virtual and geolocated on-site options.
- Basics: home page (including news and navigation), user profile (including settings), communication mechanisms allowing users to spend their savings, and scored verification tools and statistics.

The process enabled us to establish a partnership for all GC contributors, which included the following:

- Managing the partnership including shared responsibility between the city and academia.
- System development and implementation mechanism to be performed in cooperation between academia and business.
- Functionalities development partnership within which the city, NGOs, and academia can incorporate new options any time by fulfilling the application framework to maintain user engagement.
- Services management dedicated to the institutional partners to offer city services and businesses to sponsor or discount various options to be available in the marketplace. The idea is to support only pro-environmental and ecological services to enhance the GC user's impact.

All partners share responsibilities but also find benefits resulting from the engagement, as follows:

- Users: act pro-environmentally and spend savings on different activities.
- NGOs: promote digital currency and can implement statutory goals.
- City: provides free urban services while implementing climate change mitigation strategy.
- Academia: delivers the solution and generates research data.
- Business: promotes ecological engagement by supporting the solution.

Such a holistic approach and partnership can ensure climate change mitigation, and, when developed, it can respond to both global and local challenges that appear.

6. Discussion

6.1. Shaping Climate Awareness and Encouraging Mitigation Contributions

Responding to our research gaps and first research questions (R1, G1), we show that digital tools can not only help disaster management [31–33] but also be considered supportive when educating and shaping and implementing mitigating policies. Still, the problem which remains is that most of the tools that enhance the implementation of the smart city concept do not address climate-related issues. The discussions we had with the stakeholders confirm that smart governance requires collaborative innovations [37,104] and should offer a wide spectrum of different engagement mechanisms [39], which responds to the second research question (R2, G2). We strongly agree with Mees et al. [4], Cattino and Reckien [39], and Chu et al. [5] that digital tools should focus on providing justice and equity, as it was found by the authors that these are crucial factors for the final success. When designing the GC system, we built on the findings of McKinley et al. [30], as the codesign process showed that broadened participation can indeed support climate change mitigation (A2, G2, A3, G3). The engagement of stakeholders during the process and the attention received from both the private and third sector showed that such digital tools have the potential to mobilize communities and share resources [34], which addresses the second and third research questions (A2, G2, A3, G3).

6.2. Challenges

The process itself also brought to our attention local needs that are crucial to fostering healthy urban conditions [35]. As the research of Ergazakis et al. [36] brought to our attention the challenges of the need for digital inclusion, to respond to the third aims (G3, A3), we kept the process as open and engaging as possible. The lesson we learned is that engagement at an early stage can facilitate networking and can catalyze cooperation towards urban sustainability [37]. An extensive network of partners and stakeholders should determine broader, more universal, and inclusive GC regulations and gamification elements, which contributes to the third research question (A3, G3). Moreover, involved and empowered end-user groups and strong social networks should strengthen systematic pro-environmental actions and community eco-initiatives. Participants who feel encouraged by others are likely to undertake actions more frequently, feel related to the community, and coach each other [92] (A3, G3).

While designing the GC concept, we emphasized developing climate awareness [8] and presenting the impact of single actions for the system users, as this was found to be important by Mees [4,105] and Chu et al. [5]. Adger [42] argued that behavioral change leading towards more resilient societies can be achieved only when such tools strengthen community cooperation. This lesson was used while building the framework of the GC system to respond to our research questions. We found it crucial to give the users the opportunity to have an impact on decision-making processes to foster the implementation of climate adaptive policies [40,41]. However, the key role of public authorities should be emphasized, and various stakeholders should be involved to support the GC project. Public authorities could remove formal obstacles, support overall project coordination and life, and promote more sustainable patterns of behaviors.

7. Conclusions

We introduced an application that fills a gap that was found among existing innovation tools. It is focused strongly on ensuring social engagement in climate change mitigation, education, and shaping urban resilience. Until now, almost none of the similar solutions focused on such a challenge, and therefore, the residents remain outside the process of implementation of climate strategies, while they should join the efforts of implementing mitigation actions. The novelty of such research is the introduction of an open tool which can be implemented in any city worldwide with an opportunity to design process-based activities that are oriented to local challenges. This is ensured by the introduced framework, which can be fulfilled by the local administrators. Our ambition was to find a solution that integrates the engagement of all residents. Figure 8 shows the efforts undertaken to ensure such an approach. With such an approach, local authorities can implement a similar solution in their cities to involve residents in mitigation efforts. It can further be used by the local communities themselves to build partnerships toward climate change mitigation, enabling bottom-up initiatives strengthening positive impacts. The limitation of this study is that the system has not been implemented yet; however, the next phase includes 9 months of all-city tests.

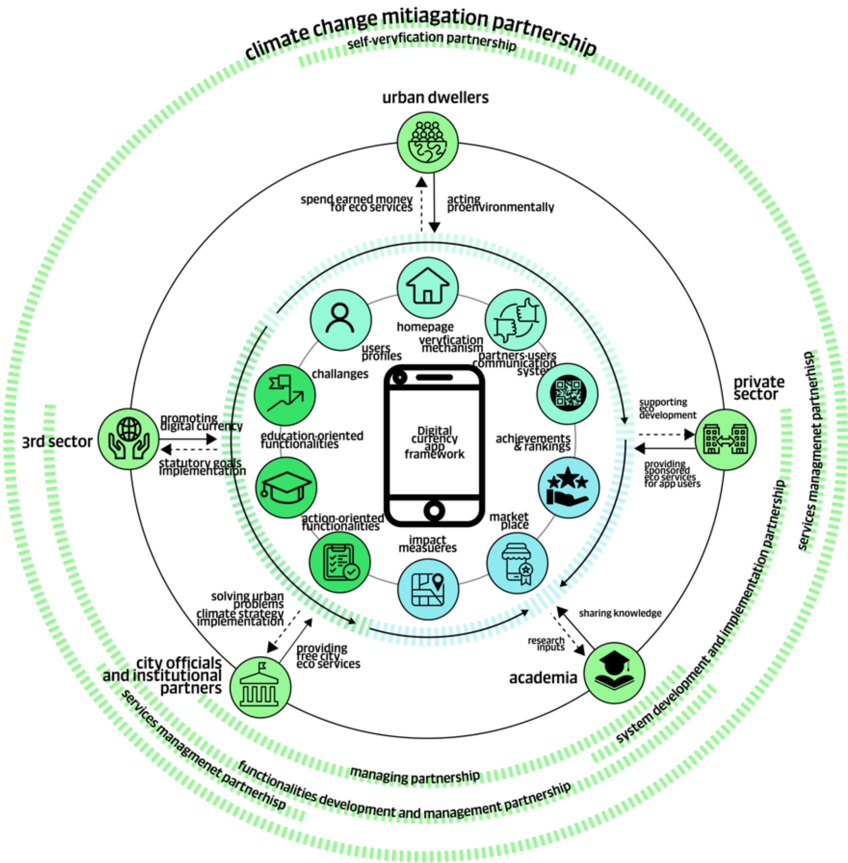

Figure 8. Simplified visualization of GC system design. Authors' own elaboration.

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