

Gamification: A Catalyst to Achieve Carbon-Neutral Cities

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Abstract. In addressing the challenges of climate change, it is crucial to develop effective strategies for implementing climate policies. This article aims to provide a comprehensive overview of gamification's potential as a tool for fostering sustainable communities and achieving carbon-neutral cities. Based on state-of-the-art literature, it examines the impact of game apps and gamified places (Urban gamification) in tackling climate change. The article is structured in three main stages: an extensive literature review to pinpoint scholarly works relevant to gamification and carbon neutrality, an analytical synthesis to examine gamification's impact on sustainable urban development, and a comparative analysis to evaluate the effectiveness of game apps and gamified places in promoting carbon-neutral cities. The article introduces gamification as a catalyst for building sustainable communities and advancing toward carbon-neutral cities. It highlights the need for empirical research and practical trials to choose the most suitable gamification approach, considering societal preferences, method legitimacy, and community acceptance.

Keywords: Gamification · Carbon-neutral Cities · Game App · Gamified Place · Urban Gamification · Sustainability

1 Introduction

Humankind must proactively address the severe challenges caused by climate change [1]. Climate change caused by excessive carbon emissions has become one of the most severe problems facing the world's ecosystems and human society [2]. The causes of global warming are related to socioeconomic activities [3], and this human-caused climate change needs human efforts and knowledge to change the socio-technical and socio-ecological systems we have constructed [4].

As the climate crisis seriously threatens ecologic, economic, societal, and cultural systems, urgent action toward reducing greenhouse gas (GHG) emissions and coping with its impacts in the near term is fundamental [5]. As of February 2021, 124 countries worldwide have declared their intention to become carbon neutral and achieve net-zero carbon emissions by 2050 or 2060 [1].

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Due to the increasing urban population and the amount of time people spend in buildings, cities are responsible for significant amounts of carbon emissions [1]. Cities have become primary actors in climate change and are increasingly setting goals aimed at net-zero emissions [6] and playing a key role in achieving the climate goals of the Paris Agreement [7]. Despite the limitations in GHG reduction capability, numerous cities have committed to reaching carbon neutrality within a certain time, and sometimes before national carbon neutrality targets [8]. In addition to international and national efforts [9], consortiums such as Cites40, Covenant of Mayors, and ICLEI have been organized to advance the goal of carbon neutrality and general carbon reduction actions in their member cities [8]. Additionally, the Carbon Neutral Cities Alliance (CNCA) comprises foremost global cities committed to attaining carbon neutrality within the next 10 to 20 years [10]. They strive to foster concepts that promote societal well-being, communal destinies, and collective welfare [11].

Consensus, intelligence, and actions are requirements for the pathway toward a greener society [9] and carbon-neutral cities. For instance, sustainable food, energy, and water resource consumption can significantly reduce GHG emissions [12]. Hence, the role of citizens in adopting sustainable practices in food, energy, and water consumption becomes crucial in reducing GHG emissions and achieving the goals of the carbon-neutral city network.

Therefore, guiding people to put low-carbon actions into practice more effectively is crucial to the success of long-term environmental sustainability [2]. Successful nudging for such behaviors requires an intimate knowledge of messaging that resonates and inspires actions in households [12]. Although pro-environmental behavior is often considered commendable, in many cases it is more unprofitable, unpleasant, time-consuming, or effort-consuming than harmful behavior to the environment [2]. Nowadays, online applications aim to attract citizens to discuss issues related to the environment to enhance the process of participation [13]. Today, our reality and lives are increasingly game-like, not only because games have become a pervasive part of our lives, but also because activities, systems, and services are increasingly gamified [14]. Thus, integrating engaging online platforms with effective messaging strategies becomes imperative in encouraging citizens towards more profitable and enjoyable pro-environmental behaviors, paving the way for a sustainable future.

The insights provided by recent studies highlight gamification's pivotal role in promoting low-carbon behaviors and offer practical guidance for the design of related green and low-carbon platforms [2]. Therefore, in the quest for building sustainable communities and achieving Carbon Neutral Cities (CNC), gamification has emerged as a powerful tool. This study discusses game apps and gamified places and their significant contributions to fostering sustainable communities in the journey toward achieving carbon neutrality. It underscores the role of gamification in deepening our understanding of its influence on the development of carbon-neutral cities. By drawing on scientific and scholarly works, the article provides a comprehensive literature overview, offering an analytical synthesis and a comparative analysis, showcasing the potential of gamification as a powerful tool in the pursuit of sustainability. Based on this approach, the study

poses a main research question: How does gamification through game apps and gamified places contribute to fostering sustainable communities within the framework of achieving carbon-neutral cities?

This study unfolds through three main stages, beginning with an extensive literature review aimed at identifying scholarly works pertinent to gamification and carbon neutrality. This is followed by an analytical synthesis that delves into the impact of gamification on sustainable urban development, exploring how gamification can influence and propel the transition toward more sustainable, carbon-neutral urban environments. The final stage comprises a comparative analysis assessing the effectiveness of game applications and gamified places in fostering carbon-neutral cities, offering insights into the practical applications and potential benefits of gamification in achieving sustainable urban goals.

2 Methodology

The research aims to explore the intersection between gamification strategies and the pursuit of carbon neutrality within sustainable communities. To achieve this goal and address the research question, the study adopts a structured approach. Each stage builds upon the previous one, ensuring a comprehensive exploration of how gamification can contribute to sustainability efforts. The process is detailed in Fig. 1 as follows:

Stage 1- Identifying Relevant Literature
In this step, a review was conducted on a set of scientific publications by researching through several databases. These databases included ScienceDirect, Scopus, Web of Science, and Google Scholar. The adopted approach involved searching using keywords such as gamification, carbon neutral*, communit*, sustainabl*, and climate*. The review process was narrowed down to papers relevant to the objective of this study by screening in two steps: first, the abstract, and then the whole article. This approach identified 41 relevant papers which are categorized into two main groups based on the factors discussed. These categories are crucial for answering the research question. The first category relates to carbon neutrality and sustainable communities. The second category, which contains many of the articles, explores the role of gamification in achieving carbon-neutral cities. By reviewing the articles obtained in this stage, significant topics were identified, which are detailed in the subsequent sections.

Stage 2- Analytical Review and Synthesis
This stage is designed to synthesize existing knowledge, involving the definition of the concepts of carbon-neutral cities and gamification in two distinct aspects: game apps and gamified places. It also entails identifying key elements essential for achieving carbon neutrality within sustainable communities. Additionally, this stage recognizes the potential impacts of gamification on achieving carbon-neutral cities and their impact domains. In alignment with the social approach of this article, only factors within the social impact domain will be selected, and their explanation will highlight the relationship between these elements and game apps and gamified places.

Stage 3- Concluding Synthesis
The final stage combines the information gained from the previous stage and addresses the research question in two parts: one part illustrates a diagram explaining how gamification, in two aspects—game apps and gamified places—contributes to achieving carbon-neutral cities; the other part involves a discussion comparing these two aspects of gamification for selection.

In summary, this paper presents a model for using gamification to guide communities toward carbon neutrality. It provides a structured framework and actionable steps to effectively employ gamification strategies aimed at fostering sustainable behaviors and increasing eco-social awareness, ultimately contributing to the collective goal of mitigating carbon emissions.

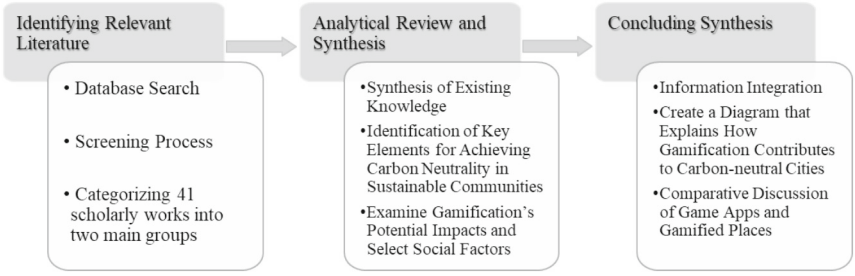


Fig. 1. Phases of the Research Methodology

3 Carbon-Neutral Cities

Carbon neutrality refers to net-zero carbon dioxide (CO2) emissions [15], which can be achieved by balancing the total amount of carbon dioxide or GHG emissions produced directly or indirectly by a country, company, product, activity, or individual over a certain period via carbon offset or removal initiatives [1]. Carbon neutrality will greatly slow global warming and solve our energy crisis, with accompanying benefits to air quality, ecological recovery, and landscape beautification [15]. Carbon neutrality is a mutable idea [11], and it is not an ultimate phase but a temporary status, which constantly fluctuates with annual carbon emissions [9].

The academic discourse on the definition of a carbon-neutral city is sparse, primarily exploring it through urban climate concepts, emission accounting scopes, analysis of climate policy documents, stakeholder dialogue, and definitions provided by cities' climate networks [7]. CNCs generate a net zero increase in emissions by reducing primary carbon emissions and offsetting residual emissions [9]. CNCs are urban areas that achieve carbon neutrality through a coordinated effort from various stakeholders, including local governments, citizens, businesses, and civil society organizations [16].

C40 Cities' outline of a carbon-neutral city outlines four benchmarks for achieving carbon neutrality: 1. Net-zero GHG emissions from fuel use in buildings, transport, and industry, 2. Net-zero GHG emissions from the use of grid-supplied energy, 3. Net-zero

GHG emissions from waste treatment generated within the city boundaries, and 4. Where a city accounts for additional sectoral emissions in their GHG accounting boundary, net-zero GHG emissions from all additional sectors in the GHG accounting boundary [8, 9].

According to the Global Protocol for Community-Scale GHG Emission Inventories, a particular city's GHG emissions can be estimated within multiple scopes [9]. While there isn't a universally accepted definition, there's no standard interpretation of "net zero" concerning individual entities [6]. Therefore, more clarity is needed on the definition of the carbon-neutral city concept and especially on the role of offsetting emissions (a specific feature compared to other urban climate concepts) [7].

Based on the various definitions of carbon neutrality, achieving such a status requires a multifaceted approach involving both emission reductions and carbon offsetting. CNCs are urban regions that achieve a balance between the greenhouse gases they emit, and the amount of carbon dioxide absorbed by local natural resources, ensuring their overall carbon footprint is neutral.

3.1 Sustainable Communities to Implement Climate Policies

Sustainable community is a term that is widely used by policymakers in many countries, but what constitutes a sustainable community is often a cause of debate [17]. Creating sustainable communities is a complex task [18]. According to [19], sustainable communities are desirable, inclusive places that cater to the varied needs of current and future residents, promote environmental sensitivity, and enhance the quality of life by offering safety, thoughtful planning, equality of opportunity, and access to quality services for everyone.

Community-scale development projects aimed at minimizing fossil fuel use and greenhouse gas emissions, known as carbon-neutral communities, low-carbon communities (LCCs), renewable energy communities, and net-zero energy communities, have been advocated across various countries [20]. Therefore, a crucial responsibility of sustainable communities involves implementing climate policies and working towards achieving carbon-neutral cities, underscoring their pivotal role in addressing environmental challenges and promoting sustainability.

Communities must not only be informed about climate change but also deeply care, feel motivated, and possess the capability to actively engage in actions that mitigate climate risks for their members [21]. Thus, creating synergy in climate actions relies on scientific understandings of complex urban dynamics within a specific geographical, demographic, and cultural context and long-term partnerships among stakeholders involving city government, public or non-profit agencies, private entities, community-based organizations, and the public [9].In essence, fostering a collective commitment to climate action rooted in informed awareness, genuine concern, and collaborative engagement is key to addressing the intricate challenges posed by climate change within communities.

Achieving CNCs necessitates a multifaceted approach [16], and their pathway to carbon neutrality will be a long-term ecological, technical, and social process [9]. The complexity of governance at the city level hinders policy and plan implementation, and without involving citizens, efforts toward achieving carbon neutrality fall short [16]. It

indicates that community consideration and engagement might be an important aspect of climate action plans [6]. Some methods for promoting mitigation and adaptation synergies were recommended, including investments and community awareness [1]. Therefore, fostering eco-social awareness and active participation among citizens is a critical step towards achieving the ambitious goal of carbon neutrality in cities.

Social participation is crucial to minimize GHG emissions in all development plans, programs, and projects whether initiated by multi-lateral agencies, the government, or the private sector [3]. A comprehensive review of the literature on social participation in achieving sustainability goals highlights the significance of public education and awareness campaigns, citizen-led initiatives, partnerships between local government and community groups, and building a sense of ownership and responsibility among communities [16]. In addition, the government also encourages residents to participate in the supervision of environmental regulation policies to strengthen public recognition of the concept of low-carbon green energy, develop a low-carbon green lifestyle, increase green consumption demand, and guide enterprises to low-carbon green production [22].

Achieving an eco-friendly lifestyle, like any other lifestyle, is done by adopting habits and attitudes, in this case, ecologically conscious ones [23]. Considering lifestyle shifts as one critical transformation for achieving CNC [9], social participation, knowledge sharing, and community involvement are crucial for a successful environmental transition. These elements empower individuals and groups to make informed choices for sustainability. Cultivating this informed and active community spirit accelerates sustainable practices, fostering shared responsibility and enhancing efforts towards carbon neutrality.

Based on the previous discussion, the key that previous literature has found necessary to achieve carbon-neutral cities in sustainable communities, and their descriptions are shown in Table 1. These elements together form a comprehensive strategy for creating sustainable, carbon-neutral communities by addressing both the environmental and social aspects of sustainability.

4 Gamification

Gamification, i.e. the use of game design elements in nongame contexts [24]. Gamification is to take elements that normally operate within the game universe and apply them effectively in real situations [13]. The concept of gamification is not new, having its roots in marketing endeavors [25]. Gamification is the process of adding games or game-like elements to something (such as a task) to encourage participation [26]. The rationale is to leverage game mechanics' power for a non-entertainment purpose [24].

Gamification refers to designing information systems to afford similar experiences and motivations as games do, and consequently, attempting to affect user behavior [14]. It has been explored and used in many sectors, such as education, health and wellness, crowdsourcing, and sustainability [24]. In the context of sustainability, gamification has been applied to various areas including sustainability education, energy conservation, transportation, air quality improvement, waste management, and water preservation [27]. It means that game dynamics can be used to stimulate sustainable behaviors [24]. Games are renowned for their capacity to captivate and stimulate individuals. When participating

Table 1. Key Elements for Achieving Carbon-Neutral Cities in Sustainable Communities

Key Item Group	Description	References
Informed Communities & Collective Commitment	Fostering community knowledge alongside a unified effort towards climate policy and action	[17–20]
Community Engagement & Social Participation	Involving communities in climate action and policy decision-making	[3, 6, 9, 16]
Eco-social Awareness & Public Education	Educating the public on sustainability and eco-friendly behaviors	[1, 9, 16, 21, 22]
Sense of Ownership & Responsibility	Cultivating responsibility among individuals for environmental stewardship	[16, 22]
Lifestyle Shifts towards Sustainability	Promotes adopting sustainable habits and attitudes for ecological well-being	[9, 23]

in games, people often encounter feelings such as mastery, competence, enjoyment, immersion, or flow, all of which are indicative of intrinsically driven human behavior [14]. A relatively new concept was developed in the latter part of the 20th Century when people started to consider games to increase productivity in everyday life [28].

The gaming world is boundless [13]. Gamification mentioned in this paper refers to Serious Games, a dynamic concept that leverages game mechanics and design elements to enhance user engagement, motivation, and behavior. This article focuses on two primary categories: game apps and gamified places (urban gamification). Game apps refer to dedicated applications that incorporate gamification elements, while gamified places involve the integration of game mechanics into physical environments.

The term serious game refers to a set of methodologies that involve role play and immersive game situations for the management of diverse types of activities [29]. Gamification does not turn everything into a game, but it is about finding the monotonous activity that usually requires collaboration and engagement [28]. There are three essential steps in gamifying a specific process: Firstly, determining the goals of the activity or system. Secondly, identifying the players and categorizing them based on recognizable behavioral traits. Finally, employing suitable game elements to inspire and encourage player participation [24].

4.1 Game Apps: Enhancing Engagement and Awareness

The use of digital and online games has increased rapidly in recent years, suggesting that gaming is now part of everyday life for many [30]. Games and gamified applications hold potential as effective instruments for encouraging sustainable behaviors, especially when juxtaposed with alternative approaches to behavior modification [27]. Well-designed

digital games utilize intrinsically motivating qualities to shape human behavior, attitudes, and cognitions [31].

Studies [32] indicate that while the intervention initially spurred positive behavior changes—particularly in energy-saving actions—its impact was most significant in the short term. Engagement in these behaviors peaked at the study's midpoint but subsequently declined, leading to lower levels of engagement by the study's conclusion. This pattern underscores the necessity for ongoing support and innovative strategies to sustain and enhance the effectiveness of such interventions over time. It suggests that while initial engagement can be high, maintaining this momentum is crucial for long-term behavior change. Thus, efforts should focus on identifying methods to keep individuals motivated and engaged, ensuring that the positive changes initiated by such interventions are durable and continue.

4.2 Gamified Places: Transforming Physical Spaces

Nowadays, the idea that cities shouldn't just be smart but also playable is gaining more and more recognition [33]. Using a real city as a gamified scenario is not new [34]. Many of us have likely engaged in playful interactions with urban spaces, such as avoiding walking on pavement lines, encountering hopscotch chalk drawings on sidewalks, or hopping through them on one leg, even if just once [33].

Gamified places or urban gamification can be a way for the citizens to reclaim their right to the city, as well as a way for gamifiers to attempt to influence the behavior of the citizens by rewriting the urban spaces around them [35]. Urban Gamification claims that urban play can be instrumental in empowering citizens and helping them reappropriate public spaces [33].

Gamification can be very simple small elements, like in Stockholm where the stairs of one metro station saw little use over the escalator until each step was made into a piano key playing sounds as people stepped on the steps [28]. Similarly, examples like Volkswagen's Fun Theory aim to shape behavior through fun activities, the World's Deepest Bin makes disposing of trash enjoyable with its funny sounds, and the Speed Camera Lottery promotes safe driving by combining fines with rewards for those adhering to speed limits [33]. Furthermore, MEECO is a platform that leverages the real-world setting of a city, enabling users to use their mobile devices to log eco-friendly actions like recycling or biking, integrating digital interaction with environmental sustainability [23]. These activities revolve around strategically placing cutting-edge gadgets throughout the urban landscape, allowing them to remain there for an extended duration. The aim is to engage citizens in enjoyable or playful interactions that ultimately influence their behavior [35].

Since gaming significantly influences our cognition, behaviors, and emotions, thereby boosting our intrinsic motivation, the mentioned features allow us to utilize game mechanics and dynamics to guide citizens' behaviors as players within the urban context in a predetermined manner [36]. However, while urban gamification presents opportunities for positive behavior change and engagement, it also raises concerns. Excessive gamification may lead to the commodification of everyday life, reducing genuine interactions and autonomy. Additionally, there is a risk of reinforcing inequality if certain

groups are excluded from or disadvantaged by gamified systems. Therefore, while leveraging gamified places can promote sustainable and positive urban experiences, careful consideration of ethical, social, and equity-related implications is essential to ensure their responsible and equitable implementation.

5 Gamification for Carbon-Neutral Cities

Individual cases of implementation are not sufficient for the widespread societal transformations needed for cities to become carbon-neutral [37]. Engaging citizens with climate change is an urgent and complex issue, requiring a multifaceted approach to foster cognitive (knowing), affective (caring), and behavioral (acting) connections to the issue [5]. Goal-framing theory suggests that individuals' behaviors, influenced by hedonic, gain, and normative motivations, can significantly impact their engagement in environmentally friendly behaviors [2]. Gamification, transforming activities to offer game-like experiences, has proven effective in promoting these types of engagement with climate change, combining educational goals with behavioral change [5].

Gamification emerges as a promising strategy to encourage eco-friendly behaviors, offering an alternative to traditional methods like taxes, subsidies, and restrictions, which may have undesired effects [24, 27]. It mobilizes public participation, shifting from passive information reception to active involvement in low-carbon practices, and is seen as a useful tool for learning and sustaining engagement in non-entertaining activities. The pleasure derived from game mechanics increases willingness to participate and boosts activity levels, suggesting that gamified interactions in the environmental sector can lead to more low-carbon actions [2, 38].

Digital tools, especially smartphone apps, enable social innovation for low-carbon transitions, engaging people to act more sustainably and leveraging collective action [39]. The effectiveness of smartphone technologies as a foundation to improve community-based and citizen-based environmental monitoring is not clear [40]. While gamification shows promise in promoting low-carbon actions, its effectiveness depends on careful conception, deployment, and management to ensure maximum user involvement. Addressing this challenge requires finding ways to make adopting an eco-friendly lifestyle appealing at an individual level for broader societal benefits [2, 23, 24].

In summary, gamification stands out as a groundbreaking and impactful strategy for mobilizing individuals and communities in the crucial battle against climate change. It plays a pivotal role across a broad range of areas vital to the realization of carbon-neutral cities, as shown in Table 2. This includes fostering increased social participation, deepening education and awareness, cultivating community spirit, and encouraging shifts in lifestyle and behavioral patterns—fundamental components that this paper emphasizes for nurturing sustainable communities. Moreover, gamification extends its influence on other significant domains such as data collection and analysis, fostering innovation and creativity, boosting investments in green technologies, enhancing policy engagement and support, improving health and well-being, and advancing sustainability reporting and transparency, though these topics fall outside the scope of this discussion. By infusing everyday activities with game-like elements, gamification not only sparks interest but also cultivates a collective commitment to adopting sustainable practices. This method

stands out by transforming environmental responsibility from duty into an enjoyable pursuit, thereby overcoming the limitations of traditional, often less engaging strategies. For gamification to realize its full potential in promoting eco-friendly behaviors, it must be carefully designed, implemented, and managed to resonate with a broad spectrum of motivations and lifestyles. Looking ahead, leveraging gamification as a catalyst for environmental action offers a promising avenue to redefine our engagement with sustainability, making it more accessible, enjoyable, and ultimately, more effective.

5.1 Increasing Social Participation

Alongside technology, using different ways to increase social participation is more important than ever, and future researchers should continue to explore novel ways to achieve this [16]. Serious games have been proposed by several studies as a tool to foster civic participatory processes [41]. Games inherently increase engagement and motivation [12] and Gamification mobilizes the initiative of public participation [2]. Gamification is an effective strategy to engage more citizens in the co-creation of livable, resilient, and sustainable cities [25]. Gamification catalyzes increasing social participation in the implementation of climate policies.

Gamification can make the process of learning about carbon neutrality more engaging and accessible to the public. By turning sustainability efforts into a game, it can encourage more people to participate in activities that reduce carbon footprints. In both game apps and gamified places, community members are motivated to adopt sustainable practices, collaborate on environmental initiatives, and actively contribute to the overarching goal of achieving carbon-neutral cities.

Table 2. Potential Impacts of Gamification to Achieve Carbon-Neutral Cities

Item	Impact Domains	References
Increasing Social Participation	Social Engagement, Awareness	[2, 12, 25, 41]
Lifestyle and Behavioral Change	Social Behavior, Environmental Action	[2, 13, 24, 27, 30, 42]
Data Collection and Analysis	Governance, Urban Planning	[23, 24, 39, 40]
Education and Awareness	Education, Social Awareness	[1, 13, 27, 30, 43, 44]
Creating a Sense of Community	Community, Social Cohesion	[2, 9, 24, 30]
Innovation and Creativity	Innovation, Environmental Solutions	[13, 24, 28]
Increased Investment in Green Technologies	Business, Technology	[2, 27]
Policy Engagement and Support	Governance, Policy	[5, 24, 25]

5.2 Education and Awareness

According to the literature, among the different techniques of experiential learning, simulation games are particularly suited for providing a structured environment for learning complex problems [43]. Among the learning tools, serious games represent a very promising medium for adoption in this context [13] and have rapidly gained momentum as a method to support both knowledge transmission and development [1].

Game-based learning in simulated Serious Games creates a significantly greater potential for learning over other media [12]. Studies have shown that gamification in education can lead to improved learning outcomes, including increased knowledge retention, and better understanding of concepts [44]. Online games and gaming offer great potential as a novel and innovative communication strategy to inform the public and citizens [30]. Serious gaming capitalizes on active, personalized, and experiential learning, sur-passing passive instruction [12]. Utilizing gamification, especially via board games, proves to be an effective method for educating individuals about sustainability in a broad sense [27]. Gamification, by making learning more interactive and enjoyable, significantly influences learning, motivation, and outcomes [44].

One of the key strengths of gamification is its ability to educate and inform. By integrating educational content within game apps and providing interactive experiences in gamified environments, citizens are empowered with knowledge about climate policies, environmental challenges, and the consequences of their actions. This accumulation of knowledge serves as a foundation for informed decision-making and fosters sustained engagement with environmental issues. Moreover, through engaging in interactive games and facing challenges, citizens deepen their understanding of how their behaviors impact the environment. This heightened awareness is crucial, as it paves the way for the adoption of more sustainable lifestyles and choices.

5.3 Creating a Sense of Community

Highly socially motivated individuals enjoy meaningful relationships and teamwork, and a team may create a sense of connectedness among players [2]. The domain of digital gaming holds substantial potential as a medium to motivate people's participation in activities that extend beyond mere entertainment [24].

When people believe that their individual actions contribute to protecting the environment, it can create or reinforce a sense of social obligation and responsibility toward environmental protection [2]. Moreover, cities are increasingly adopting urban intelligence by enhancing information systems and utilizing advanced analytics for decision-making and operations [9]. Gamified cooperation represents a way in which individuals assist each other and work collectively to achieve a specific goal within a game [2]. Additionally, games can provide players with the opportunity to discuss any issues raised by the game [30].

Gamification has the powerful ability to cultivate a sense of community and inspire collective action. As residents collaborate to meet game objectives, they become integral to a broader movement toward achieving carbon neutrality in their city. Whether through digital platforms or real-world interactions, gamification unites participants, creating a vibrant community. The cooperative essence of challenges, the dynamic competition

on leaderboards, and the celebration of shared achievements all play a critical role in forging strong communal ties. This cultivated sense of belonging and unity is crucial for maintaining prolonged engagement and driving enduring changes in behavior.

5.4 Lifestyle and Behavioral Change

Changes in technology have been proposed as solutions to our current problems in cities [42]. Gamification helps create an environment in which individuals are intrinsically motivated to engage with material related to the area where behavior change is desirable [27]. It also encourages the public to transition from practices with high carbon emissions to actively participating in low-carbon practices [2]. To foster the expected behavior change, one should appropriately conceive, deploy, and manage gamification [24]. Equally, researchers claim that it is important to consider the potential of modern digital games to engage players in novel, memorable ways that contribute to their understanding, perceptions, and even behaviors [30].

By rewarding positive behavior, gamification can lead to significant changes in individual and collective behaviors. This innovative approach can encourage a wide range of environmentally friendly actions, such as promoting the use of public transportation, reducing energy consumption, and minimizing carbon footprints. Beyond these immediate benefits, gamification has the power to instill long-term lifestyle changes. It can foster a deeper awareness of sustainable living, encouraging people to rethink their daily habits and choices. Moreover, these gamified systems can create a ripple effect, inspiring others within the community to adopt similar behaviors through a combination of competition, collaboration, and the desire to achieve shared environmental goals. Ultimately, gamification not only transforms individual actions but also cultivates a collective movement towards a more sustainable and eco-conscious society.

6 Gamification Strategies for Carbon-Neutral Communities

The collaboration of gamification to foster sustainable communities towards achieving carbon-neutral cities is illustrated in Fig. 2. This model is based on the items identified earlier from scholarly works, and it shows the relationship among them. As seen in the figure, all key elements of sustainable communities are interconnected and must work collectively to achieve the goal. Previous discussions reveal that gamification has four main impacts in the realm of eco-social science, supported by game apps and gamified places. This figure illustrates the flow from game apps and gamified places to sustainable communities, aiming to achieve carbon-neutral cities.

‘Creating a sense of community’ through gamification, derived from ‘building a sense of ownership’ in gamified places, helps achieve two key elements of sustainable communities: ‘community engagement and social participation’, alongside ‘fostering a sense of ownership and responsibility’. Moreover, another gamification item, ‘increasing social participation’, also impacts ‘community engagement and social participation’. This is supported by ‘fostering community engagement’ through gamified places and ‘increasing social participation’ through game apps. Two other key elements of sustainable communities, ‘informed communities and collective commitment’ and ‘eco-social awareness and public education’, are supported by ‘education and awareness’ in

gamification, with contributions from game apps including 'increasing engagement and awareness' and 'scalability'. 'Informed communities and collective commitment' and 'lifestyle shift towards sustainability' are further supported by 'lifestyle and behavioral change' from gamification, with 'influencing public behavior' from gamified places and 'intrinsic motivation' from game apps facilitating these objectives.

Gamified places, featuring three items—'building a sense of ownership', 'influencing public behavior', and 'fostering community engagement'—are categorized in green colors. Game apps, with three items—'increasing engagement and awareness', 'intrinsic motivation', and 'scalable'—are presented in pink color. These two categories are linked to the gamification category, depicted in violet color with four items. As the elements in the gamification category originate from both gamified places and game apps, it is evident that each item from gamified places and game apps contributes to cultivating sustainable communities to achieve carbon-neutral cities.

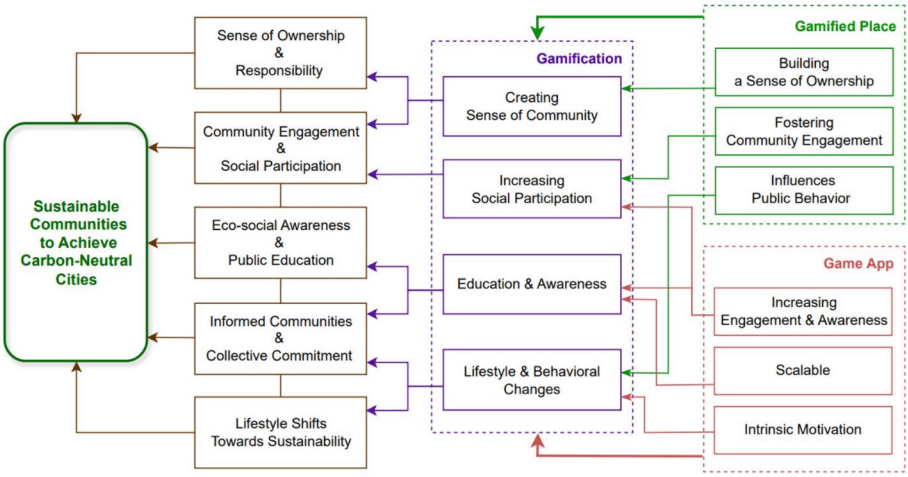


Fig. 2. From Gamification to Carbon-Neutral Cities

7 Choosing the Right Approach-Game App or Gamified Place

In determining whether to adopt a game app or a gamified place to encourage sustainable urban behaviors, one must consider the insights and recommendations outlined in the references. This decision should be informed by an understanding of both the unique and common impacts of these approaches, as well as their respective positive and negative aspects. According to the research reviewed in this article, the positive and negative aspects of game apps and gamified places, as well as their common impacts, are shown in Table 3.

The game app offers scalability and the ability to reach a broad audience through digital means, harnessing intrinsic motivation to increase engagement and awareness. However, their impact tends to be most significant in the short term, with engagement

potentially declining over time. This highlights the need for ongoing innovation and support to sustain interest and promote long-term behavioral change.

On the other hand, a gamified place empowers citizens to actively engage and build a sense of ownership, fostering a sense of community and influencing public behavior toward sustainability. While they present opportunities for meaningful interaction and community engagement, there is also a risk of commodifying everyday life and exacerbating inequality if not carefully designed and implemented.

Both approaches share common impacts in fostering increased social participation, education, and awareness, creating a sense of community, and encouraging lifestyle and behavioral change. These shared benefits underscore the potential of gamification to significantly contribute to the goal of achieving sustainable urban environments.

Table 3. Comparative of Game Apps and Gamified Places to Achieve Carbon-Neutral Cities

Aspect	Impact	References
Game Apps – Positive	Increases engagement and awareness; utilizes intrinsic motivation; scalable	[27, 30, 31]
Game Apps – Negative	Impact most significant in the short term; engagement declines over time; Uncertain efficiency of smartphone tech in environmental monitoring	[32, 40]
Gamified Places – Positive	Building a Sense of Ownership; influences public behavior; and fosters community engagement	[28, 33, 35]
Gamified Places – Negative	Risk of commodification of everyday life; potential reinforcement of inequality	[35, 36]
Common Factors	Fosters increased social participation, education, and awareness; creates a sense of community; encourages lifestyle and behavioral change	[2, 9, 13, 24, 30]

Simplified scenarios used in gaming may not be fully generalizable to real-life decision-making and behaviors [12]. Gamification per se is not necessarily capable of inducing the desired results but needs to be tailored according to the user's preferences [24]. Therefore, regardless of whether a game app or a gamified place is selected, meticulous attention to the design, implementation, and continuous management of the gamification strategy is crucial. This ensures it not only effectively engages users but also promotes sustainable behaviors and supports the overarching objective of achieving carbon-neutral cities. Ultimately, the right approach will depend on a balanced consideration of the advantages and limitations of each option, as well as societal preferences, the legitimacy of the methods, and their acceptance by society.

8 Conclusion

As climate change threats intensify, the urgency to shift towards carbon-neutral cities and sustainable communities has become undeniable. To achieve carbon neutrality, it's essential to comprehend social science deeply, enabling us to navigate the complexities of transitioning societies towards sustainability amidst climate change. Therefore, success relies on a collective effort that integrates advancements in social science with proactive community involvement. In this manner, employing innovative strategies has the potential to actively engage individuals in embracing eco-friendly behaviors.

This paper in Fig. 2 highlights the collaborative role of gamification in nurturing sustainable communities towards achieving carbon-neutral cities. This model intricately depicts the interconnectedness among various elements essential for sustainable communities, emphasizing their collective endeavor towards a common goal. By fostering a sense of community and ownership, gamification effectively contributes to essential components of sustainable communities such as community engagement, social participation, and a shared sense of responsibility. Moreover, boosting social participation and eco-social awareness further bolsters community engagement and fosters informed decision-making and collective commitment towards sustainability. Gamified places, with their focus on building ownership and influencing public behavior, complement the intrinsic motivation and scalability offered by game apps, collectively contributing to the cultivation of sustainable communities and the pursuit of carbon-neutral cities.

When deciding between adopting game apps or gamified places to encourage sustainable urban behaviors, it is crucial to consider the unique impacts and considerations associated with each approach. While game apps offer scalability and engagement, gamified places empower communities and foster a deeper sense of belonging. Despite their differences, both approaches converge in fostering social participation, education, awareness, and lifestyle change, underscoring the potential of gamification in advancing sustainable urban environments. Therefore, the selection of the most suitable approach depends on a nuanced understanding of societal preferences, method legitimacy, and their alignment with the overarching objective of achieving carbon neutrality.

Future research in achieving carbon-neutral cities should focus on the intersection of technology, human behavior, and urban planning. This includes exploring the scalability of gamification strategies, understanding the long-term impacts of behavior change on carbon reduction, and investigating the integration of digital and physical gamification elements within urban environments. Additionally, studies should examine the role of public attitudes and societal values in the adoption and effectiveness of these strategies, as well as the potential for policy and infrastructure to support and amplify the benefits of gamified approaches. By addressing these areas, future research can provide critical insights and innovative solutions to guide cities toward a sustainable, carbon-neutral future.

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