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From Trash to Treasure: Assessing the Effectiveness of the Green@Community Recycling Network in Hong Kong

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Abstract: Municipal solid waste (MSW) is a growing problem worldwide posing a variety of environmental and human health impacts. Despite recycling being one major strategy to alleviate MSW production, the effectiveness of recycling has been equivocally dependent on local policy implementation and citizen environmental behavior. To enhance recycling effectiveness in Hong Kong, the government has established Green@Community, a unified community-based network for recycling and public environmental education. Since its establishment, the number of visitors to and the amount of recyclable materials collected at the network increased steadily over time. Our study is the very first to investigate the effectiveness of this territory-wide recycling network. Through a questionnaire survey, we found that respondents' recycling traits were stronger if they have accrued gift tokens through participating in recycling activities. Visiting a Green@Community facility could also enhance knowledge of the types of acceptable recyclables, and respondents who had visited a Green@Community facility agreed that education and publicity could increase the recycling rate in Hong Kong. These findings highlighted the effectiveness and uniqueness of this community-based recycling network, its role in raising recycling knowledge, and its implications for policymakers and urban planners of densely populated cities to leverage society's recycling participation, but also called for more efforts on developing, promoting, and incentivizing the usage of such a network to further enhance recycling and alleviate MSW production in Hong Kong.

Keywords: community-based recycling; environment; economic incentives; public awareness

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1. Introduction

About 2.1 billion tons of municipal solid waste (MSW), which equals to 0.74 kg of waste per person, are generated in the world every day [1]. The East Asia and Pacific regions, in particular, contribute 23% of the total global MSW production [2]. An increase in the world population, rapid urbanization, and booming economy are all expected to accelerate future MSW worldwide, leading to a number of environmental, societal, and economic consequences [1].

To counteract the impacts of MSW, the European Union introduced the waste hierarchy in 1975 to establish priorities for various stages of the waste management process: prevention, followed by reduction, reuse, recycling, recovery, and disposal as the last resort [3]. Among these, recycling often receives more attention from policy makers compared to other stages such as prevention and reduction, which are also influenced by consumption behavior and are therefore difficult to be controlled or managed [4]. As a result, recycling has been a major waste management policy for a number of governments, particularly in regions with a developed economy and strong consumer market [5].

1.1. Waste Management in Hong Kong

Hong Kong, as a global financial center grappling with a dense population (7.35 million as of 2022, [6]), acute land scarcity and elevated consumption patterns, serves as an exemplary case study for evaluating the effectiveness of localized environmental interventions. This developed economy faces considerable challenges related to MSW production, as in other major cities/countries in Asia such as Bangkok [7], Singapore [8], Seoul [9], Tokyo [10] or outside Asia as in London and the United States [11,12]. The MSW disposal rate per capita in the city has generally increased, rising from 1.33 kg/person/day in 2009 to 1.51 kg/person/day in 2022 [13]. Despite a slight decrease from 1.53 kg/person/day in 2018 to 1.46 kg/person/day in 2020, it rebounded to 1.53 kg/person/day in 2021 [14,15]. In 2022, the majority of municipal solid waste (MSW) disposed of in landfills consisted of food waste, accounting for 31% (1.28 million tons). This was followed by plastics, which amounted to 21% (0.86 million tons), and paper, comprising 20% (0.82 million tons). These top three waste categories were consistent with those in 2009, where food waste was the largest component, making up 41% (1.36 million tons), followed by paper at 23% (0.75 million tons), and plastics at 19% (0.62 million tons). Comparatively, however, the amount and proportion of food waste decreased over the years, while those of plastics and paper waste increased [13,14].

The imperative for recycling arises primarily from Hong Kong's constrained geographical area and thus its limited landfill capacities. In 2020 alone, local landfills were already accommodating approximately 4 million tons of MSW [16]. It is challenging to implement recycling effectively in Hong Kong due to this scarcity of land (and thus the lack of room for large-scale recycling industry) and high operation costs [17]. Local recycling companies have therefore often opted for high-valued recyclables such as metals and paper, while low-valued recyclables such as plastics have low recycling rate and are often exported to foreign recycling companies or landfills for disposal [18,19]. However, such exporting of recyclables has been more challenging after 2018 due to tightened regulatory frameworks in neighboring municipalities [20]. China's 2018 standards on 24 types of solid waste recyclables, including requirement such as no more than 0.5% contaminants in plastics, have substantially impacted the landscape of exported recyclables since many cities including those in the United States and Hong Kong face difficulties in meeting the new standards [21]. Apart from the limited types of recyclables, high operating costs also constrain recycling facilities at the community level, which further hinders citizens' incentive to recycle [22]. As a result, the amount of collected recyclables remained low and the recycling rate in Hong Kong was only 32% in 2022, despite MSW production and disposal showed steady increasing trends from 2009 to 2022 ([13], see also Appendix B).

The low recycling rate is one major bottleneck facing waste management in Hong Kong. Such weak environmental initiative among Hong Kong citizens has often been attributed to the limited environmental education in Hong Kong's school curriculum [23,24]. The framework for environmental education in Hong Kong was first developed in the 1990s, but it was not until 2009 that specific courses and topics on environmental education began to be integrated with the formal curriculum [25,26]. However, this shortfall in environmental education may be mediated by ad hoc campaigns (e.g., "Reduce Your Waste and Recycle Your Plastics" in 2011–2012) which have been shown to improve the attitude and knowledge of citizens towards recycling [27].

Community-based recycling initiatives have emerged as another solution to deal with the mismatch in recycling and MSW production, particularly in places with high population density [28]. A community-based recycling network is defined/characterized by an extensive and accessible system of recycling facilities, such as incentive-driven participation, a diverse collection of recyclables, and flexible collection points that encourage active citizen involvement [29]. Community-based networks have received growing research interest since the early 2000s to test if recycling efficiency increases by using bottom-up instead of top-down approaches [30], and to identify ways to enhance recycling in cities [31]. These previous studies show that recycling networks have offered an alternative means

to boost recycling rate, which may subsequently facilitate recycling behavior and better management of MSW in densely populated cities.

1.2. Community-Based Recycling Network in Hong Kong: Green@Community

The Environmental Protection Department (EPD) of the Hong Kong Special Administrative Region (SAR) Government plays a pivotal role in local waste management by developing a variety of recycling infrastructure to alleviate the strain on landfills. Historically, EPD lacked stringent monitoring on the handling of recyclables, resulting in a substantial portion being directed to landfills rather than downstream recycling facilities [32]. Studies, such as that by King [18], reveal that during 2015–2018, a mere 5.4% of plastic waste underwent successful recycling and reuse, with the bulk destined for landfills. This trend eroded public confidence in the recycling process and casted doubt on the effectiveness of the former recycling facilities. In response, since 2015, the government has established a community-based recycling network known as Green@Community. It is a local recycling network designed to facilitate citizens' recycling, deliver recyclables to trustable companies, and promote recycling knowledge to the general public. Green@Community consists of facilities with different operating modes and frequencies to cater for the needs of local citizens: Community Recycling Stations (CRS), Recycling Stores (RST), and Recycling Spots (RSP). CRSs are large in area to process more recyclables as compared to RSTs and RSPs (Table 1). However, RSTs are more widespread than CRSs and also support night-time self-service recycling which is not available at CRSs. RSPs are pop-up booths set up by local CRSs and RSTs on a regular weekly schedule to target citizens who do not have recycling bins, CRSs, or RSTs nearby. There were 11 CRSs, 22 RSTs, and over 100 RSPs being established in Phase 1 (September 2020 to August 2021, Figure 1), and these figures have expanded to 77 RSTs and around 350 RSPs currently (while CRSs remain the same). These facilities are established among all administrative districts of Hong Kong and, for many of these, a designated social media page was developed to promote the facility- and district-specific details for recycling. As such, these promotions are targeting citizens living and/or working within the district and include details such as location/operating hour of new RSPs, non-recyclables being dumped at the facility (calling for future avoidance by the citizens), and publicity posts such as festive greetings [33]. This active, target-specific promotion using everyday language in Green@Community is in contrast with previous, passive approaches by the use of recycling bins, where promotion has been limited and communication channels were lacking. Communication with specific targets and messages has been shown to be more effective as compared to broadcast promotions [34,35], and this may play an important role in boosting the weight of recyclables collected by the Green@Community network, which already reached ~18 million kg in total in Phase 1 (Figures 2 and 3, Table 2, see also Appendix C).

Table 1. Recyclables accepted by the Green@Community network in Hong Kong (denoted by a tick symbol). In general, a Community Recycling Station (CRS) accepts more types of recyclables as compared to a Recycling Store (RST) and a Recycling Spot (RSP).

Recyclable	CRS	RST	RSP
Paper	✔	✔	✔
Plastics	✔	✔	✔
Metals	✔	✔	✔
Glass bottles	✔	✔	
Electrical appliances and computer products	✔	✔*	✔*
Fluorescent lamps/tubes	✔	✔	✔
Rechargeable batteries	✔	✔	✔
Beverage cartons	✔	✔	✔
Old books	✔		
Clothes	✔		
Other second-hand materials	✔		

* Small electrical appliances and computer products only.

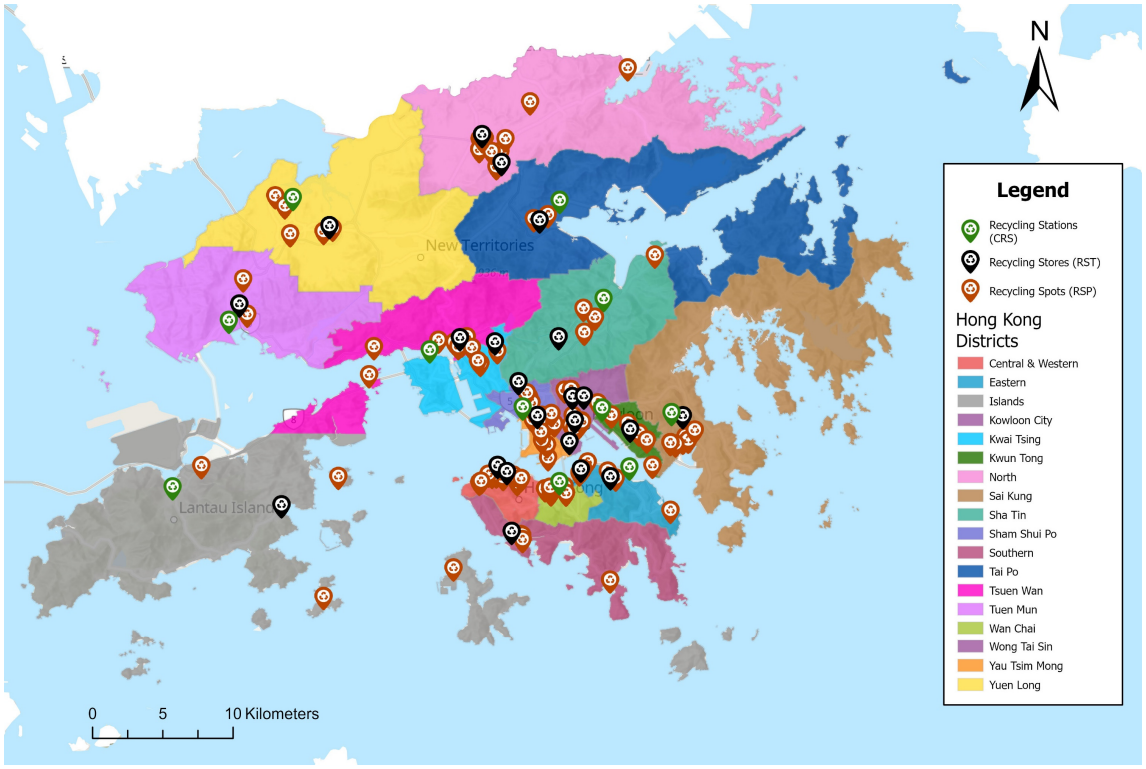

Figure 1. The spatial distribution of Community Recycling Stations (CRSs, green pins), Recycling Stores (RSTs, blue pins), and Recycling Spots (RSPs, red pins) across Hong Kong's territory in Phase 1 (September 2020 to August 2021). Colors indicate the administrative districts of Hong Kong.

Figure 2. The spatial distribution of MSW volume collected and eventually disposed of at landfills across the 18 districts of Hong Kong in 2020. The names of the districts are indicated as such.

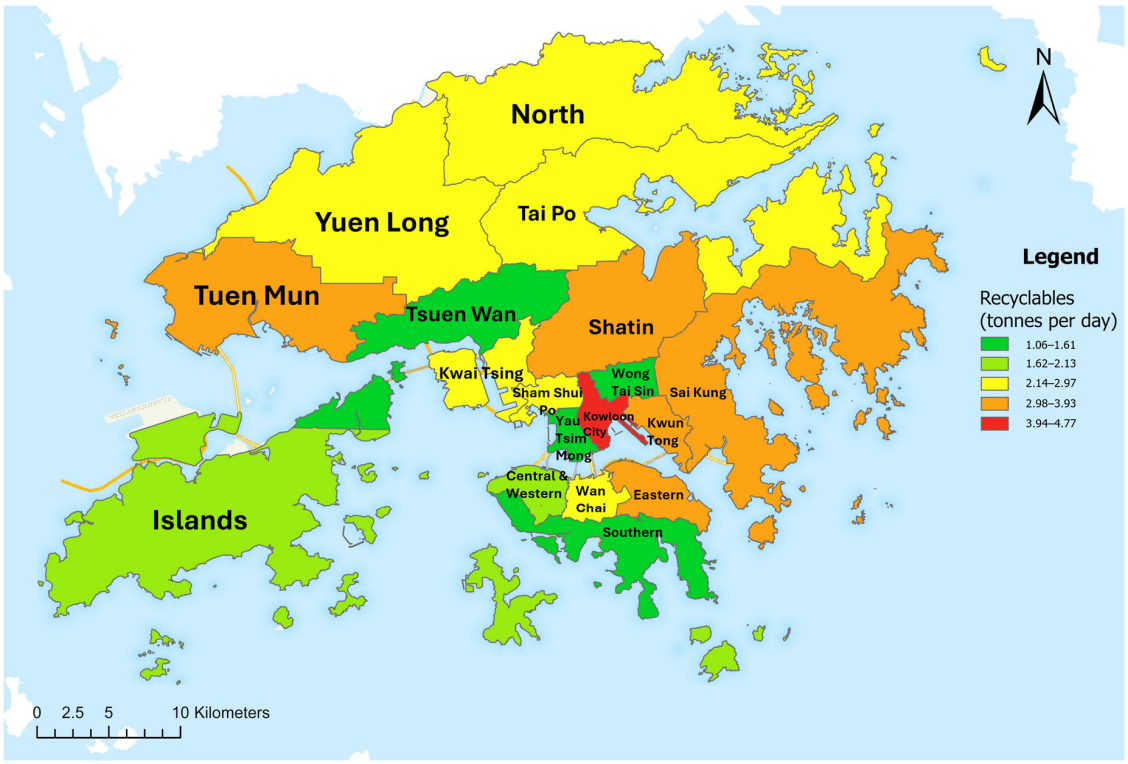

Figure 3. Spatial distribution of the amount of recyclables collected by the Green@Community network (Phase 1, September 2020 to August 2021) across the 18 districts of Hong Kong. Names of the districts are indicated as such.

In Green@Community, at least nine types of recyclables are collected, sorted, and delivered to downstream recyclers for further processing (Table 1). Citizens recycling at Green@Community can further apply for a Green$ smart card to earn tokens and redeem for daily necessities, groceries, and other gifts [33]. Recyclables provided by the citizens would be weighted and tokens would be issued proportional to the types and weights of the recyclables [33]. Similar economic incentives have been used in Santiago de Compostela, Spain, and Bracknell, United Kingdom, where recycling has been shown to be positively influenced, as expected, from behavioral economic theory [36,37]. However, the implementation of such a scheme depends heavily on whether the recycling agent is able to partner with the government, corporates, and community [38]. Consequently, while both economic incentive and target-specific communication are expected to improve citizens' environmental behavior [39], the costs in implementing these such as vouchers and daily necessities may vary substantially between localities.

Table 2. Weights of recyclables collected by the Green@Community network across the 18 districts of Hong Kong in Phase 1 (September 2020 to August 2021) (Source: Facebook pages of relevant recycling stores, retrieved in 2023).

District	Paper (kg)	Plastics (kg)	Metals (kg)	Glass Bottles (kg)	Waste Electrical and Electronic Equipment (kg)	Small Electrical Appliances (kg)	Rechargeable Batteries (kg)	Fluorescent Lamps and Tubes (kg)	Beverage Cartons (kg)
Islands	89,831	72,088	19,358	238,237	15,281	18,667	556	361	3255
Kwai Tsing	157,433	184,878	24,727	354,715	106,213	17,200	3185	4018	3824
Sai Kung	161,264	280,167	30,644	295,629	25,571	10,509	733	1883	4802
Sha Tin	177,422	151,819	21,038	593,645	127,971	29,431	1111	5368	8232
Tai Po	187,145	241,733	24,428	109,889	26,459	41,991	1809	1547	6339
Tsuen Wan	63,336	119,743	8126	32,144	9499	19,497	235	855	2210
Tuen Mun	96,103	321,265	12,535	41,314	10,486	21,207	267	439	3722
Yuen Long	126,304	230,893	28,566	360,857	82,060	27,917	1968	2331	8415
Kowloon City	310,014	366,118	36,781	192,533	28,394	65,143	1240	3513	9694
Kwun Tong	148,560	202,171	18,802	397,807	83,118	29,545	4733	3617	4891
Sham Shui Po	141,477	235,033	25,062	294,108	61,494	17,072	1684	3631	6273
Wong Tai Sin	93,401	246,787	15,361	45,958	9429	20,231	857	1233	4491
Yau Tsim Mong	59,172	180,695	10,046	105,184	4951	11,616	136	210	1904
Central and Western	103,999	250,383	17,051	85,648	17,217	30,404	528	3087	5586
Southern	57,819	97,187	9732	28,694	11,988	15,212	148	563	1871
Wan Chai	80,698	116,722	15,954	81,585	11,326	21,690	510	600	4488
Eastern	179,474	237,790	35,163	461,617	101,912	26,147	3249	4907	10,347
North	221,464	240,109	33,532	95,879	22,897	38,818	853	905	5899

The Green@Community network has greatly extended the previous recycling regime in Hong Kong, which was mainly based on the passive recycling of papers, metals, and plastics through recycling bins; it remained unclear whether citizens of Hong Kong are aware of such a network, increased types of recyclables and incentives, and the network's education role. To examine these knowledge gaps and to evaluate the network's effectiveness in enhancing citizens' awareness, knowledge, and behavior, these attributes were measured through a questionnaire survey to test whether the recycling traits of Hong Kong citizens varied with their experience with Green@Community, and whether the enhanced incentives and promotion of this network can raise the recycling rate in Hong Kong. This research contributes to urban sustainability by empirically examining the network's impact on citizens' awareness, knowledge, and recycling behaviors, which are important factors to consider in establishing recycling networks [40,41]. Hong Kong's Green@Community network represents a novel case study in this domain to investigate how localized environmental solutions may work in megacities where recycling has not been a prevailing practice among citizens and, as such, provides an exploratory scheme which could be adopted by growing cities with similar problems such as those in China or southeast Asia [42]. This novel case study highlights the critical role of community-based approaches and economic incentives in fostering waste management practices, underscoring the potential for scalability and adaptation to diverse urban settings. Consequently, the findings of this study will not only bear policy implications for Hong Kong, but also offer transferable lessons for other densely populated urban centers, especially in the Asia-Pacific region [43].

2. Results

The statistical associations between socio-demographic background and recycling attributes are shown in Table 3 (analyses of deviance on generalized linear models; numbers are chi-squared statistics and significant factors ($p < 0.05$) are highlighted by asterisks). The post hoc Tukey's test results are presented in ascending order of means with statistically different/homogenous subgroups as indicated in the table. More than half of the respondents had heard about the Green@Community recycling network, and socio-demographic background did not influence whether respondents had heard of the network or not (Table 3). However, in terms of recycling behavior and frequency, respondents in the age range of 18–25 recycled the least and respondents with post-secondary education level were more likely to recycle compared to respondents with secondary education (Table 3). Females also recycled more frequently than males (Table 3).

Table 3. Analyses of deviance of the generalized linear models investigating how socio-demographic variables (gender, education level, age class, and occupation) influenced whether the respondents had heard of Green@Community, recycled, and the frequency of recycling by the respondents or their family members. Significant factors ($p < 0.05$) are highlighted by asterisks.

Socio-Demographic Variable	Heard of Green@Community	Recycling Behavior	Recycling Frequency
Gender	$\chi^2_1 = 0.66$	$\chi^2_1 < 0.01$	$\chi^2_1 = 10.56$ *
Education level	$\chi^2_1 = 0.05$	$\chi^2_1 = 4.14$ *	$\chi^2_1 = 2.14$
Age class	$\chi^2_3 = 3.43$	$\chi^2_3 = 8.10$ *	$\chi^2_3 = 18.24$ *
Occupation	$\chi^2_5 = 4.62$	$\chi^2_5 = 1.17$	$\chi^2_5 = 7.64$
	Post hoc Tukey's tests		
		Education level: 2 < 3	Gender: M < F
		Age class: 1 = 3 = 2 = 4	Age class: $1 \leq 3 \leq 2 = 4$

Among those who had heard of the Green@Community network, over 80% of the respondents did not earn any Green$ tokens or use the tokens to redeem gift items, and 40% of the respondents did not regard Green$ smart card as an incentive for recycling. However, respondents who possessed a Green$ smart card were more likely to recycle, participate in Green@Community environmental activities, visit the recycling network and accept longer recycling distance, as shown in Table 4 (numbers are *z*-statistics where significant factors are highlighted by asterisks ($p < 0.05$) and positive/negative numbers indicate positive/negative impacts). As seen in Figure 4 (bars are mean + SD, $n = 60$ and 65 for respondents not having and having the Green$ smart card, respectively), respondents who possessed a Green$ smart card had higher mean scores (Likert-scaled scores from 1 to 5, see questionnaire in Supplementary Materials) in recycling distance and behavior, and also in visiting Green@Community network and participating in its environmental activities. Respondents were also more likely to visit the network and participate in the network's environmental activities if they earned Green$ tokens and/or redeemed gifts, or if they regarded the Green$ smart card as an economic incentive (Table 4).

Table 4. Analyses of deviance of the generalized linear models investigating how various attributes of the Green$ smart card, including possession, gift redemption, and economic incentives influenced whether the respondents had recycled, the frequency of recycling by the respondents or their family members, participated in Green@Community environmental activities, the frequency of visiting Green@Community network, and acceptable recycling distance. Significant factors ($p < 0.05$) are highlighted by asterisks.

	Recycling Behavior	Recycling Frequency	Environmental Activities	Visiting Frequency	Recycling Distance
Possession of Green$ smart card	2.50 *	1.83	2.58 *	5.92 *	3.44 *
Green$ smart card gift redemption	1.80	−0.02	4.06 *	4.99 *	1.75
Green$ smart card economic incentives	1.84	0.76	3.68 *	3.43 *	0.63

Respondents having been to RSTs of the network were more likely to recycle ($\chi^2_1 = 8.91$, $p = 0.003$) and choose education/publicity as a way to increase the recycling rate ($\chi^2_1 = 6.65$, $p = 0.010$). As seen from Figure 5 (bars are mean + SD, $n = 52$ and 73 for respondents not having been to and having been to RSTs, respectively), respondents who had been to RSTs had higher mean scores in recycling behavior and agreed that education/publicity could enhance recycling rate. The majority of the respondents were able to identify common recyclables such as paper, metals, plastic, and glass bottles. However, more than half of the respondents failed to recognize other recyclables, including regulated electrical equipment, fluorescent lamps, and paper packaging. Figure 6 shows how such knowledge on recyclables could be influenced by whether respondents had been to RSTs/passed by a Green@Community network (data were extracted from respondents who had heard of the Green@Community recycling network, $n = 127$). In general, the knowledge on recyclables improved, as reflected by higher proportions of respondents being able to identify acceptable recyclables (blue vs. green bars in Figure 6). Although being to RSTs did not alter the overall knowledge on the types of accepted recyclables (deviance = 16.96, $df = 1$, $p = 0.09$, Figure 6), respondents who knew Green@Community by passing by the network's recycling facilities had a different overall recyclable knowledge compared to those who did not (deviance = 20.76, $df = 1$, $p = 0.04$, Figure 6). In particular, respondents who knew the network due to passing by were more likely to know that fluorescent lamps and tubes were accepted recyclables ($\chi^2_1 = 8.66$, $p = 0.003$, Figure 6).

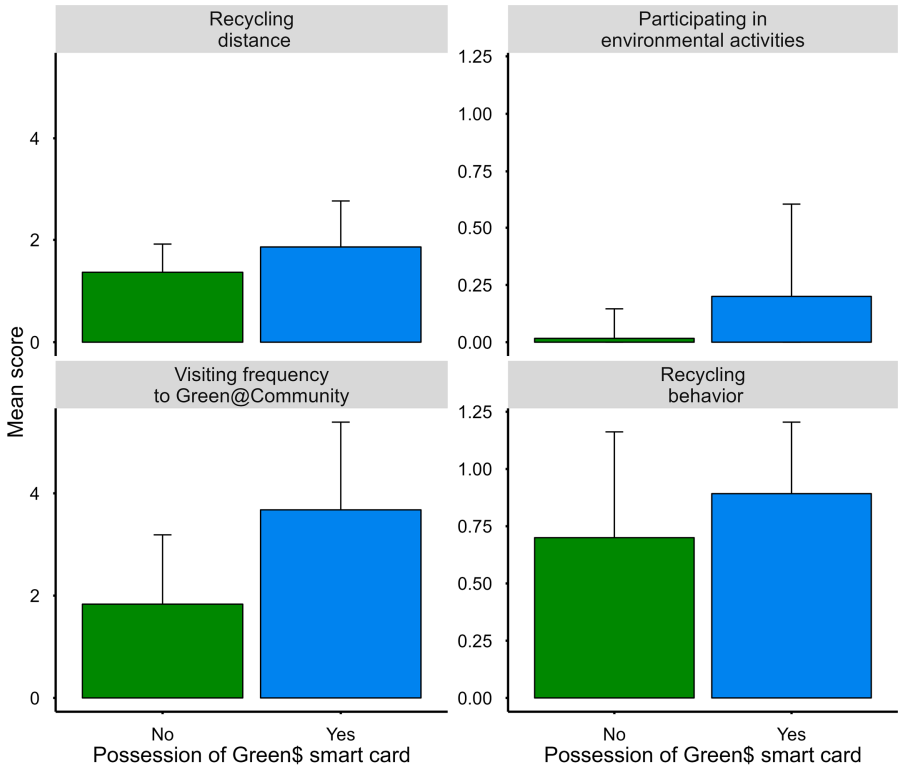

Figure 4. Relationships between possession of Green$ smart card (green bars = no and blue bars = yes) and recycling attributes: acceptable recycling distance, visiting frequency to Green@Community network, participating in Green@Community environmental activities, and recycling behavior. Bars are mean + SD of Likert-scaled scores from 1 to 4 (recycling distance), 1 to 6 (visiting frequency), or binomial scores (1 or 0, for both environmental activities and recycling behavior).

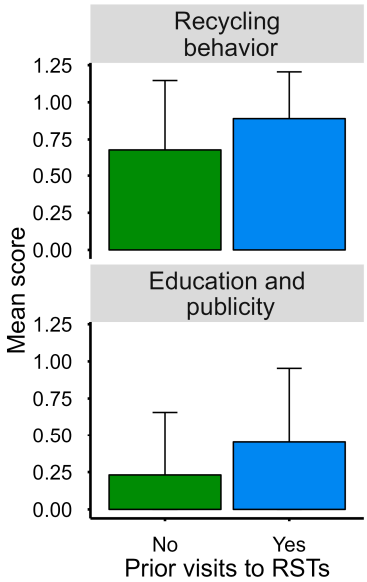

Figure 5. Relationships between prior visits to Recycling Stores (RSTs, green bars = no and blue bars = yes) and (1) recycling behavior (**top**), as well as (2) choosing that education and publicity should be enhanced to increase the recycling rate in Hong Kong (**bottom**). Bars are mean + SD of binomial scores (1 or 0) for both recycling behavior and whether respondents chose education and publicity as an enhancement option.

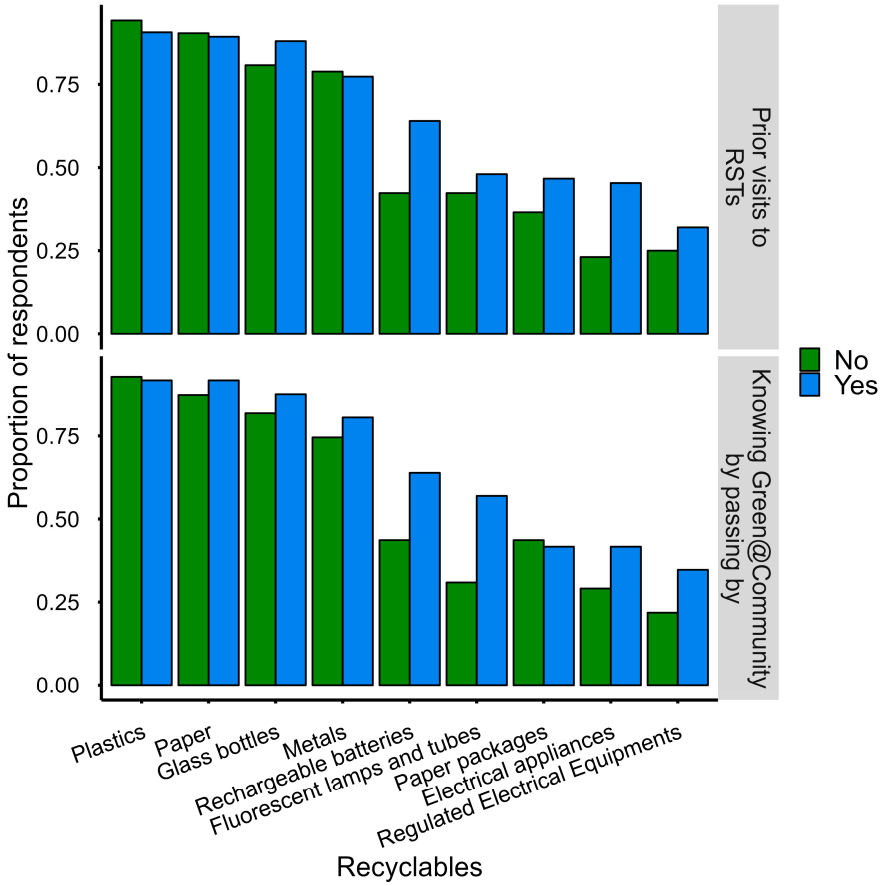

Figure 6. Differences in the proportions of respondents knowing the types of accepted recyclables by Green@Community between those who have or have not been to Recycling Stores (RSTs, **top**), or those who knew or did not know the network by passing by the network's recycling facilities (**bottom**).

3. Materials and Methods

Questionnaire to Investigate Citizens' Recycling Behavior and Awareness of the Green@Community Network

To examine economic incentives in promoting recycling behavior and the public awareness of community recycling network, a questionnaire was designed and distributed via snowball sampling on social media platforms from March to May 2022. A snowball sampling approach was used to include participants who had previous experience using the Green@Community network, which were not large in number relative to the total Hong Kong population (see Appendix A). A total of 200 responses were collected, out of which 199 were deemed valid for analyses. This yielded a response rate of 39.8%, indicating a satisfactory level of participation in the questionnaire. Despite the relatively low sample size, our study provided some of the first empirical and quantitative evidence on the use status of the network, citizens' perceptions and willingness of recycling in these newly established facilities, and how various strategies such as economic incentive and recycling experience may boost the future recycling rate in Hong Kong.

The questionnaire consisted of four sections (Supplementary Materials): socio-demographic characteristics including gender, age group, education level, and occupation (see Table A1 in Appendix A for the respondents' socio-demographics); participation in and understanding of Green@Community, such as visits to CRS/RST/RSP and the types of accepted recyclables; economic incentives entailed by the Green$ smart card; and general recycling behavior and perception such as the frequency of recycling and ways to increase recycling in Hong Kong.

To test if socio-demographic factors could explain whether citizens had heard of the Green@Community recycling network, and also whether citizens had recycled before and their recycling frequency, these three response variables were regressed against gender (two levels: M: male; F: female), education level (two levels: 2: secondary level; 3: post-secondary level), age class (five levels: 1: 18–25; 2: 26–35; 3: 36–49; 4: 50–60) and occupation (five levels: student, housewife, retired, employed, unemployed) via generalized linear models with binomial (whether they had heard of Green@Community and recycled before) or ordinal distribution (recycling frequency). Respondents with level 1 education (primary level or below, $n = 2$) and level 5 age class (61 or above, $n = 5$) were excluded due to low sample sizes. Post hoc Tukey's tests were performed for statistically significant factors. For those respondents who had heard of the Green@Community network, further analyses were performed to test how the usage and perception of Green$ smart card influenced recycling decisions. Specifically, generalized linear models were constructed to test how recycling behavior, frequency, participation in Green@Community environmental activities, visiting frequency to Green@Community and acceptable recycling distance varied separately with the possession of the smart card (two levels), smart card gift redemption (two levels), or perceived economic incentives of the smart cards (five levels). Either binomial (recycling behavior and participation in environmental activities) or ordinal distribution (recycling frequency, visiting frequency, and acceptable recycling distance) was used. To test how being exposed to Green@Community RSTs influenced recycling among citizens and whether citizens valued educational approaches to increase recycling rate, recycling behavior, and whether choosing education and publicity as a way to increase recycling, were regressed against the respondents' visits to RSTs via generalized linear models with a binomial distribution. To further test how recycling knowledge varied with being exposed to RSTs or not, a multivariate approach was adopted. Specifically, for each respondent, a multivariate response was constructed based on whether the respondent knew which types of the recyclables were accepted by Green@Community. For instance, if the respondent knew that paper and plastics were acceptable recyclables among the nine options, then the multivariate response for this respondent would be [1,0,1,0,0,0,0,0,0]. This constitutes an overall understanding of the types of recyclables accepted by the network, and was tested against whether the respondents had been to RSTs and whether the respondents knew Green@Community by passing by one of the recycling facilities, using multivariate generalized linear models with binomial distributions (package mvabund in R, [44]). All analyses were performed in R 4.1.0, Vienna, Austria [45]. The flow diagram in Figure 7 outlines the methodology and analytical approaches.

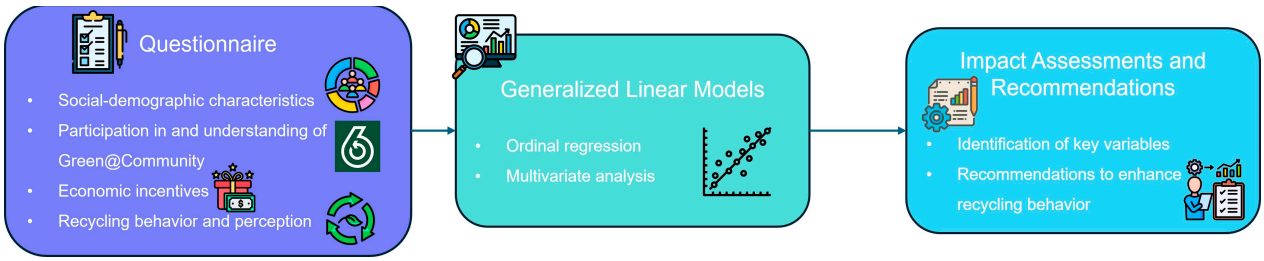

Figure 7. Flow diagram showing the data collection and analysis processes. Briefly, empirical data were collected through questionnaires measuring the socio-demographic background of citizens with experience using the Green@Community recycling network. Statistical analyses using generalized linear models were then performed and key variables were identified from the analyses, which were subsequently examined to evaluate strategies to improve effectiveness of the network.

4. Discussion

This study is the first to investigate how Green@Community, an exemplary community-based recycling network in a high-density urban environment, may influence the recycling traits of citizens. Our findings contribute to the growing body of literature on urban sustainability by quantifying the impact of a comprehensive and mobile recycling initiative on public engagement and waste management outcomes.

Our results reveal that the visibility and accessibility of recycling facilities are strong determinants of recycling behavior. Both the number of recyclables collected at RSTs and the number of visitors showed a steady increase from 2020 to 2021. In particular, the number of visitors had increased substantially by 330% between 2020 and 2021 (see Appendix B). Such an increasing trend was likely driven by the more extensive network of Green@Community since 2020, where the number of RSTs has increased rapidly and RSP pop-up booths have been set up in the community on a regular basis [46]. As a result, more citizens were aware of the network and, indeed, passing by the recycling facilities is an effective way allowing citizens to know about the Green@Community network (according to ~36% of the respondents). Establishing an extensive set of recycling booths, despite it being temporary, may drive a positive feedback loop to enlarge the network by engaging more citizens and perpetuating a stronger demand for recycling. This could be an effective strategy since RSPs are highly mobile and convenient to set up, thus allowing the network to reach small villages and localities where a permanent, indoor facility is difficult to establish. Such a small-scale recycling network has also been implemented in Santiago de Compostela, Spain, in 2015. Citizens recycled at designated locations in the city to gain recycling vouchers [37]. For Green@Community, this mobile and diverging network has been coupled with active, target-specific promotion/information sharing on social media, an important means to enhance the participatory role of citizens in recycling practice, communication, and promotion [47].

Another key factor in promoting Green@Community is the utilization of economic incentives in terms of tokens and gift redemption. Economic incentives have been shown to be effective in reducing MSW and increasing recycling behavior [38,48,49]. Green@Community enables citizens who recycled to redeem daily goods and environmentally friendly products via the Green$ smart card [50], and this gift redemption was positively associated with recycling behavior and engagement in the network for both visiting frequency and environmental activities. Our research therefore provides evidence for the impact of economic incentives in promoting recycling behavior within dense urban contexts. Citizens with the Green$ smart card were also willing to travel a longer distance to recycle as compared to those who did not possess the card. Whilst this could be explained by the fact that respondents who were more environmentally friendly would engage more in Green@Community, the Green$ smart card might enhance such motivation and strengthen public recycling behavior. In June 2024, the HK EPD introduced a sixfold increase in the membership points promotion, lasting until July 2024. This promotion consisted of rewarding users with 1 kg of rice (~HKD 20) per 2.5 kg of plastic recyclables brought to the network, and led to a notable 25% rise in the collected recyclables, from 2240 tonnes to 2790 tonnes within two months [51]. This substantial increase underscores the positive impact of economic incentives on promoting recycling behaviors among citizens. In Bracknell, United Kingdom, leisure incentives such as discounts at sporting facilities were offered to citizens participating in household recycling, which eventually eliminated 1000 tons of residual waste [36]. In fact, waste recycling is inherently susceptible to the "tragedy of the commons" due its reliance on collective actions, which often involve a time cost to achieve desirable environmental outcomes. This dilemma could be mitigated by reward systems, such as those adopted in this study and previous studies, which have been suggested to motivate individuals to engage more in collective actions and recycling [43,52].

A key contribution of this study is the identification of specific barriers to community-based recycling in high-density urban areas. The possession of the Green $ smart card was only 33% among the respondents, while a mere 12% of the respondents indicated that

they had redeemed gifts at Green@Community. This might reflect a lack of promotion, or that the economic benefits in terms of gift redemption are not attractive to the general public. Therefore, to maximize the potential of economic incentives, a promotion of the Green$ smart card and/or gift item surveys should be conducted to better identify the daily needs of the general public. This could be performed by matching incentives for citizens with different demographic backgrounds, as has been shown in China [31]. Indeed, targeted incentivization should be formulated for young citizens 18–25 in age who were shown to engage the least in recycling. Such incentive schemes should be monitored periodically to record, forecast, and improve their effectiveness in promoting environmental behaviors [31,53].

Despite the growing trends in recycling by the Green@Community network, the amount of recyclable collected is still low compared to the total amount of MSW production (1.54 million tons vs. 5.49 million tons in 2020, [16]). The efforts of the recycling network also appeared to be offset by the increasing waste disposed of at landfills. Tightened international import policies further impacted the overall recycling rate in Hong Kong recently, as recyclables were unable to be exported overseas and were eventually disposed of at landfills [54]. This offset has challenged the effectiveness of Green@Community in the overall waste reduction in Hong Kong and called for a stronger participation of citizens to maximize the benefits as delivered by this territory-wide recycling program.

The need for better promotion of Green@Community is also reflected by the observation that although more citizens have heard of the network (64%) as compared to 2017 (38%, [55]) and RSTs have established publicity pages on social media, more than 60% of the respondents did not know about RSPs and 89% did not join any Green@Community education activities. These indicated that either the public did not pay attention to the recycling activities/stores held by the network, or the network is lacking publicity to raise citizens' awareness [56]. Ari and Yilmaz [30] suggested that participation in recycling activities is an effective means of promotion and, given that most respondents learnt about the Green@Community network when passing by the recycling facilities, a more extensive coverage of RSP/RST should be beneficial for promotion. This could be achieved by more flexible locations of RSPs (instead of having pop-up booths fixed in location) with promotion on the local CRSs and Green$ smart card, so that citizens would be more exposed to information on the Green@Community network and its economic benefits. In fact, since 2023, several actions have been taken along these lines by the Green@Community network to enhance effectiveness. These include the establishment of new recycling points in underserved areas, more attractive incentive programs to encourage greater participation, and the launch of targeted educational campaigns aimed at raising awareness about recycling practices [57]. Survey results indicated that those who were unaware of Green@Community were more concerned about the distance to recycling facilities. By increasing the number of conveniently located recycling points, the network can attract these individuals to recycle. Studies have demonstrated that the proximity of recycling facilities significantly influences recycling behavior, particularly in urban settings [58,59]. For instance, research conducted in South Korea has shown that strategically placing recycling facilities closer to residential areas can enhance participation and foster sustainable waste management practices [60]. Therefore, the recent measures adopted by Green@Community align well with the specific needs and preferences identified by the current study, which are expected to strengthen the overall impact and reach of the Green@Community network.

In terms of raising community awareness around recycling, individual environmental behavior plays a key role by driving subjective norm, attitudes toward behavior and perceived behavioral control at the society level [61,62]. Consistent with Chung and Poon [63], most of the respondents (72%) of the current study had recycled before, which might reflect a positive attitude towards recycling. However, the majority of the respondents only had modest knowledge of the types of recyclables (e.g., paper, metals, and plastics) accepted by Green@Community, while more than half of the respondents failed to recognize over half of the accepted types of recyclables (e.g., fluorescent lamps and tubes). However, this

could be significantly improved by passing by or visiting the Green@Community facilities. As a result, encouraging citizens to recycle at the network is expected to provide positive feedback on individual recycling knowledge and, ultimately, to influence community awareness and recycling as a social norm.

To further increase recycling knowledge and awareness among citizens in the long term, however, waste management education is crucial. In fact, teaching waste management at a young age and integrating waste management education into school curriculums and community programs can significantly enhance public understanding and participation in recycling [64]. One future avenue for Green@Community is therefore more extensive school and public education to foster a culture of environmental responsibility among Hong Kong citizens, which is fundamental to the city's waste management in the long run.

Our findings offer practical implications for policymakers and urban planners. The study demonstrates that a combination of mobile recycling facilities, targeted social media promotion, and economic incentives can effectively increase recycling participation in high-density urban areas. Although the small sample size in our study provided only a preliminary glimpse into the usage and perception of Green@Community, this is the first systematic study assessing the effectiveness of Hong Kong's first community-based recycling network and its potential for future growth. Our results also underscore the need for continuous monitoring, larger scale studies, evaluation and adaptation of the network to ensure its long-term effectiveness, particularly in the face of changing international recycling policies and local waste management challenges.

5. Conclusions

Despite the increasingly extensive network of Green@Community and the number of citizens using the network, improvement in recycling rate has been lagging behind the local MSW production. Our study has identified the strengths of the network in promoting recycling behavior through extensive networking, social media promotion, and economic incentives, providing recycling experience and raising awareness on the types of accepted recyclables. Despite this effort and the increasing number of citizens recycling at the network, the majority of the Hong Kong population were not aware of the facilities provided by Green@Community. Therefore, to maximize the potential of such a community-based recycling network, measures such as more flexible RSP locations, promotional effort, and targeted incentives for citizens with different socio-demographic background should be adopted. An effective recycling network is fundamental for enhancing public awareness and encouraging environmental behaviors. Expanding community engagement programs could further bridge the gap between awareness and participation, fostering a culture of waste management practices across diverse sectors of the population. It is recommended that future initiatives focus on integrating educational campaigns with recycling activities to enhance the utility of the network. Additionally, expanding the recycling network to include more accessible drop-off points should help increase participation. This study not only contributes to a better understanding of the role of community-based recycling but also offers actionable insights for policymakers aiming to improve recycling rate and public engagement. Further research should explore the long-term impacts of these measures on recycling rates and public awareness. Larger and more representative samples will be necessary to validate these results and ensure their generalizability to the broader population. As such, the Green@Community network has provided a model system that may be adopted elsewhere to strengthen community recycling, enhance citizens' recycling knowledge, and ultimately reduce local MSW production.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/recycling9060110/s1, Part 1—Introduction; Part 2—Questions; Part 3—Understandings on Green Stations; Part 4—Understandings on Green Card; Part 5—Recycling behaviour.

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Abbreviations

CRS	Community Recycling Stations
MSW	Municipal Solid Waste
RST	Recycling Stores
RSP	Recycling Spots

Appendix A

Table A1. Socio-demographic characteristics of the respondents who participated in the questionnaire investigating citizens' recycling behavior and the usage of the Green@Community recycling network. *N* = 199 effective responses.

Socio-Demographic Variable	Number of Respondents
Gender	
Male	83
Female	116
Age group	
18–25	73
26–35	41
36–49	40
50–60	40
61 or above	5
Education level	
Primary level or below	2
Secondary level	47
Post-secondary or above	150
Occupation	
Student	40
Employed	122
Unemployed	9
Housewife	8
Retired	13
Others	7

Table A2. Percentage increases in the number of citizens visiting Recycling Stores of the Green@Community recycling network in September 2021, as compared to October 2020 (Source: Facebook pages of relevant recycling stores, retrieved in 2023).

Recycling Store Location	Percentage Increase (%)
Tin Wan	252.18
Tin Hau	183.43
Sai Ying Pun	200.95
San Hui	37.68
Sheung Wan	69.58
Shek Wu Hui	331.31
Po Lam	274.81
Cheung Sha Wan	402.71
Yue Man Square	905.26
Quarry Bay	554.38
Tai Wai	879.87
Fanling	678.21
Walled City	897.97
San Po Kong	90.45
To Kwa Wan	230.35
Hung Hom	288.30
Kwai Chung	123.07
Lo Tak Court	215.40
Tai Kok Tsui [1]	246.01
Tai Po Market [1]	263.69
Yuen Long Hui	166.39
Mui Wo [2]	99.23
Average	335.69

[1]: Tai Kok Tsui Recycling Store and Tai Po Market Recycling Store has started since January 2021. [2]: Mui Wo Recycling Store has started since February 2021, and there are no data between April 2021 and September 2021.

Appendix B

Current status of MSW in Hong Kong and visitor numbers of Green@Community

To examine the current MSW production and visitor numbers of Green@Community in Hong Kong, the following sets of data were extracted from publicly available databases maintained by the Environmental Protection Department of the Hong Kong Government as well as records available from RSTs: daily domestic waste disposals in landfills and municipal waste production from 2009 to 2020; the number of citizens visiting RSTs from October 2020 to September 2021; and also the amount of recyclables collected by RSTs at the same period of time.

The MSW production in Hong Kong had increased by ~24% from 8963 tons per day in 2009 to 11,128 tons per day in 2021, but disposed solid waste had increased by ~17% during the same period and achieved a relative high rate at 1.51 kg per person per day in 2022 (HK EPD, 2023). The quantity of recyclables recovered from MSW also decreased from 2009 to 2022 by ~41% (from 3.2 to 1.9 million tons) (HK EPD, 2010; HK EPD, 2023). More recently, the amount of recyclables received at the RSTs increased from October 2020 to September 2021. The number of citizens visiting RSTs also increased from ~10,000 on average in October 2020 to more than 40,000 in September 2021. Among the 21 RSTs, overall, the number of visitors had increased by 330% between 2020 and 2021 (Table A2 in Appendix A).

Appendix C

Collected recyclables by Green@Community during Phase 1 (September 2020 to August 2021) (Source: Facebook pages of relevant recycling stores, retrieved in 2023).

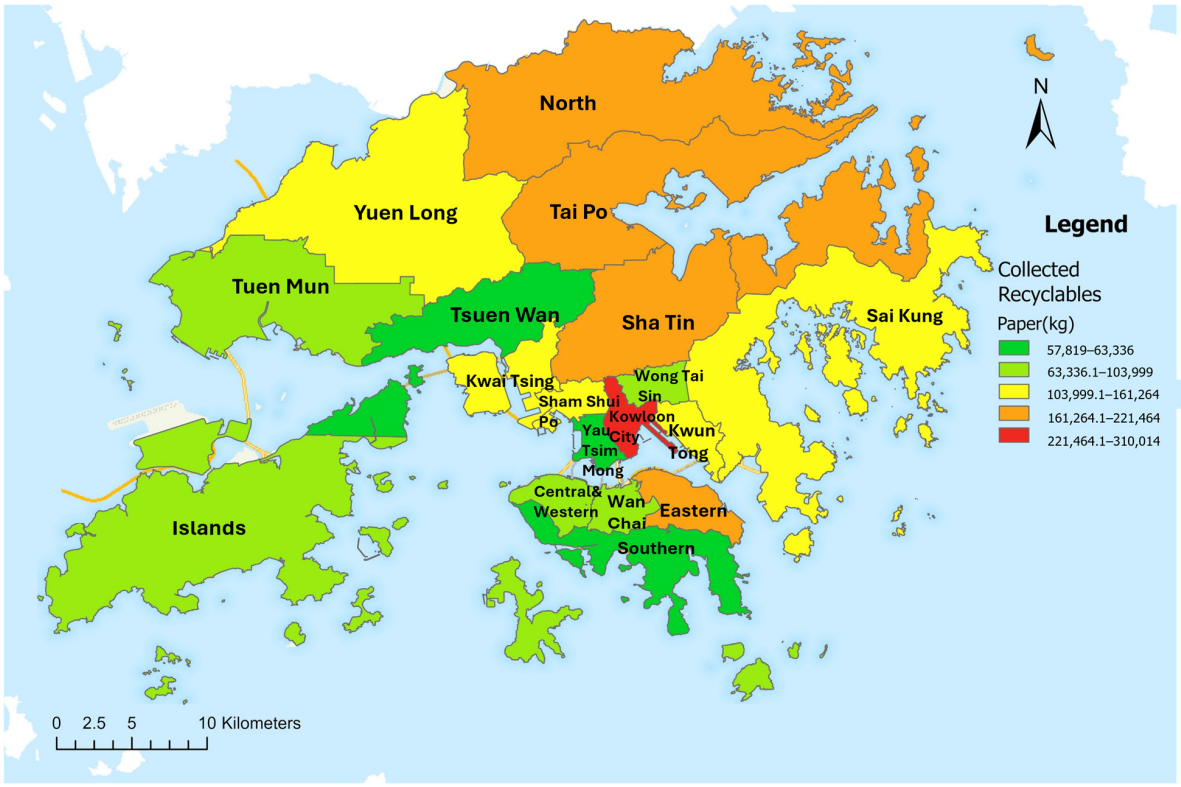

Figure A1. Collected paper by Green@Community during Phase 1 (September 2020 to August 2021).

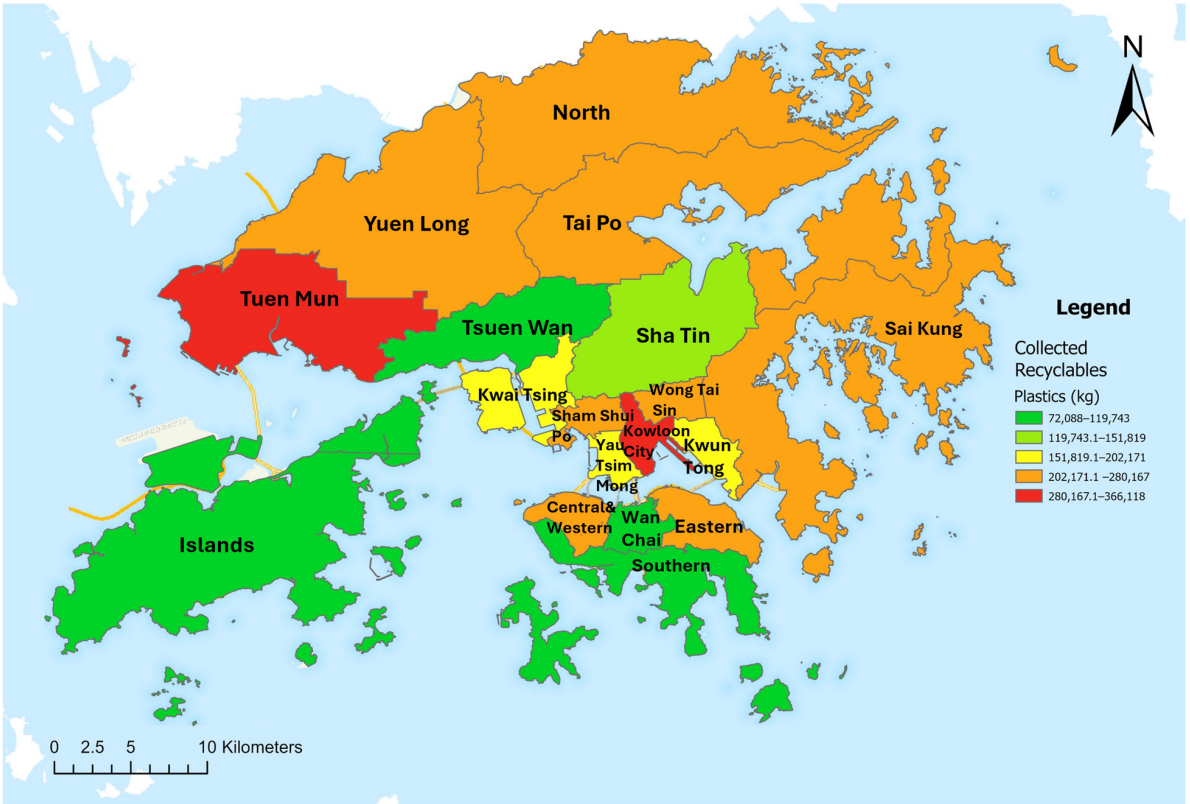

Figure A2. Collected plastics by Green@Community during Phase 1 (September 2020 to August 2021).

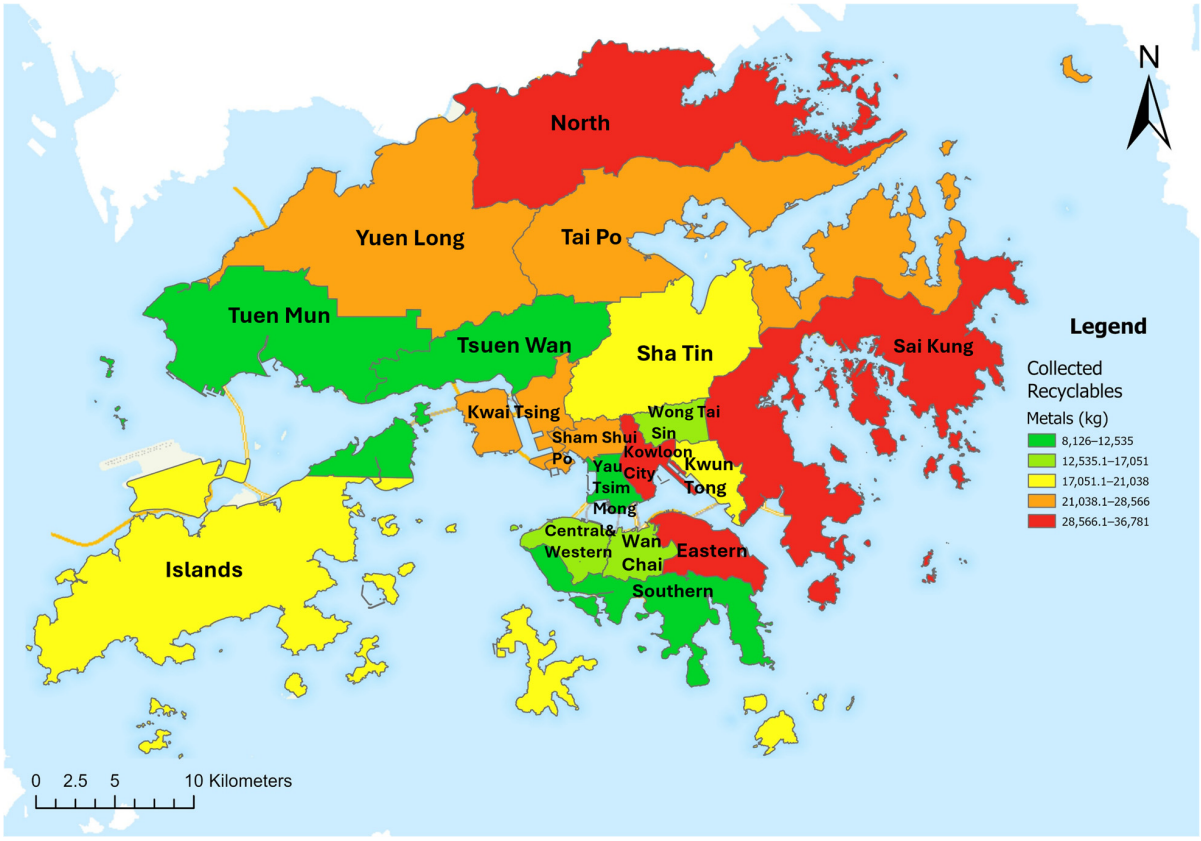

Figure A3. Collected metals by Green@Community during Phase 1 (September 2020 to August 2021).

Figure A4. Collected glass by Green@Community during Phase 1 (September 2020 to August 2021).

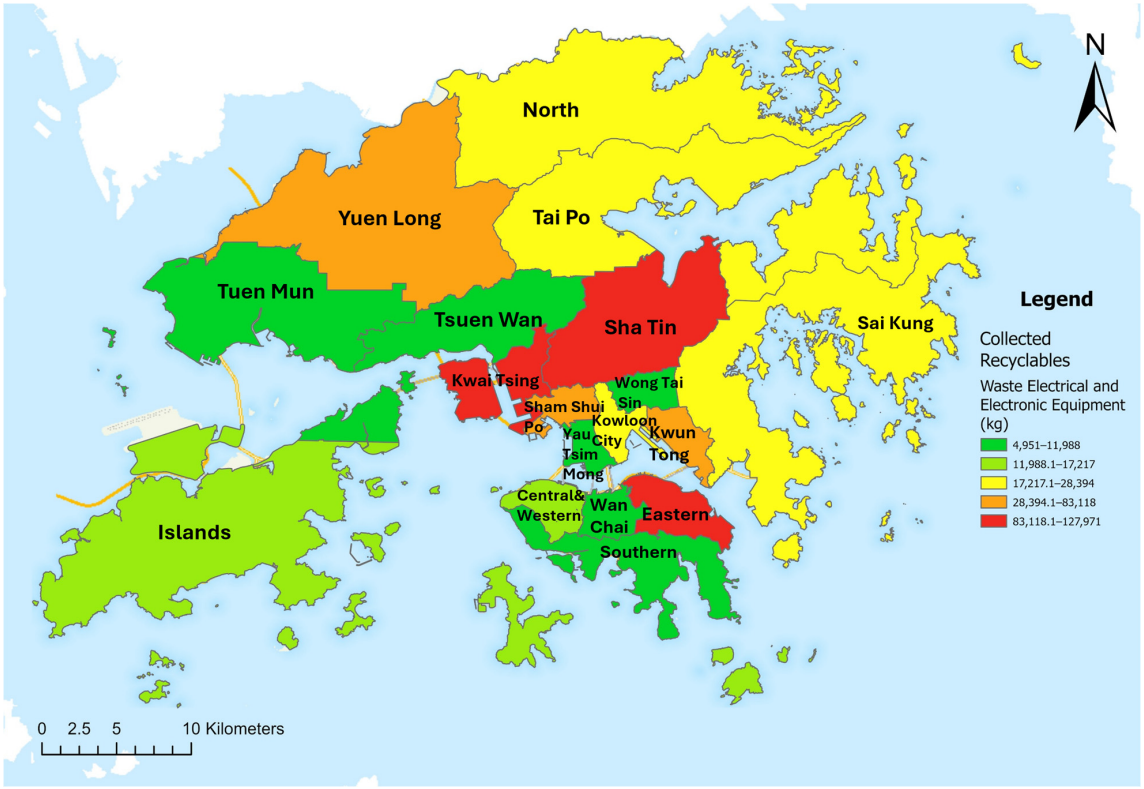

Figure A5. Collected waste electrical and electronic equipment by Green@Community during Phase 1 (September 2020 to August 2021).

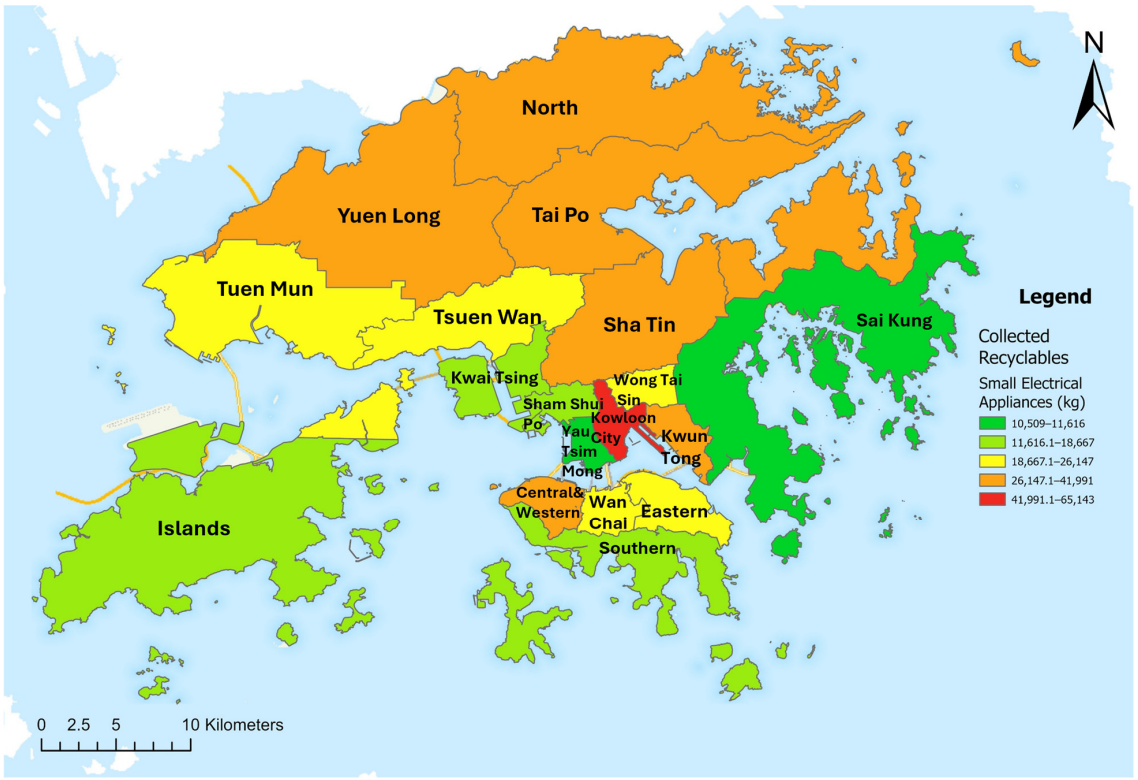

Figure A6. Collected small electrical appliances by Green@Community during Phase 1 (September 2020 to August 2021).

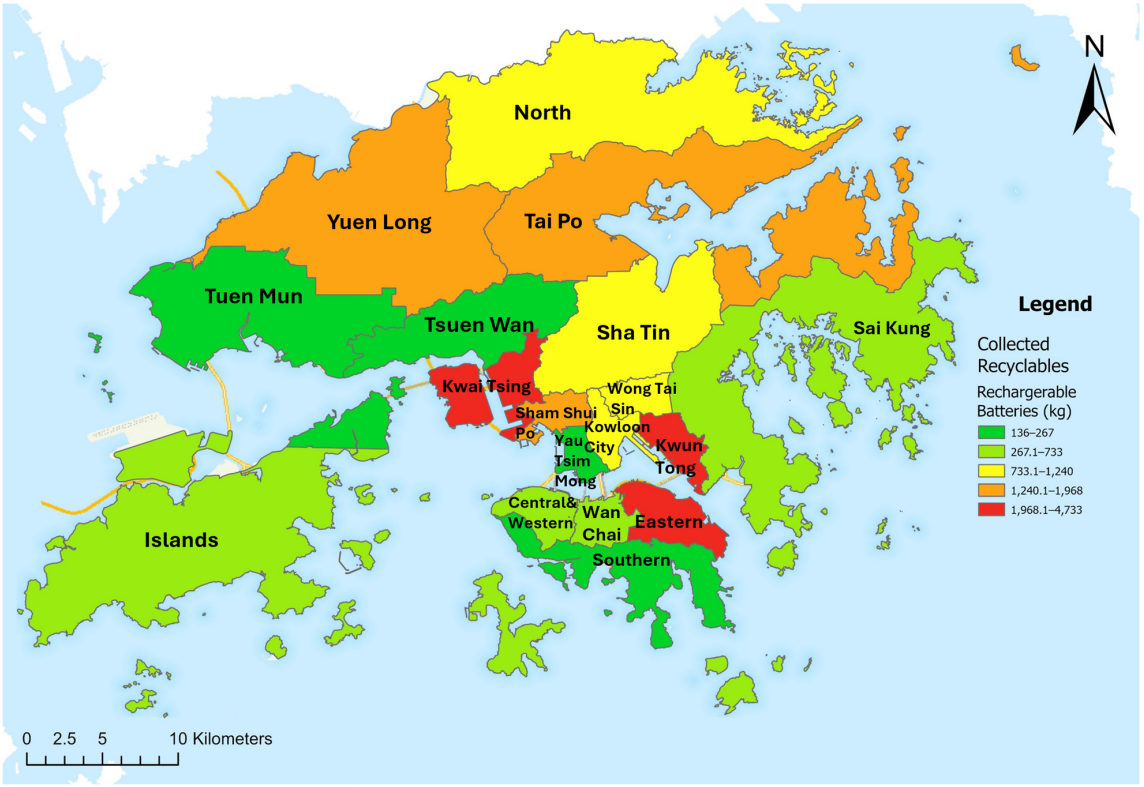

Figure A7. Collected rechargeable batteries by Green@Community during Phase 1 (September 2020 to August 2021).

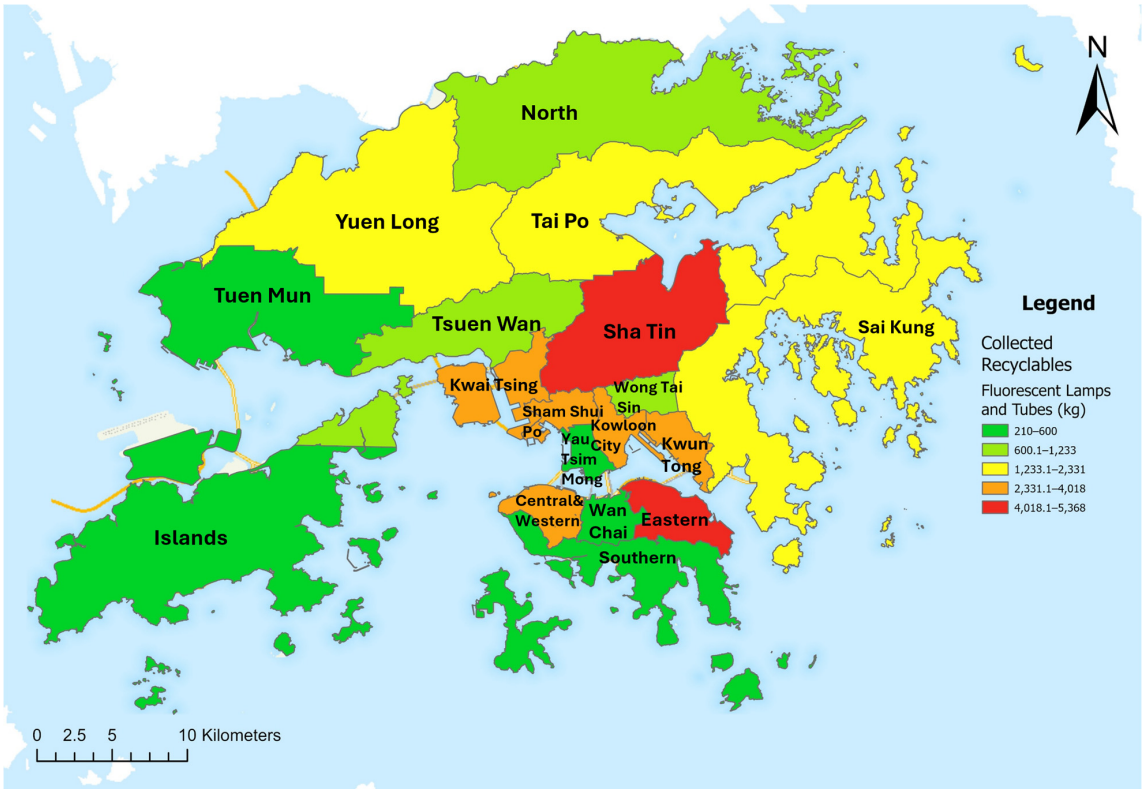

Figure A8. Collected fluorescent lamps and tubes by Green@Community during Phase 1 (September 2020 to August 2021).

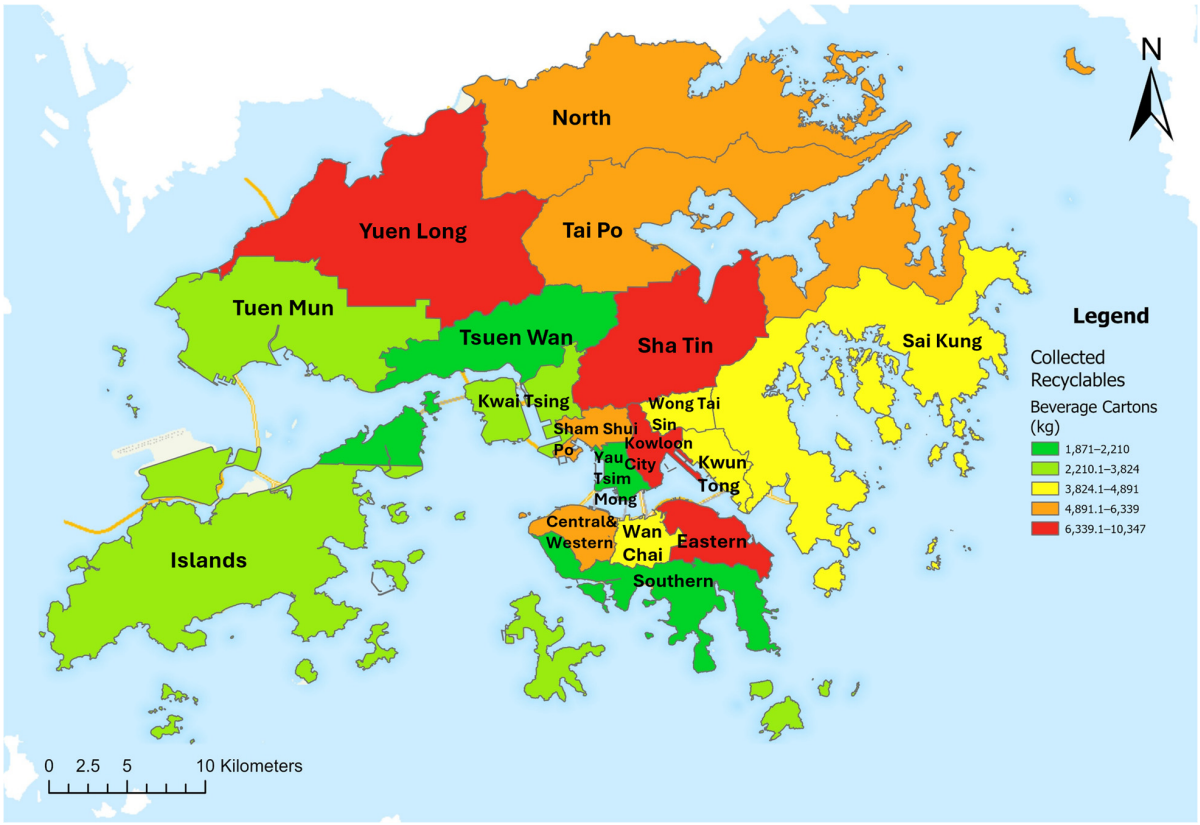

Figure A9. Collected beverage cartons by Green@Community during Phase 1 (September 2020 to August 2021).

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