Community Carbon Reduction: Measurement Methods, Emission Characteristics, and Implementation Pathways

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Abstract. Achieving carbon neutrality requires sustained and broadly based carbon-reduction action. Cities are major sources of emissions and therefore bear a substantial share of this responsibility, yet effective pathways for reducing emissions at the community scale remain insufficiently resolved. From the perspective of residents' activities, this study develops a comprehensive carbon-accounting model for urban communities and applies it to five communities in Shanghai, Shenzhen, Chongqing, and Quzhou. The results show that socioeconomic factors - including household income, everyday behavior, and residential patterns - and physical-spatial factors - including functional mix, building technologies, and spatial design - have significant effects on community emissions. On this basis, the study proposes five implementation pathways: improving the community microenvironment, adopting appropriate green construction technologies, greening mobility, promoting low-carbon lifestyles and consumption, and strengthening policy support.

Keywords: community carbon reduction; carbon emissions; carbon accounting; green community renewal.

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In September 2020, President Xi Jinping announced that China would achieve carbon neutrality before 2060, reaffirming the country's determination to pursue green development under the framework of ecological civilization. Research suggests that China's urbanization rate will be approximately 74% when carbon emissions peak [1]. As urbanization continues, the choice of a carbon-peaking pathway is therefore critical. Cities, which carry major strategic development functions, are both the key leverage point and an essential testing ground for low-carbon development [2-3]. They account for roughly 85% of energy consumption. International experience indicates that energy demand accelerates once per capita GDP exceeds USD 10,000 (Figure 1). As economies restructure, urban energy use is likely to shift from production-oriented consumption toward household and service consumption. Because Chinese urban consumption remains well below that of advanced economies in Europe and North America, future growth in demand will bring additional energy use and carbon emissions. Low-carbon renewal of communities - which combine spatial and social attributes - from the perspective of residents' behavior is thus a major entry point for achieving China's dual-carbon goals in the residential and building sectors [4].

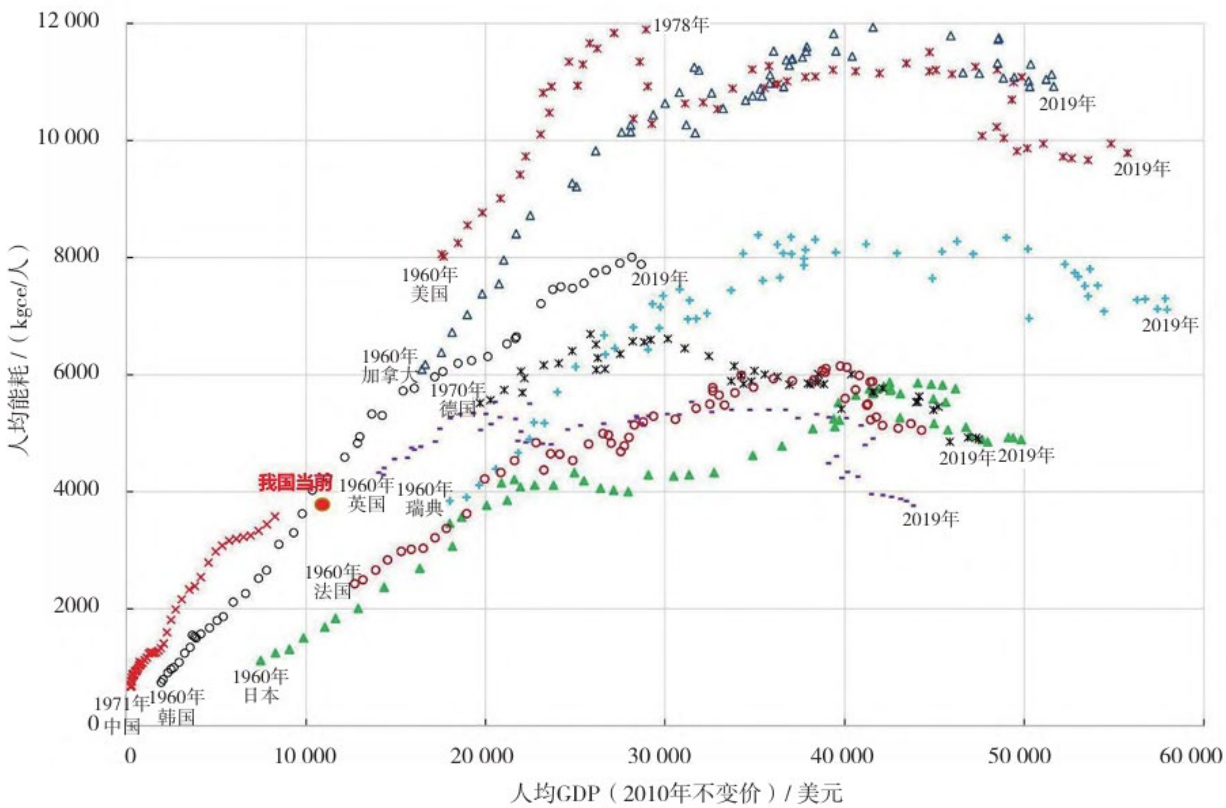

Figure 1. Relationship between total energy consumption per capita and GDP per capita in selected developed countries

Source: CCICED, Community Green Renewal under the Dual-Carbon Goals: Major Green Technology Innovation and Its Implementation Mechanisms, 2021.

When attention turns to carbon reduction in urban communities, however, no consensus has yet emerged on measurement and accounting. Drawing on participation in the CCICED study “Community Green Renewal under the Dual-Carbon Goals: Major Green Technology Innovation and Its Implementation Mechanisms,” the authors constructed a systematic carbon-accounting model for urban communities, tracked emissions data from five representative communities, and analyzed the factors shaping carbon emissions in community renewal. The study further explores targeted, effective, and affordable reduction strategies and green-technology applications at the community level, with the aim of providing practical support for fulfilling China's national dual-carbon commitments.

1 Importance of Community Carbon Reduction under the Carbon-Neutrality Goal

1.1 Community Carbon Reduction Is Critical to Urban Decarbonization and Green Community Renewal

As demand for a better life grows, community carbon emissions are likely to rise further. The report to the 19th National Congress of the Communist Party of China redefined the principal contradiction in Chinese society: from the contradiction between people's growing material and cultural needs and backward social production to that between people's growing need for a better life and unbalanced and inadequate development. A better life implies greater material enjoyment, consumption, and energy use. In ten Chinese cities with high consumption levels (per capita disposable income of at least RMB 50,000), per capita household energy consumption increased two- to threefold over the past two decades (Figure 2). Without systematic intervention, resource and energy consumption and carbon emissions in urban communities will continue to rise substantially and may become a major obstacle to achieving the dual-carbon goals.

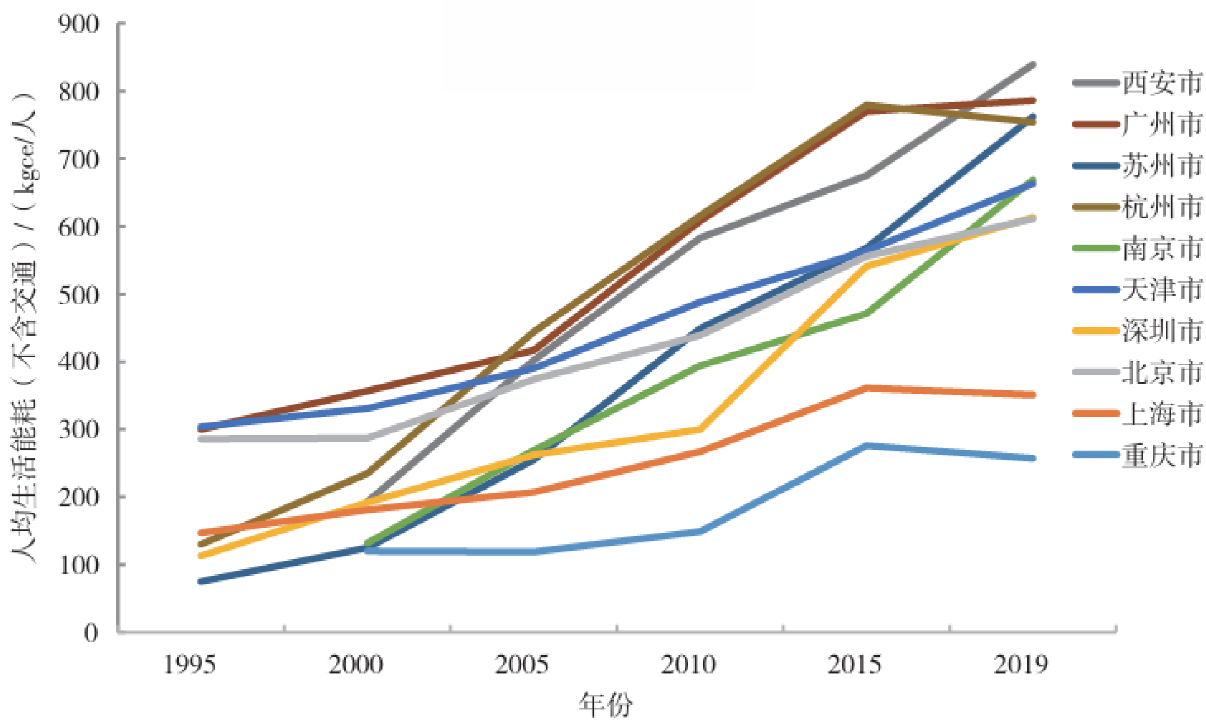

Figure 2. Per capita household energy consumption in ten Chinese cities

Source: CCICED, Community Green Renewal under the Dual-Carbon Goals: Major Green Technology Innovation and Its Implementation Mechanisms, 2021.

Green renewal offers a broad field of application for community carbon reduction. Since 2020, China has treated the renovation of old urban residential compounds as a major livelihood and development program [5]. By the end of the 14th Five-Year Plan period, the government seeks to complete, in principle, the renovation of approximately 220,000 old urban communities built before the end of 2000. In July 2020, six ministries and commissions, including the Ministry of Housing and Urban-Rural Development and the National Development and Reform Commission, jointly issued the Action Plan for Creating Green Communities. The plan calls for green development principles to guide the full process of community design, construction, management, and services and for community environments to be improved in a moderate, resource-efficient, green, and low-carbon manner. As China's urban carbon-neutrality strategy is progressively implemented, community retrofits will receive stronger policy and fiscal support; they will also require more reliable research to provide a sound scientific basis.

1.2 Research Needs and Progress in Community Carbon Reduction

1.2.1 Need for Precise Community Carbon Accounting

Based on the IPCC Guidelines for National Greenhouse Gas Inventories, China has issued greenhouse-gas inventory guidance for provinces and cities. These macro-scale inventories cover energy, agriculture, land use and forestry, industrial processes and product use, and waste, and are calculated from total consumption and sectoral statistics. Yet communities, despite being important units of climate action, still lack a unified accounting system.

Community emissions generally comprise three components: direct greenhouse-gas emissions within the geographic boundary; indirect emissions from the production and transmission of electricity and heat consumed within the community; and mobile emissions generated by cross-boundary travel and waste treatment. Researchers have developed various community-scale models, most commonly including energy use, transport, and waste [6]. Some also include residents' respiration, consumption of food and clothing, water use [7], and carbon sequestration by public green space [8]. In the absence of a standardized accounting framework, China has yet to establish a widely accepted evaluation system for low-carbon community performance. It is therefore difficult to compare low-carbon levels or track long-term changes in emissions and implementation progress [9].

1.2.2 Need for Differentiated Low-Carbon Community Development under Multiple Influences

Few studies have examined the determinants of emissions at the community scale. Most focus on a single city, and findings vary because communities differ substantially. Yang Xuanmei et al. [6], studying 1,000 households in Nanjing, identified the number of permanent residents, travel behavior, and dwelling size as the three principal determinants of household emissions. Zhu Xuemei et al. [10], examining 2,045 households in Guangzhou, found significant differences by neighborhood type, income group, and dwelling size. A comparative analysis of multiple cities and community types, based on consistent methods and criteria, is therefore needed to explain why influencing factors differ.

1.2.3 Need for Diversified Guidance Combining Green Technologies and Low-Carbon Living

Recent Chinese research on district-scale carbon-reduction technologies has gradually developed integrated technical systems and implementation strategies that balance performance and feasibility [11]. Research at the community scale remains preliminary. One strand summarizes pioneering international low-carbon communities and recommends energy-efficient buildings, renewable energy, environmentally responsible materials, optimized land use, green mobility, and public participation [12-13]. Another summarizes China's low-carbon community pilots, including low-carbon management, building retrofits, infrastructure, culture and lifestyles, and improvements to environmental quality and livability [14]. Together, these approaches cover green technologies and low-carbon living. Nevertheless, international experience is not yet well integrated with domestic practice, and Chinese pilots often lack evaluation of actual carbon-reduction performance. The scientific validity and effectiveness of current strategies therefore require further investigation.

Overall, community carbon-reduction research in China remains fragmented and cannot yet provide a systematic and reliable pathway for renewal. From the perspective of residents' behavior, this study calculates emissions associated with household energy use, mobility, food and clothing consumption, and other typical activities, while deducting carbon sequestration by green space. It then applies a full-scope model to five cases and compares them horizontally to reveal the relationships between community emissions, social conditions, and the built environment. The findings provide a basis for selecting green technologies and guiding low-carbon lifestyles in green community renewal.

1.3 Research Framework for Green Renewal of Urban Communities

This study conducts an empirical analysis of community carbon accounting, emission characteristics, and influencing factors from the perspective of residents' behavior. First, emissions are calculated for household energy use, travel, and food- and clothing-related activities, and carbon sequestration by green space is subtracted to establish a comprehensive accounting model. Second, five representative communities in four cities are selected to identify emission characteristics. Cross-community comparison is then used to reveal the internal relationships between emissions, social factors, and built-environment conditions. The results are intended to support the application of appropriate green technologies and the promotion of low-carbon lifestyles in community renewal.

2 Construction of a Community Carbon-Accounting Model from the Perspective of Residents' Behavior

2.1 Four Dimensions of Community Carbon Accounting

The selection of accounting dimensions draws on existing community-emission studies and on the availability of residents' activity data through field investigation. Four dimensions are included: community energy use, residents' travel, food and clothing-related living consumption, and carbon sequestration by greenery. Community energy use covers lifecycle emissions from the production and transport of the main forms of energy consumed within the community. Travel covers emissions from residents' trips, regardless of whether the movement occurs within the community boundary. Food and clothing-related living consumption covers lifecycle emissions from waste treatment and food consumption. Green sequestration measures the carbon absorbed by community green space.

2.2 Model Construction and Parameter Selection

Drawing on established accounting methods, the study constructs a model using data available at the community level and calibrates parameters with reference to relevant research. Total community emissions are calculated as follows:

$$E = E_e + E_m + E_l - E_g$$

where E is total community carbon emissions; E_e is emissions from community energy use; E_m is emissions from residents' travel; E_l is emissions from food- and clothing-related living consumption; and E^g is carbon sequestration by greenery.

2.2.1 Carbon Emissions from Community Energy Use

Total emissions from community energy use (E_e) include lifecycle emissions from the production, transport, and use of electricity, gas, and water:

$$E_e = E_{electricity} + E_{gas} + E_{water}$$

$$E_{electricity} = Q_{electricity} \times f_{electricity}$$

$$E_{gas} = Q_{gas} \times f_{gas}$$

$$E_{water} = Q_{water} \times f_{water}$$

Q denotes total consumption and f the corresponding carbon-emission factor. The adopted factors are f_gas = 2.2 kg/m³ [15] and f_water = 0.3 kg/t [16]. Because electricity factors vary significantly among regional grids, f_electricity is calculated using the factor for the grid serving each community.①

2.2.2 Carbon Emissions from Residents' Travel

Total travel emissions (E_m) are the sum of emissions from all trips that begin or end within the community:

$$E_m = \Sigma_k A_k \cdot L_k \cdot GHG_k$$

A_k is the frequency of trips by mode k; L_k is the travel distance by mode k. Trip frequencies are obtained from household travel surveys and distances from mobile-phone signaling data. GHG_k is the emission factor for mode k (Table 1).

Table 1. Emission factors for different transport modes

Transport mode	Emission factor (kg/km)			
	Beijing carbon-reduction study	Guangzhou carbon-emission study	Shenzhen road-transport study	Shanghai commuting-emission study
Private car	0.2500	0.2331	0.240	0.1630
Rail transit	0.0286	0.0209	0.026	0.0073
Conventional bus	0.0540	0.0260	—	0.0213
Bicycle	0.0072	—	—	0.0153
Freight vehicle	—	—	0.388	—
Shuttle bus	—	0.0203	—	0.0266

Source: CCICED project "Major Green Technology Innovation and Its Implementation Mechanisms."

2.2.3 Carbon Emissions from Food- and Clothing-Related Living Consumption

Total emissions from food- and clothing-related living consumption (E_l) include lifecycle emissions from solid-waste and wastewater treatment and from residents' food consumption:

$$E_l = E_{solid\ waste} + E_{wastewater} + E_{food}$$

$$E_{solid\ waste} = W_{solid\ waste} \times f_{solid\ waste}$$

$$E_{wastewater} = W_{wastewater} \times f_{wastewater}$$

$$E_{food} = P \times f_{food}$$

W_solid waste and W_wastewater denote the amounts of solid waste and wastewater generated. The solid-waste factor is locally specific; for areas with waste sorting, a factor of 0.62 kg/kg, based on European and North American practice, is used. The wastewater-treatment factor is 6.7×10^{-4} kg/kg [4]. P denotes population density, and the annual per capita food-consumption factor is 62.8 kg/(person·year) [3].

2.2.4 Carbon Sequestration by Greenery

Total carbon sequestration by greenery (E^g) measures the carbon absorbed by green spaces of meaningful scale within the community:

$$E_g = O \times T \times S$$

O is the CO_2 absorption rate of green space, taken as 62 g/(m^2·day) [17]; T is the number of effective photosynthesis days in each city; and S is the green-space area.

3 Empirical Study and Analysis of Community Emission Characteristics

3.1 Selection of Case Communities Based on Social and Physical Factors

3.1.1 Selection of Multiple Community Types

Case selection considered both social and physical conditions. The determinants of community carbon emissions can be broadly divided into social factors and physical-spatial factors. The selected cases vary in economic level, household structure, residential form, location, building layout, construction quality, and use of green technologies, allowing a broad discussion of different community types. Five communities in four cities were selected: Expo Homeland and Jingjiangyuan in Shanghai, Heyi in Shenzhen, Dongtang in Jiangshan, Quzhou, and Hongyupo in Chongqing.

3.1.2 Socioeconomic and Physical-Spatial Conditions of the Case Communities

The five cases differ markedly in both physical construction and residents' social conditions (Table 2). Expo Homeland and Jingjiangyuan are standard urban residential communities with similar locations and conditions. Both lie about 15 km from central Shanghai, are served by rail transit and complete community-life-circle facilities, and are dominated by nuclear families. Their main difference lies in building technology: Expo Homeland uses insulated walls and double-glazed windows. Heyi is a recently developed rental-oriented urban-village community adjacent to an industrial park in Shenzhen; most residents are young manufacturing workers, per capita living space is small, and public services are limited. Dongtang is a low-income, privately owned old community in central Jiangshan, with the lowest education and income levels among the cases. It is close to central public services, but building quality and municipal infrastructure are poor. Hongyupo is an aging, work-unit-compound-style old community in central Chongqing. It has convenient rail access but low-quality public space and supporting facilities.

Table 2. Socioeconomic and physical-spatial conditions of the case communities

Dimension	Indicator	Expo Homeland	Jingjiangyuan	Heyi	Dongtang	Hongyupo
Basic profile	Type	Standard urban community with low-carbon technologies	Standard urban community without low-carbon technologies	Rental-oriented young urban-village community	Low-income old community	Aging work-unit-compound community
Basic profile	Location	Pujiang Town, Minhang District, Shanghai	Pujiang Town, Minhang District, Shanghai	Shajing Subdistrict, Bao’an District, Shenzhen	Core of old Jiangshan city	Jiulongpo District, Chongqing
Basic profile	Year built	2006	2004	2010	1990s	1970s-1980s
Basic profile	Residents	10,119	6,268	Approx. 9,000	1,734	Approx. 16,000
Socioeconomic	Income level	Upper-middle	Middle	Relatively low	Relatively low	Middle

Dimension	Indicator	Expo Homeland	Jingjiangyuan	Heyi	Dongtang	Hongyupo
Socioeconomic	Household structure	Nuclear families	Nuclear families	One- and two-person tenants	Nuclear families	Stem families
Socioeconomic	Share aged 60+ (%)	35	22	1	13	60
Socioeconomic	Rental share (%)	20	29	98	0	60
Socioeconomic	Property rights	Commodity housing	Commodity housing	Rural collective ownership	Private ownership	Mixed private ownership and commodity housing
Physical-spatial	Location conditions	15 km from city center	15 km from city center	Adjacent to industrial park	City center	Traditional commercial center
Physical-spatial	Public green space	Central park and cluster green spaces	Central park and cluster green spaces	No park or green space	Scattered greenery	Green spaces between clusters
Physical-spatial	Building height	Multistory and mid-rise	Multistory	Multistory	Low-rise	Mainly mid-rise, with some multistory buildings
Physical-spatial	Building quality	Good	Good	Good	Poor	Poor
Physical-spatial	Low-carbon technologies	Yes	No	No	No	No

3.2 Measurement and Characteristics of Residents' Living-Related Emissions

3.2.1 Collection and Measurement of Residents' Activity Data

Residents' activity data can be collected through top-down or bottom-up methods. This study primarily used bottom-up sampling to obtain monthly average household electricity, water, and gas consumption in 2020 for residents of the five communities. Travel frequency and distance were derived from mobile-phone signaling data, while mode shares were estimated with reference to research on dominant travel distances. Solid-waste and food-consumption data were obtained from community authorities and property-management companies. The accounting model was then used to calculate per capita emissions, emissions per unit of residential floor area, and the emission structure across the four dimensions for each case in 2020.

3.2.2 Total Emissions and Emission Structure

The five communities differ significantly in both total emissions and composition, forming three emission levels and two broad structural types (Figure 3). In per capita terms, the two Shanghai communities are clearly high-emission cases, at approximately twice the level of the others. Hongyupo has an intermediate level, while Heyi and Dongtang are low-emission communities. The largest differences occur in community energy use, followed by travel. Energy-use emissions in the Shanghai cases are three to four times those in the other communities, and travel emissions are also substantially higher. Food- and clothing-related living emissions mainly reflect waste treatment; because Shanghai implements waste sorting, this component is comparatively lower there. Expo Homeland, Jingjiangyuan, and Hongyupo have some centralized green space, but the areas are modest and their sequestration contribution is small.

Emissions per unit of residential floor area also fall into approximately three levels (Figure 4). Expo Homeland, Jingjiangyuan, and Hongyupo have similar values. Heyi, with its high population density, is markedly higher, whereas the low-income old community of Dongtang is substantially lower than the other cases.

The emission structure can be divided into energy-dominated and food-and-living-dominated types. Expo Homeland, Jingjiangyuan, and Hongyupo are energy-dominated: community energy use accounts for approximately 40%-55% of total emissions, travel for 20%-30%, and food- and clothing-related living consumption for 20%-40%. Heyi and Dongtang are food-and-living-dominated: this component accounts for approximately 50%-65%, energy use for about 30%, and travel has the smallest share; travel contributes less than 5% in Dongtang. Green sequestration is relatively low in all five cases and has only a minor effect on the overall structure, although its relative contribution is somewhat larger in Hongyupo because total emissions are lower.

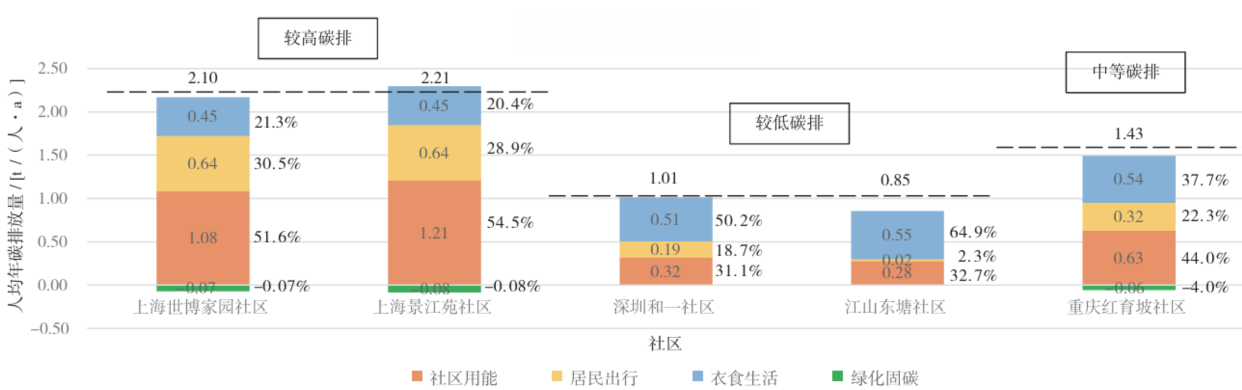

Figure 3. Structure of annual per capita carbon emissions in the case communities

Figure 4. Structure of annual carbon emissions per unit of residential floor area in the case communities

3.3 Factors Influencing Carbon Emissions in the Five Communities

3.3.1 Social Factors

Under current economic conditions, higher household income is associated with higher per capita emissions. Economic growth and carbon emissions generally exhibit an inverted-U relationship [18-19], with the turning point occurring at per capita GDP of approximately RMB 100,000-180,000 [13, 20-21]. Before this point, household emissions rise with income. None of the case communities has reached the turning point. Residents' needs and consumption therefore continue to increase as income rises. Expo Homeland and Jingjiangyuan have the highest income levels, larger per capita living space, more frequent use of household appliances, higher car ownership, and more motorized travel, all of which increase emissions. Dongtang is located in a less affluent city, while most Heyi residents are workers in nearby electronics factories; both groups have lower incomes, lower consumption, and lower per capita emissions.

Everyday behavior also has a pronounced effect. Age structure, household form, and rental share influence daily routines and energy use. Hongyupo is an aging community whose residents use energy relatively frugally, resulting in lower per capita emissions. Heyi has a high rental rate, and residents are typically away from home for long working days, reducing community energy use. Even within a single community, differences are evident: in Expo Homeland, older residents show stronger awareness of energy conservation and use approximately 15% less energy than ordinary households.

Residential patterns strongly influence emissions per unit area. Expo Homeland, Jingjiangyuan, and Hongyupo are conventional commodity-housing communities or work-unit compounds dominated by family living. Although household energy intensity and travel vary, their emissions per unit area are similar. Heyi is a high-rental, high-density urban village. Its per capita living space is less than one-third that of the Shanghai communities, so even though individual tenants consume relatively little energy, emissions per unit area are much higher. Dongtang consists of privately owned dwellings with outdated utility networks. Residents rely more on natural water sources and natural ventilation, and emissions per unit area are approximately half those of ordinary residential communities. The influence of residential patterns is nevertheless complex and also reflects demographic composition and land-use mix.

3.3.2 Physical-Spatial Factors

A higher degree of functional mix around the community helps reduce emissions. In particular, close jobs-housing balance can substantially shorten travel distances. Heyi lies next to an industrial area; jobs and housing are relatively balanced, 75% of residents travel no more than 3 km, and walking and electric bicycles predominate. Hongyupo and Dongtang are centrally located, with complete facilities and convenient public transport; residents travel shorter distances and travel emissions account for a small share. By contrast, the two Shanghai communities are suburban and provide fewer nearby jobs than housing. Average travel distance exceeds 10 km, and travel emissions are the highest of the cases. Improved jobs-housing balance can therefore markedly reduce total household emissions.

Building energy-saving technologies have clear carbon-reduction effects, but technical cost and maintenance must be considered. Low-carbon communities using green technologies generally consume less building energy per capita than conventional communities. Expo Homeland, for example, has lower per capita energy use than Jingjiangyuan despite their similar location and population structure. Yet the technologies applied were not fully mature and require periodic repair of walls and roofs, generating high maintenance costs. Technology maturity and lifecycle maintenance should therefore form part of technology selection.

Building layout and spatial design also affect emissions. Research shows that layout, density, and height influence residential energy consumption [22-23]. Sound spatial design can improve the living environment and reduce the need for artificial lighting and temperature control. A comparison of multistory and high-rise buildings in the Shanghai cases indicates that per capita electricity use in high-rise buildings is approximately 1.3 times that in multistory buildings.

The direct carbon-sequestration capacity of community greenery is limited, but its indirect effects on microclimate and residents' behavior are important. Well-designed green space combined with high-quality public facilities encourages outdoor activity and can reduce energy use inside dwellings. Expo Homeland, for example, includes a central park and public square that are frequently used by older people and children.

4 Recommended Pathways for Carbon Reduction in Urban Communities

International and Chinese experience indicates that community carbon reduction depends on both green low-carbon technologies and green lifestyles (Figure 5). Technologies intervene through physical space, infrastructure, and equipment to improve energy efficiency and the use of clean energy. Energy-related measures include microclimate design, green building renewal, and renewable energy. Mobility measures include more efficient transport organization and lower-emission modes. Living-related measures include smart energy-saving systems and solid-waste sorting and recycling. Green-sequestration measures include expanding green space and planting high-carbon-sink species. Green lifestyles reduce emissions by changing behavior: using fewer appliances, spending more time outdoors, choosing public and shared transport, working from home, conserving resources, and adopting lower-carbon diets. Green technologies generally offer larger and more stable reduction potential, while behavioral change requires institutional design and sustained guidance.

Drawing on residents' preferences and experience from other green-renewal projects, and considering the reduction potential of different actions, the following measures are proposed across spatial planning, building technology, mobility, and consumption.

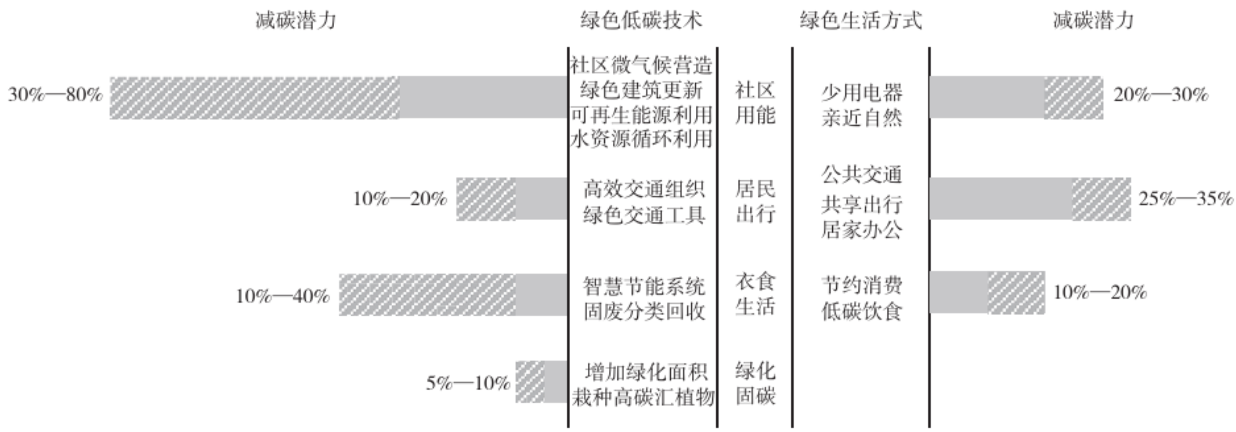

Figure 5. Carbon-reduction potential of different community measures

4.1 Improve the Community Microenvironment

Community form influences energy-use behavior and ultimately total emissions. Four priorities are proposed. First, adopt mid-rise, medium-density development [24] to balance residential density with environmental quality while reducing lifecycle maintenance costs and energy demand. Second, use small blocks and dense street networks to improve connectivity and public frontage, create comfortable and convenient walking environments, and reduce private-car use. Third, apply transit-oriented development principles to community services and provide diverse green connections to public transport. Fourth, use water bodies, trees, and vertical greenery to regulate the community microclimate.

4.2 Adopt Green Construction Technologies

The building sector is central to reducing community energy use. Green construction should first reduce emissions throughout construction and operation. Priority should be given to locally available, low-carbon, non-polluting, and low-energy materials, especially certified green building materials. A greater share of prefabricated construction and fit-out can reduce construction energy. Operational energy can be lowered through high-efficiency retrofits, including energy-saving doors and windows, shading, additional insulation, and light-colored finishes.

Second, communities should promote energy-efficient appliances, equipment, and distributed-energy systems. Idle land can accommodate complementary energy stations integrating conventional energy, distributed generation, and storage. Smart energy-management technologies should modernize supply systems and balance demand and supply in real time. Third, vertical greening should be promoted on roofs, open ground floors, balconies, windowsills, façades, and other building surfaces, with integrated consideration of structural systems, maintenance, and plant selection.

4.3 Shift Transport and Travel Modes

Transport reductions involve both modal guidance and energy transition. New-energy vehicles account for only 3.23% of China's vehicle fleet [25], so energy transition is unlikely to dominate in the near term. The immediate priority is to increase the share of green modes and reduce travel frequency and distance through effective spatial organization; over the longer term, transport-energy structures should be optimized.

First, improve the quality of walking and cycling. Continuous, safe connections should link homes and public-transport stations through pedestrian bridges, publicly accessible buildings, and open spaces. According to topography and climate, vertical connections, covered corridors, and weather-protected walkways should be provided. Second, improve interchange with bus and rail systems. Dedicated slow-traffic routes, additional community entrances, and more conveniently located bus stops and station entrances can raise public-transport attractiveness. Community shuttle services during peak periods can address first- and last-mile gaps. Third, manage shared mobility precisely by matching the number and scale of shared vehicles to actual demand and improving utilization.

4.4 Optimize Lifestyles and Consumption Patterns

Changing lifestyles and consumption has one of the most far-reaching effects on emissions and should begin early. Communities should promote water conservation, waste sorting, food saving, and other green practices and increase public acceptance of low-carbon living. Three forms of guidance are particularly important. First, low-carbon consumption should encourage products and services that use less energy, emit less carbon, and last longer, as well as green mobility and lower-carbon diets. Second, reduced use should minimize the energy and emissions generated during the operation of appliances, vehicles, and other equipment. Third, shortening the carbon chain should reduce the number and length of carbon-intensive activity links by changing where and how people work, study, and live, thereby reducing commuting emissions.

4.5 Strengthen Policy Support

Policy support spans energy, buildings, households, transport, and municipal services. In energy, market pricing should widen peak-valley electricity-price differentials, subsidize energy-saving technologies and products, and activate distributed-generation markets. In buildings, lifecycle monitoring and assessment should cover design, construction, operation, and demolition and support full-lifecycle green-building governance. Household and individual incentives could include special personal-income-tax deductions for homes that meet excellent energy-performance standards; households with seriously excessive consumption could receive retrofit subsidies subject to monitoring.

In transport, low-carbon incentive policies should include travel credits, subsidies for replacing old vehicles, incentives for low-carbon vehicles and vessels, and pilot low-emission zones. In municipal services, tiered water pricing should promote conservation and efficiency; water-resource management should coordinate community supply, drainage, and energy use; and fresh water, rainwater, and reclaimed water should be managed intelligently by quality and source. Waste-sorting supervision should be strengthened, reward and penalty mechanisms introduced, and the quality of separated waste improved. Charging systems should encourage source reduction, while market mechanisms and social capital should expand recycling and reduce residual waste requiring end-of-pipe treatment.

5 Conclusion

Communities are the principal settings of urban residence and everyday life. Achieving the dual-carbon goals while improving living standards is therefore a central challenge of community renewal. Without early and active intervention through green technologies and green lifestyles, community renewal will remain a persistent carbon-reduction challenge in urban and rural development.

With this understanding, the study focused on the practical application of green technologies, considered both socioeconomic and physical-spatial factors, and selected five communities in four cities for comprehensive quantitative analysis. It identified current emission characteristics, future trends, and major decarbonization difficulties. Four principal contributions emerge: (1) a community carbon-accounting model suited to accessible data and long-term monitoring; (2) identification of the factors through which residents' behavior affects emissions, providing analytical dimensions for future low-carbon community development; (3) technical recommendations for buildings, energy, transport, and municipal services from the perspective of residents' activities; and (4) specific methods for guiding green lifestyles. The results are intended to inform carbon monitoring and green-technology application in community renewal and low-carbon development in China.

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Note

① The parameter f_electricity is taken from the Ministry of Ecology and Environment, Baseline Emission Factors for China's Regional Power Grids for 2019 Emission-Reduction Projects.

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