Research on the Design of Shanghai Affordable Rental Housing

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Abstract: This research paper focuses on Shanghai's affordable rental housing development in alignment with the national "dual-carbon" policy and energy efficiency standards. The primary objectives include enhancing the quality of housing through energy-efficient, environmentally friendly, and healthy design, addressing challenges and new demands arising from epidemic prevention and control. The paper presents an overview of the affordable rental housing landscape in Shanghai, emphasizing the stable and substantial supply during the 13th Five-Year Plan period. It delves into the challenges posed by green and energy-efficient demands, compound functional needs in the post-epidemic era, and material supply demands during emergencies. Design suggestions encompass low-carbon principles, functional settings, and spatial considerations. The paper concludes with recommendations for optimizing the "Shanghai Rental Housing Planning and Construction Guidelines," incorporating principles of energy efficiency, low carbon, and comprehensive facility improvement. The proposed measures aim to contribute to the accelerated development of affordable rental housing in Shanghai, promoting sustainability, resilience, and high-quality living.

1. Introduction

Adhering to the concept of "People's City" and emphasizing the role of houses for living rather than speculation, relevant units in Shanghai strive to promote the construction and supply of affordable housing. The focus is on enhancing the quality of affordable housing to meet the living needs of new residents, young people, and basic urban public service groups with "small units, full functionality, and a joyful life." This paper provides an overview of the general situation and challenges faced by affordable rental housing in Shanghai. It also takes into account the new situations and issues arising from epidemic prevention and control and integrates with the national "dual-carbon" strategy. The goal is to construct more energy-efficient, environmentally friendly, livable, and healthy affordable rental housing. The paper proposes planning and design suggestions based on the principles of emergency response to the epidemic, carbon reduction, and enhancement.

2. Overview of Affordable Rental Housing in Shanghai

(1) A Large Proportion and Stable Total Supply of Affordable Rental Housing. During the 13th Five-Year Plan period, rental housing in Shanghai accounted for nearly 50% of the new housing supply, with nearly 10 million square meters of rental housing land supply, much of which is in the construction phase. This will transform into affordable rental housing during the 14th Five-Year Plan period, with a planned supply of over 420,000 units, accounting for 40% of the total housing supply^[1].

The "2022 Annual State-owned Construction Land Supply Plan in Shanghai" on April 26, 2022, indicates that the land supply plan for affordable rental housing in that year is 135-160 hectares. This includes new commodity housing land, industrial project land, the use of enterprise-owned idle land, and the use of collective land, among other channels. Looking at the land supply from 2020 to 2022 from Table 1, the supply of affordable rental housing land has been relatively stable and substantial, making a significant impact on the living security of new residents and young people in Shanghai.

Land Type	2022	2021	2020
Affordable Rental Housing (ha)	135-160	130-180	900-1100
Affordable Housing (ha)	220-260	360-450	_
Commodity Housing (ha)	522-592	340-430	_
Commercial Office (ha)	155-210	160-200	200-360
Industrial Land (ha)	1320-1400	900-1100	650-900
Old Reconstruction Land (ha)	Housing	50-55	20-40
	Commercial	25-30	10-20
Total (ha)	2427-2707	1920-2420	1750-2360

Table 1: State-owned Land Supply in Shanghai from 2020 to 2022

3. Challenges and New Demands for Affordable Rental Housing

3.1 Green and Energy-Efficient Demands under the "Dual-Carbon" Goals

Against the backdrop of increasingly severe global climate issues, China proposed in September 2020 to strive for the peak of carbon dioxide emissions before 2030 and achieve carbon neutrality by 2060^[2]. As an important contributor to carbon emissions, the construction industry urgently needs to transition to green and low-carbon practices. Affordable rental housing, which accounts for a significant proportion of new residential construction in Shanghai, still has room for optimization in terms of overall planning, unit design, material usage, and decoration. Under the guidance of the "dual-carbon" strategic goals, it is necessary to promote green construction practices, such as the adoption of green building materials, the development of prefabricated technology, and the implementation of environmentally friendly construction. This will advance the green and low-carbon development of housing.

3.2 Compound Functional Demands in the Post-Epidemic Era

Since the outbreak of the COVID-19 pandemic in 2020, the situation has persisted for three years, showing characteristics of long duration, complexity, and recurrence. In the context of normalized epidemic prevention and control, the lives of various population groups have been severely affected. Students attend online classes from home, office workers engage in remote work, and key individuals undergo home isolation. Cities attempt to reduce the movement of people. Against the background of the "stay-at-home" phenomenon during the epidemic, residential areas, as spaces where people spend the longest time and with increasing multifunctional needs, urgently need to change from a single residential function to providing a variety of services. This shift aims to address comprehensive needs such as learning, exercise, sports, office work, leisure, shopping, etc., in response to the prolonged coexistence with the epidemic.

3.3 Material Supply Demands Under the "Vegetable Grabbing" Phenomenon

During the outbreak of the epidemic in March-April 2022, Shanghai was divided into sealed-off areas, controlled and preventive areas, with public transportation suspended, implementation of home office work, and residents isolated. Under the impact of major emergencies, the "vegetable grabbing" phenomenon in Shanghai became a sensation on the internet. Traffic control throughout the city made it difficult for goods logistics to connect with communities. Residents faced a shortage of supplies due to the disruption of the food supply chain, resulting in social problems such as frenzied shopping at supermarkets. Residents relied on various e-commerce platforms such as Ele.me, Hema, Wumart, and Cainiao, or spontaneously organized community group purchases to crazily "grab vegetables." Life supplies were hard to guarantee, and the pressure on survival was enormous. There is an urgent need for sustainable, shareable, emergency, and self-sufficient supplies, represented by basic vegetables and fruits, to cope with sudden situations. The "vegetable grabbing" phenomenon is a microcosm of the scarcity of life supplies. In the event of major public health emergencies, the planning and design of affordable rental housing need to consider basic vegetable and fruit supply by providing residents with green spaces for planting and replenishing resources.

4. Design Suggestions

4.1 Low Carbon Design Suggestions

4.1.1 Carbon Reduction Design

(1) Use of Low Carbon Materials

Buildings contribute significantly to carbon emissions. To reduce carbon emissions, the design should incorporate photovoltaic curtain walls, rooftop solar panels, solar photovoltaic glass materials, and solar photovoltaic tiles. Additionally, olive sand coatings, which absorb carbon dioxide, can be applied to building facades. Using self-luminous concrete and power-generating flooring in pedestrian pathways can harness vibrations generated by foot traffic for energy, promoting resource conservation.

(2) Prefabricated Residential Construction

Embracing the trend of prefabricated construction, as advocated by French architect Le Corbusier in 1921. Shanghai's housing commission encourages 100% prefabrication and full decoration for new public rental housing, affordable housing, and long-term rental apartment projects. The national "Carbon Peak Implementation Plan for Urban and Rural Construction" urges the development of prefabricated buildings, aiming for a 40% share in urban new construction by 2030^[3]. Prefabricated housing reduces construction time and labor costs by about two-thirds compared to traditional methods, with significant savings in water, energy, materials, and land use ^{[4][5]}.

(3) Greenery and Plant Pairing

In order to maximize green spaces, we propose the utilization of ground-level spaces, rooftops, and open public spaces between buildings. Our approach involves introducing various plants, including vegetables, fruit trees, and diverse landscape vegetation, to increase green coverage. The focus will be on Carbon Assimilation Mechanism (CAM) plants, such as cacti, orchids, lilies, agaves, and pineapples, to enhance carbon fixation efficiency. Consider incorporating CAM plants like cacti, aloe vera, agave, sedum, aloe, and pineapple in the residential areas. Additionally, introduce fish-plant symbiosis in water ponds with a priority order based on carbon fixation capacity^[6].

(4) Deployment of Energy-Efficient Landscape Facilities

1) Photovoltaic Energy Landscape Corridor: Implementing a zero-energy community with a landscape waterfall connected to a water turbine generator. As part of our proposal, we recommend installing photovoltaic panels on the corridor roof to seamlessly integrate interactive installations with the community's energy self-circulation.

2) Photovoltaic Energy Roof: Aiming for a zero-energy community by incorporating large-scale rooftop solar panels as a primary node in the community's energy self-circulation.

4.1.2 Carbon Emission Calculation Method

Including carbon emission accounting requirements in the design of affordable rental housing. As part of our focus, we aim to address building carbon emissions, carbon emissions from human respiration, and transportation carbon emissions to enhance overall carbon reduction efficiency.

(1) Building Carbon Emissions

Using a case study of residential plots from a design competition, calculate the full life cycle carbon emissions, including material production and transportation, construction, demolition, building operation, and carbon sequestration. The proposed design achieved a 57% reduction in average design energy consumption compared to the 2016 energy efficiency standard^[7].

(2) Calculation of Carbon Emissions from Human Respiration

Calculating carbon emissions from human respiration using the formula Eh = N * Fr * E, where N is the population, Fr is the carbon dioxide exhalation rate per day, and E is the ratio of time spent in the community to the full day.

(3) Transportation Carbon Emissions

Calculating transportation carbon emissions by considering vehicle types, vehicle quantities, average mileage, fuel consumption, and carbon emission coefficients.

$$E mission = \sum_{i,j} F_{i,j} \times EF_i \times M_{ij} \times L_{ij}$$

Combining building carbon emissions, carbon emissions from human respiration, and transportation carbon emissions to determine the basic carbon emissions of the rental community, providing a reference for energy conservation and emission reduction.

4.2 Functional Setting Suggestions

(1) Basic Residential Function

Prioritizing small-sized units, maximizing residential functionality. Orient building layouts predominantly north-south, with the majority of residential units having an area less than 70 square meters.

(2) Mixed Commercial Function

Integrating commercial facilities along city roads, offering essential services within the community. As part of our plan, we propose to include various services such as art training for youth, dining, shopping, parenting, etc. These services will cover a range of amenities, including food establishments, pharmacies, hair salons, convenience stores, entertainment venues, early education centers, creative shopping malls, community libraries, self-service libraries, pet shops, electronics repair, wellness centers, art galleries, tea rooms, etc. This diverse array of services is anticipated to constitute approximately 12% of the total building area.

(3) Enhanced Public Space Leisure Function

Planning and layout a community sports park with fitness equipment, basketball courts,

children's beaches, wading pools, leisure corridors, and roller skating rinks. Utilize outdoor spaces for recreational balconies.

(4) Additional Natural Office and Study Function

Setting up study rooms in each residence, along with a community library and meeting room, providing short-term study and office space for students and working individuals, ensuring workspace during emergencies.

(5) Characteristic Vegetable Garden Agricultural Function

Including urban agriculture vegetable gardens to provide emergency food security.

4.3 Space Design Suggestions

4.3.1 Residential Rental Housing Unit Space Design

(1) 45 sqm Unit

Designed for singles, young couples, or married couples, featuring a "one-bedroom, one-living room, one-kitchen, one-bathroom" layout. The sofa in the living room is designed with a pull-out folding bed, allowing for the transformation into a temporary bedroom when needed, creating a "two-bedroom, one-living room, one-kitchen, one-bathroom" layout, accommodating 2-3 people.

(2) 67.5 sqm Unit

Designed for young couples or families of three, featuring a "two-bedroom, two-living room, one-kitchen, one-bathroom" layout. The master bedroom includes a study partition to meet daily office needs. This layout is economical and compact, making it an ideal choice for young individuals and can accommodate 3-4 people.

(3) A Few 90 sqm Units

As part of our design strategy, we propose, in addition to meeting the 70 sqm unit requirement, to include a small number of 90 sqm units. Tailored for families of three or multi-generational living, this "four-bedroom, two-living room, one-kitchen, two-bathroom" layout provides a comprehensive solution for family living. This layout optimally utilizes the limited 90 sqm space, meeting the demand for smaller unit sizes and can accommodate 4-6 people.

(4) Entrance Management — Resident-Specific Staircase

Each building has ground-level commercial and service spaces. Entrance management is facilitated through dedicated entrance halls and staircases with card access, ensuring separation between residential and commercial spaces during post-pandemic times.

4.3.2 Three-Dimensional Neighborhood Spaces in the Post-Pandemic Era

(1) Coexistence of Public Activities and Emergency Control

Allocating a flexible public activity space on each floor of the building, featuring a vegetable garden, fitness center, research and creation workshop, leisure club, etc. These spaces act as threedimensional neighborhood spaces, serving as emergency control zones during outbreaks and facilitating nucleic acid sampling points.

(2) Urban Vegetable Garden Three-Dimensional Farm

Implementing a stepped design for some buildings, creating rooftop vegetable gardens. As part of our urban planning proposal, we recommend establishing an aerial corridor every two floors between buildings. This corridor will connect both sides of the residential areas while forming a three-dimensional agricultural space. The three-dimensional farm adds interest to the community while effectively addressing potential food shortages during emergencies.

4.4 Recommendations for "Shanghai Rental Housing Planning and Construction Guidelines"

4.4.1 Principles Under Energy Efficiency and Low Carbon

(1) Supplementary Building Energy Efficiency Design Standards

In addition to "General Requirements" in "Section 4.1," it is recommended to introduce major building energy efficiency design standards based on the national mandatory engineering construction specification "General Specification for Building Energy Conservation and Renewable Energy Utilization" (GB55015-2021). Reference should be made to Shanghai's "Shanghai Green Building Management Measures" (2021) and "Implementation Plan for Carbon Peaking in Shanghai" (2022)^[8].

In "4.6.5," supplement: Domestic hot water supply should comply with the national "General Specification for Building Energy Conservation and Renewable Energy Utilization." For retrofit projects, priority should be given to using industrial waste heat, urban heating networks, and solar energy.

(2) Supplementary "Low Carbon Application Technologies" Section

Suggesting adding a new section after the existing Table 2 "Comprehensive Supporting Facilities" to promote the application of green and low-carbon technologies.

Supplementary clause for "Prefabricated Buildings" 1: Promoting integrated and standardized design for prefabricated buildings, covering planning, component production, construction, and operation management.

Supplementary clause for "Prefabricated Buildings" 2: Encouraging the use of standardized building components, especially for non-load-bearing structures and partitions.

Supplementary clause for "Green and Low Carbon" 1: Ensuring that rental housing meets the one-star standard of green buildings, with encouragement for government-funded projects to achieve higher green building standards.

Supplementary clause for "Green and Low Carbon" 2: Encouraging the implementation of integrated photovoltaic and solar-thermal building designs for new rental housing. Additionally, encourage retrofit projects to install solar photovoltaic systems.

4.4.2 Principles of Comprehensive Improvement in Guidelines

Recommend detailed planning for medical, commercial, and comprehensive management services in Table 2 "Comprehensive Supporting Facilities."

 Table 2: Proposed Planning and Construction Requirements for Supporting Facilities in Affordable

 Rental Housing

Category	Educational Facilities	Medical and Health Facilities	Commercial Service Facilities	Comprehensive Management Service Facilities
New Residential Rental Housing	0	0	•	•
Dormitory-type Rental Housing (New)	0	0	•	•
Dormitory-type Rental Housing (Retrofit)	0	0	•	•

Note: • Should strictly adhere to the "Urban Residential Area Planning and Design Standards" and Shanghai's local standards for public service facility planning.

O Can be selectively implemented based on the actual project conditions, following the "Urban Residential Area Planning and Design Standards" and Shanghai's local standards for public service facility planning.

5. Conclusion

Shanghai's affordable rental housing is in a phase of accelerated development. To align with the national "dual-carbon" policy and energy efficiency standards, it is recommended to prioritize energy conservation and carbon reduction. The following key recommendations are proposed:

(1) Energy-Efficient and Low-Carbon Construction:

Emphasizing the use of low-carbon building materials and various CAM (Crassulacean Acid Metabolism) plants.

Increasing the proportion of prefabricated buildings, incorporating various energy-saving facilities.

Implementing solar photovoltaic panels to generate electricity, reducing overall energy consumption.

(2) Green Space Enhancement:

Elevating the green space ratio and establish carbon sinks to ultimately reduce carbon emissions and achieve the goal of a "zero-carbon community."

(3) Carbon Reduction Impact:

Considering the cumulative impact of various low-carbon measures, the calculated carbon emissions for a specific type of affordable housing show an average reduction of approximately 57% compared to the 2016 energy design standards. This aligns with the national "General Specification for Building Energy Conservation and Renewable Energy Utilization" (GB55015-2021).

(4) Functional Diversification for Pandemic Resilience:

Integrating various functions into residential communities, including commercial spaces, temporary offices, community libraries, study rooms, sports facilities, urban farming, and versatile leisure spaces.

Implementing detailed design for diverse small unit types to address various needs during periods of remote work, online learning, and static management within affordable rental housing communities.

(5) Optimization of Guidelines:

In light of the evolving national and local energy efficiency and carbon reduction standards, we propose optimizations to the 'Shanghai Rental Housing Planning and Construction Guidelines' (2021) based on principles of carbon reduction and comprehensive facility improvement.

In conclusion, the integration of low-carbon design, functional enhancements, meticulous spatial planning, and the optimization of construction guidelines is recommended. These suggestions aim to provide practical and effective decision-making references for the high-quality development of affordable rental housing in Shanghai, further advancing the quality of housing in the region.

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