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Building a climate-neutral future together

Sino-Swiss Cooperation on Zero Emissions Building

Technical Report

Survey on Improved Livelihood through Zero-Emission Buildings

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This report has been produced within the framework of the Sino-Swiss Zero Emissions Building Project; an international collaboration funded by the Swiss Agency for Development and Cooperation in partnership with the Chinese Ministry of Housing and Urban-Rural Development.

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The Sino-Swiss Zero Emissions Building Project is an international collaboration funded by the Swiss Agency for Development Cooperation in partnership with the Chinese Ministry of Housing and Urban-Rural Development. The project aims to reduce greenhouse gas emissions and enable carbon neural development of the building sector in China by sharing Swiss know-how on sustainable and zero emission building.

Implementation partners:

Intep Integrated Planning

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Abstract

To advance the low-carbon transition in the building sector and tangibly enhance the quality of the living environment, this study—conducted under the framework Memorandum of Understanding on the development of cooperation in the field of building energy efficiency—focuses on a systematic evaluation of user experience in ZEBs. By selecting demonstration projects spanning China's four major climate zones and comparing them with conventional buildings, the research employed a mixed-method approach including questionnaires, in-depth interviews, and field observations to thoroughly investigate the actual performance of ZEBs in terms of environmental comfort, energy efficiency, and operation and maintenance management.

The findings reveal that ZEBs demonstrate significant advantages in indoor environmental quality, with user satisfaction regarding temperature and humidity stability, air quality, and natural lighting markedly higher than in conventional buildings. In terms of energy use, occupants of ZEBs exhibited more rational energy consumption behaviors, and the application of smart control systems effectively enhanced energy efficiency. Meanwhile, the study also identified challenges such as the complexity of operational technologies and insufficient outdoor activity facilities, while confirming that positive user experiences actively promote the adoption of energy-saving behaviors.

Based on the research results, it is recommended that future large-scale development of ZEBs prioritize five key areas: technological optimization, policy support, community integration, public participation, and international cooperation. This study provides an empirical foundation for the scaled-up development of ZEBs and suggests that continuous long-term tracking research be carried out to refine relevant systems and mechanisms, thereby enabling ZEBs in China to play a greater role in the global green building sector.

1. Project Background

1.1 About Sino-Swiss Zero Emission Building (ZEB) Project

In order to jointly respond to global climate change and strengthen the cooperation between China and Switzerland in the field of emission reduction in the building sector, on 24 November 2020, the Ministry of Housing and Urban-Rural Development of the People's Republic of China and the Swiss Federal Department of Foreign Affairs (FDFA) signed a Memorandum of Understanding (MoU) on the development of cooperation in the field of building energy efficiency. Under the framework of this memorandum, the Swiss Agency for Development Cooperation (SDC) initiated and funded the Sino-Swiss Zero Emission Building Project, which aims to support China in developing technical standards for ZEBs and a medium- and long-term carbon emission reduction roadmap for the construction sector by introducing Swiss experience and technology, and constructing demonstration projects for ZEBs in different climatic zones, as well as carrying out a variety of capacity-building activities, which will ultimately promote the development of a carbon-neutral construction sector in China. The programme will also carry out various forms of capacity building activities, ultimately promoting the carbon neutral development of China's construction industry.

1.2 About GDRI

To thoroughly evaluate the differences in user experience between ZEB demonstration projects and non-green retrofitted buildings (tranditional projects), the intep-skat consortium of Sino-Swiss ZEB Project commissioned Xiongan Green Development Research Institute Co.(GDRI), Ltd. to conduct a user experience survey. The aim is to provide support for further enhancing the design, construction, and management of ZEBs.

GDRI established in November 2017, was among the first companies approved for establishment in the Xiongan New Area. Founded jointly by Shenzhen Institute of Building

Research Co., Ltd. and China Xiongan Group Co., Ltd., it is an international high-end new-type think tank operating through innovative enterprise models. Adhering to the positioning of "rooted in Xiongan, radiating to the Beijing-Tianjin-Hebei region, and serving the nation," GDRI provides high-end think tank services and consulting on theories, policies, and technologies for the planning, construction, and operation of green urban development, committed to becoming a "catalyst for urban green development."

1.3 Purpose and Significance of the Study

Current research on ZEBs predominantly focuses on energy-saving and carbon reduction technologies, while systematic and quantitative analyses remain scarce regarding whether and how such buildings genuinely enhance user experience, and to what extent. Against this backdrop, this survey aims to evaluate the actual effectiveness of ZEBs in improving user experience through a systematically and scientifically designed questionnaire. Furthermore, it seeks to enhance awareness and disseminate knowledge about ZEBs among users and operators during the research process, thereby promoting subsequent optimization of ZEB design and operational strategies from the perspective of user experience.

1.4 Work flow

A multidimensional experience questionnaire was developed through systematic analysis of mainstream building standards, and ZEBs along with control samples across multiple climate zones and building types were selected for investigation. Focusing on three key stakeholder groups—users, operators, and investors—the study employed a combined methodology of questionnaires and interviews to systematically evaluate the actual performance and promotion potential of ZEBs.

(1) Questionnaire Development

Through systematic comparison and analysis of existing mainstream building evaluation

standards—including Active House criteria, LEED Zero, the ZEB Technical Standard, and the Nearly Zero Energy Building Technical Standard—it was found that user experience-related indicators in current standards primarily focus on indoor environmental parameters, alignment of building design with user needs, and interaction between the building and its regional environment. Based on this, the questionnaire for this study emphasized the following aspects:

①Sensory experience inside the building, covering the specific impacts of environmental factors such as ventilation, daylighting, and acoustics on user comfort;

②Interaction between the building and its users, including whether spatial functions meet practical needs, as well as the channels and effectiveness of user feedback on building operation and control mechanisms;

③Relationship between the building and its surrounding area, such as the integrated effects of external transportation convenience and outdoor microclimate on the overall user experience.

Additionally, to enhance public awareness and promotion of ZEB concepts, a dedicated section on ZEB knowledge was included to survey users' basic understanding and awareness of the advantages of such buildings, thereby increasing public attention and comprehension of this green building concept. Through the above multidimensional analysis, the questionnaire can systematically and scientifically assess the actual effectiveness and optimization potential of ZEBs in terms of user experience.

(2) Project Selection Principles

The selection of research projects adhered to the following principles:

- ZEB samples must cover different climate zones and major building types in China, and must be completed and officially operational demonstration projects;
- Conventional building control samples must closely correspond to the ZEB samples in terms of climate zone, floor area, and building functional type to ensure the scientific validity and effectiveness of the comparative study.

However, during implementation, some initially identified ZEBs were not yet fully constructed or were unsuitable for research. Accordingly, the project team selected alternative projects as supplementary samples. These alternative projects not only had to meet national high-star green building certification or equivalent advanced sustainable building standards, but their selection in terms of climate zone and building type also needed to structurally complement areas and types not covered by the demonstration projects. This approach ensured the overall sample's representativeness in spatial distribution and building typology, enhancing the comprehensiveness of the research findings.

Based on the above principles, the final selected research projects are as follows:

Table1 List of projects

NO.	Project	Climate zone	Building type
1	**The Second Science and Technology Building of Heilongjiang Province Academy of Cold Area Building Research**	Severe Cold Region	Office Building
2	The headquarters of Heilongjiang Province Academy of Cold Area Building Research		
3	**The Xianxi Community Service Center in Xiongan New Area, Hebei**	Cold Region	Community Center+Residential Building
4	The Rongxiang Community Service Center in Xiongan New Area, Hebei		
5	**Longshanshuyuan Middle School, Shaoxing, Zhejiang**	Hot Summer and Cold Winter Region	School
6	**Dameisha Vanke Carbon Neutral Experimental Park, Shenzhen**	Hot Summer and Warm Winter	Office Park

7	Xinhaijialan, Shenzhen	Region	Residential building+Shops
8	Yundingtianhai, Shenzhen		

(3) Research Subjects and Key Questions

The design of the questionnaires and interviews centered on three main groups: users, operators, and investors.

For users, approximately 20 questions were designed in a questionnaire format, focusing on their overall impressions and detailed experiences, while also soliciting feedback on existing issues and improvement suggestions.

For operators, interviews were primarily planned to focus on operational practices unique to ZEBs. These include management systems and training mechanisms, equipment maintenance and control, differences in daily upkeep, as well as data collection and monitoring, precise regulation, and the application of smart platforms.

For investors, interviews were also the main method, concentrating on key aspects such as investment models and cost recovery cycles, construction motivations and reasons, the extent of top-level policy support, and external publicity strategies.

2. Introduction to Research Findings

The research team collected user experience data through online questionnaires distributed to occupants of demonstration projects and conventional buildings in Harbin (Heilongjiang Province), Xiongan New Area (Hebei Province), Shaoxing (Zhejiang Province), and Shenzhen (Guangdong Province). As of September 16, 2025, a total of 150 valid questionnaires had been collected (95 from demonstration projects and 55 from conventional buildings). The questionnaire covered four key aspects: "satisfaction with indoor environment," "building operation performance," "building-surroundings relationship," and "knowledge of ZEBs."

In terms of overall satisfaction, 56.84% of respondents from demonstration projects

reported being "very satisfied," while 16.84% were "satisfied." In contrast, 47.27% of respondents from conventional buildings reported being "very satisfied," and 38.18% were "satisfied." These results indicate a significantly higher level of user satisfaction in demonstration projects compared to conventional buildings.

This section provides a comprehensive analysis integrating questionnaire data, feedback from interviews, and on-site observations. It also includes a cross-analysis of differences between demonstration projects and conventional buildings, as well as variations in user experience across different climate zones and building types. The findings are presented along the following four dimensions:

2.1 Comparison of Indoor and Outdoor Environmental Comfort

Satisfaction with the indoor environment was assessed across multiple dimensions, including indoor temperature and humidity, air quality, accessibility facilities, artificial lighting, natural lighting, natural ventilation, air/water leakage through doors and windows, indoor greenery, noise levels, building exterior design, and heating season temperature.

The comparative analysis revealed that demonstration projects received significantly higher ratings than conventional buildings in areas such as indoor temperature and humidity, air quality, accessibility facilities, natural lighting, natural ventilation, airtightness of doors and windows, and building exterior design. Meanwhile, they performed slightly better or similarly in aspects such as artificial lighting, indoor greenery, and noise control.

After accounting for variables like building orientation and regional climate influences, it is evident that the demonstration projects substantially improved user experience in critical areas like indoor temperature and humidity, air quality, and building airtightness through the application of technical measures such as high-efficiency energy-saving doors/windows and fresh air systems.

(1) Indoor Temperature and Humidity

In the questionnaire survey on indoor temperature and humidity, 50.53% of users in demonstration projects reported being "very satisfied," while 25.26% were "satisfied." In contrast, only 30.91% of users in conventional buildings reported being "very satisfied," with 45.45% being "satisfied" and 18.18% indicating a "neutral" response.

Through on-site interviews and physical assessments of building interiors, it was found that demonstration projects effectively optimize the use of natural resources to improve indoor temperature and humidity conditions through design strategies such as thermal insulation and shading in the building envelope.

Figure1 ZEBs' facade

Figure2 Traditional buildings' facade

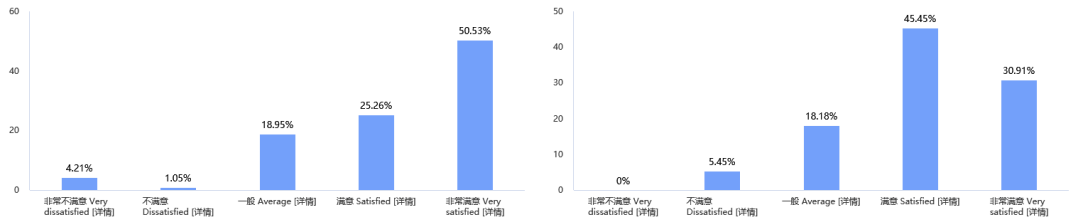


Figure3 Comparison of User Experiences with Indoor Temperature Between the Two Building Types

Research findings indicate that building quality and environmental comfort are the core drivers of overall satisfaction. Among users who were "very satisfied" with temperature and humidity, 95.38% also provided "very satisfied" feedback overall. Conversely, 75% of those who were "very dissatisfied" with temperature and humidity also expressed overall dissatisfaction.

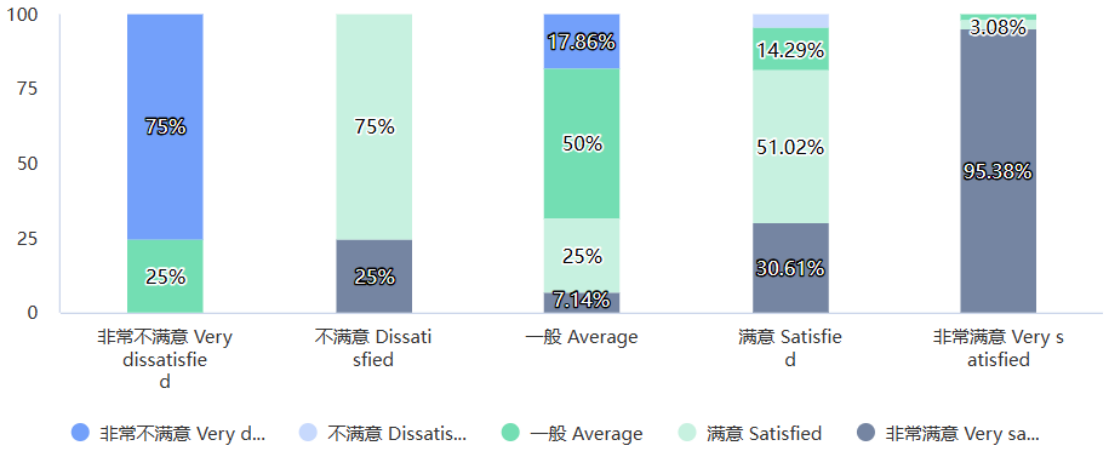


Figure4 Cross-Analysis: Satisfaction with Temperature/Humidity vs. Overall Building Satisfaction

(2) Indoor Air Quality and Natural Ventilation

Regarding indoor air quality, 51.58% of users in demonstration projects reported being "very satisfied," and 23.16% were "satisfied." In contrast, only 30.91% of users in conventional buildings reported being "very satisfied," 38.18% were "satisfied," and 25.45% indicated a "neutral" response.

Concerning natural ventilation, 41.05% of users in demonstration projects reported frequently perceiving natural airflow, while 35.79% perceived it occasionally. For conventional

buildings, only 34.55% of users reported frequently perceiving natural airflow, and 40.00% perceived it occasionally.

Through on-site interviews and physical assessments, it was determined that most demonstration projects are newly constructed buildings. Their effective improvement in air quality is attributed to optimized ventilation design and the installation of fresh air systems.

Figure4 Ventilation Openings in Demonstration Projects

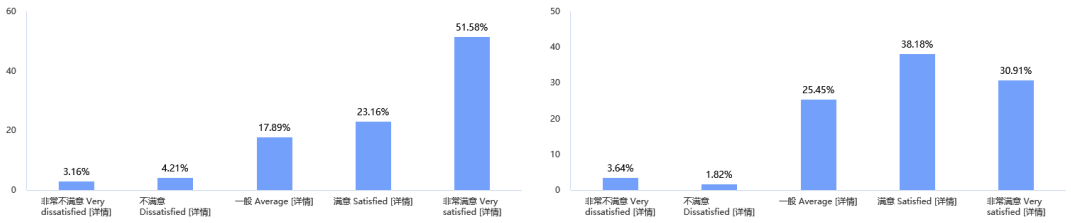


Figure5 Comparison of Perceived Indoor Air Quality Between the Two Building Types

(3) Natural Daylighting

Regarding natural daylighting, 56.84% of users in demonstration projects reported that the light was "often soft and comfortable," while 20% described it as "consistently soft and comfortable." In contrast, only 30.91% of users in conventional buildings found the light "often soft and comfortable," and 23.64% reported that the light was "sometimes glaring."

On-site interviews and physical walk-throughs revealed that the demonstration projects employed optimized design strategies—such as skylights and adjustable shading facilities—to enhance the quality of natural daylighting.

Figure6 Natural Daylighting Design in Demonstration Projects

(4) Air and Water Leakage through Doors and Windows

In the survey on air and water leakage through doors and windows, 52.63% of users in demonstration projects reported that leakage "almost never occurs," while 25.26% considered it "uncommon." In conventional buildings, however, only 38.18% of users reported that leakage "almost never occurs," and 30.91% deemed it "uncommon."

On-site interviews and physical assessments revealed that most demonstration projects are newly constructed and employ doors and windows with superior airtightness. In contrast, conventional buildings, often older and with longer periods of use, are more susceptible to such leakage issues.

Figure7 High-Performance Doors and Windows in Demonstration Projects

(5) Satisfaction Variations Across Climate Zones

The survey covered locations spanning from northern to southern China, specifically including the Severe Cold Region (Harbin), Cold Region (Xiongan New Area), Hot Summer and Cold Winter Region (Shaoxing), and Hot Summer and Warm Winter Region (Shenzhen). User satisfaction with and priorities regarding indoor temperature, humidity, daylighting, and ventilation varied significantly across regions and building types.

In the Severe Cold Region, users placed high importance on winter thermal insulation and air humidity. Satisfaction with temperature and humidity in demonstration projects was significantly higher than in conventional buildings.

In the Cold Region, users valued both winter insulation and summer thermal mitigation, with high expectations for natural comfort during transitional seasons.

In the Hot Summer and Cold Winter Region, the dual needs of winter heating and summer cooling/dehumidification were the primary concerns. Issues of high energy consumption and significant indoor environmental fluctuations were commonly reported.

In the Hot Summer and Warm Winter Region, users strongly focused on efficient summer cooling and dehumidification, demanded high shading and insulation performance, and had minimal requirements for winter heating.

Regarding daylighting, northern regions prioritized maximizing winter sunlight exposure, while southern regions emphasized shading and glare prevention. For ventilation, the north focused on airtightness to prevent cold drafts in winter, whereas the south emphasized natural ventilation to facilitate heat dissipation and moisture removal.

2.2 Comparison of Building Energy Efficiency and Economic Performance

The questionnaire on building energy efficiency and economic performance covered multiple dimensions, including: "air conditioning control methods, heating control methods, tasks undertaken by operators, user problem reporting, issues encountered compared to conventional buildings, differences in operational costs, and building attractiveness to users." A comparative analysis revealed the following findings:

(1) Regarding Energy Usage

Air Conditioning Usage Duration: In demonstration projects, 60% of users reported operating air conditioning for 5–8 hours daily during summer. In conventional buildings, 46.15% of users fell within the same range, while 30.77% reported usage of 16–20 hours. This indicates superior energy-saving performance and reduced reliance on air conditioning in demonstration projects, attributable to their enhanced insulation capabilities.

Air Conditioning Control Methods: In demonstration projects, 51.35% of users controlled operation and temperature via room-level switches. In conventional buildings, only 34.38% had this level of control.

Heating Control Methods: In demonstration projects, 35.14% of users regulated temperature through room-level valves, while 21.62% utilized smart controls that automatically adjust based on sensor data. Conversely, in conventional buildings, 40.63% of users were subject

to centralized municipal control with no individual adjustment capability, and only 21.88% could control heating via room-level valves.

This disparity stems from the fact that most demonstration projects are newer constructions equipped with room-level controls for responsive temperature adjustment, whereas conventional buildings often rely on centralized municipal heating systems that limit user autonomy. Overall, demonstration projects show significantly higher proportions of user-adjustable and smart controls for both air conditioning and heating.

Demonstration projects outperform conventional buildings in energy usage. For winter heating, they utilize air-source heat pumps, graphene-based radiant floor heating, and geothermal resources to reduce dependence on traditional municipal gas heating, which remains the standard for conventional buildings in northern China.

Notable differences in energy management exist between demonstration projects dominated by public buildings and those primarily comprising residential buildings. Public building-focused projects benefit from single ownership and clear management responsibilities, enabling the consistent implementation of photovoltaic energy storage systems and unified energy management platforms for highly efficient and precise energy control.

Figure8 HVAC and Control Systems in Demonstration Projects

(2) Regarding Energy Costs

Electricity Expenses: In demonstration projects, 31.43% of users reported monthly electricity bills under ¥100, while 77.14% fell under ¥200. In conventional buildings, the corresponding figures were 31.58% and 63.16%.

Gas Expenses: For demonstration projects, approximately 54.29% of users reported monthly gas costs under ¥100, and about 77.15% under ¥200. In conventional buildings, these figures were approximately 44.74% and 96.05% respectively.

The data indicates a slight advantage in electricity costs for demonstration projects, though the difference is not pronounced. This may be attributed to their superior insulation, which reduces energy demand for heating and cooling.

Impact of Building Type: Building type significantly influences air conditioning and heating usage. Among residential buildings, 30.77% of users reported average daily air conditioning use of 16–20 hours during summer—significantly higher than in campus or office buildings. Additionally, the proportion of residential users reporting feeling "too cold" or "cold"

during winter was notably lower compared to occupants of office-type buildings.

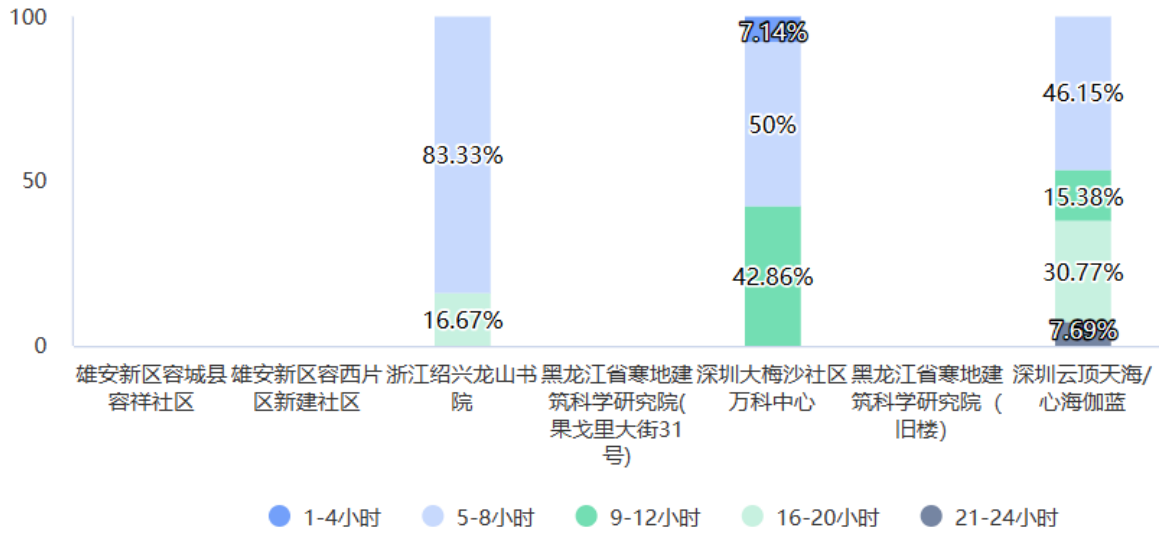


Figure9 Statistics on Air Conditioning Usage Duration by Building Type During Summer

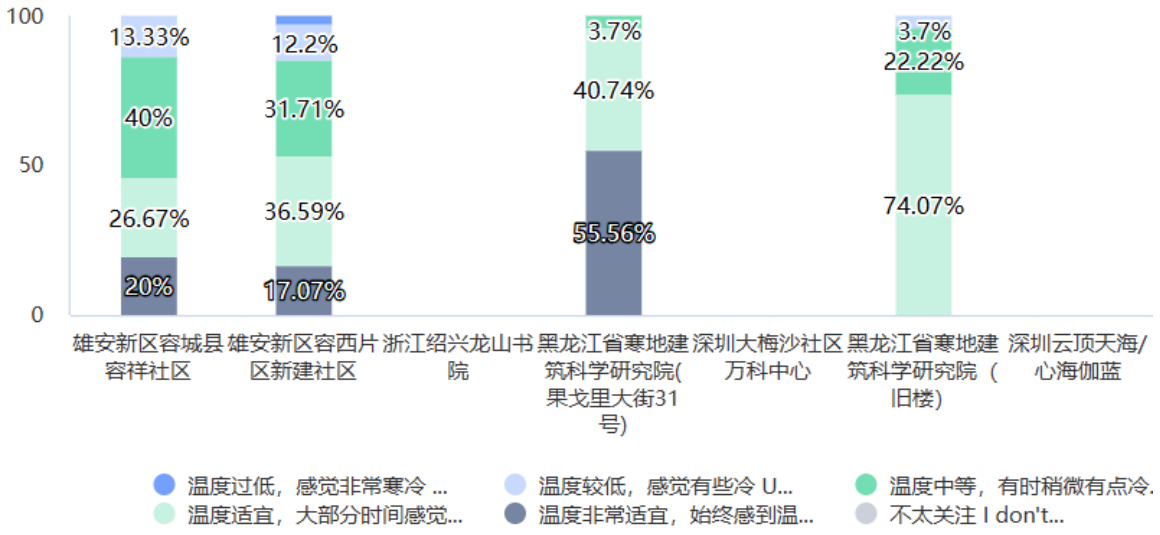


Figure10 Statistics on Indoor Temperature Satisfaction by Building Type During the Heating Season

2.3 Comparison of Building Operation, Maintenance, and Sustainability

Analysis of questionnaires administered to building operation and maintenance staff revealed that the primary challenges faced in demonstration projects are concentrated in two areas: insufficient knowledge base for applying new technologies and higher operational costs,

each reported by 50% of respondents.

When compared to conventional buildings, 50% of operational staff indicated that the operational costs of ZEBs had decreased, with energy costs showing the most significant reduction.

Although demonstration projects exhibit lower operational costs than conventional buildings, operational teams continue to face challenges related to inadequate technical knowledge and a lack of practical experience in applying new technologies.

2.4 User Satisfaction and Feedback

(1) Issue Reporting Status

Analysis of questionnaire surveys administered to building operation and maintenance staff revealed that in demonstration projects, user-reported issues primarily focused on facility repairs, maintenance, and comfort problems, accounting for 50% of feedback. In contrast, users of conventional buildings primarily reported safety concerns along with facility repair and maintenance issues, which constituted 60% of their feedback.

Figure11 Comparison of Major Issues in Building Operation and Maintenance

Indoor Environment: Users of conventional buildings in northern regions commonly reported low temperatures in corner rooms during winter, stuffiness in south-facing rooms during summer, and occasional noise disturbances.

Building Operation: Some users in demonstration projects noted that equipment operation is complex and requires guidance, while also expressing concerns about data security and privacy protection.

Outdoor Environment and Activity Spaces: Certain conventional buildings face issues such as lack of vehicle-pedestrian separation, cramped spaces, and insufficient amenities.

Interviews with operators highlighted the following challenges:

- Complexity of technical system maintenance: Specialized equipment is difficult to maintain, requiring highly skilled personnel, yet systematic professional training is currently lacking.
- Insufficient adaptability of certain technologies to local conditions: For instance, in severe cold regions, fresh air heat recovery systems exhibit high energy consumption and low efficiency, while photovoltaic systems have short effective power generation hours due to a lack of localized research and validation for low-carbon technologies.
- Underutilization of data systems: Installed monitoring facilities (e.g., sub-metering) have not been effectively leveraged for refined management, and the high cost of on-site data validation hinders widespread implementation.
- Aging issues in conventional buildings: Problems such as aging electrical circuits and pipelines, water leakage, and mold growth on walls during heating seasons are common. Most of these buildings can only undergo routine maintenance as they fall outside the scope of major retrofits.
- Misunderstandings about new technologies: Some residents hold misconceptions about technologies like photovoltaics (e.g., concerns about electromagnetic radiation), leading to low cooperation and increased operational difficulties.

In the investment and promotion of ZEBs, investors face multiple challenges:

- Extended payback periods: High incremental costs required to meet ultra-low or zero-carbon energy standards result in cost recovery periods far exceeding market expectations (e.g., over 25 years in Harbin, 8–10 years for energy storage projects in Shenzhen), significantly dampening investment motivation.
- Inadequate policy support systems: Existing subsidies offer limited support for systematic ZEB construction, favoring single energy-saving measures (e.g., insulation retrofits, window replacements) instead. The absence of long-term stable policy signals further increases uncertainty.
- Mismatch in green financial products: Financial products typically have terms of around 3 years, far shorter than the actual return period of technological investments, hindering large-scale application.
- Carbon market mechanisms misaligned with actual needs: Despite general optimism about the future market potential of ZEBs, the current real estate downturn, coupled with limited client funding and insufficient policy subsidies, makes large-scale promotion difficult. Without specific policy requirements, investors are often reluctant to commit to incremental costs.
- Challenges in scaling demonstration projects: While such projects have strong promotional value and attract visits from governments, schools, and research institutions, achieving large-scale replication requires stronger industrial chain collaboration and clearer, sustainable business models.

(2) Comparison of Building Attractiveness to Users

Over half of the surveyed individuals recognized the demonstration projects for their high comfort level for living or use (55.68%) and their low-carbon, sustainable living environment (53.41%). Additionally, 40.91% of respondents believed these projects possess a positive social image. These two factors were significantly more prominent than other options, indicating that

users place dual importance on both fundamental functionality and environmental attributes.

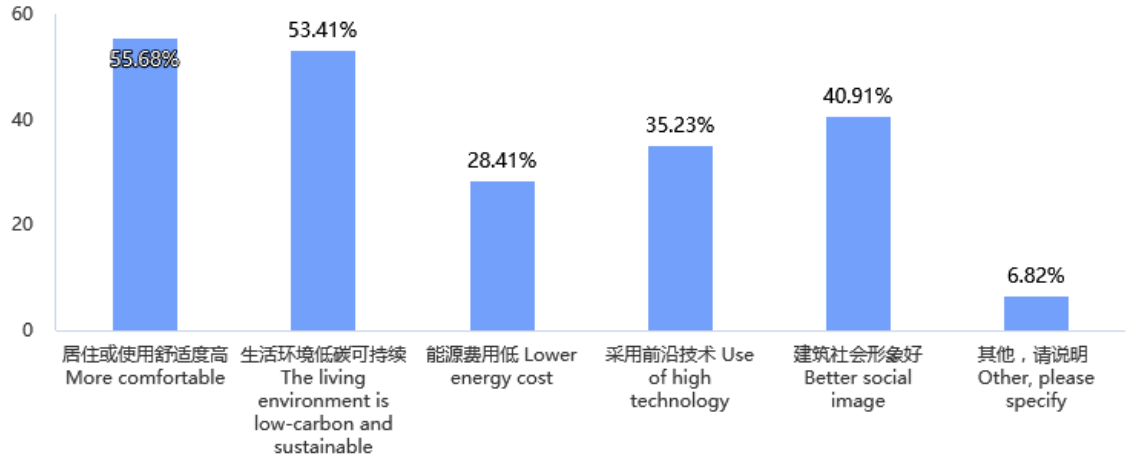


Figure12 User Perceptions of Building Attractiveness

(3) Comparison of Buildings and Their Surrounding Environment

The questionnaire covered aspects such as: "availability of bus stops and service facilities within a 5-minute walk, activities feasible around the building and their reasons, outdoor greenery, outdoor shading, and outdoor ventilation."

Both building types showed similar access to public transport and nearby service facilities. However, traditional buildings demonstrated significantly better accessibility to outdoor sports facilities (60% vs. 48.42%) and health services (45.45% vs. 28.42%) compared to demonstration projects.

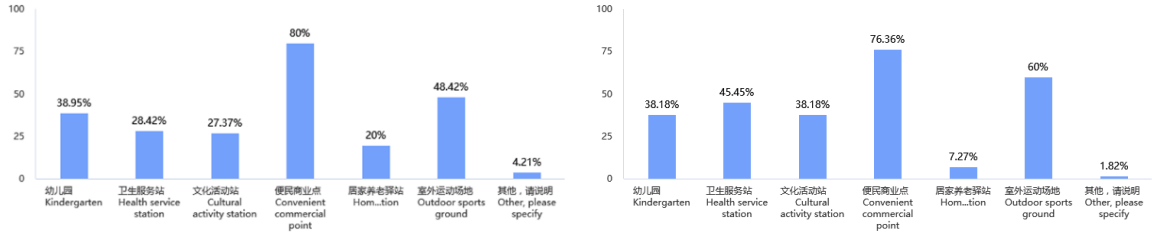


Figure13 Comparative Analysis of Surrounding Service Facilities Between the Two Building Types

Outdoor Activities: Users of both building types commonly engaged in conversations, leisure/fitness activities, and solitary sitting. Traditional buildings showed slightly higher participation rates in these activities (conversations: 74.55%, leisure/fitness: 67.27%, solitary

sitting: 69.09%), while the corresponding rates for demonstration projects were 64.21%, 61.05%, and 51.58%.

Primary Obstacles to Outdoor Activities: For demonstration projects, 72.22% of users cited "lack of interactive recreational facilities," 44.44% reported "insufficient shading and rain shelters," and 33.33% indicated "insufficient seating" and "unappealing or noisy environments."

In contrast, users of traditional buildings universally (100%) reported issues with "lack of interactive recreational facilities, mixed pedestrian-vehicle traffic, insufficient shading and rain shelters, and lack of private spaces." Additionally, 50% of users cited "cramped spaces" and "insufficient seating" as concerns.

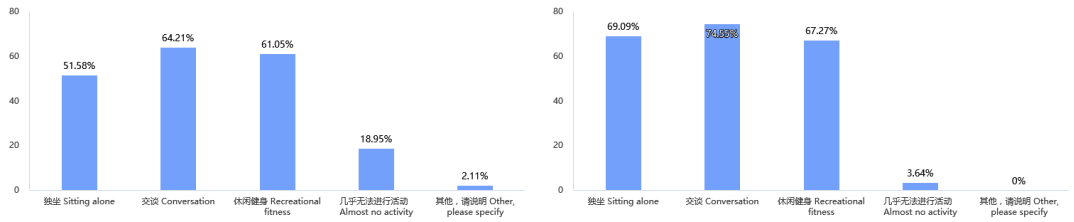


Figure14 Comparative Analysis of Feasible Outdoor Activities Between the Two Building Types

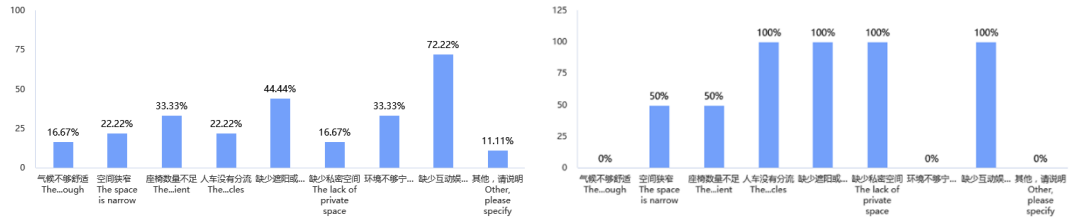


Figure15 Analysis of Obstacles to Outdoor Activities in the Two Building Types

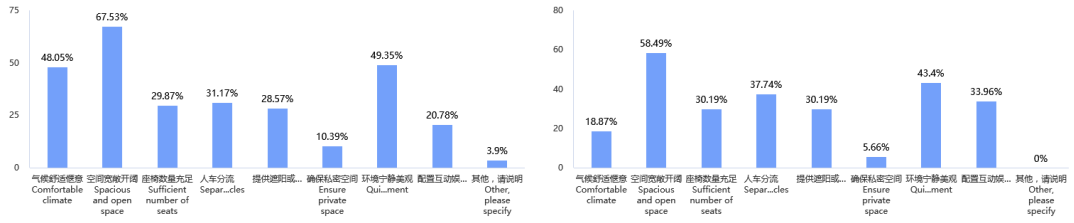


Figure16 Analysis of Motivations for Outdoor Activities in the Two Building Types

Greenery: A majority of users in both building types expressed that greenery needs

enhancement (27.37% in demonstration projects vs. 29.09% in traditional buildings). However, 29.09% of users in traditional buildings believed that "more greenery could improve aesthetics," while 21.05% in demonstration projects considered the existing greenery "both aesthetically pleasing and comfortable."

Shading: Regarding shading perception, 36.84% of users in demonstration projects reported "occasionally intense sunlight," and 30.53% found it "comfortable most of the time." In traditional buildings, 40.00% reported "occasionally intense sunlight," and 36.36% perceived conditions as "comfortable most of the time."

Ventilation: Acceptance of wind conditions was similar between the two building types, with 32.63% of users in demonstration projects and 41.82% in traditional buildings considering wind speed acceptable.

(4) Level of ZEB Awareness

Regarding the public awareness of ZEBs, over half of the respondents possess only a vague understanding. Specifically, 50.91% have heard of the concept but lack detailed knowledge. Combined with the 9.09% who are entirely unfamiliar with it, this indicates a significant knowledge gap among the general public.

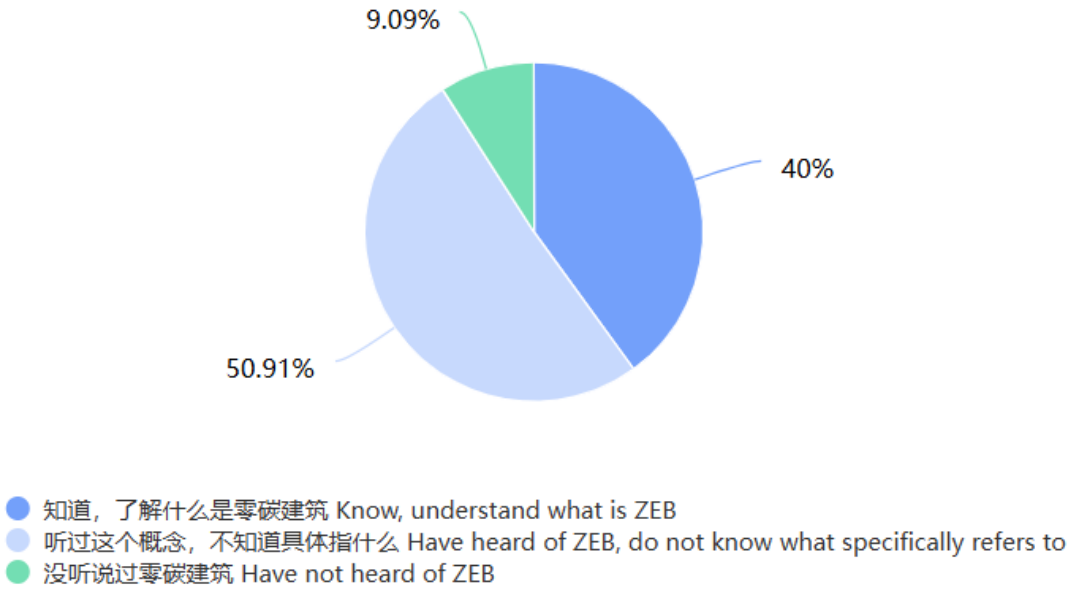


Figure 17 Awareness of ZEBs

Regarding the perceived features of ZEBs, users of demonstration projects showed stronger recognition of their advantages in areas such as low-carbon recyclable materials (47.37%), natural ventilation conditions (37.89%), temperature and humidity comfort (33.68%), and lower energy costs (31.58%). Furthermore, 32.63% of these users expressed willingness to proactively adopt energy-saving behaviors.

Concerning the perceived significance of ZEBs, users of demonstration projects prioritized their role in guiding the building industry toward low-carbon transition (67.37%) and enhancing comfort (71.58%). In contrast, users of traditional buildings placed greater emphasis on improved comfort (72.73%), higher energy efficiency (58.18%), and emission reduction (56.36%).

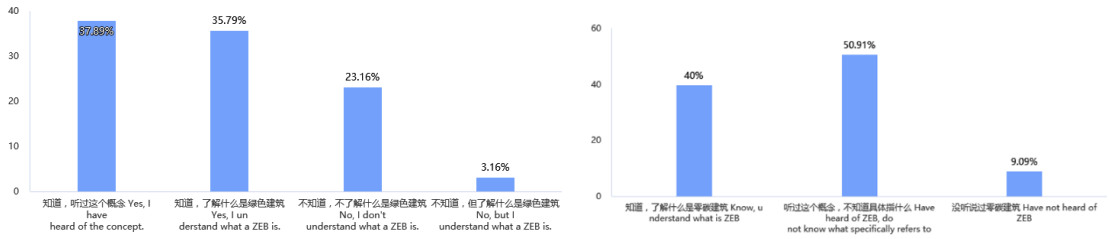


Figure 18 Comparison of Green Building Understanding Between Users of the Two Building Types

The perception of ZEBs' significance is notably influenced by firsthand experience, with comfort and energy efficiency being core concerns. Enhancing living comfort is perceived as the most central value of ZEBs. 72.73% of respondents ranked improved comfort as the primary benefit, a proportion that rises to 76%-82.35% among those highly satisfied with temperature and humidity, indicating that positive real-world experiences reinforce this perception.

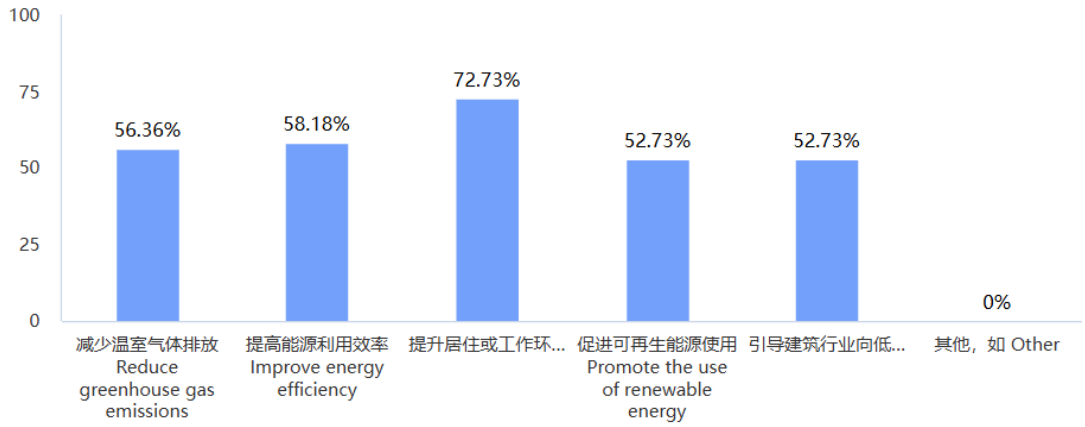


Figure 19 User Perceptions of the Significance of ZEBs

(5) Suggestions for Building Improvement

Optimizing environmental comfort emerged as the core demand for building improvements. Specific aspects including daylighting, shading, ventilation, and acoustic comfort were identified as the primary needs for enhancement. This option was selected by 56.36% of respondents, significantly surpassing all other improvement directions, indicating that environmental comfort is the most prominent shortcoming in current buildings. It is recommended to prioritize the optimization of building envelope design and equipment system configuration.

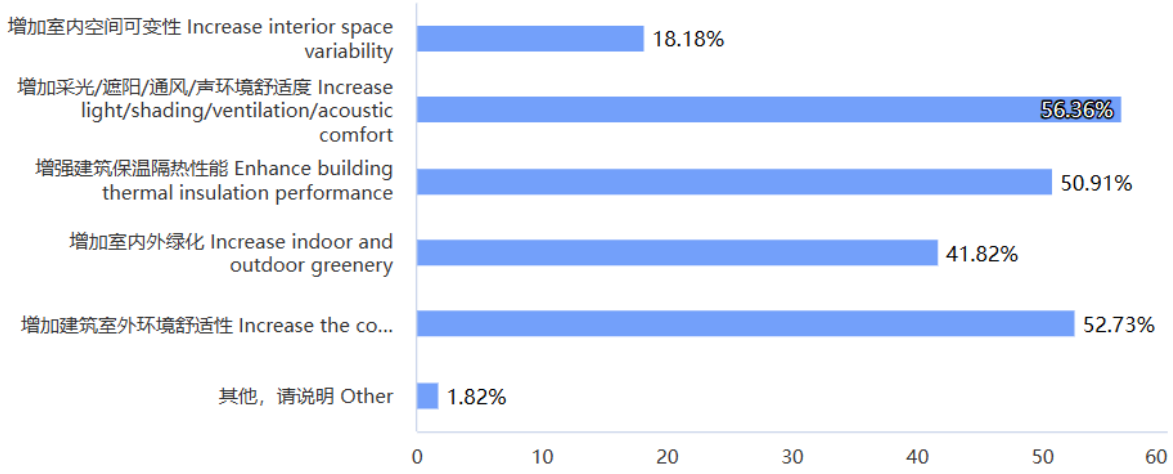


Figure 20 User Suggestions for Building Improvement

A positive correlation exists between building environmental quality and the adoption of

energy-saving behaviors, highlighting the need to enhance spatial experience design. A significant association was observed between the experience of using green buildings and changes in energy-saving behaviors. The proportion of individuals who proactively adopt energy-saving practices increases with higher satisfaction levels regarding temperature and humidity. Notably, 39.58% of the "very satisfied" group reported significant behavioral changes, compared to only 25% in the "dissatisfied" group. It is recommended to strengthen energy-saving awareness by optimizing indoor environmental comfort.

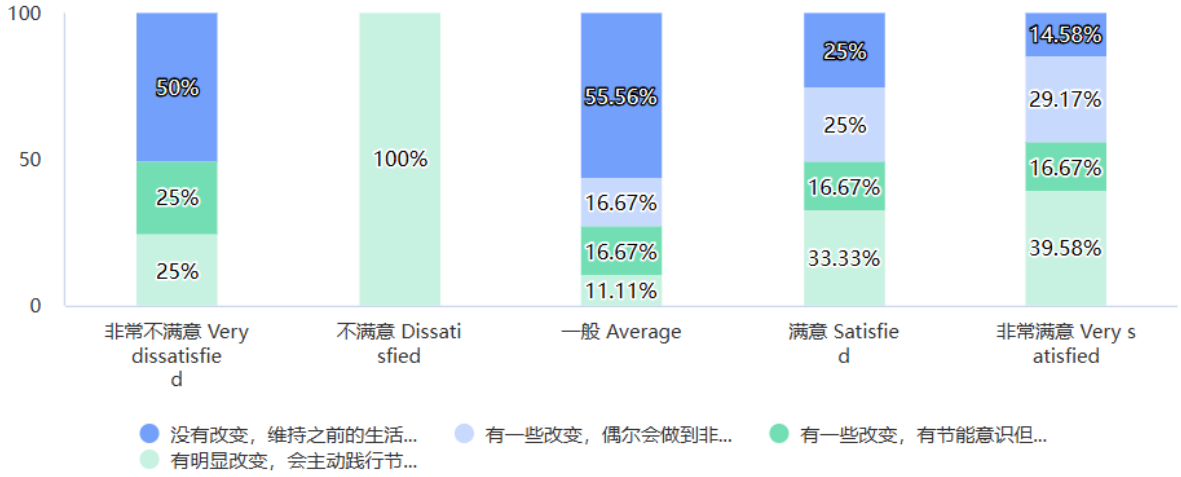


Figure 21 Relationship Between Satisfaction with ZEBs and Adoption of Energy-Saving Behaviors

2.5 Research Conclusions

This study fully demonstrates that ZEBs exhibit significant advantages in enhancing user experience, primarily reflected in the following aspects:

(1) ZEBs Significantly Improve Indoor Environmental Comfort and User Satisfaction

ZEBs demonstrate systematic advantages in indoor environmental quality, performing exceptionally well across core dimensions such as temperature and humidity stability, air quality, natural daylighting, natural ventilation, and door/window airtightness.

Survey data indicate that over 56.84% of users in demonstration projects reported being "very satisfied" with the overall indoor environment—significantly higher than the 47.27% in

conventional buildings—confirming their practical effectiveness in enhancing user comfort.

In terms of temperature and humidity, ZEBs achieve precise regulation of the indoor thermal environment by integrating high-performance building envelopes, intelligent control systems, and passive design strategies.

Regarding air quality, through efficient fresh air systems and optimized natural ventilation design, ZEBs effectively control indoor CO_2 concentrations and pollutant levels. Data show that 51.58% of users in demonstration projects expressed being "very satisfied" with air quality—nearly 21 percentage points higher than in conventional buildings—highlighting their outstanding performance in creating a healthy environment.

In natural daylighting and ventilation, ZEBs utilize skylights, adjustable shading, and optimized ventilation openings to ensure ample natural light while avoiding glare issues.

For door and window performance, demonstration projects employ high-performance systems with significantly improved airtightness and thermal insulation. Notably, user satisfaction with winter thermal performance improved most markedly in cold climates. This can be attributed to technical measures such as composite insulation systems, detailed thermal bridge treatment, and high-efficiency window assemblies adopted in ZEBs. These effectively address common issues in conventional buildings, such as large indoor temperature variations and high energy consumption during winter, fully demonstrating the technical adaptability and reliability of ZEBs under extreme climate conditions.

(2) Significant Energy-Saving Effects and More Rational and Intelligent Energy Usage Behavior

ZEBs demonstrate notable advantages in energy efficiency and energy usage patterns. In terms of building performance, the synergistic application of high-efficiency envelope structures and renewable energy systems substantially reduces baseline energy demand. In demonstration projects, 60% of users reported concentrated summer air conditioning usage of 5–8 hours per day—nearly 14 percentage points higher than in conventional buildings—

reflecting an optimization of energy use patterns resulting from improved thermal performance.

Regarding energy regulation experience, over half of the users in demonstration projects can autonomously adjust indoor air conditioning temperatures. Smart control systems not only grant users greater autonomy but also enable precise management.

From an economic perspective, 77.14% of users in demonstration projects maintained monthly electricity bills within ¥200, significantly outperforming users of conventional buildings. This economic benefit further reinforces users' willingness to conserve energy.

It is noteworthy that energy-saving outcomes exhibit distinct characteristics across different climate zones. Northern projects significantly reduce heating energy consumption through enhanced insulation and utilization of renewable energy, while southern projects effectively lower cooling demand by integrating shading, ventilation, and high-efficiency air conditioning. Such region-specific technical pathways not only ensure energy-saving effects but also enhance regional adaptability, providing important references for the promotion of ZEB technologies.

(3) Outdoor Environment and Community Functions Still Have Room for Optimization

The research reveals that ZEBs exhibit a noticeable tendency of "prioritizing indoor spaces over outdoor environments," with significant room for improvement in community-level interactivity and service functions.

Although users highly praised the physical comfort of the indoor environment, their satisfaction with outdoor activity spaces was generally low. Data indicate that over 72% of users in demonstration projects cited a "lack of interactive recreational facilities," while 44% reported "insufficient shading and rain shelters." In contrast, traditional buildings performed better in terms of accessibility to outdoor sports areas (traditional 60% vs. ZEBs 48%) and health services (traditional 45% vs. ZEBs 28%), directly impacting users' overall community living experience.

This contrast reflects, to some extent, that current ZEB efforts are predominantly focused on energy-saving technologies for the building itself and the indoor environment, lacking

systematic consideration within the broader community ecosystem. The strong user desire for increased greenery, improved recreational facilities, and enriched community functions represents a higher-level demand for "better living."

(4) Operation and Maintenance Management Faces New Technical Challenges, but Initial Long-Term Benefits Are Emerging

At the operational and maintenance level, ZEBs are undergoing growing pains in the transition from traditional models to smart operation, exhibiting typical characteristics of simultaneous short-term challenges and long-term benefits.

Survey data indicate that approximately 50% of operators reported significant reductions in energy costs for demonstration projects, confirming the economic advantages of zero-carbon technologies in long-term operation. However, operational teams face systemic challenges in practice. New systems such as integrated energy management systems, photovoltaic energy storage equipment, and intelligent control platforms demand updated professional knowledge structures from maintenance personnel.

Unlike conventional buildings, where the focus is primarily on addressing fundamental issues like equipment aging, pipeline leakage, and electrical circuit risks, the difficulties in operating and maintaining ZEBs concentrate more on soft skills—specifically, the ability to understand, analyze, and optimize complex technical systems. Notably, this challenge marks an inevitable stage in the transformation and upgrading of the building operations sector from labor-intensive to technology-intensive.

(5) Positive Correlation Between User Experience and Energy-Saving Behavior, But Awareness Still Needs Improvement

This study reveals that user experience serves as the intrinsic driver for adopting energy-saving behaviors. Data analysis shows that among users highly satisfied with indoor temperature and humidity, 39.58% have proactively developed energy-saving habits—a rate significantly higher than the 25% observed among dissatisfied users. This gap indicates that

when users personally experience a stable and comfortable indoor environment, energy conservation becomes a conscious action to maintain their quality of life. This provides a solid behavioral foundation for promoting zero-carbon concepts, demonstrating that enhancing user experience does not increase energy consumption but is instead the most effective way to encourage behavioral energy savings.

Currently, over 60% of respondents possess only a vague awareness of ZEBs, having merely "heard of the concept," highlighting a significant knowledge gap. However, users of demonstration projects are better able to appreciate the core value of ZEBs in areas such as "enhancing comfort," "reducing energy costs," and "using eco-friendly materials." This shift in perception—from abstract concept to tangible benefits—shows that firsthand user experience is the most effective way to break down cognitive barriers and connect macro-level low-carbon goals with micro-level personal well-being.

(6) Market Incentives and Systematic Collaboration Require Further Development

Within the current policy framework, national-level guidance documents have established a strategic direction for green and low-carbon development in the building sector, providing clear top-level guidance for industry transformation. However, at the local implementation level, some regions still lack effective incentives directly linked to economic returns, leading to prevalent market wait-and-see attitudes and insufficient participation of social capital.

The research finds that ZEBs are currently primarily driven by government investment or leading real estate developers, with investment motivations focusing more on policy compliance and brand image building than on forming a broad market-based investment landscape. The main obstacle restricting social capital investment is the economic return model—the payback period for incremental investments in ZEBs far exceeds market expectations. Meanwhile, existing green financial products typically have terms of only 3–5 years, creating a serious mismatch with actual project return cycles and further limiting large-scale capital inflow.

On the market supply side, while a number of specialized technical suppliers have emerged in areas such as high-performance materials, renewable energy, and intelligent controls, the current cooperation model remains centered on supplying individual technological products. There is a lack of integrated service providers capable of delivering comprehensive solutions oriented towards end-user experience and overall energy efficiency. This situation increases project management costs for owners and further constrains the overall performance optimization of ZEBs.

It should be noted that this survey has certain limitations:

First, regarding sample size, a total of 150 valid questionnaires were collected. The overall sample size is limited, which may affect the representativeness and stability of some statistical results.

Second, in terms of project selection, some originally planned demonstration projects were either not yet completed or unsuitable for surveying. Consequently, alternative projects meeting high-star green building standards were used in the actual research. This may, to some extent, weaken the typical representation of zero-carbon features.

Furthermore, regarding data completeness, most demonstration projects have been recently operational and have not yet undergone a full climatic cycle of operational testing. There is a lack of long-term operational data and systematic performance tracking; therefore, some conclusions remain preliminary and require ongoing observation and verification.

In summary, ZEBs, through the deep integration of technology and behavior, achieve quantifiable energy savings while simultaneously fostering a social atmosphere of rational energy use. They provide a technically feasible, economically viable, and user-approved implementation pathway for the industry's low-carbon transition. Promoting ZEBs is both a technological revolution and a reshaping of cognition and behavior. Future efforts should transcend mere technical advocacy and focus on creating more perceptible, experiential, high-quality architectural spaces, thereby transforming green and low-carbon concepts from

abstract ideas into a widely understood and actively pursued way of life.

3. Recommendations for Next Steps

Based on the findings of this research, the project team proposes that the future scaled development and quality enhancement of ZEBs should focus on the following key areas:

(1) Strengthen Technological Innovation and System Optimization to Enhance Overall Building Performance

Advance innovation in ZEB technology systems, focusing on key areas such as high-performance building envelopes, smart energy management systems, and the efficient utilization of renewable energy. Continue to promote technological innovation aimed at improving indoor environmental comfort in ZEBs, with emphasis on optimizing natural daylighting and ventilation system design. By fostering synergistic operation and holistic optimization among various systems, establish a user-experience-centric ZEB technology system that prioritizes both energy efficiency and spatial comfort.

(2) Establish Differentiated Technological Pathways to Promote Climate- and Human-Oriented Development

Develop more refined, regionally adaptive technological pathways tailored to the characteristics of different climate zones. Strengthen technology verification and performance evaluation based on regional climate features, and establish technology applicability evaluation systems for different climate zones to avoid the simplistic replication of technical solutions.

Simultaneously, incorporate users' regional cultural habits into technology localization considerations. When selecting technical solutions, consider both climatic characteristics and fully respect local users' living habits and comfort perceptions. This ensures the technical performance of buildings under specific climate conditions while meeting the practical needs of users in different regions, achieving simultaneous improvement in technology applicability and user satisfaction.

(3) Improve the Policy System and Market Mechanisms to Build an Industrial Development Ecosystem

Enhance policy incentives, innovatively employ diverse support measures such as financial subsidies, tax incentives, rental subsidies, and floor area ratio bonuses to support the scaled development of ZEBs. Promote deep integration of industry, academia, research, and application to build a complete industrial chain ecosystem. Foster emerging service markets and promote professional service models like energy cost trusteeship, carbon asset management, and smart operation and maintenance. Drive innovation in green financial products and broaden project financing channels.

(4) Strengthen Public Participation and Build an Integrated Community Development Model

Gradually advance ZEBs from excelling in individual building performance towards integrated building-community-culture development. Establish user feedback mechanisms to continuously optimize building functional design and operational services. Conduct diverse promotional activities to showcase the advantages of ZEBs in improving quality of life and reducing energy costs, thereby enhancing public recognition and participation, and promoting the adoption of green, low-carbon lifestyles.

At the community level, extend the zero-carbon concept from inside buildings to community public spaces. Strengthen the integrated design of grey and green infrastructure, and foster an all-age-friendly community atmosphere. Through scientific site layout and vegetation configuration, guide natural ventilation, improve the local microclimate, and create sustainable communities that integrate low-carbon features, comfort, and livability.

(5) Deepen International Cooperation and Win-Win Development to Jointly Build a Global ZEB Development System

Integrate green, low-carbon concepts with regional cultural characteristics to develop ZEBs with local cultural connotations. Actively participate in international ZEB standard setting

and technical exchanges, extensively learn from advanced international experience, and demonstrate China's achievements in ZEB development through the construction of international demonstration projects, thereby promoting global sharing and collaborative progress in green building technologies.

Through the thorough implementation of the above systematic measures, a more favorable innovation environment, policy environment, and market environment will be created for the development of ZEBs. This will facilitate their transition from pilot demonstrations to scaled promotion, making a greater contribution to building a green, low-carbon living environment and driving the transformation and upgrading of the building sector.

Appendix 1: Survey Record - Harbin

Appendix 2: Survey Record - Xiongan New Area

Appendix 3: Survey Record - Shaoxing

Appendix 4: Survey Record - Shenzhen

Appendix 5: Interview Outline for Discussions

让我们共同打造气候中和的未来
Building a climate-neutral future together

Schweizerische Eidgenossenschaft
Confédération suisse
Confederazione Svizzera
Confederaziun svizra

Swiss Agency for Development and Cooperation SDC

中华人民共和国
住房和城乡建设部

IBEE 环能科技

intep

skat

4. Appendix 1:

Survey Record – Harbin

From December 8 to 10, 2024, the research team conducted a survey in Harbin. The projects investigated included the Second Technology Building Renovation Project into a ZEB (Demonstration Project) of the Heilongjiang Provincial Cold Region Building Research Institute, and the main office building of the same institute (Traditional Building). Additionally, the Sino-German Eco-Tech Town project was visited on-site as a supplementary case study for ZEB demonstration.

1. Project Introduction

(1) Heilongjiang Provincial Cold Region Building Research Institute

The Second Technology Building of the Heilongjiang Provincial Cold Region Building Research Institute has a total floor area of 8,657.28 square meters (above-ground: 7,340.72 sq m; below-ground: 1,316.56 sq m). The building has 7 above-ground floors (with a partial mezzanine) and 1 underground floor. The total investment for the renovation was 19.986 million RMB. Originally constructed in 1995 and previously affiliated with the Highway Development Center under the Heilongjiang Provincial Department of Transport, the building was later converted into a hotel. Post-renovation, its functions now include office space, scientific research, and demonstration. The renovation construction started in October 2022, and occupancy for office use began progressively after March 2024. The investor, operator, and user is the Heilongjiang Provincial Cold Region Building Research Institute.

Figure 1: Building Facade of the Heilongjiang Cold Region Building Research Institute

To achieve the ultra-low energy consumption target, the project primarily employs various forms of external wall insulation systems, high-insulation windows suited to the local environment, efficient heating and fresh air systems, and renewable energy utilization technologies. The project is not connected to the municipal heating network; instead, heating energy during winter is provided by a combined air-source heat pump system and an electric boiler thermal storage system. Renewable energy utilization is enhanced through the combined use of solar PV panels and cadmium telluride (CdTe) photovoltaic glass, forming an auxiliary energy supply. Specifically, the rooftop solar PV system generates approximately 80 kWh per day in winter and around 200 kWh per day in spring/autumn. The exterior features 20 CdTe photovoltaic glass panels and 8 battery storage units, currently providing trial power supply for lighting on the first floor, generating about 10 kWh per day in winter. The project includes a building monitoring platform capable of tracking aspects such as the building structure, outdoor and indoor environment (temperature, humidity, CO_2 concentration, etc.),

building energy efficiency (heating supply, cooling supply, heat consumption), and it also performs carbon emission calculations and energy-saving analysis.

Figure 2: Schematic Diagram of the Air-Source Heat Pump and Electric Boiler Thermal Storage System

Figure 3: Temperature Sensors Installed to Monitor Temperatures at Different Points

on the Glass

(2) Main Office Building of Heilongjiang Provincial Cold Region Building Research Institute

The main office building of the Heilongjiang Provincial Cold Region Building Research Institute has a total floor area of 2,910 square meters, expanding to approximately 5,000 square meters when including laboratory equipment. The building is over 35 years old, featuring brick-concrete structure with four above-ground floors. Its exterior walls consist of 240mm thick red brick. In 2019, triple-pane double-cavity windows and LED lighting were installed as the only energy efficiency improvements, with no other energy-saving facilities added. The building functions as an office space, currently accommodating about 150 staff, including inspection personnel.

Figure 4: Main Entrance of the Building

Figure 5: Interior Corridor of the Building

Figure 6: Rear Courtyard of the Building

(3) Sino-German Eco-Tech Town

The Sino-German Eco-Tech Town project is located in Songbei District, Harbin. Developed through collaboration between Harbin New Area, the German Energy Agency (dena), and the Chinese Ministry of Housing and Urban-Rural Development, the project spans a total site area of 200,000 square meters. The first phase covers 66,000 square meters with a total floor area of 100,000 square meters, comprising approximately 56,000 square meters of ultra-low energy consumption buildings (residential) and 44,000 square meters of low-energy consumption buildings (exhibition center, offices). Construction of the first phase commenced in 2019 and was fully completed in 2022. The project was invested in and constructed by Haoning Construction Technology Co., Ltd., with Harbin Haiping Hi-Tech Property Co., Ltd. responsible for implementation and development. With a total investment of approximately 700 million RMB, it is the first passive ultra-low energy consumption building industrial park project in China's severe cold region.

The buildings within the project employ four major systems: high-performance external wall insulation, passive energy-saving doors and windows, mechanical ventilation with heat recovery systems, and new energy heating systems. The project is not connected to the municipal heating network. For heating, the exhibition center and office buildings utilize air-source heat pumps, while the residential buildings use graphene electric heating films. The heating costs are approximately half of those associated with conventional municipal heating.

Figure 7: Sand Table Model of the Project's First Phase

Figure 8: Service Center of the Sino-German Eco-Tech Town

Figure 9: Ultra-Low Energy Consumption Building (Residential)

Figure 10: External Wall Insulation Material

Figure 11: Energy-Saving Door and Window System

2. Interview Records

(1) Discussions with Operators

The project team held discussions with the operators of the three projects regarding areas such as division of operational responsibilities, operational data, user feedback, and operational problems and challenges.

Division of Responsibilities: Both the demonstration and traditional buildings reported that office administration is responsible for ensuring normal project operation and use, including paying energy bills, and maintaining equipment and the building itself, while property management handles services like sanitation, security, and cleaning.

Operational Data: The primary energy expenditure for all three projects is electricity costs.

Notably, the demonstration project is not yet connected to the municipal heating network and uses air-source heat pumps and electric boilers for heating. The equivalent heating cost based on electricity consumption is approximately half that of conventional heating methods.

User Feedback: Users of the traditional building reported the most issues, including cold corner rooms during the heating season, stuffiness in south-facing rooms at noon during summer, and occasional external noise.

Operational Problems and Challenges: Key issues reported for the demonstration project primarily involve the high specialization and complexity of equipment maintenance, necessitating professional training. For the residential buildings, challenges include the immaturity of heat recovery ventilation technology in severe cold regions, leading to high preheating energy consumption, and the inability of the indoor fresh air system to regulate humidity, resulting in dry indoor air during the heating season. Main issues reported for the traditional building include aging electrical circuits and pipelines, water leakage, and mold growth on walls caused by leaks during the heating season.

Regarding the demonstration project, users identified its main comfort advantages as better thermal insulation, effective soundproofing, and the high practicality of the fresh air system in winter. Operators attributed energy savings and carbon reduction primarily to three aspects: the building envelope, daily operations, and user behavior. A better insulated building envelope lowers heating energy consumption. In daily operations, setting temperature thresholds allows for automatic equipment control, and reasonably adjusting these thresholds based on outdoor temperatures reduces energy waste. Regarding user behavior, habits such as turning off lights when not needed and avoiding

unnecessary air conditioning use also contribute to building energy savings and carbon reduction.

(2) Discussions with Investors

For investors, the project team primarily interviewed them on four topics: the payback period for ZEBs, top-level policy support, future market potential, and corporate promotion.

Payback Period for ZEBs: The total investment for the demonstration project was 19.986 million RMB, with an incremental cost of 5-6 million RMB specifically to meet the ultra-low energy consumption building requirements. Considering the investments in solar PV and air-source heat pump equipment alongside the energy cost savings, the estimated annual cost recovery is around 200,000 RMB, resulting in a payback period exceeding 25 years.

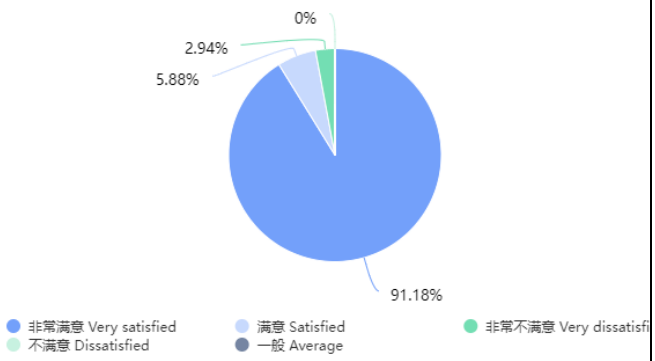
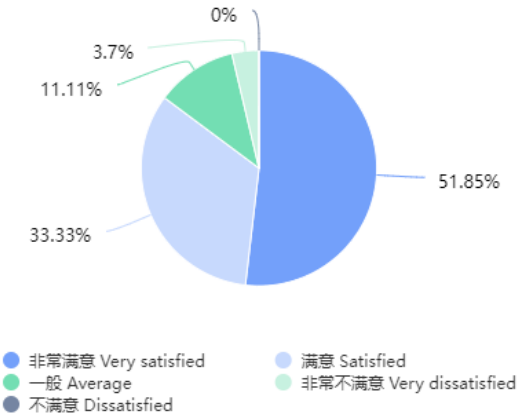
Top-Level Policy Support: Heilongjiang Province has currently issued the "Several Policy Measures to Support the Development of the Ultra-Low Energy Consumption Building Industry." Demonstration projects can receive subsidies of up to 300 RMB/square meter, while residential buildings within the Sino-German Eco-Tech Town can receive subsidies of up to 600 RMB/square meter and a 10% floor area ratio bonus.

Future Market Potential: Investors in the demonstration project believe there is future market potential for ZEBs and retrofits to ultra-low energy consumption standards. However, constrained by factors like insufficient top-level policy subsidies and limited client funding, clients tend to prioritize measures such as adding insulation layers or replacing windows with high-efficiency ones to improve comfort, rather than undertaking retrofits specifically aimed at achieving ultra-low energy consumption building standards.

Corporate Promotion: Both the demonstration project and the Sino-German Eco-Tech Town reported that their demonstration projects benefit corporate promotion and branding, attracting visits or cooperation from various entities including government departments, schools, construction companies, and research associations.

Figure 12: Survey Photos

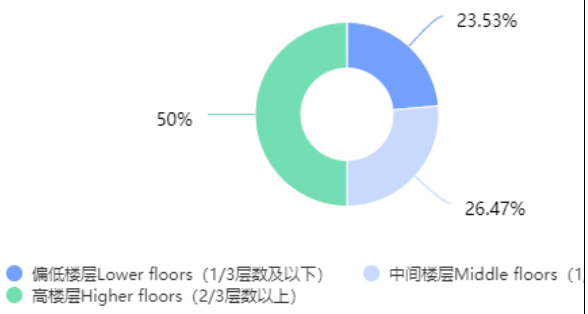
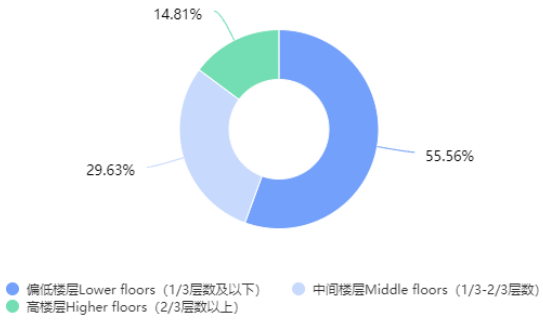
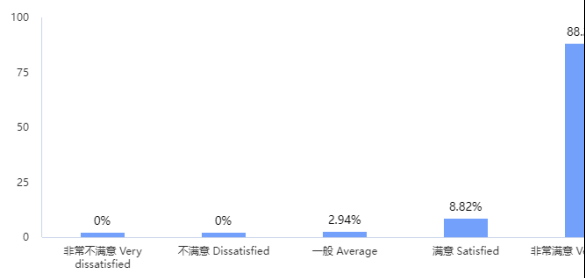
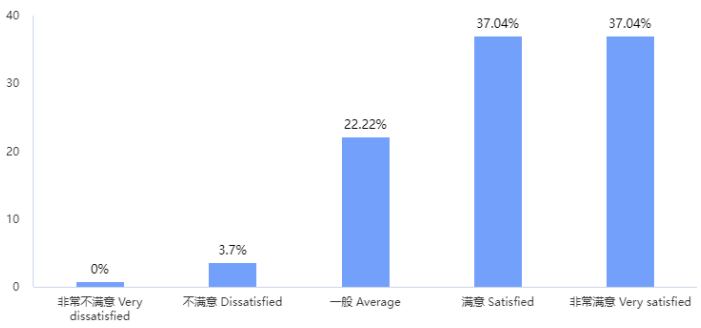
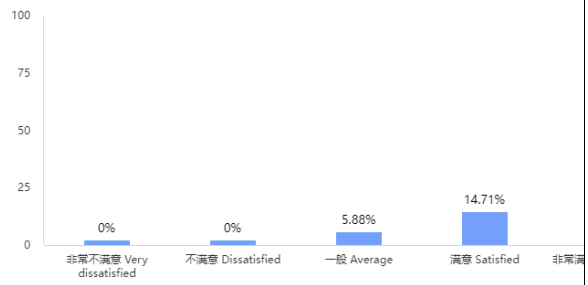
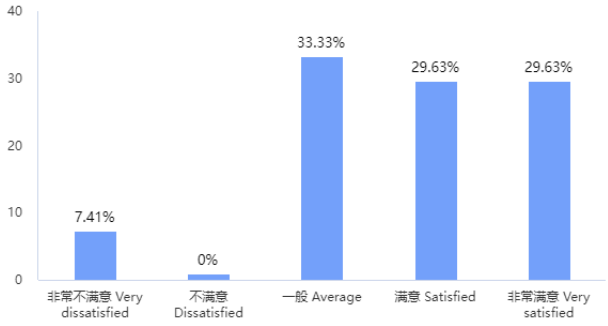
3.Questionnaire results in Harbin

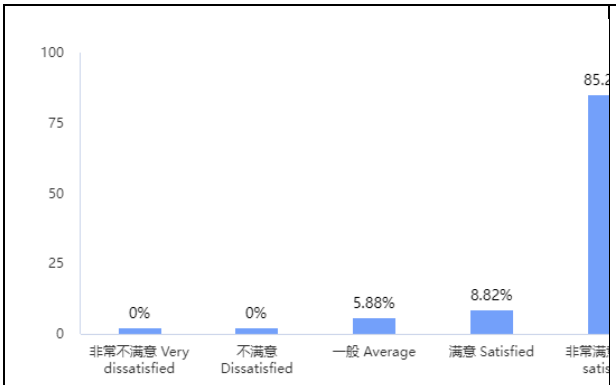
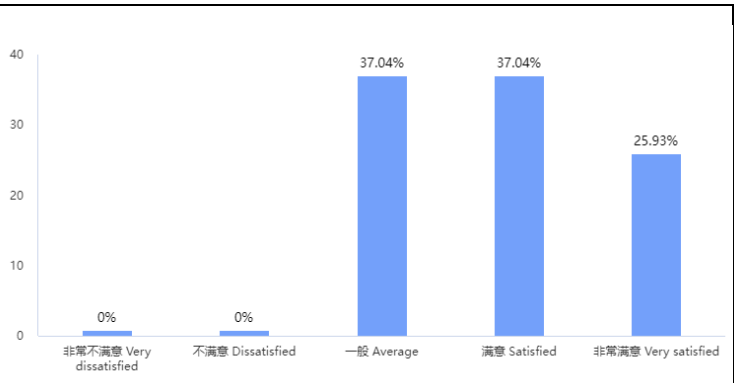
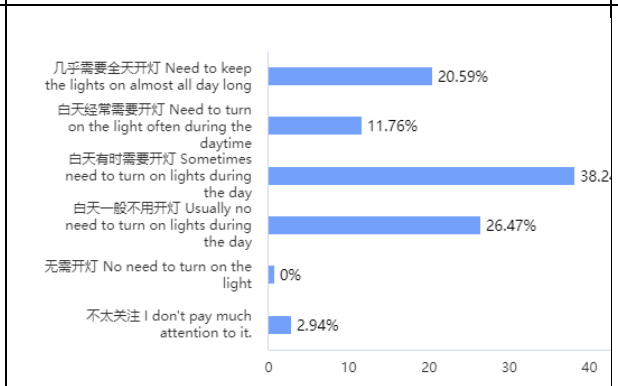
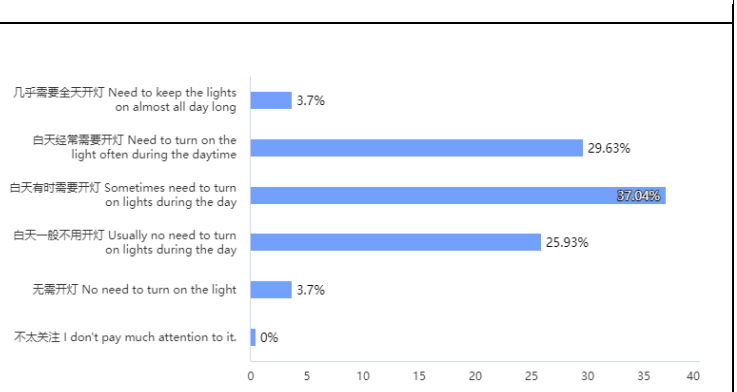
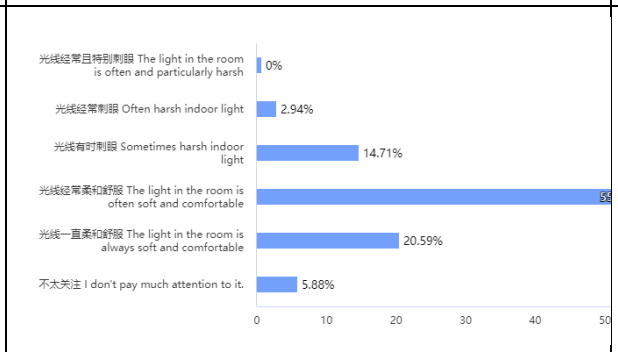
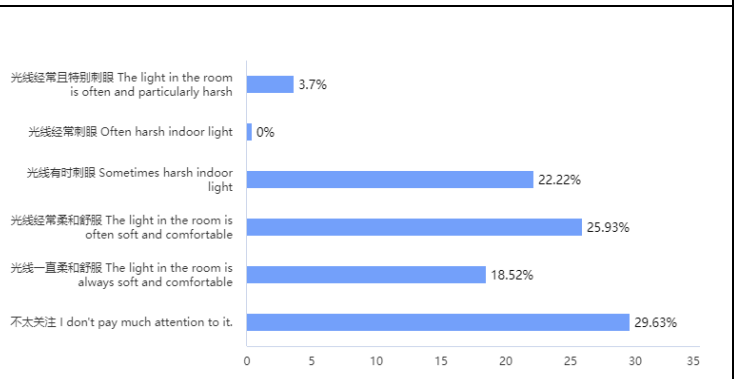
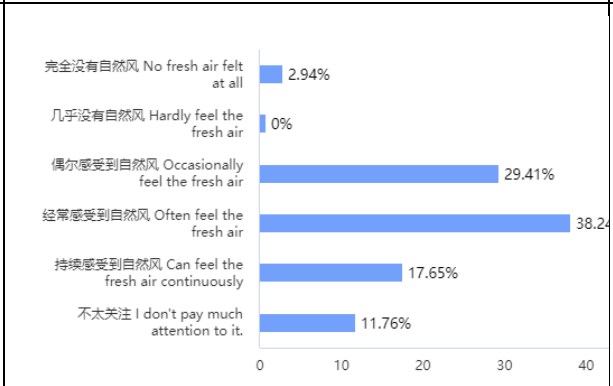
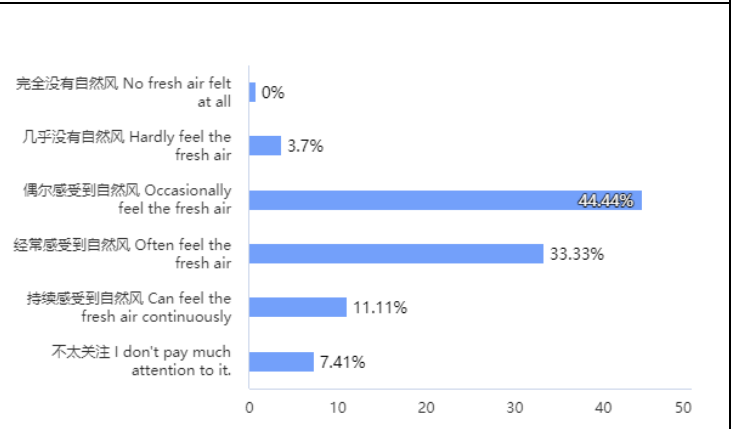
	ZEBs	Traditional Buildings
Overall Satisfaction		

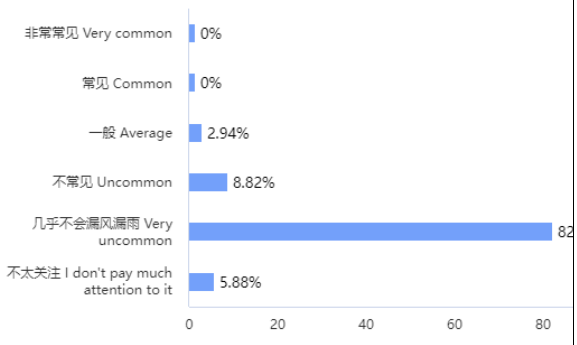
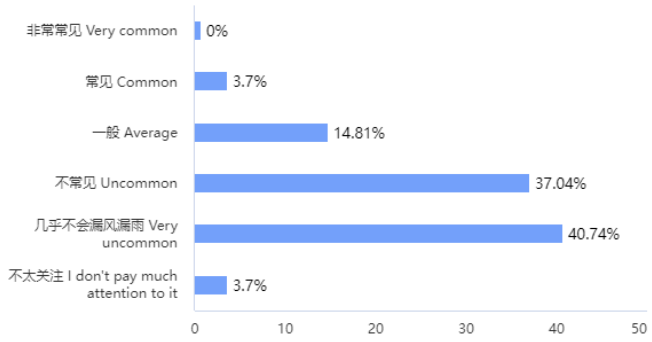
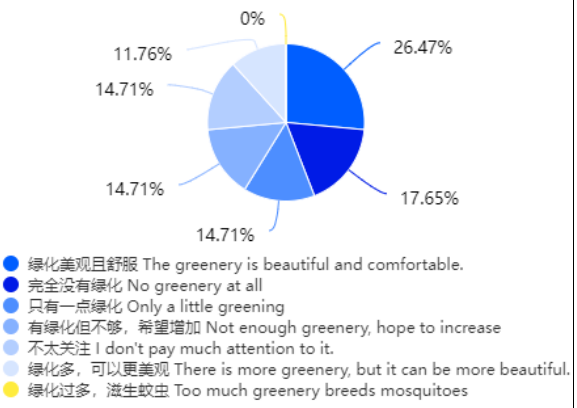
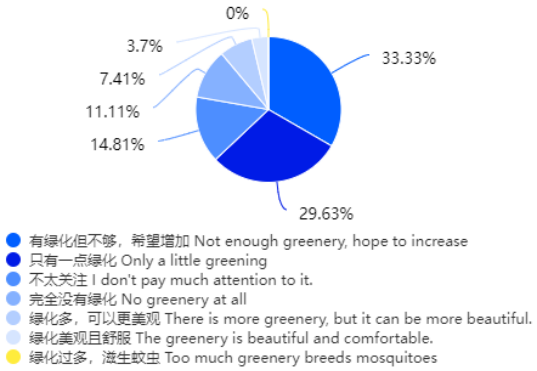
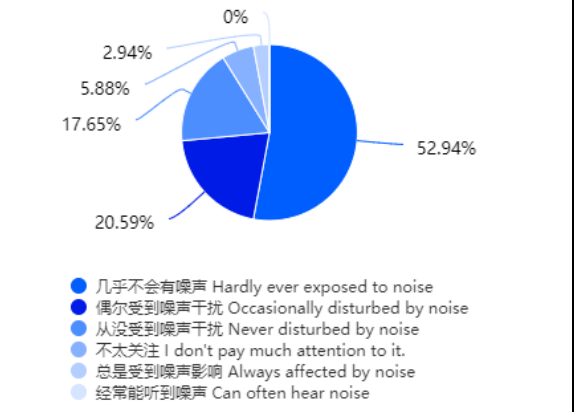
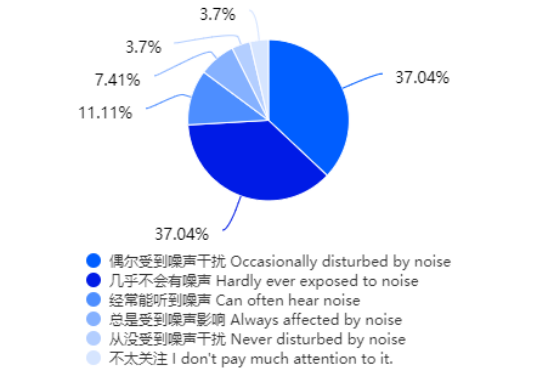
(1) Satisfaction with Indoor Environment

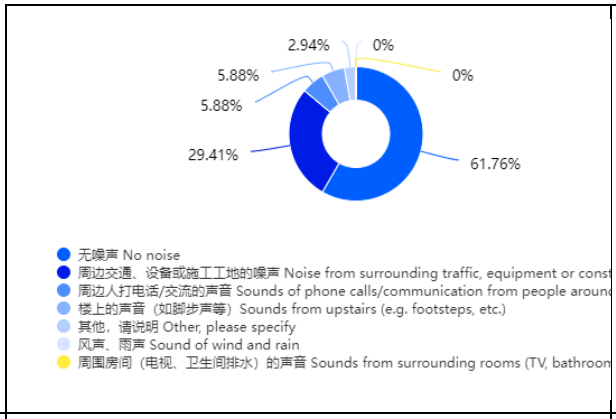
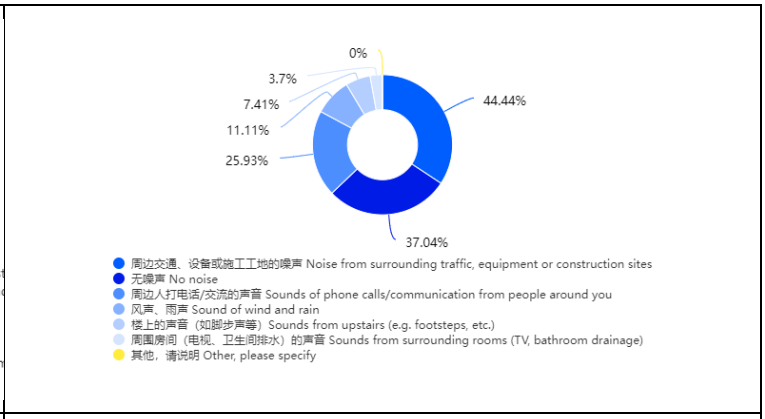
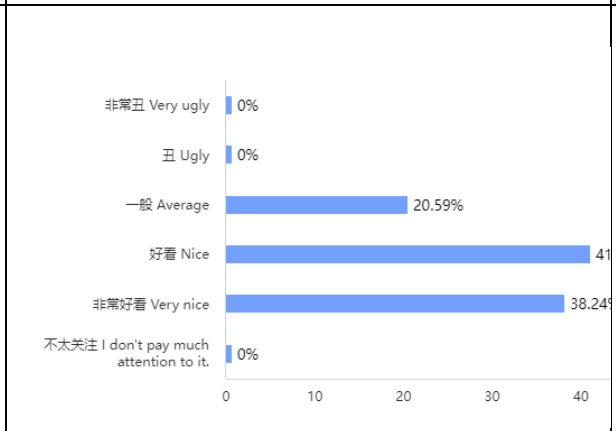
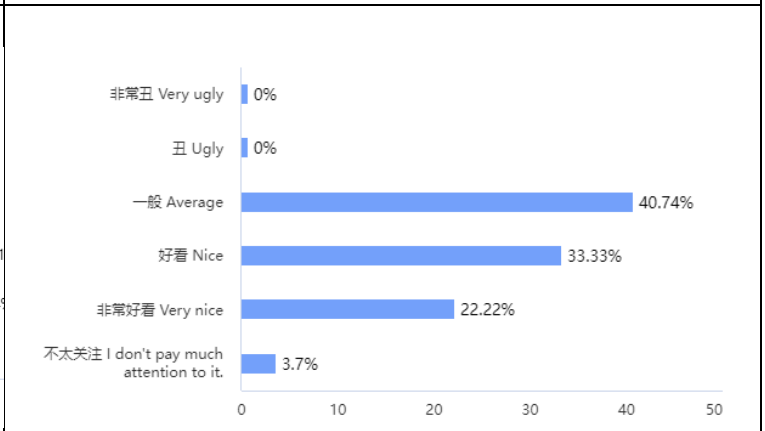
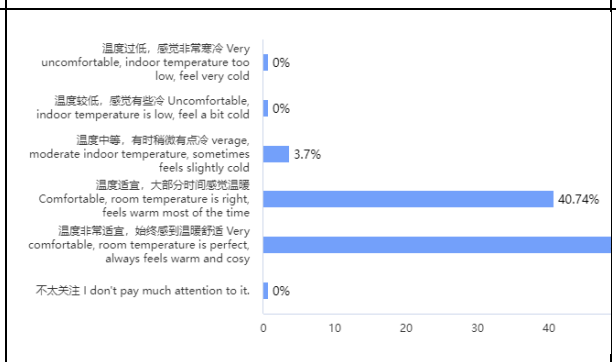
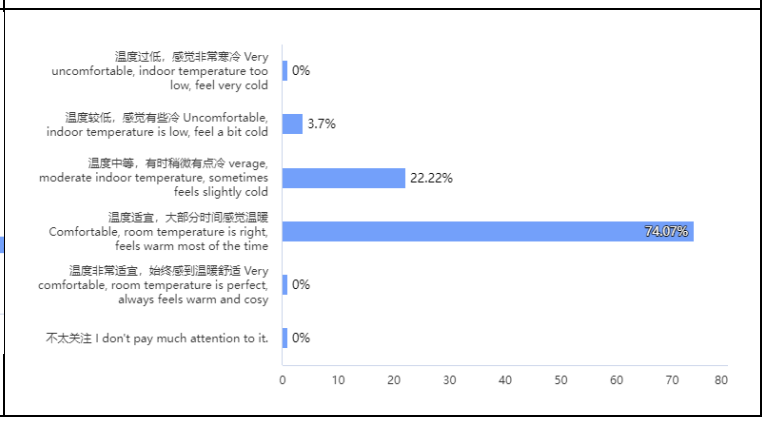
Including: floor level, temperature and humidity, air quality, accessibility facilities, artificial indoor lighting, natural lighting, natural ventilation, air/water leakage through doors and windows,

indoor greenery, noise levels, building exterior appearance, and heating season temperature.

Questions	ZEBs	Traditional Buildings
Levels		
Temperature and Humidity		
Air Quality		

Accessibility Facilities		
Lighting		
Natural Lighting		
Natural Ventilation		

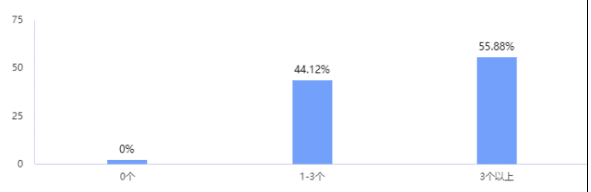
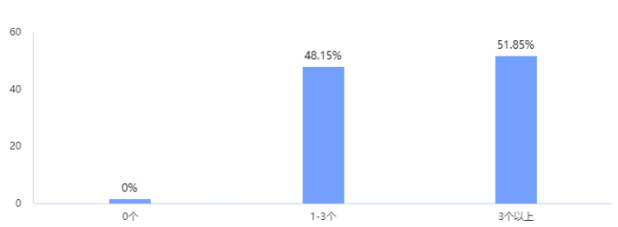
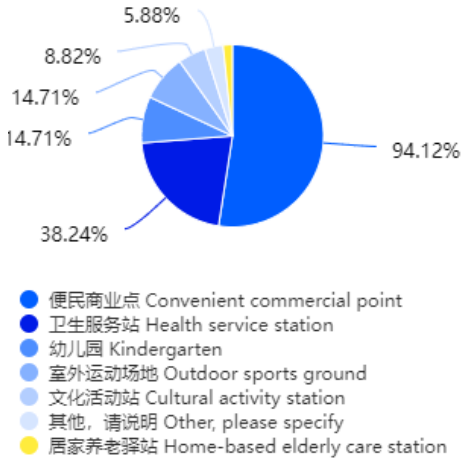
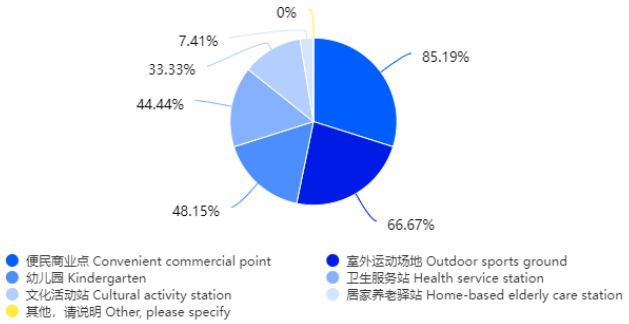
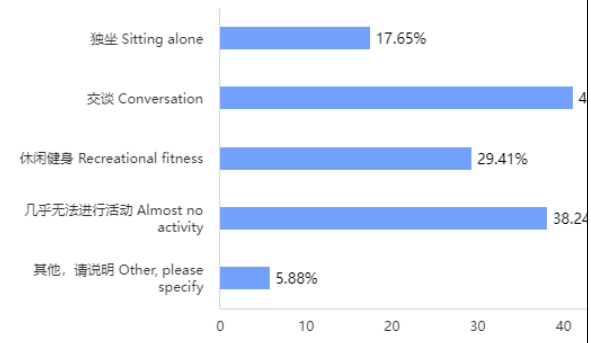
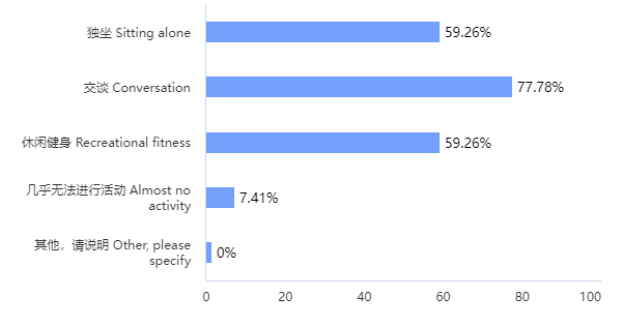
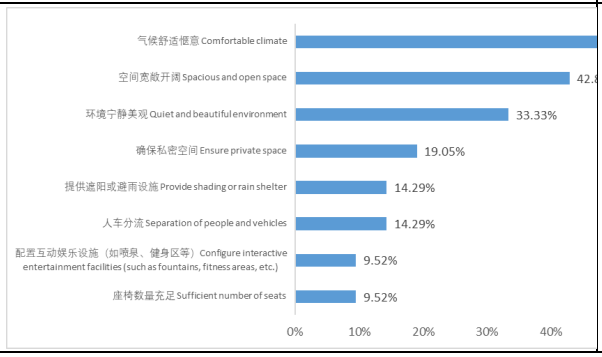
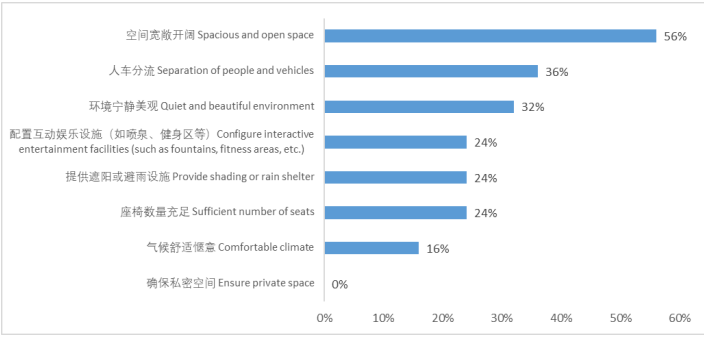
Air/Water Leakage through Doors & Windows		
Greenery		
Indoor Noise		

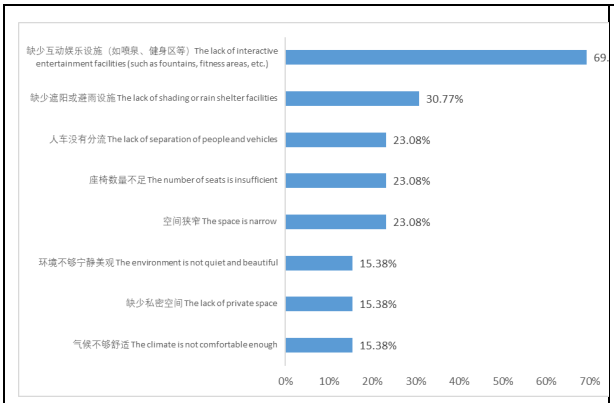
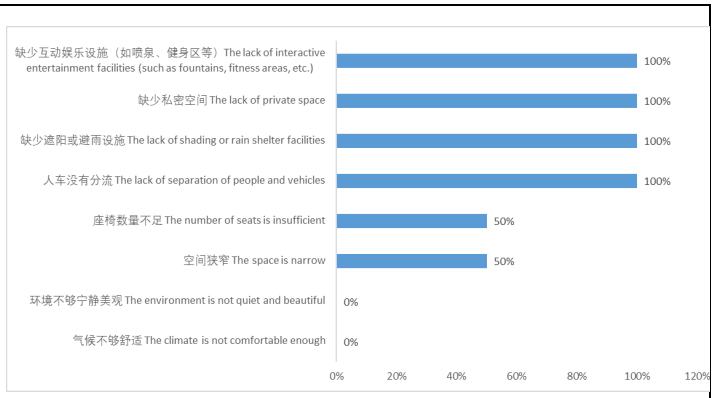
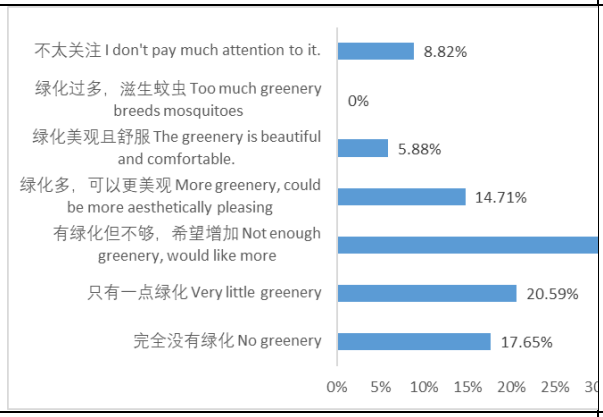
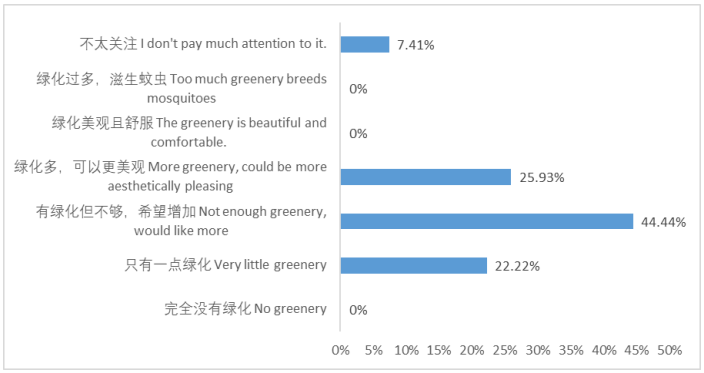
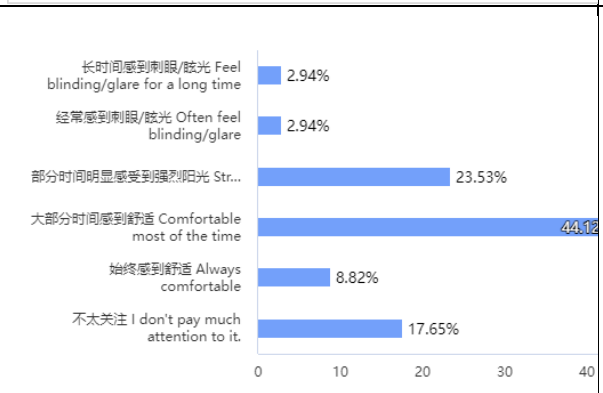
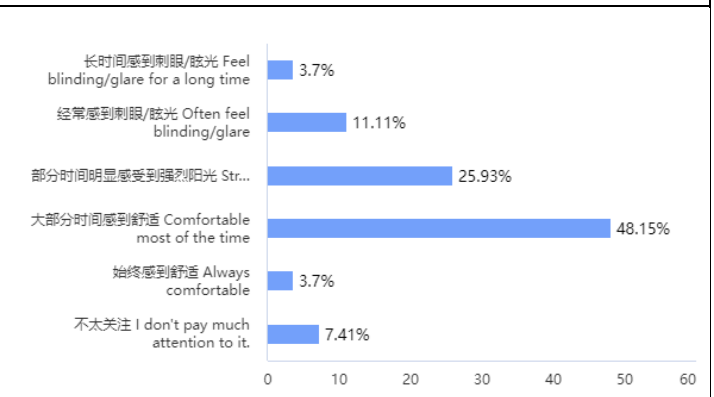
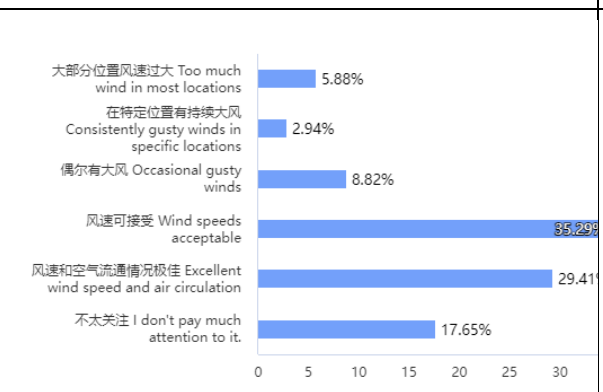
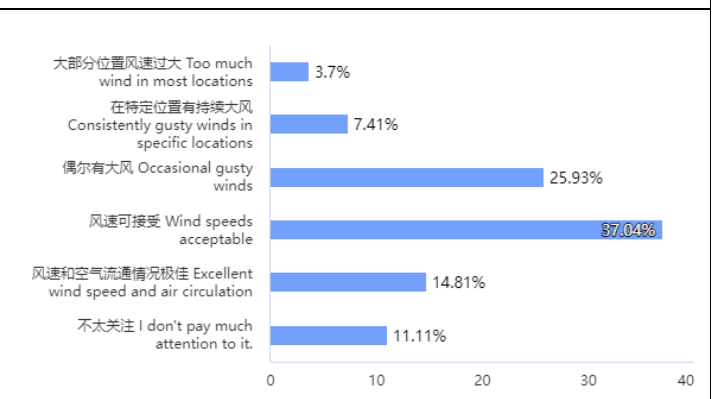
		
Building Exterior Design		
Satisfaction During Heating Season		

(2) Relationship Between the Building and Its Surrounding Environment

Including: availability of bus stops within a 5-minute walk, service facilities, activities feasible around the building and their reasons, outdoor greenery, outdoor shading, and outdoor ventilation.

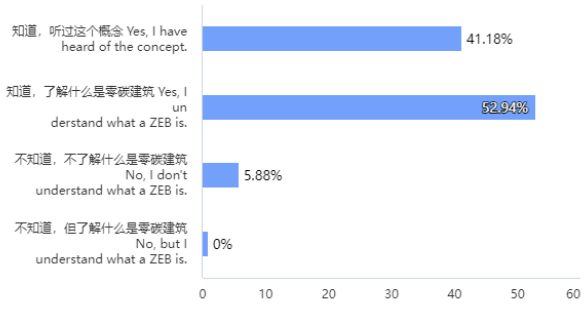
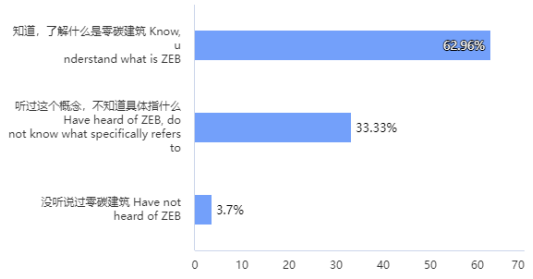
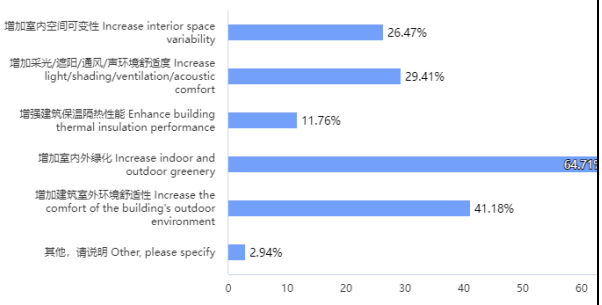
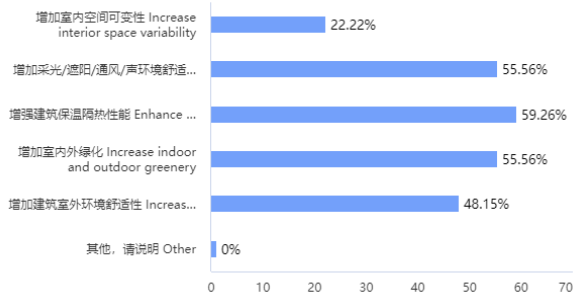
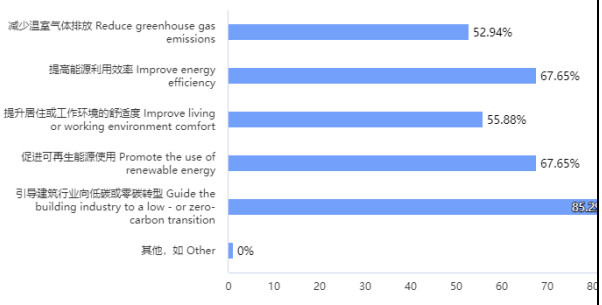
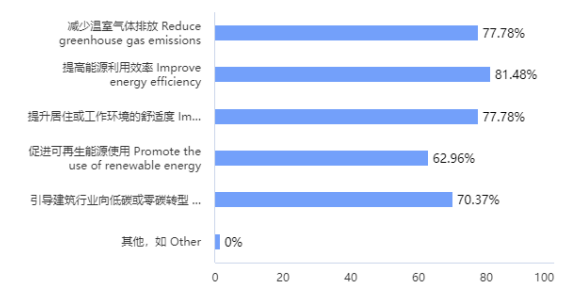
Questions	ZEBs	Traditional Buildings

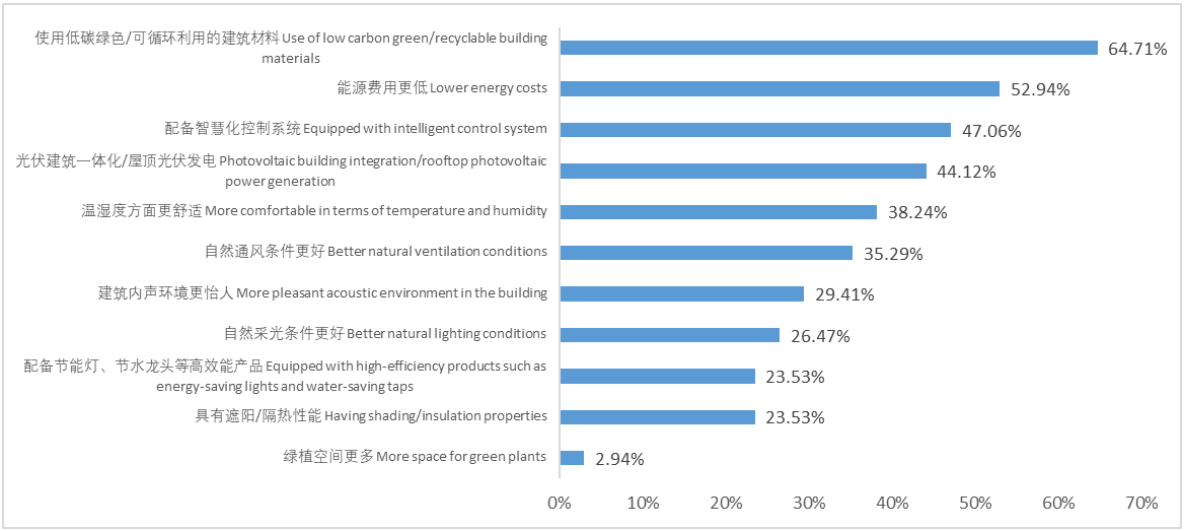
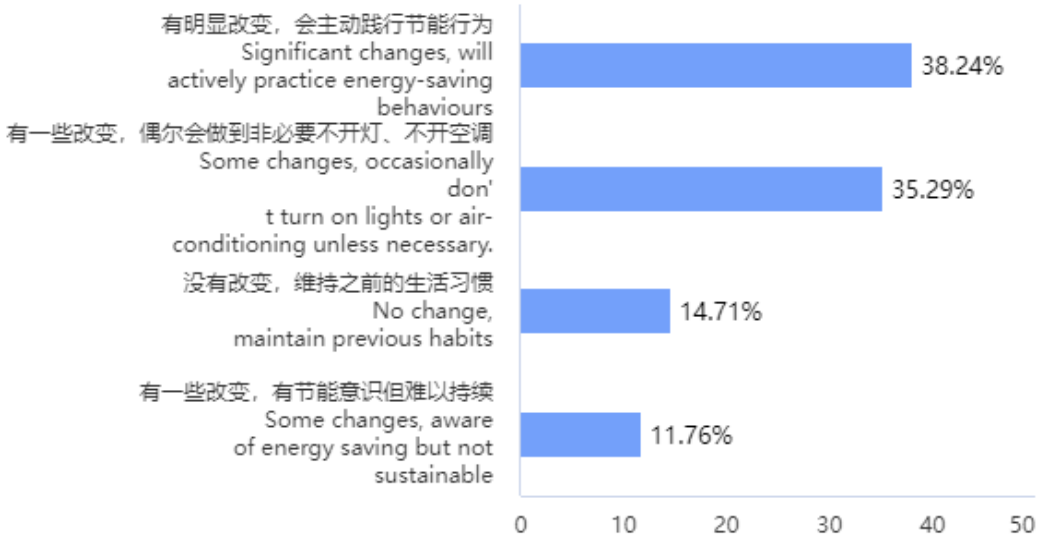
Bus Stops Within 5-Minute Walk		
Service Facilities		
Outdoor Activities Feasible		
Reasons for Feasibility		

Reasons for Infeasibility		
Outdoor Greenery		
Outdoor Shading		
Outdoor Ventilation		

(3) Understanding of ZEBs

Including: awareness of ZEBs, differences from surrounding buildings, changes to daily habits, potential building improvements, and the significance of ZEBs.

Questions	ZEBs	Traditional Buildings
Awareness of ZEBs		
Potential Building Improvements		
Significance of ZEBs		

Differences between ZEB and Surrounding Buildings	
Changes to Daily Habits	

5. Appendix 2:

Survey Record – Xiongan New Area

On July 29, 2025, the research team conducted a survey in the Xiongan New Area. The main projects investigated were the Xianxi Community Service Center (Demonstration Project) and the Xianxi Community Service Center (Traditional Building). The detailed content is as follows:

1. Traditional Building

(1) Project Introduction

Rongxiang Community, located in the southern part of Rongcheng County, was constructed and put into use in 2014. It oversees 12 residential quarters, with a current population of 2,227 households totaling 4,868 residents. The main building of the Rongxiang Community Party-Mass Service Center is three stories high, covering approximately 580 square meters. Originally designed as podium retail space, it has not undergone any green or low-carbon retrofits. Only basic interior renovations were carried out to adapt the space for its current function as a Party-Mass Service Center. The building's energy sources are primarily electricity and heating. Cooling is provided by split-type air conditioning units, while heating is delivered through radiators supplied by the municipal heating system. The service center includes public activity spaces such as a comprehensive service station, a public service workstation, a children's activity room, and a provincial-level "Women's Home."

(2) Operational Feedback

Regarding the division of responsibilities, the project is managed by the same property management company responsible for the adjacent retail podium. The property company uniformly

handles services such as paying energy bills, maintaining equipment and the building, and sanitation cleaning. Related costs are covered by the superior government budget, with no specific requirements for analyzing energy usage or improving energy efficiency. Due to the building's design, user feedback primarily highlights issues with poor daylighting and ventilation. Additionally, water leakage and cracking at wall corners were observed. A major current challenge is that, since the building's age excludes it from qualifying for green retrofits under programs targeting older residential quarters, it suffers from building aging and declining livability. Currently, only routine maintenance is performed, with no large-scale renovation plans in place.

Figure 1: Building Exterior

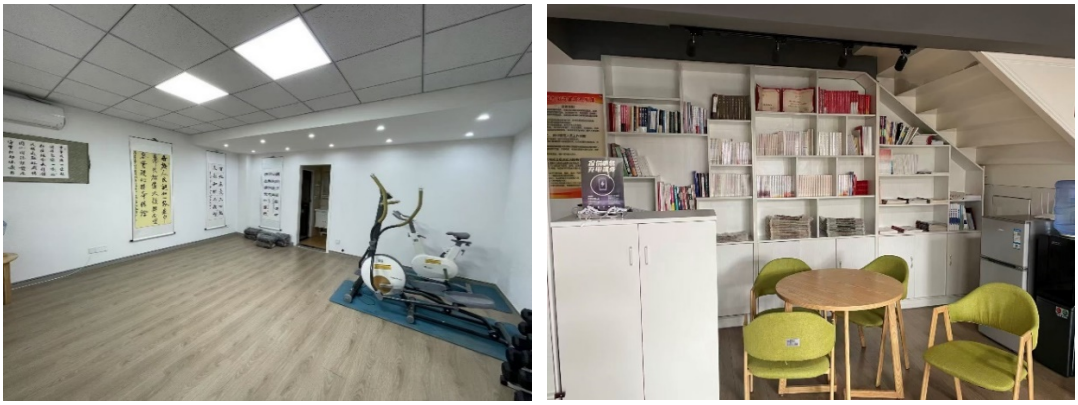


Figure 2: Public Activity Space

Figure 3: Windows, Shading, and Heating Methods

Figure 4: Daylighting on the First Floor

2.Demonstration Project

(1) Project Introduction

Xianxi Community is situated in the Rongxi area of the Xiongan New Area. It was constructed and became operational in September 2022. The community comprises 8 residential quarters with 72 residential buildings and currently has 2,915 households with a population of 6,904 residents. As a newly developed area within the Xiongan New Area, Xianxi Community has achieved a 100% application rate for 2-Star Green Building standards or higher. It was selected as a national pilot for "Complete Communities" in July 2023 and passed the first batch of near-zero carbon community acceptance assessments in the Xiongan New Area in June 2025, demonstrating a solid foundation in green and low-carbon development.

The main building of the Xianxi Community Service Center is five stories high, covering

approximately 1,000 square meters. The building primarily uses electricity and central heating for its energy needs. Cooling is provided by a central air-conditioning system, while heating is delivered through radiant floor heating, sourced mainly from a municipal system utilizing geothermal energy supplemented by natural gas. The building features a high degree of spatial integration and multi-functional use, including facilities such as an elderly care station, a children's center, a community canteen, and various multi-purpose activity rooms.

(2) Operational Feedback

Regarding the division of responsibilities, the property management company is uniformly appointed by the Area Management Committee and is responsible for services such as paying energy bills, maintaining equipment and the building, and sanitation cleaning. User feedback primarily highlights issues concerning noise disturbance and the indoor environment being too cold during the heating season.

The current challenges are mainly reflected in three aspects: First, there is the possibility of the property management company being replaced periodically (typically every 2-3 years), making it difficult to establish consistent and long-term management standards. Second, both the community and the property company lack specialized training for managing green buildings. Third, the existing sub-metering facilities are underutilized; cost accounting can currently only be accurate down to the building level, hindering refined management. However, there is potential in the future to fully leverage the existing building infrastructure to establish an energy management platform for the visual management and analysis of energy data.

Figure 5: Aerial View of the Demonstration Project[1]

[1] https://mp.weixin.qq.com/s/7fVE4e0-Vd82UshHp4-x4Q

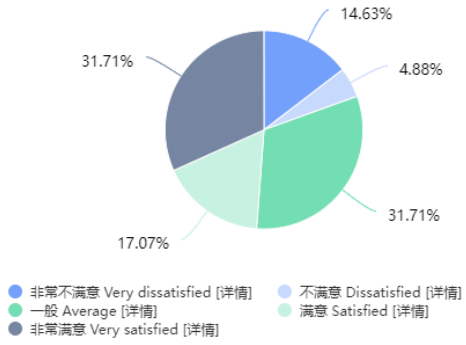
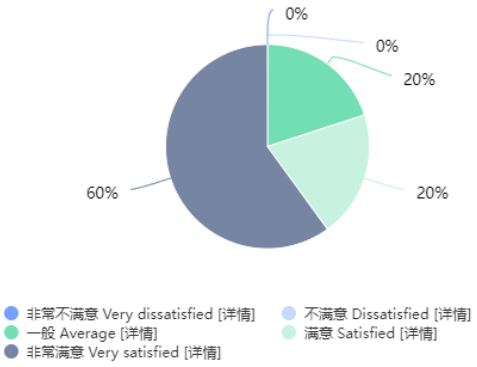
Figure 6: Full View of the Demonstration Project[2]

Figure 7: Community Space Utilization and Activity Areas

Figure 8: Survey Photo

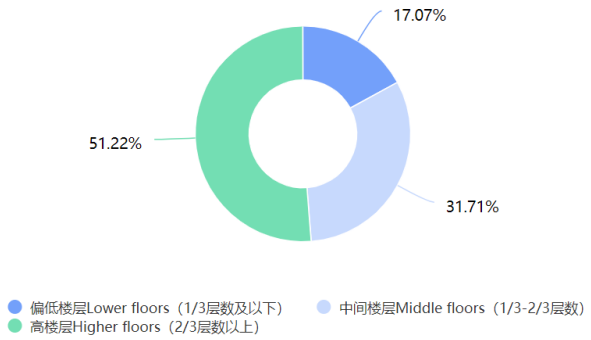
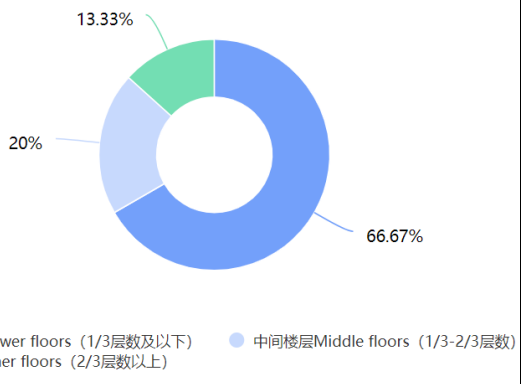
[2] https://mp.weixin.qq.com/s/7fVE4e0-Vd82UshHp4-x4Q

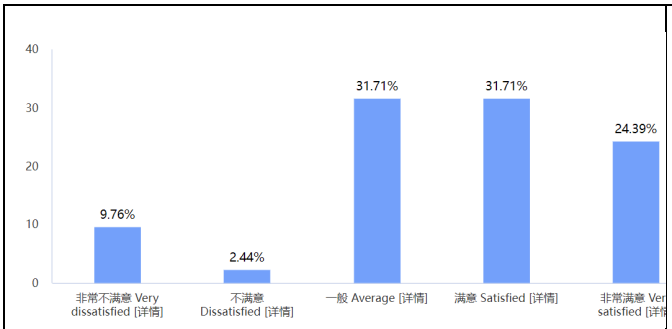
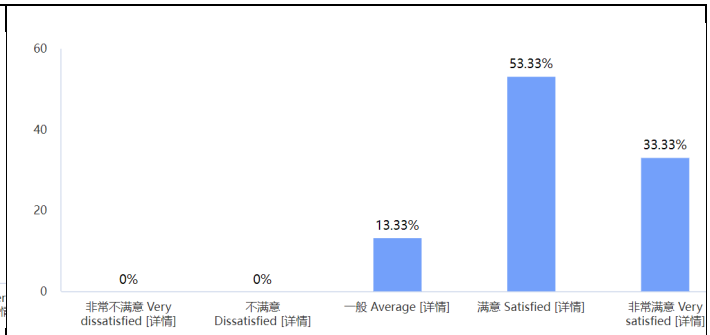
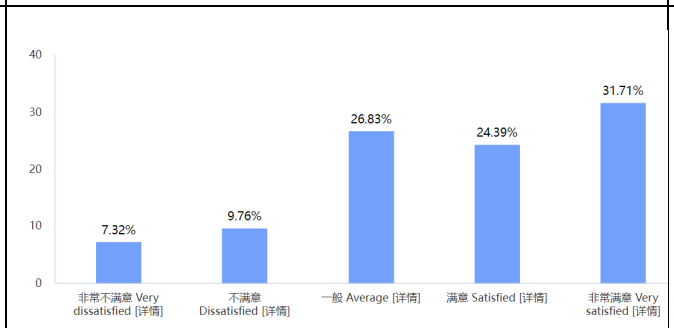
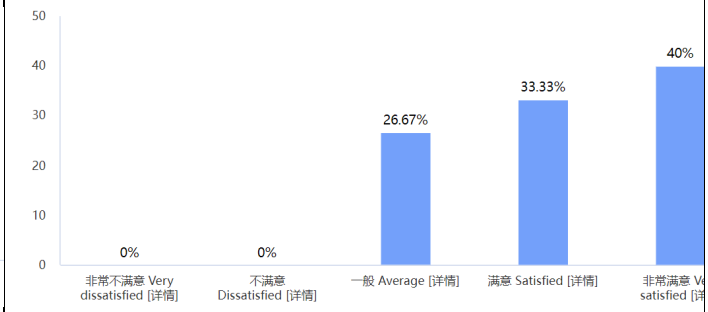
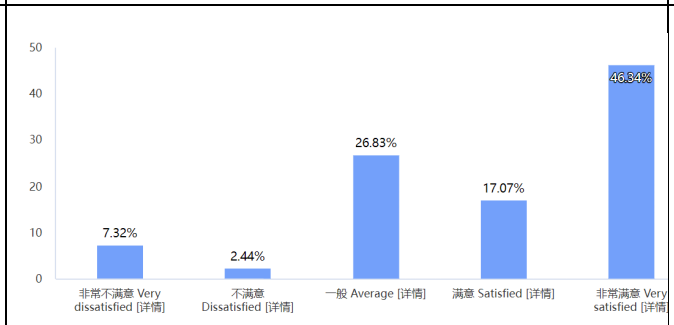
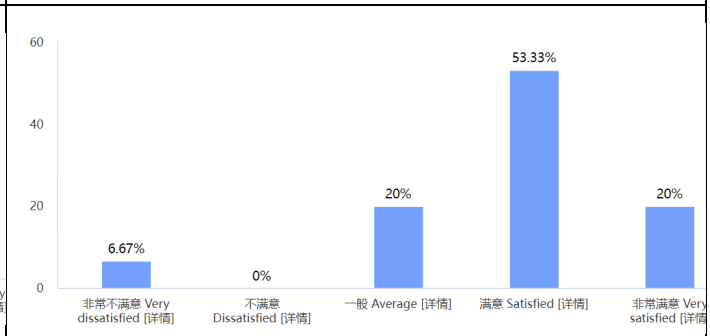
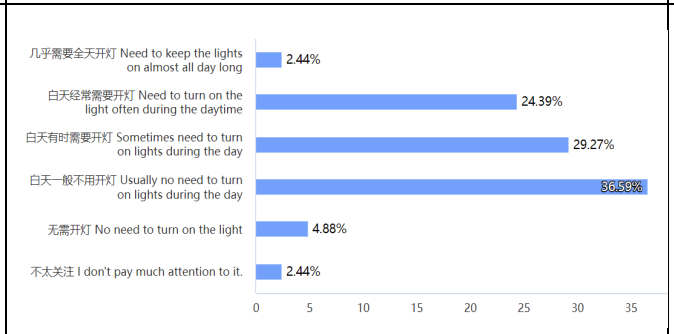
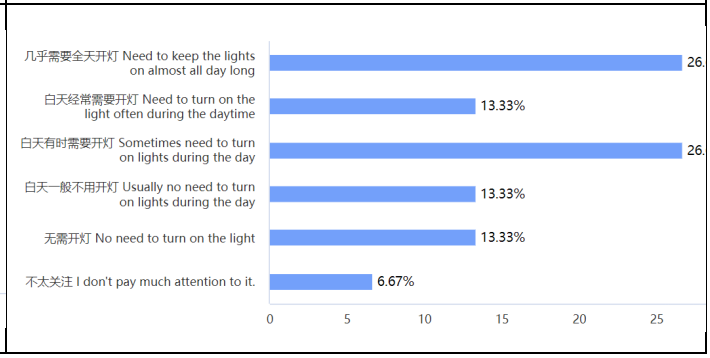
3.Questionnaire results in Xiongan New Area

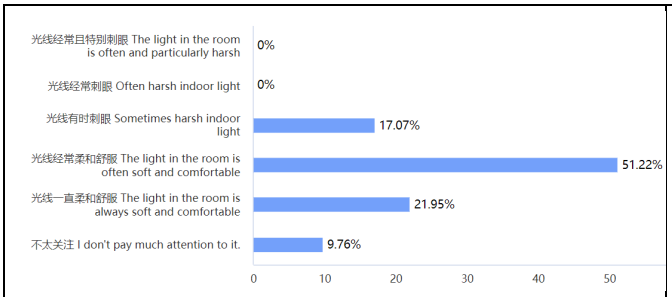
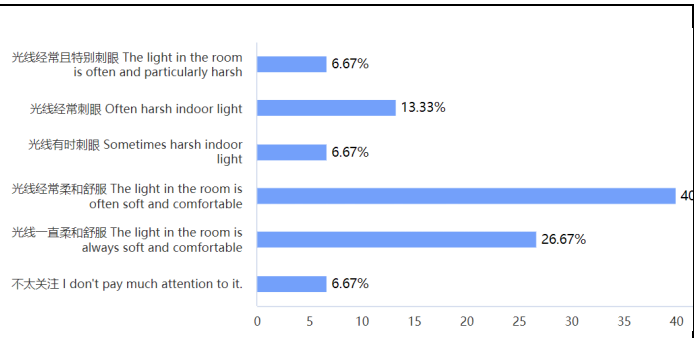
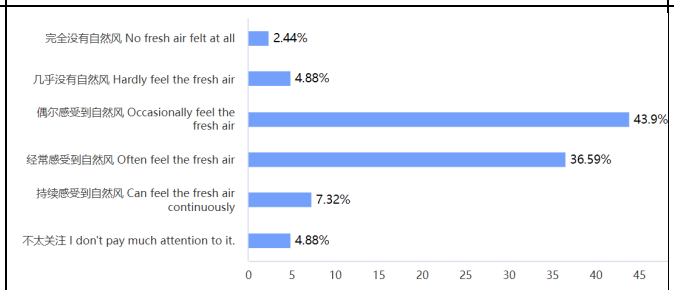
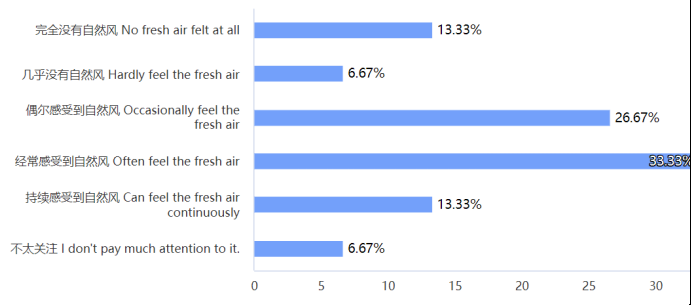
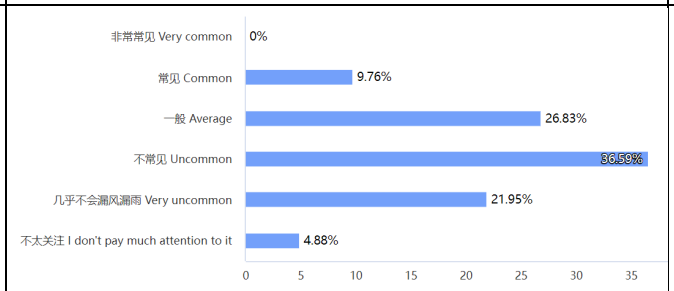
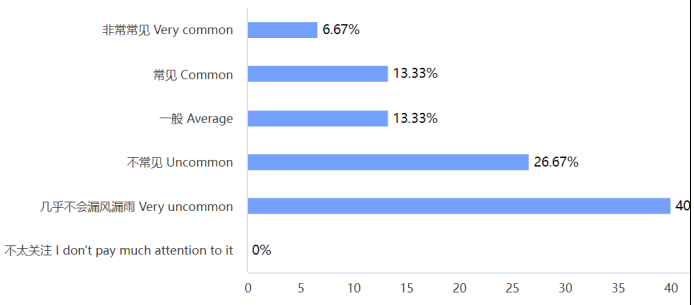
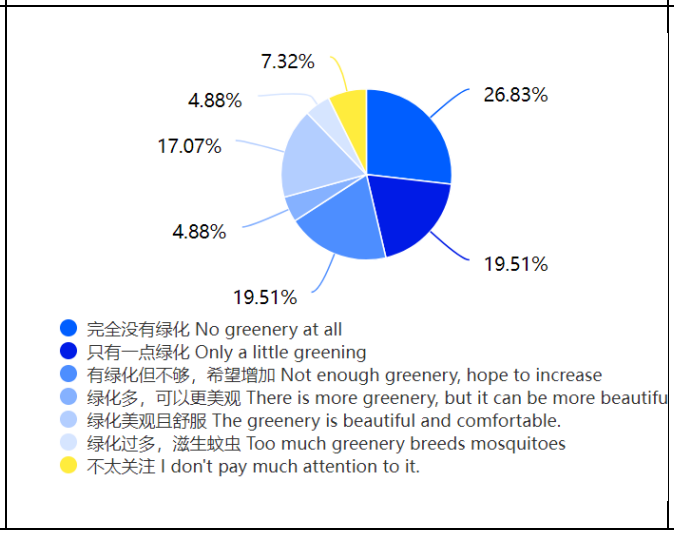
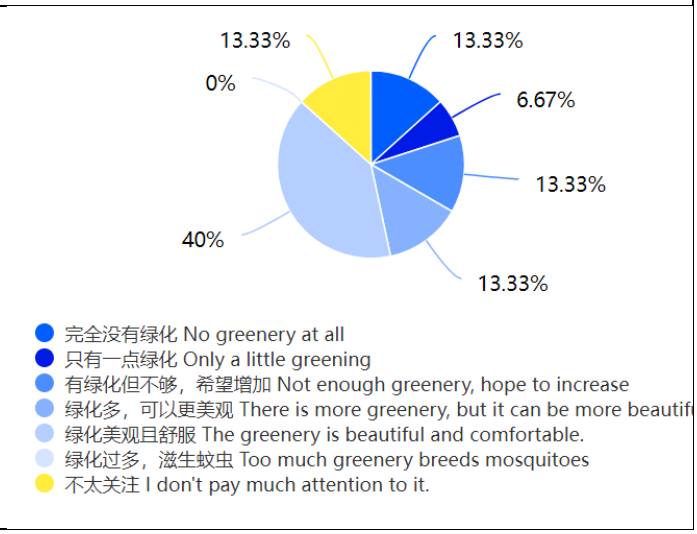
	ZEBs	Traditional Buildings
Overall Satisfaction		

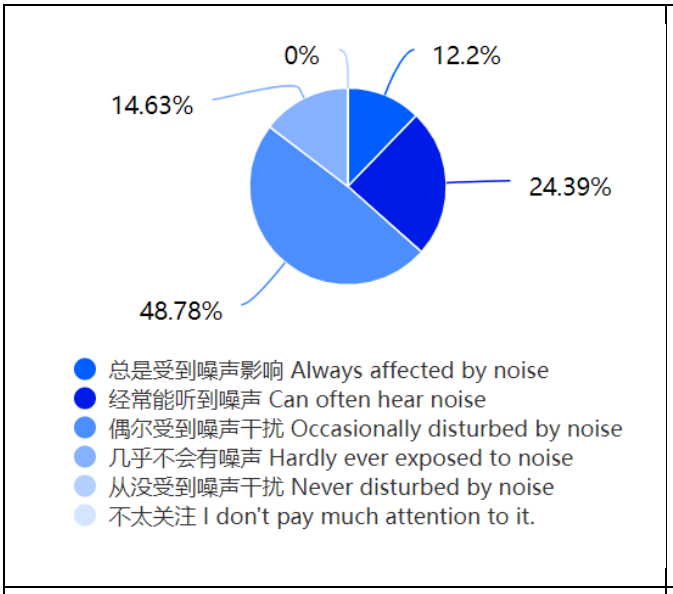
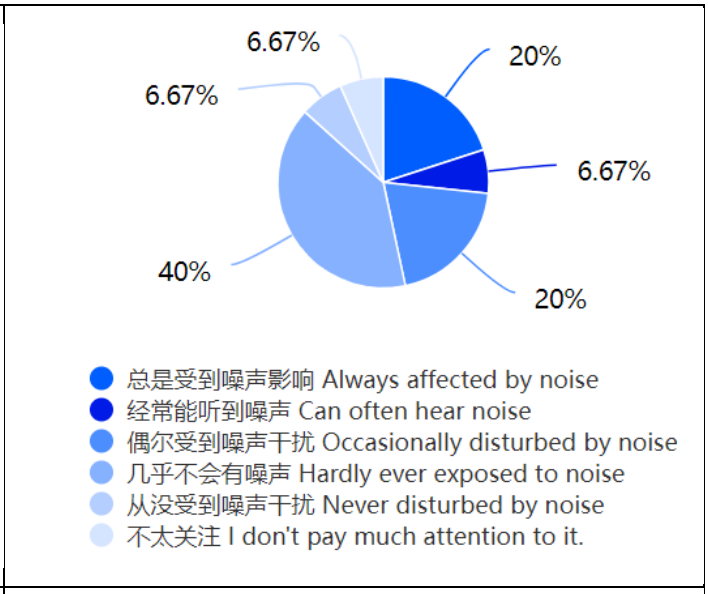
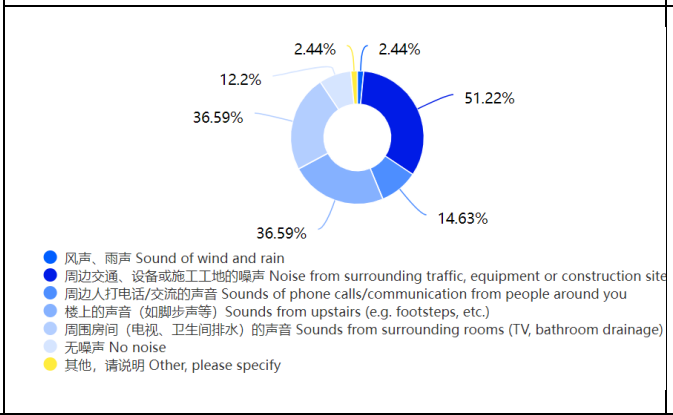
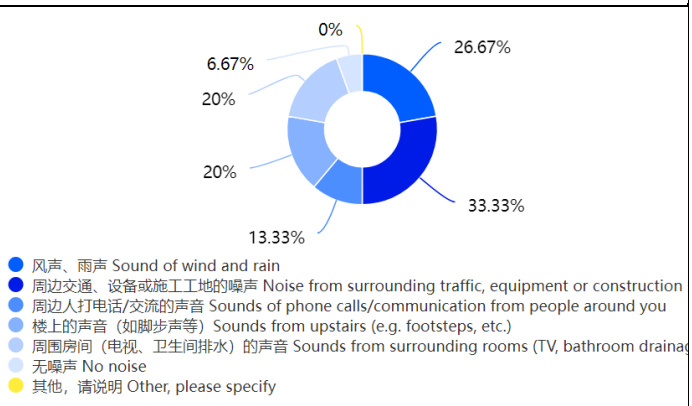
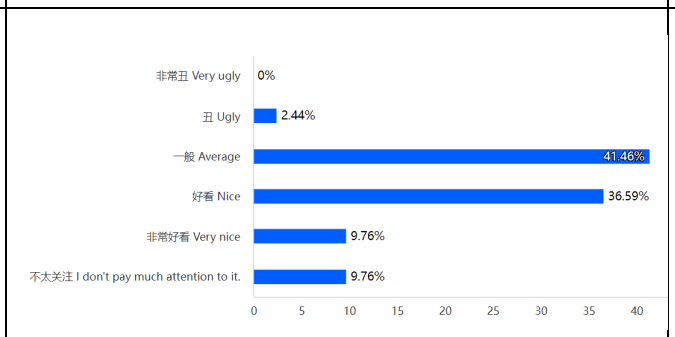
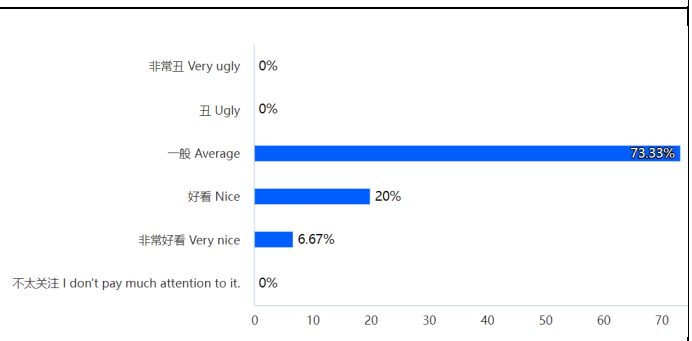
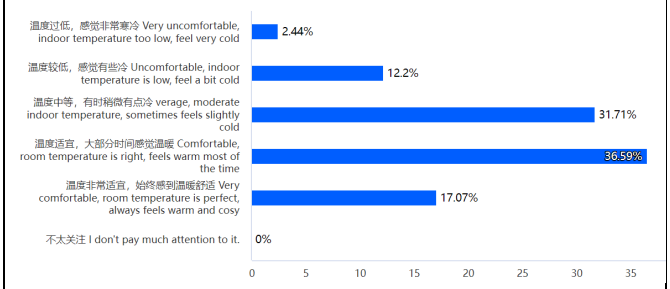
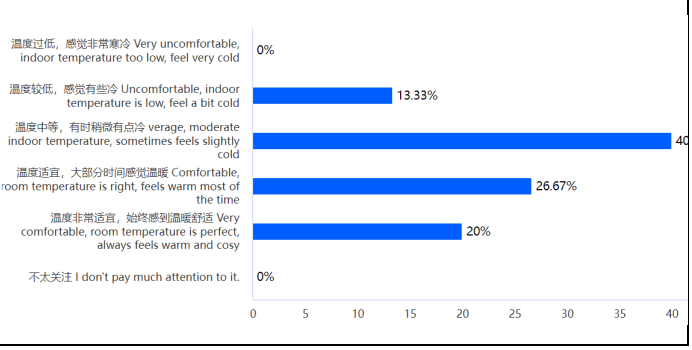
(1) Satisfaction with Indoor Environment

Including: floor level, temperature and humidity, air quality, accessibility facilities, artificial indoor lighting, natural lighting, natural ventilation, air/water leakage through doors and windows, indoor greenery, noise levels, building exterior appearance, and heating season temperature.

Questions	ZEBs	Traditional Buildings
Levels		

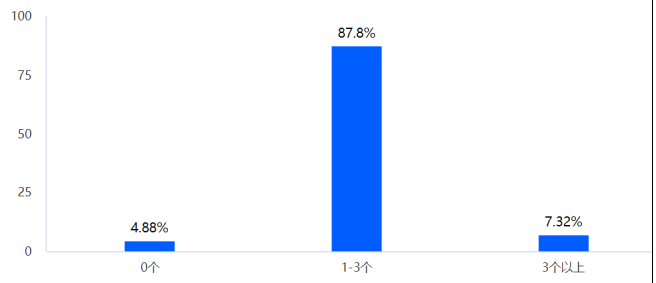
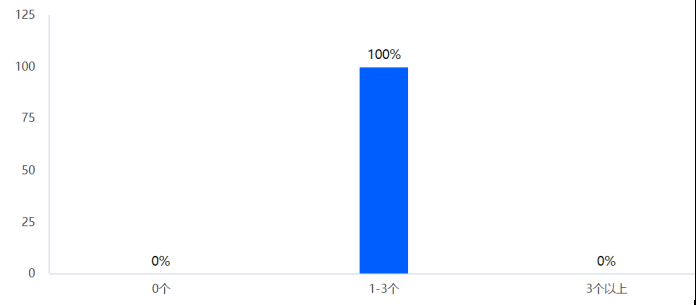
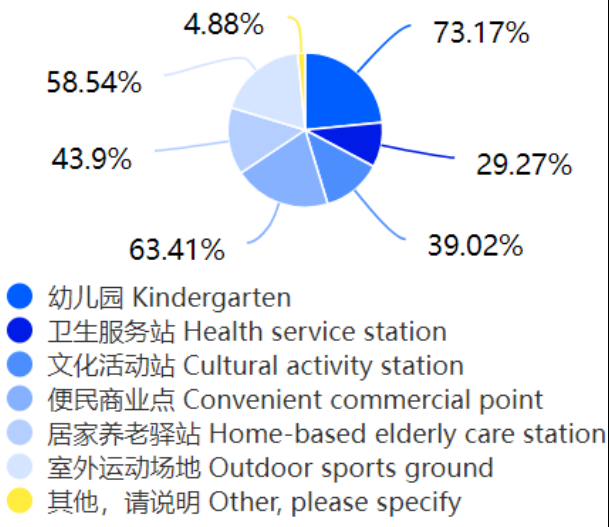
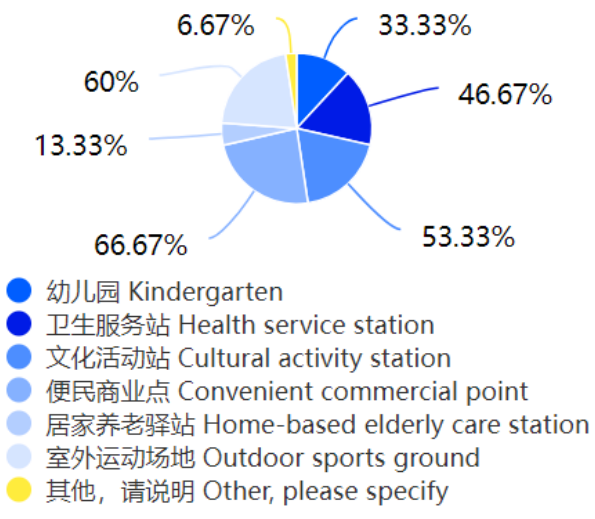
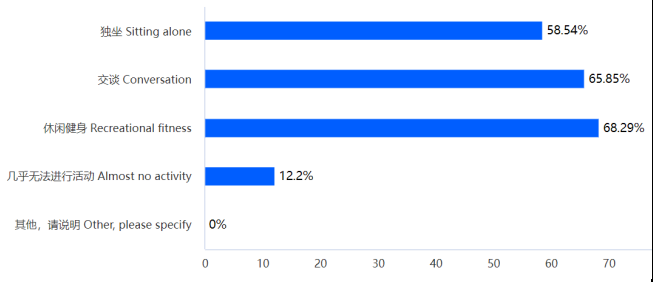
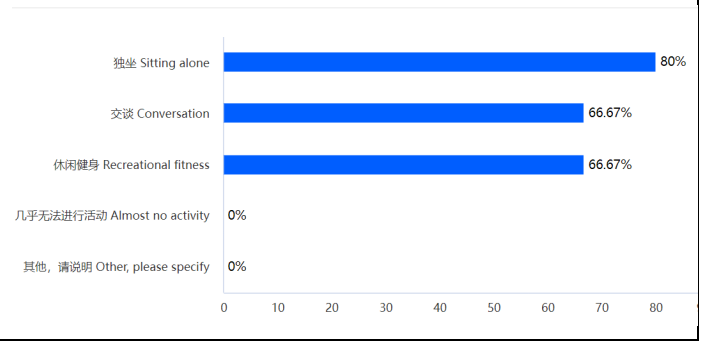
Temperature and Humidity		
Air Quality		
Accessibility Facilities		
Lighting		

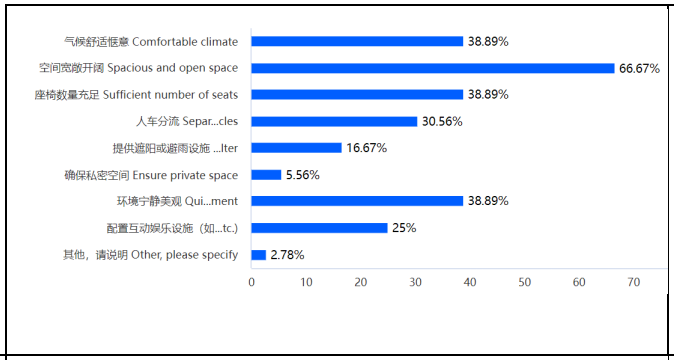
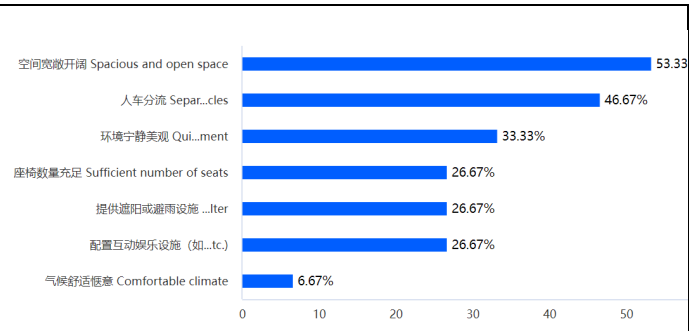
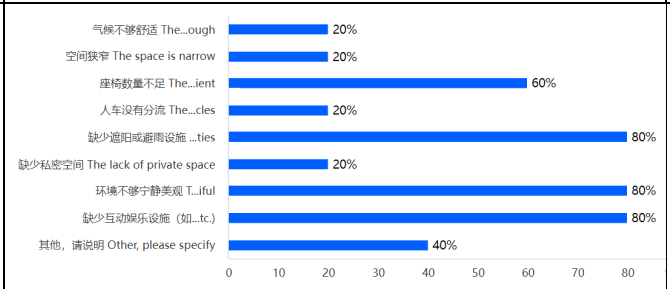
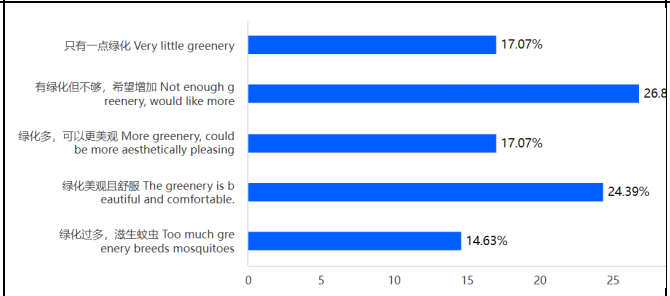
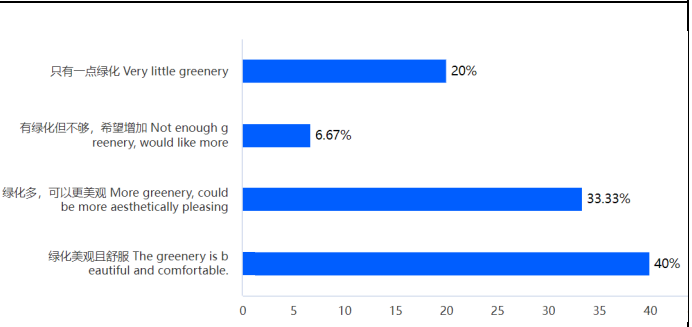
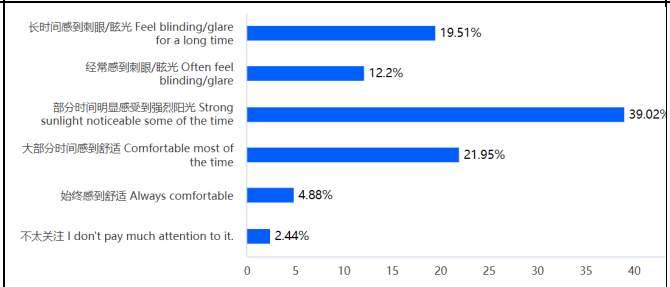
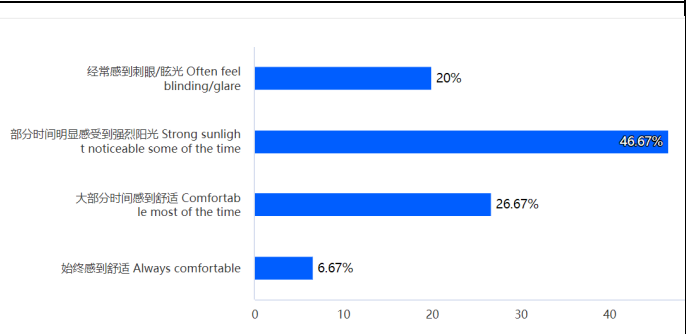
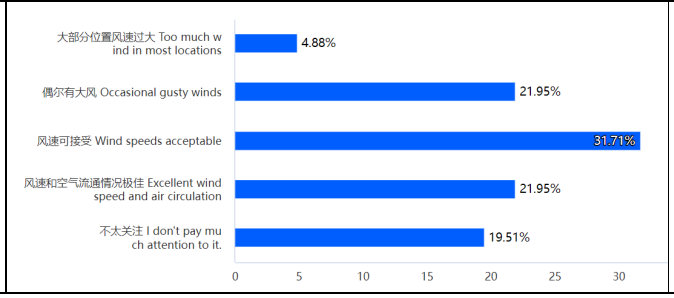
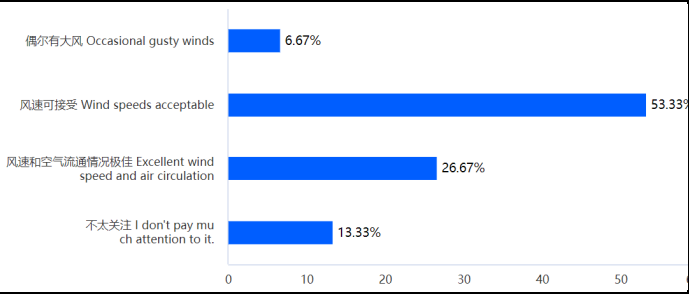
Natural Lighting		
Natural Ventilation		
Air/Water Leakage through Doors & Windows		
Greenery		

Indoor Noise		
		
Building Exterior Design		
Satisfaction During Heating Season		

(2) Relationship Between the Building and Its Surrounding Environment

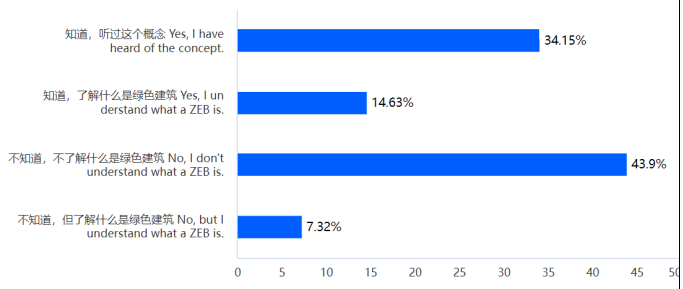
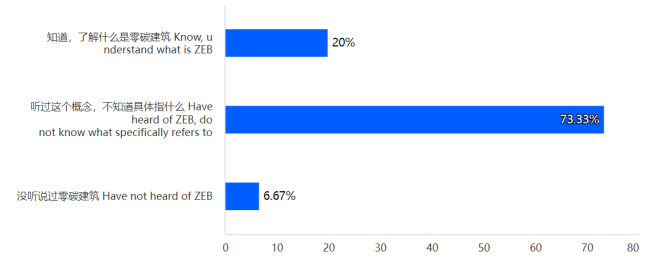
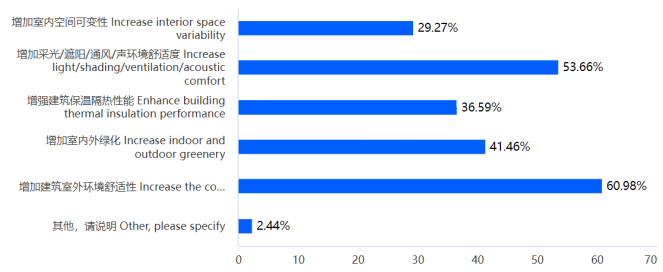
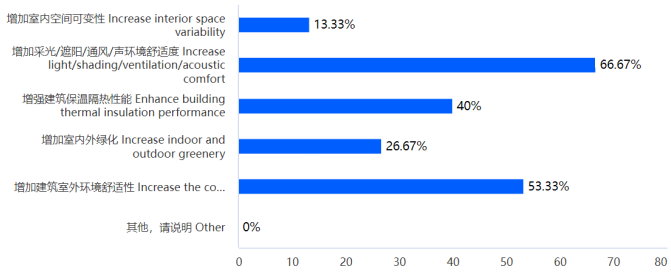
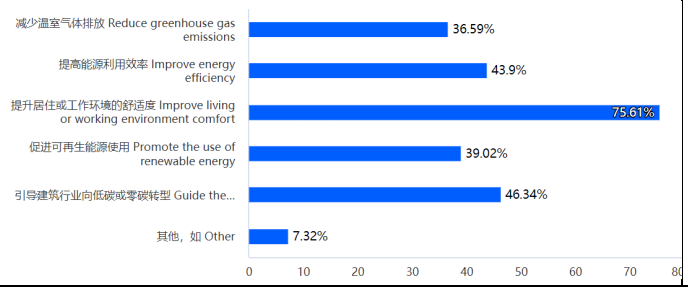
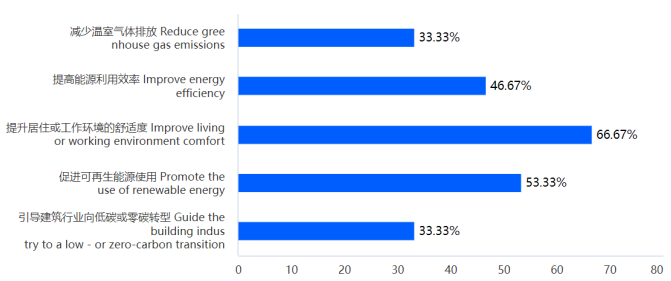
Including: availability of bus stops within a 5-minute walk, service facilities, activities feasible around the building and their reasons, outdoor greenery, outdoor shading, and outdoor ventilation.

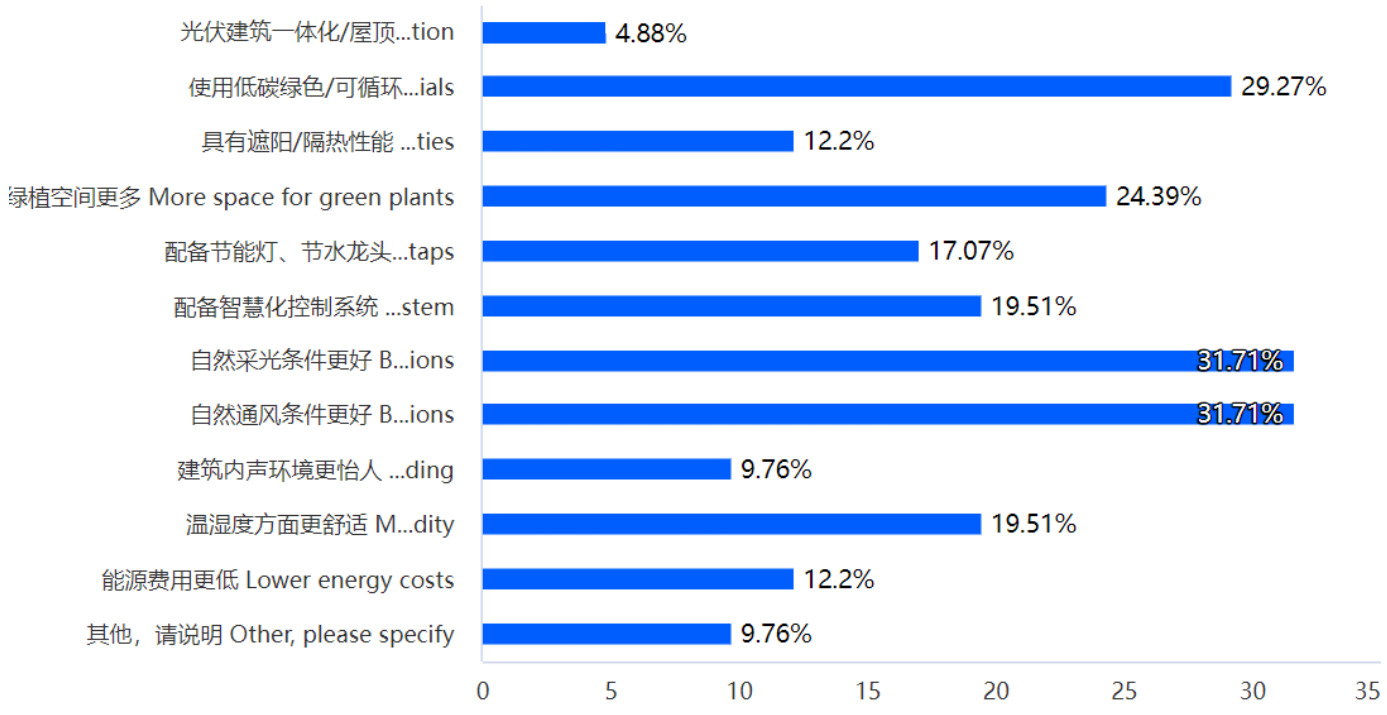
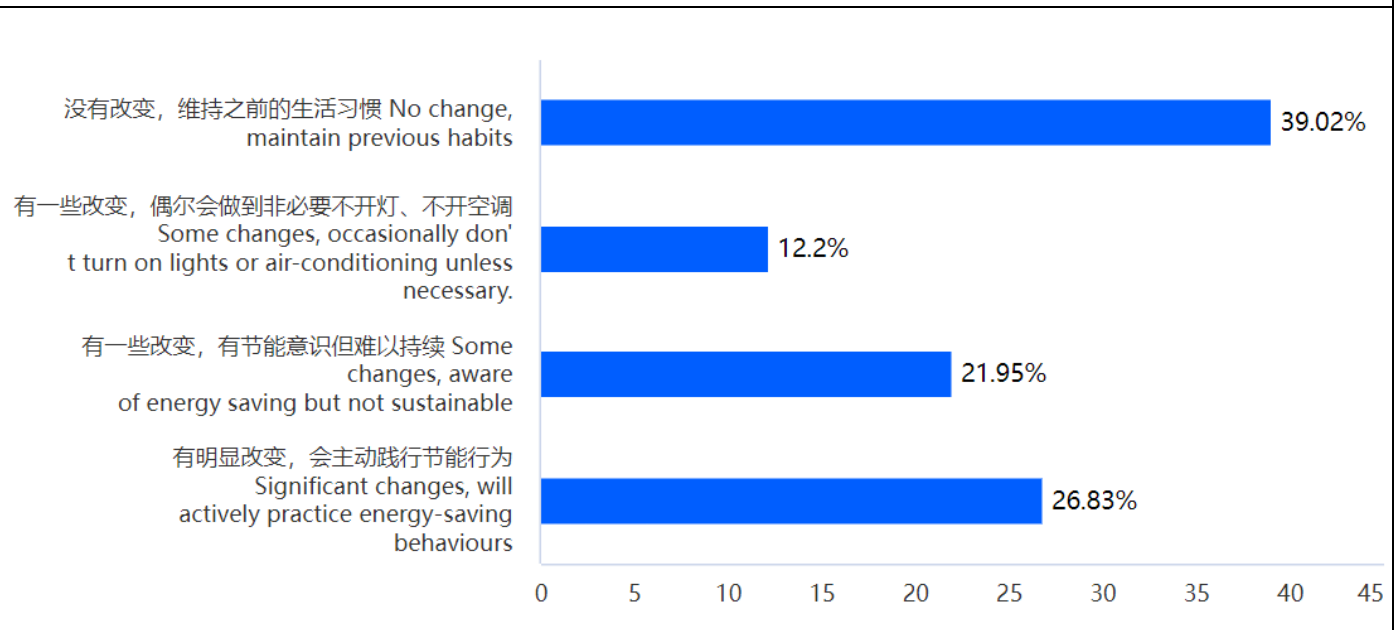
Questions	ZEBs	Traditional Buildings
Bus Stops Within 5-Minute Walk		
Service Facilities		
Outdoor Activities Feasible		

Reasons for Feasibility		
Reasons for Infeasibility		/
Outdoor Greenery		
Outdoor Shading		
Outdoor Ventilation		

(3) Understanding of ZEBs

Including: awareness of ZEBs, differences from surrounding buildings, changes to daily habits, potential building improvements, and the significance of ZEBs.

Questions	ZEBs	Traditional Buildings
Awareness of ZEBs		
Potential Building Improvements		
Significance of ZEBs		

Differences between ZEB and Surrounding Buildings	
Changes to Daily Habits	

6. Appendix 3:

Survey Record – Shaoxing

On September 2, 2025, the research team conducted an investigation into the Peixin Building, a

ZEB at Shaoxing Longshan Academy (hereinafter referred to as "Peixin Building"). The survey primarily covered aspects such as project construction status, current building operation, architectural features, and energy usage. Due to objective constraints in the Shaoxing area, it was not possible to conduct on-site surveys of comparable traditional school buildings. Therefore, the team extensively drew upon previous research findings from school-type buildings in the Beijing area. The analysis is detailed below:

1. Building Survey Details

(1) Demonstration Project Introduction

The Peixin Building has a total floor area of approximately 141,000 square meters, including 105,800 square meters above ground and 35,000 square meters below ground. After being handed over to the school, it is intended to serve as a computer lab and training center, but it is not yet officially operational and is currently used only as a temporary activity venue.

The Peixin Building utilizes a reinforced concrete structure and incorporates a sloped roof design with local characteristics. The external wall insulation features a double-layer thickened construction, contrasting sharply with the common practice of local standard teaching buildings, which typically lack external insulation. The building is equipped with a natural ventilation system, complete with a dedicated electrical panel and equipment for the ventilation system. It also has supporting photovoltaic (PV) power generation and energy storage facilities. Detailed calculations regarding the actual power generation duration and utilization efficiency of the PV system have not yet been conducted; statistics will need to be gathered through monitoring after the school officially begins

operations. Currently, the PV power generation facilities supply only the Peixin Building and are not yet connected to the municipal grid, though future grid connection is planned. Regarding energy use, campus cooling typically operates from June to September, and the heating period runs from December to January. Furthermore, fully connected elevated corridors link all buildings between the second and third floors, facilitating student movement on rainy days. The dormitories are equipped with air-source heat pump systems to supply hot water.

(2) Construction Background and Rationale

As the project investor, Zhejiang Transportation Group capitalized on the opportunity presented by the Hangzhou Asian Games to carry out comprehensive development in this area. To meet the educational infrastructure needs of the region, the Group invested in the construction of Longshan Academy. From the project's inception, demonstration construction according to ZEB standards was required by regional leadership, aiming to create a sustainable, low-carbon, and environmentally friendly benchmark educational facility.

(3) Common Building Issues in This Climate Zone

Given limited feedback from users of this demonstration building, the investigation inquired about common issues reported in local buildings. Influenced by the local climate, the two most frequent problems are air/water leakage around doors and windows and cold indoor environments in winter. Typically, the region experiences a plum rain season from June to July, characterized by high air humidity, prolonged overcast and rainy days, leading to dampness and mold inside buildings, as well as air and water leakage around doors and windows. Additionally, the area is not included in

centralized winter heating systems. However, due to the high air humidity, the perceived indoor temperature in winter is quite low, leading users to rely on electric heaters or air conditioning for warmth.

2. School Operational Status

Student recruitment began in 2024, with students temporarily attending classes at the Shaoxing No. 1 High School campus. In March of this year, the school admitted two cohorts of advanced placement classes, which have already commenced studies on the new campus. The school officially opened fully on September 1, 2025. It currently has Grade 10 and Grade 11, comprising 8 teaching classes in total. According to the overall development plan, the school's full capacity is approximately 1,600 students, with plans to establish 48 classes in total, covering junior high school, senior high school, and an international division.

3. Investor Information

The total project investment is approximately 1.22 billion RMB. To meet the ZEB requirements, the incremental cost per square meter was about 1,000 to 2,000 RMB compared to similar building types. As the school is a public service facility and the investor handed over the completed project entirely to Shaoxing No. 1 High School for operation, the payback period is not currently a consideration. Given the current downturn in the real estate market, and in the absence of specific top-level policy requirements, the investor does not currently plan to meet near-zero carbon energy consumption standards in future construction projects.

Figure 1 Air-Source Heat Pump Unit Located Below the Dormitory Building

Figure 2 Dormitory Building

Figure 3 Inter-building Landscaping and Air Conditioning Outdoor Units

Figure 4 Exterior Facade of the Peixin Building

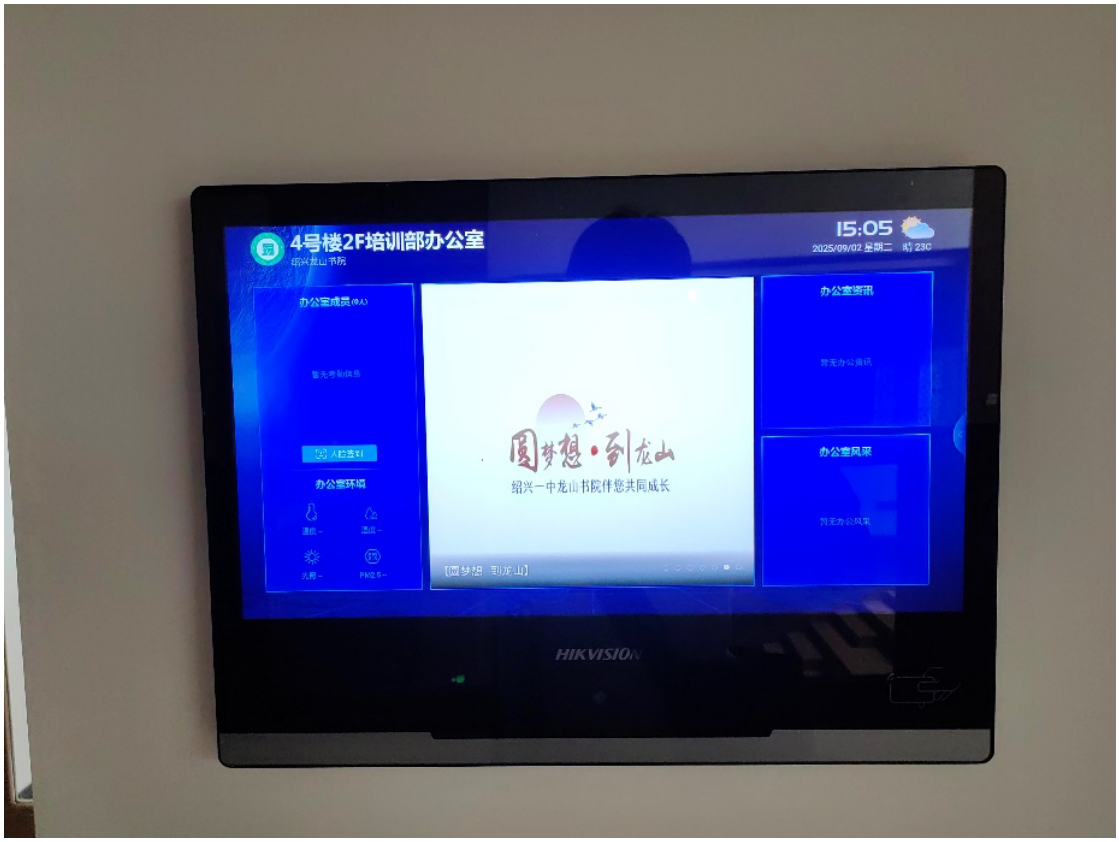


Figure 5 Office Information Platform

Figure 6 Triple-Pane Glazing Used in Windows

Figure 7 Interior Corridor of the Building

Figure 8 Operable Skylight in the Building Atrium

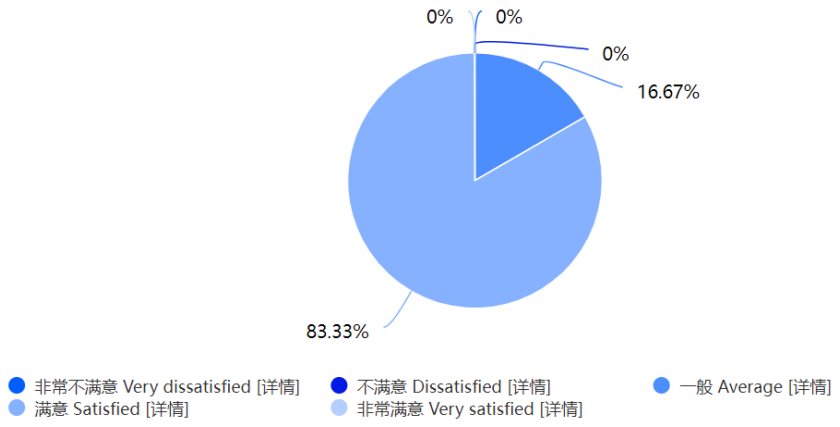
Figure 9 Building Atrium and Daylighting

Figure 10 Natural Daylighting Condition in a Classroom

Figure 11 External View of the Peixin Building

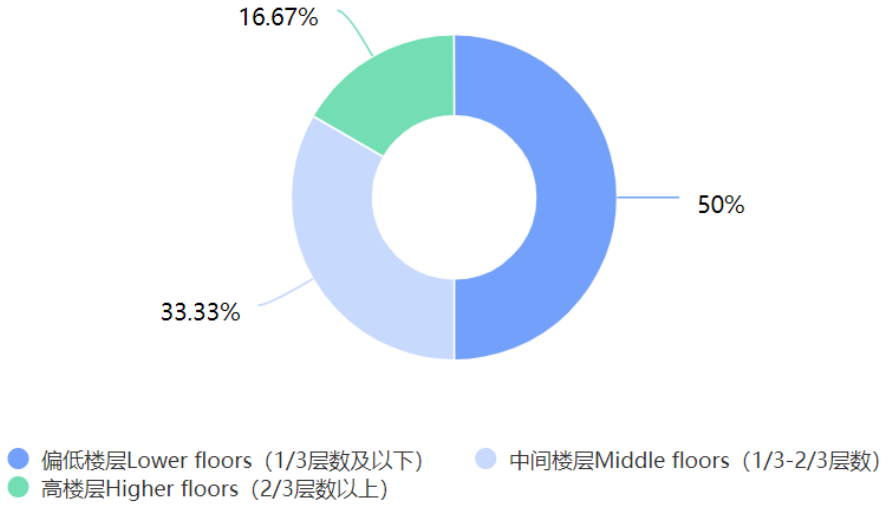
Figure 12 Survey Photo

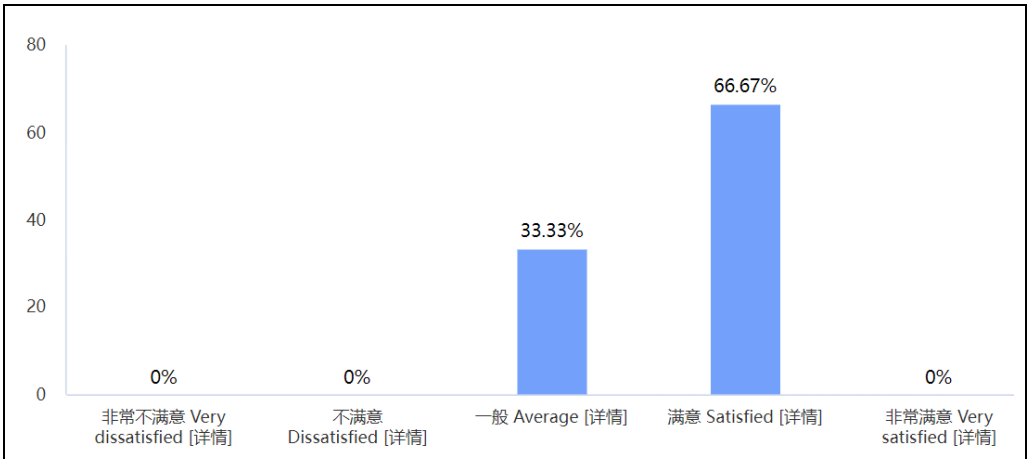
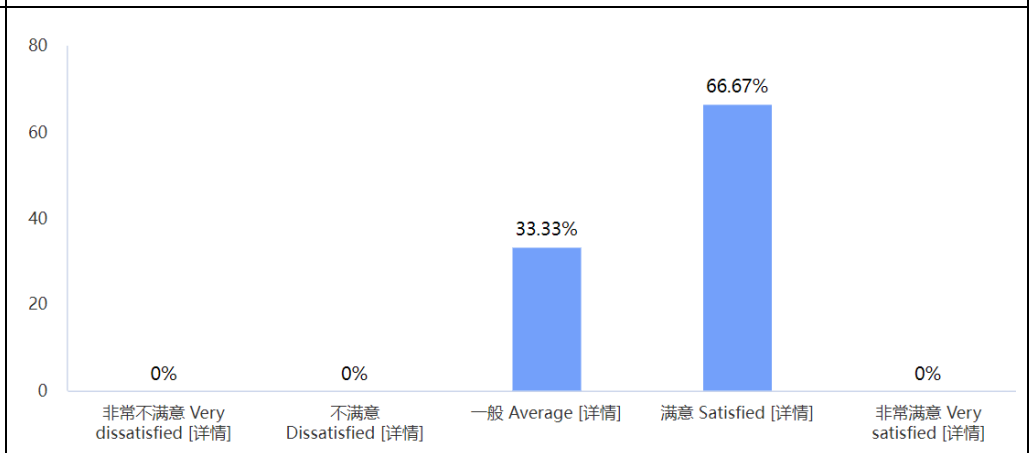
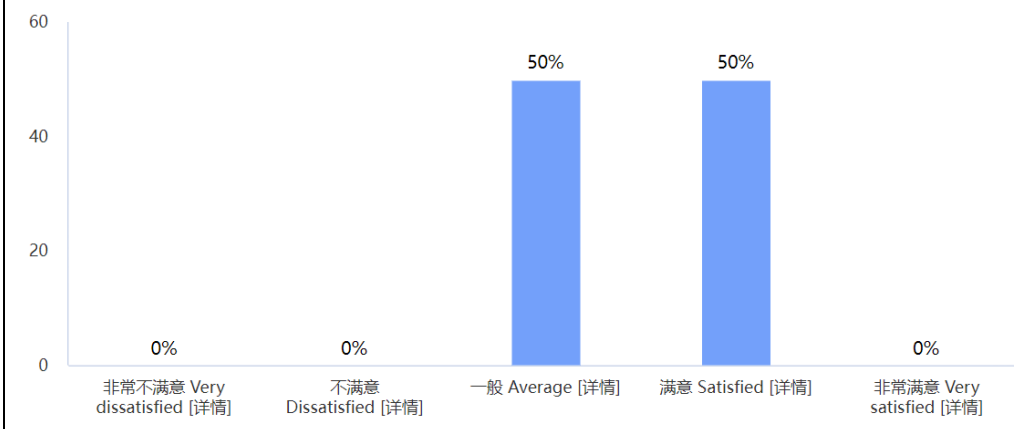
4.Questionnaire results in Shaoxing

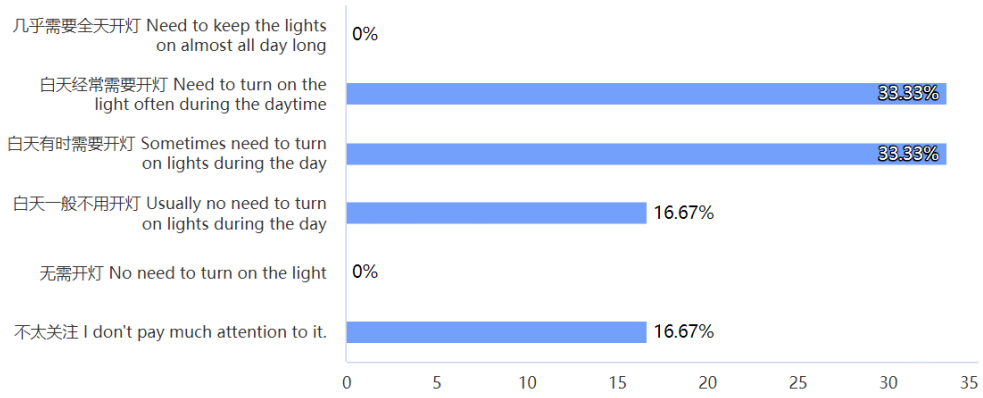
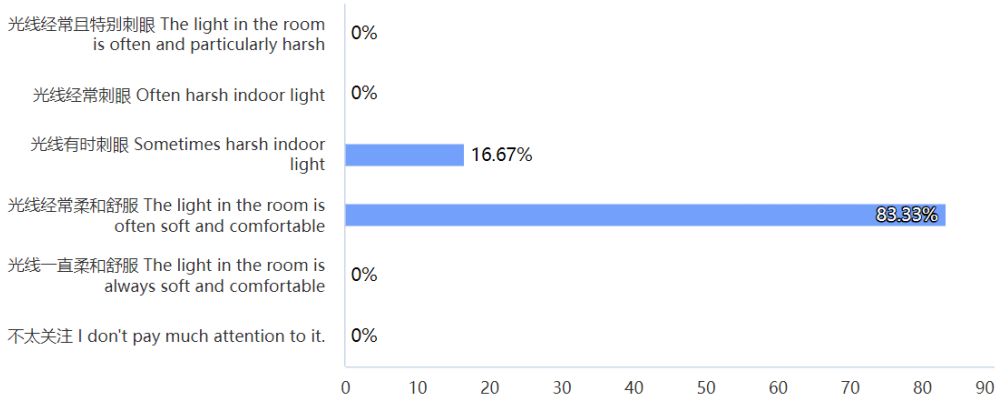
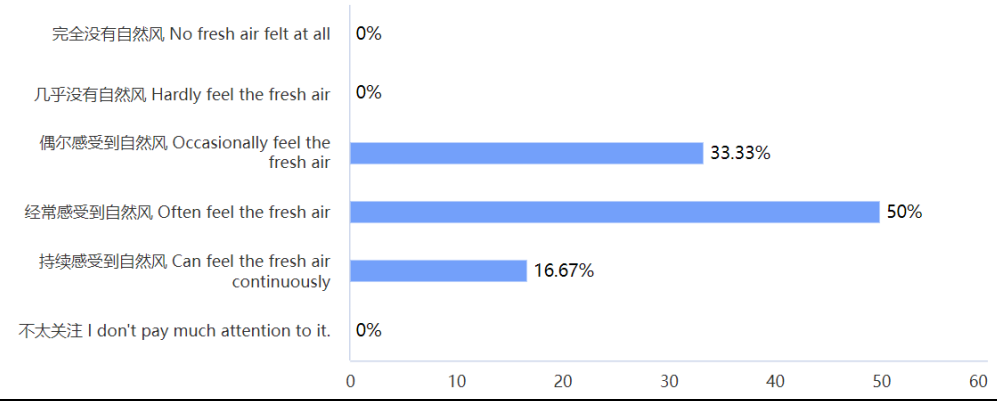
Questions	ZEBs
Overall Satisfaction	

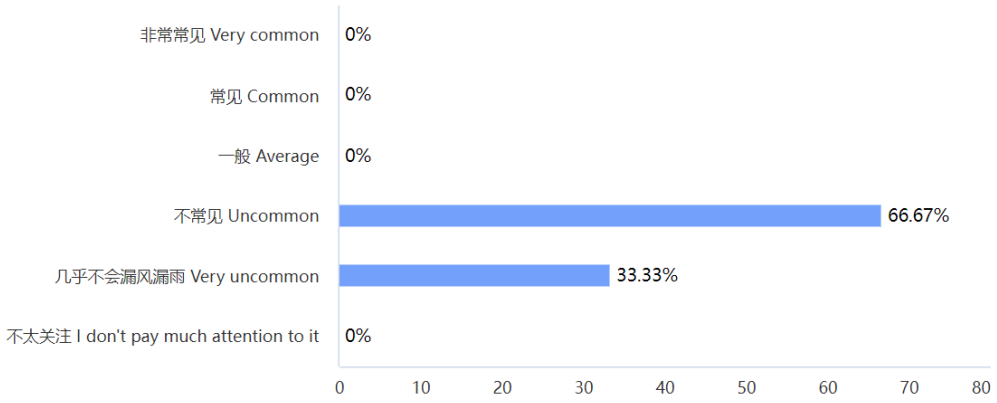
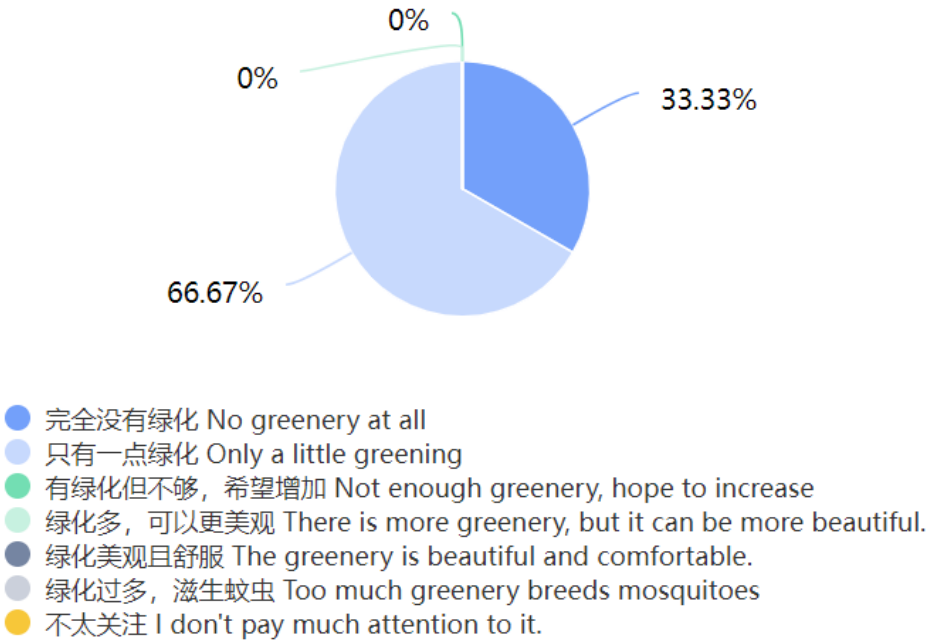
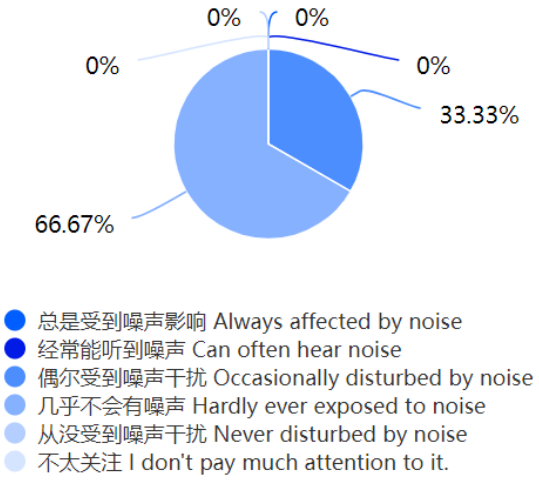
(1) Satisfaction with Indoor Environment

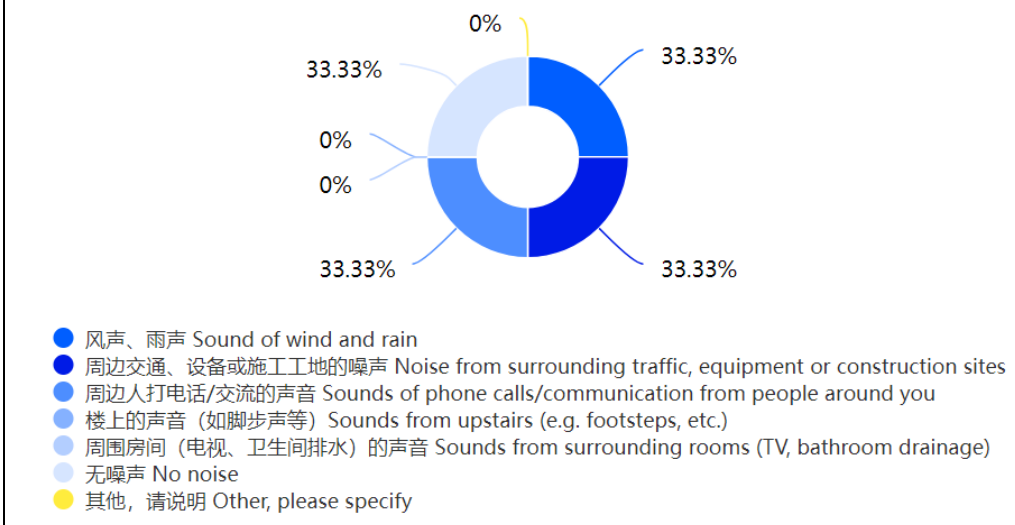
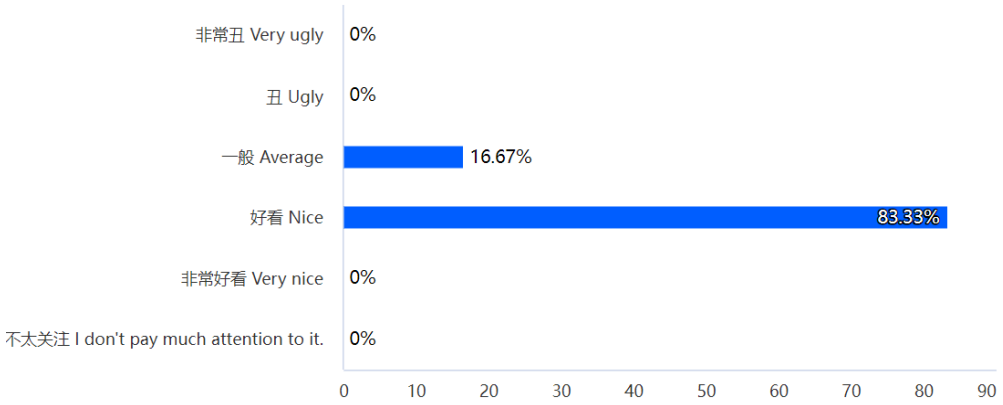
Including: floor level, temperature and humidity, air quality, accessibility facilities, artificial indoor lighting, natural lighting, natural ventilation, air/water leakage through doors and windows, indoor greenery, noise levels, building exterior appearance, and heating season temperature.

Questions	ZEBs
Levels	

Temperature and Humidity	
Air Quality	
Accessibility Facilities	

Lighting	
Natural Lighting	
Natural Ventilation	

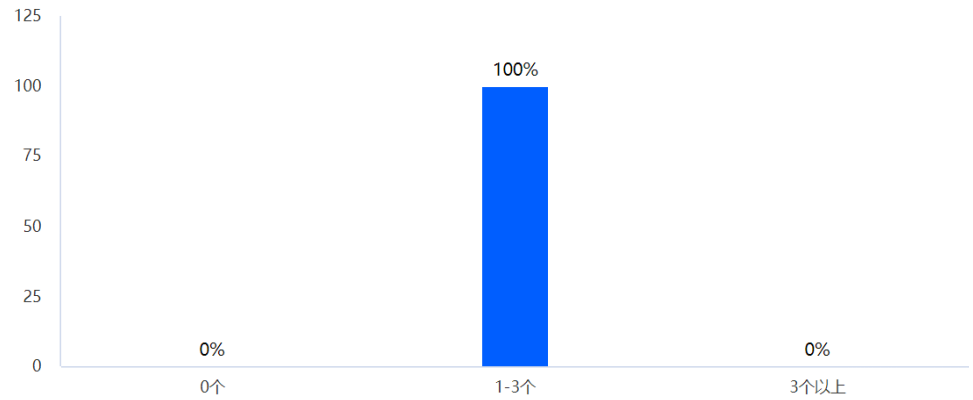
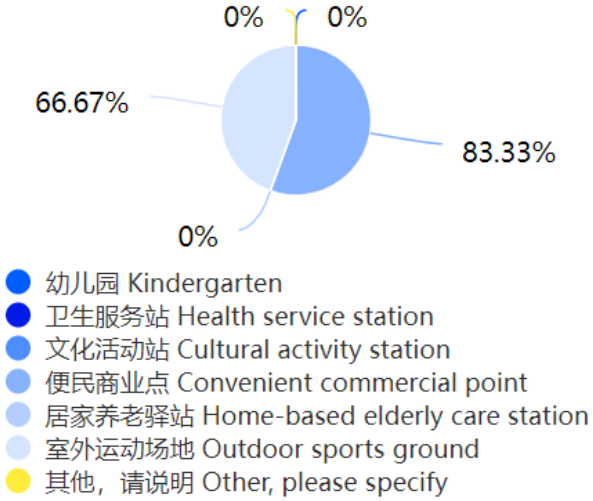
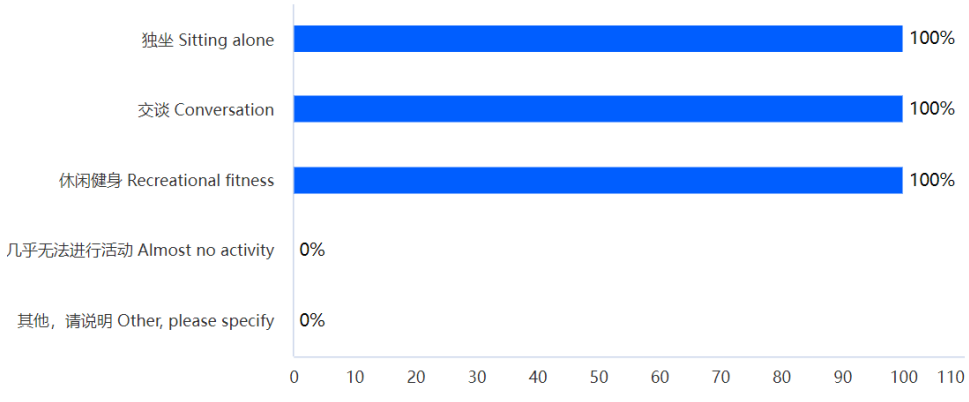
Air/Water Leakage through Doors & Windows	
Greenery	
Indoor Noise	

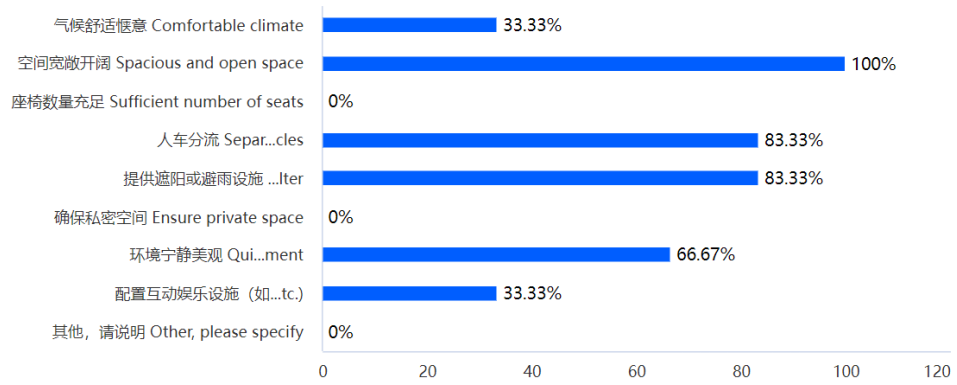
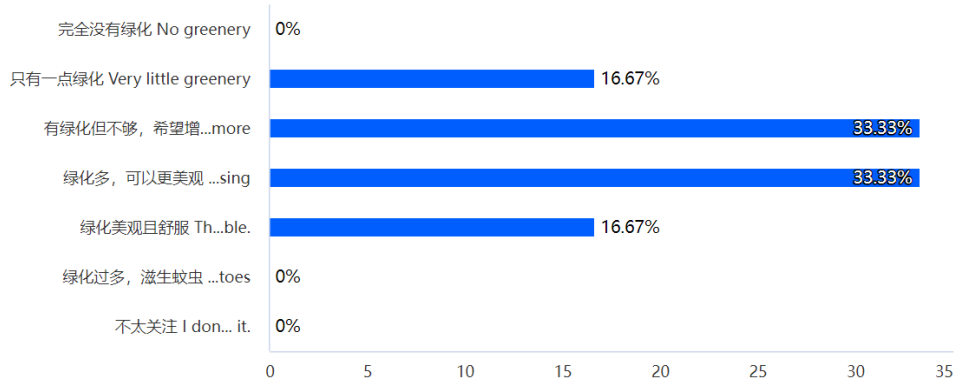
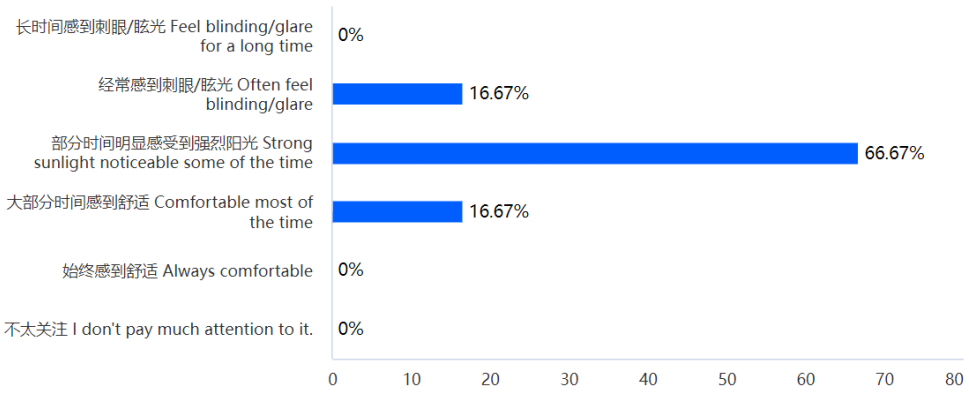
	
Building Exterior Design	

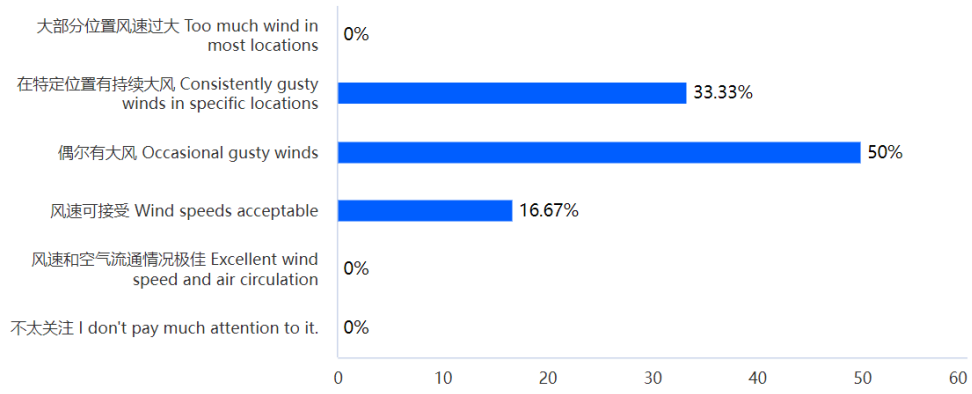
(2) Relationship Between the Building and Its Surrounding Environment

Including: availability of bus stops within a 5-minute walk, service facilities, activities feasible around the building and their reasons, outdoor greenery, outdoor shading, and outdoor ventilation.

Questions	ZEBs

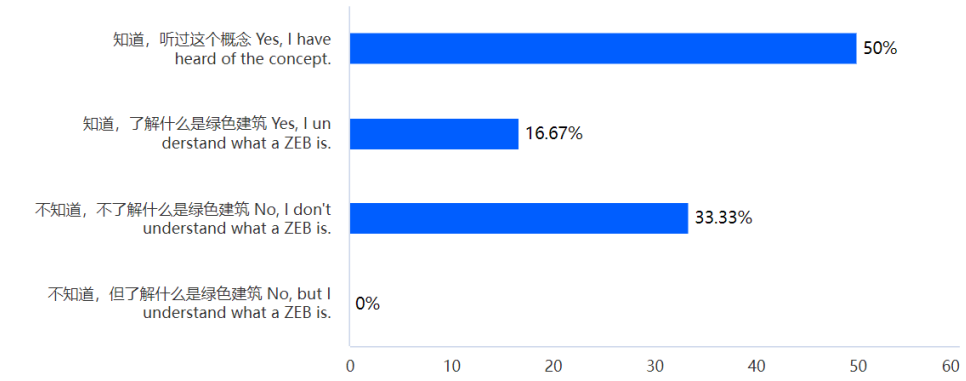
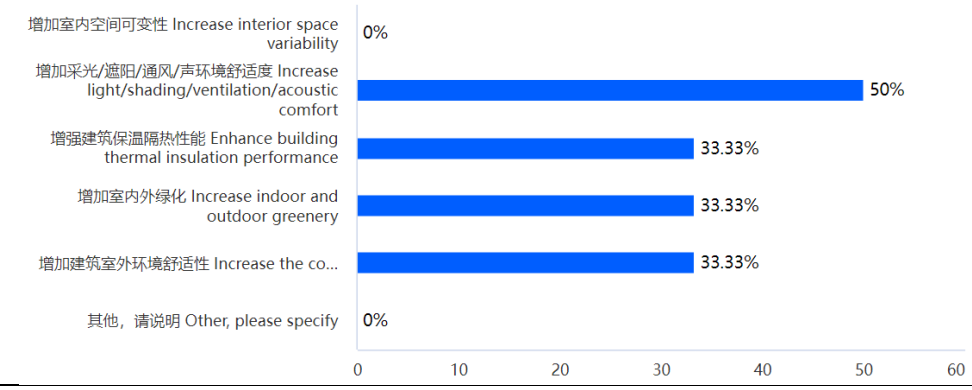
Bus Stops Within 5-Minute Walk	
Service Facilities	
Outdoor Activities Feasible	

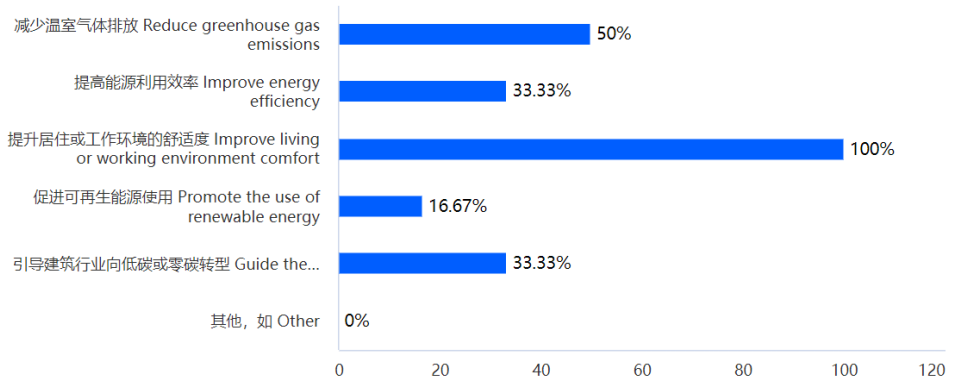
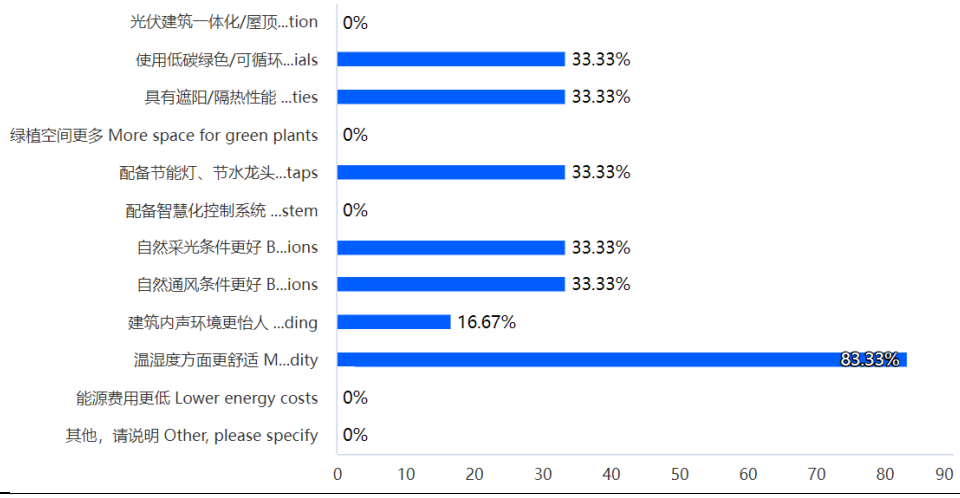
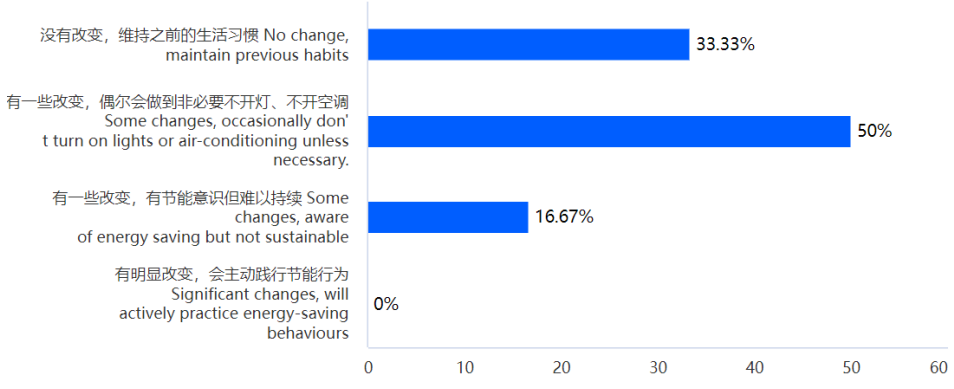
Reasons for Feasibility	
Outdoor Greenery	
Outdoor Shading	

Outdoor Ventilation	

(3) Understanding of ZEBs

Including: awareness of ZEBs, differences from surrounding buildings, changes to daily habits, potential building improvements, and the significance of ZEBs.

	ZEBs
Awareness of ZEBs	
Potential Building Improvements	

Significance of ZEBs	
Differences between ZEB and Surrounding Buildings	
Changes to Daily Habits	

7. Appendix 4:

Survey Record – Shenzhen

On September 5, 2025, the research team conducted a survey in Shenzhen, focusing on the following primary projects: Dameisha Vanke Center (Demonstration Project), as well as Xinhai Jialan and Yunding Tianhai (Traditional Buildings). The detailed findings are as follows:

1. Traditional Buildings

(1) Project Introduction

Xinhaijialan consists of five 14-story residential buildings with duplex structures, totaling 307 units. The ground floor is a commercial area housing 4 to 5 merchants. The project has been in use since 2004 and currently has an occupancy rate of approximately 80%.

Regarding building maintenance, systematic upkeep has been carried out in public areas such as the exterior walls, landscaping, and corridors. Current primary issues include air and water leakage due to aging window seals, as well as water seepage in some external walls, urgently requiring further waterproof coating work. About two-thirds of the households have undergone secondary renovations, primarily involving the replacement of wooden flooring damaged by moisture, waterproofing in kitchens and bathrooms, and the upgrading of electrical wiring and windows due to aging.

Currently, user feedback mainly centers on residential safety. Furthermore, the management formulates an annual green and low-carbon development plan and conducts awareness campaigns on initiatives like the "Zero-Waste City" and "Near-Zero Carbon City" in accordance with sub-district office requirements.

Figure 1: External View of Xinhaijialan Residential Quarter

Figure 2: Public Space in Xinhaijialan

Yundingtianhai residential quarter was commissioned in 2007. It comprises 3 buildings with 14 units, totaling 550 households and a population of approximately 1,100-1,200 residents. The occupancy rate is 95%, predominantly consisting of primary-needs families. The quarter is fully equipped with supporting facilities, including a kindergarten, primary school, high school, a dining center, and the Yantian District Sports Stadium. Public activity spaces include elevated open floors, activity rooms, and chess/card rooms, providing multi-functional areas for the elderly and children, with further renovation and enhancement plans already in place. There are 324 parking spaces with a

utilization rate of about 60%, of which 10%-20% are charging spaces. In terms of energy conservation and emissions reduction, the quarter has implemented motion-sensor lights in basements and LED lighting since 2024, resulting in a one-third reduction in energy consumption after the retrofit. Additionally, environmental facilities such as 2-3 solar-powered lights and rainwater collection tanks have been installed.

(2) User Feedback

From a physical environmental performance perspective, the overall daylighting conditions in the quarter are good, but west-facing units experience significant afternoon sun exposure, particularly from May to November. Residents commonly use sun-blocking curtains and insulation measures to mitigate this. Natural ventilation is generally effective in summer. However, indoor humidity levels are significantly high during the annual "Huinan Tian" period (typically March to April), often causing temporary condensation issues, with most households relying on dehumidifiers to improve indoor conditions. Additionally, some units have water leakage problems due to aging waterproofing layers or improper use, requiring further maintenance.

(3) Management Challenges

The residential quarter currently faces several practical difficulties in advancing green and low-carbon initiatives. Firstly, insufficient funding is a major barrier to the large-scale implementation of projects, as existing budgets struggle to cover the costs of PV systems, energy-saving retrofits, and long-term maintenance. Secondly, some residents hold misconceptions about PV facilities, particularly concerns about potential electromagnetic radiation, leading to low acceptance and

cooperation, which poses challenges for community-wide promotion. Furthermore, there is a pressing need for technical support with expertise in new energy and building energy efficiency, including capabilities in system design, energy performance evaluation, and smart operation and maintenance.

Figure 3: Landscaping in Yundingtianhai

Figure 4: Supporting Services in the Residential Quarter

Figure 5: Waste Sorting Facilities in Yundingtianhai

2. Demonstration Building

(1) Project Introduction

The Dameisha Vanke Center campus was completed in 2009 and is China's first office building to achieve LEED NC Platinum certification. It has a total floor area of 122,060 square meters and occupies a site area of 61,730 square meters. In 2017, Wang Shi, founder of DeepRock Group, invested approximately 20 million RMB in green and low-carbon retrofits to the campus's energy systems. Post-retrofit, the campus established a technological foundation for a near-zero carbon campus through a model encompassing "low-carbon building retrofits, construction of solar-PV-storage-charging facilities, comprehensive intelligent monitoring, and smart energy operation." By

organizing sports, art, and cultural activities, the campus activates underutilized assets, enriches energy usage scenarios, and integrates ecological innovation into its development, achieving a sustainable green business model. The campus has obtained both WELL Community and WELL Building Platinum certifications, was selected as a "2022 Green and Low-Carbon Typical Case" by the Ministry of Ecology and Environment, and has received 14 green innovation awards from national, provincial, municipal, and mainstream media organizations.

Figure 6: Aerial View of the Campus[3]

[3] https://mp.weixin.qq.com/s/01Cp037FEgNv3Ga21uz8Bw

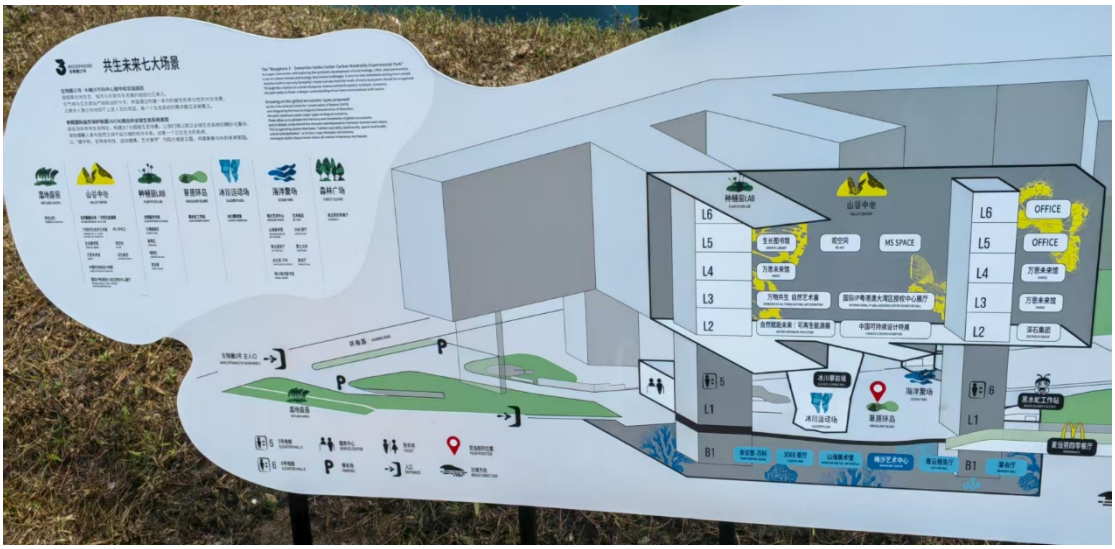


Figure 7: Campus Layout Plan

Figure 8: Building Exterior[4]

Key Approaches and Outcomes:

[4] https://mp.weixin.qq.com/s/l2OotfY1ahiRrVptZI5w3Q

① Technology Empowerment

Through retrofits, photovoltaic panels were installed on the roof of the Biosphere 3 building. Approximately 4,000 square meters of monocrystalline silicon solar PV panels were mounted on the rooftop. Based on energy consumption analysis of the building's operations, 12.5% of Vanke Headquarters' total electricity consumption is generated by these solar panels. DeepRock Group's self-developed energy and carbon management platform, relying on about 200 smart meters, enables real-time collection, monitoring, and itemized analysis of end-use electricity consumption. The platform utilizes large-scale model algorithms for PV power generation forecasting, building energy consumption prediction, and energy storage control to formulate energy dispatch plans that maximize benefits, achieving the dual objectives of supplying energy based on demand and operating at optimal economic efficiency.

Figure 9: Conceptual Diagram of the Data Dashboard Large Screen[5]

[5] https://mp.weixin.qq.com/s/Q5S_Eic0sQvT7JLr3Kn4iA

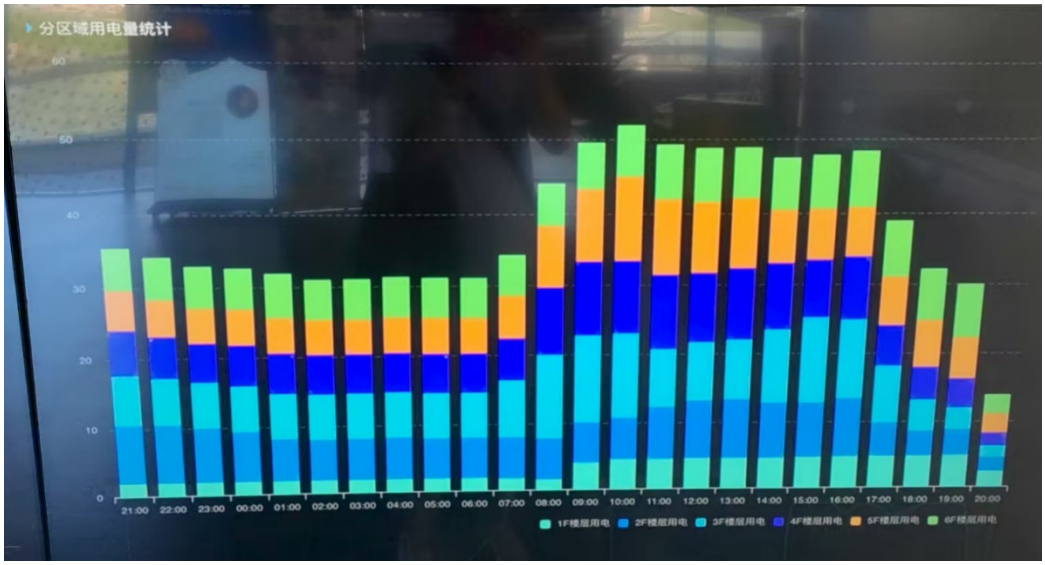


Figure 10: Actual Photo of Zonal Electricity Consumption Statistics on the Data Dashboard Screen

② Resource Circulation

The campus adheres to the Sponge City concept. Outdoor ground surfaces are paved with permeable bricks, and an "ecological garden" was created on the roof, planted with nearly 120 species of various native Shenzhen plants, forming a miniature natural ecosystem. Collected rainwater is treated and used for landscape irrigation and road cleaning, achieving annual water savings of 50,000 tons. The campus has established a "Black Soldier Fly - Community Composting - Co-created Garden" circular model, converting approximately 200 kilograms of daily food waste from the canteen into fish feed (fresh larvae) and frass (material for garden compost), achieving 100% resource utilization of food waste. The campus's Qingyun Auditorium uses foam aluminum, produced by foaming a mixture of discarded beverage cans and industrial aluminum waste, as a building material.

Wooden components within the building are made from bamboo, which not only has excellent carbon sequestration effects but is also 100% recyclable and reusable.

Figure 11: Project Rooftop Garden[6]

[6] https://mp.weixin.qq.com/s/Q5S_Eic0sQvT7JLr3Kn4iA

Figure 12: Black Soldier Fly and Aquaponics System

③ Community Operation

The campus integrates a library, art studios, educational workshops, restaurants, and a lifestyle market. By removing physical perimeter walls, it has created a sustainable living community open "24/7, 365 days a year." Leveraging the auditorium and banquet hall spaces in the campus's international conference center, Biosphere 3 focuses on building a carbon neutrality community and demonstration benchmark. It actively interacts with the Yantian District government, residents of surrounding communities, and enterprises in the "dual carbon" industry. The campus receives nearly 9,000 visitors annually and has cumulatively hosted over 20 large-scale offline events. It also initiates activities like the "Low-Carbon Behavior Check-in" during Energy Saving Promotion Week, attracting close to 20,000 participants.

(2) Key Focus Areas and Challenges for the Investor and Operator

The interviewee for this project was DeepRock Group, which serves as both the investor for the project retrofits and the energy operator for the campus, undertaking dual responsibilities.

Regarding Low-Carbon Energy Retrofits:

The photovoltaic (PV) and energy storage systems were invested in and constructed by a third party. The expected payback period for the PV investment is 6-7 years, and 8-10 years for the energy storage investment. The PV system capacity was strictly sized based on the campus's electricity consumption; the scale was not expanded to control costs. Currently, the internal PV consumption rate on the campus is 85%-90%, with surplus electricity fed into the municipal grid. The annual

electricity consumption of the office buildings within the campus is approximately 7 million kWh, with air conditioning being the primary energy consumer—accounting for 30% of electricity usage during non-cooling seasons and up to 70% during cooling seasons.

Currently, the following issues exist in energy management:

- In the PV and energy storage sectors, a mismatch between power generation and consumption periods creates operational conflicts, requiring a balance between economic benefits and green outcomes.
- While the data system enables equipment-level detailed monitoring, validating the massive amounts of data against physical reality incurs high time costs. Such energy management systems are currently primarily suitable for demonstration projects or key points.
- The term of green financial products is typically only 3 years, far shorter than the investment return period for PV and storage, hindering the large-scale application of these technologies.
- Distributed PV projects are relatively small in scale, making them economically unviable for developing CCER (China Certified Emission Reduction) products, and it is difficult to independently form an effective buyer's market.

The core driver for the investor-operator in promoting low-carbon energy retrofits is a strong belief in the high growth potential of the green energy services sector. On one hand, they aim to integrate distributed green and low-carbon technologies to establish the demonstration building as a

benchmark project—a "Carbon Neutrality Museum." On the other hand, they are committed to exploring the replicability of this technological system, thereby solidifying their positioning as an "Integrator of Resources." The ultimate goal is to build a healthy business model that does not rely on subsidies, is fully market-oriented, and achieves the dual objectives of sustainable, reasonable profits and enhanced brand value.

Looking ahead, the operator plans to systematically advance de-carbonization efforts in the following directions:

- **Strengthen Operations and Brand Influence:** Continuously organize activities to attract visitors and achieve robust attendance even during off-peak seasons ("no low season"). Donate the carbon reduction credits achieved through Black Soldier Fly food waste treatment to major events like the National Games, transforming ecological benefits into significant brand promotion.
- **Promote Scalable Expansion of Demonstration Scenarios:** Evolve from the current single demonstration campus to covering a complete area of 3.2 square kilometers, encompassing diverse entities such as villages, office buildings, and hospitals. Conduct pilot retrofits in different scenarios to explore de-carbonization pathways for comprehensive demonstration zones.
- **Commit to Business Model Innovation:** Establish a inclusive carbon credit system that connects various entities and business resources, creating synergistic effects and providing endogenous momentum for the project's long-term sustainable operation.

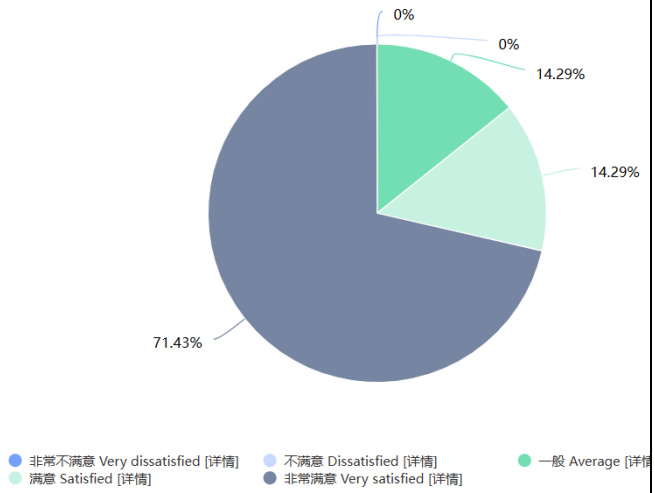
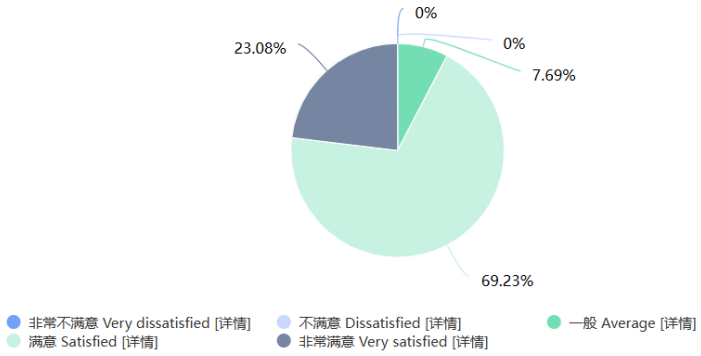
Figure 13: Building Exterior with Aluminum Panel Shading[7]

Figure 14: Floor-Level Air Supply HVAC Unit

[7] https://mp.weixin.qq.com/s/Q5S_Eic0sQvT7JLr3Kn4iA

Figure 15: Interior View of the Campus

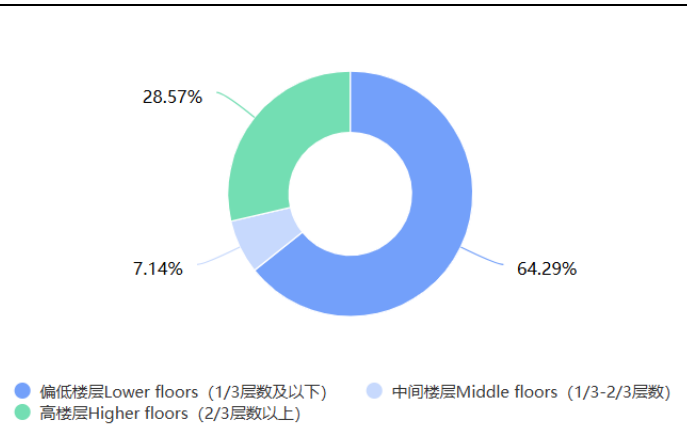
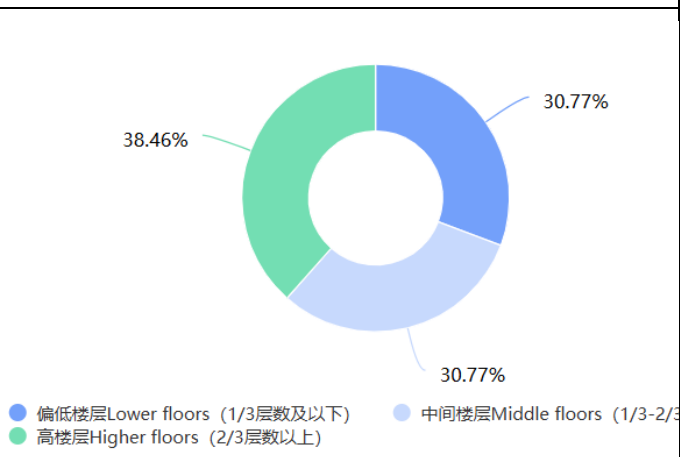
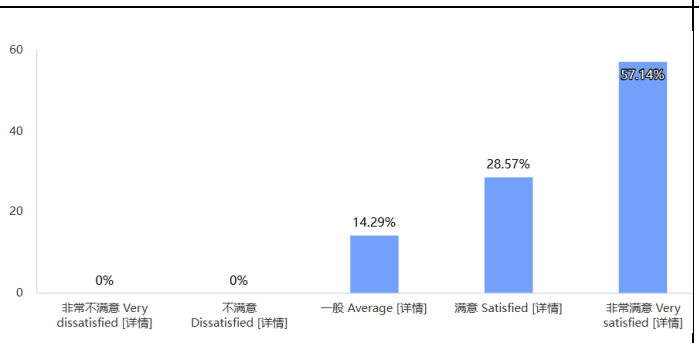
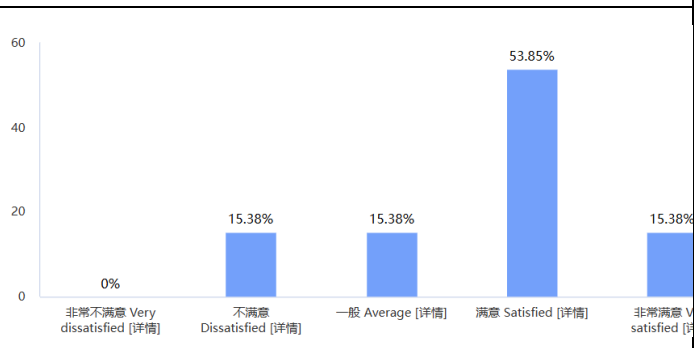
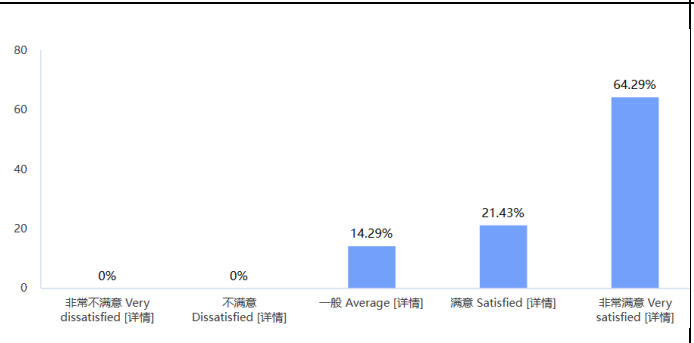
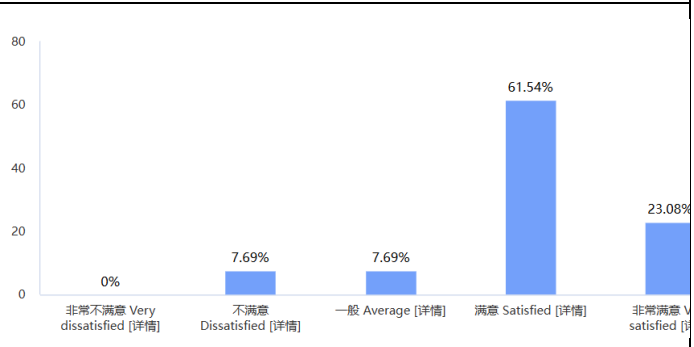
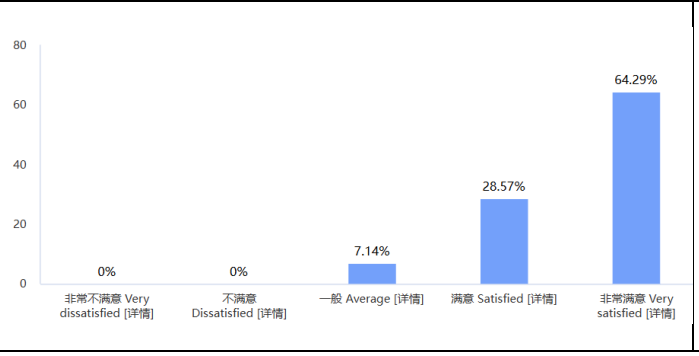
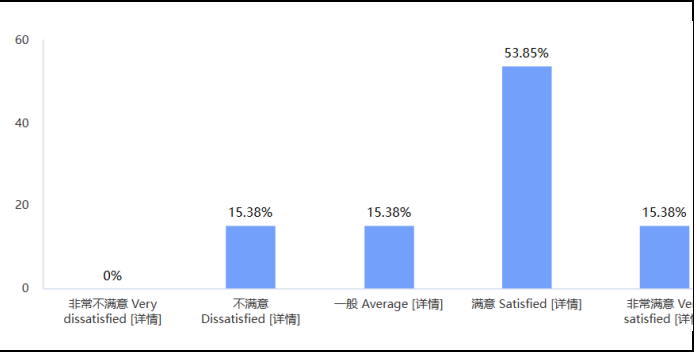
3.Questionnaire results in Shenzhen

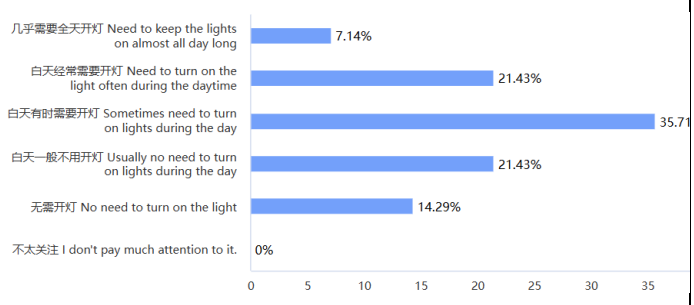
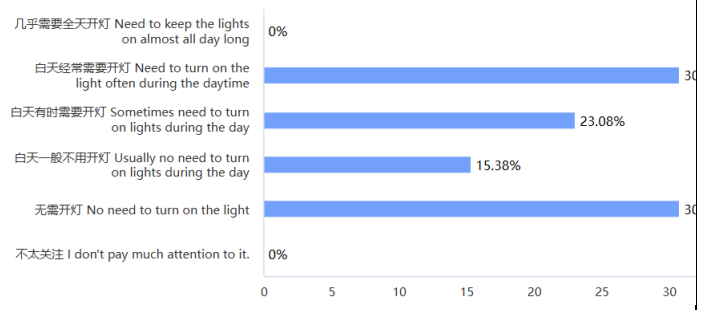
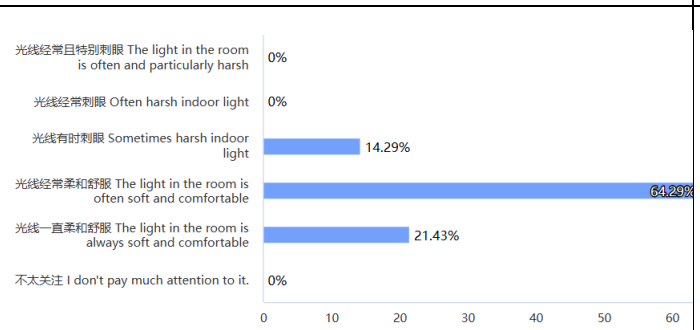
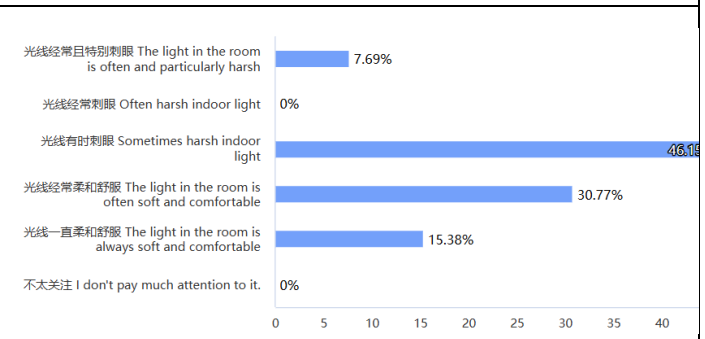
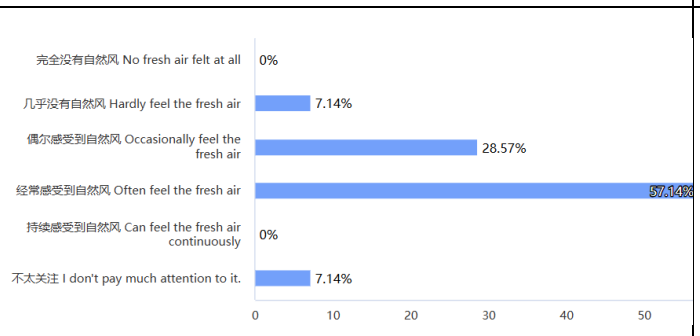
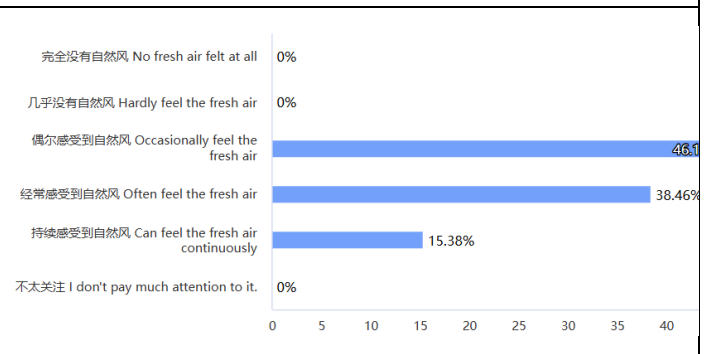
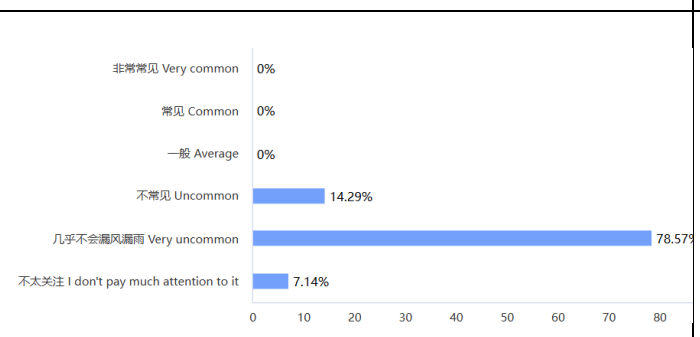
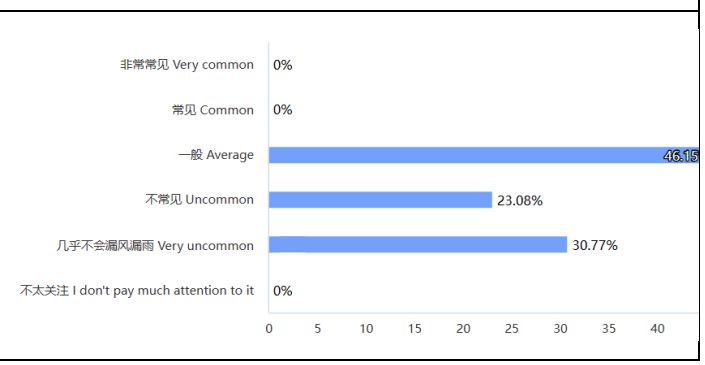
Questions	ZEBs	Traditional Buildings
Overall Satisfaction		

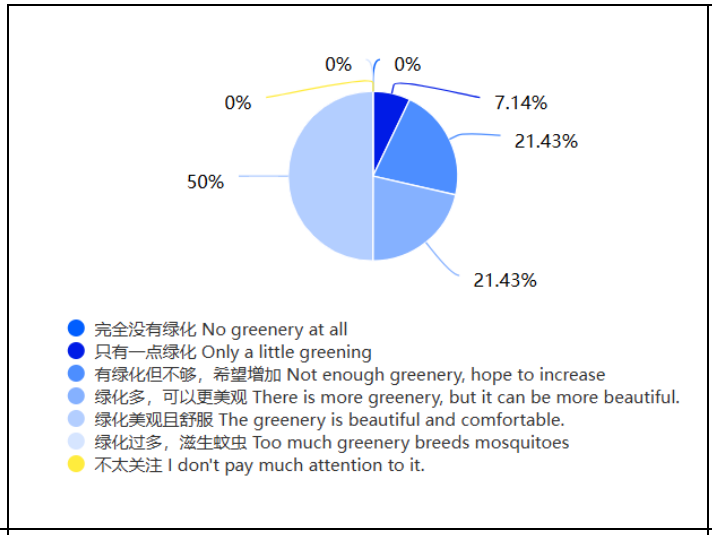
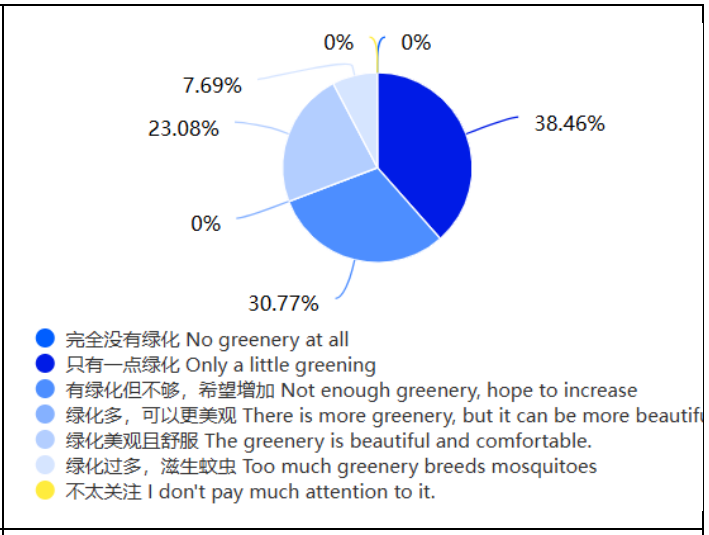
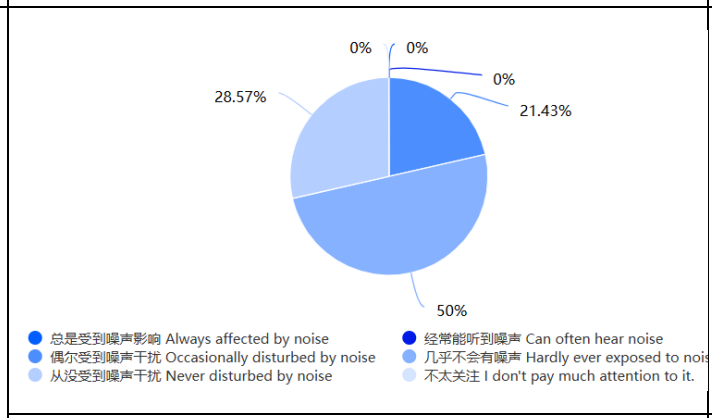
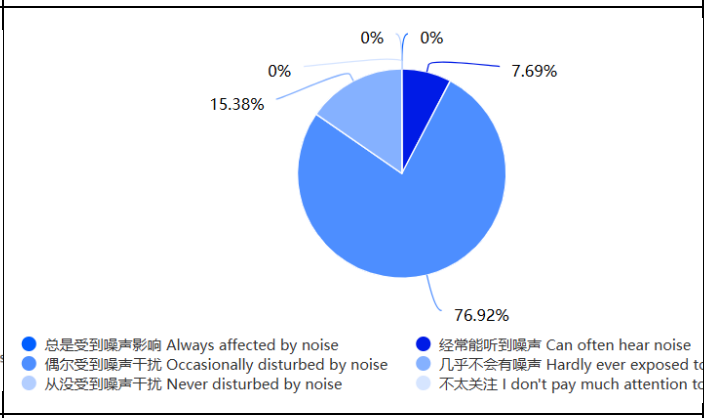
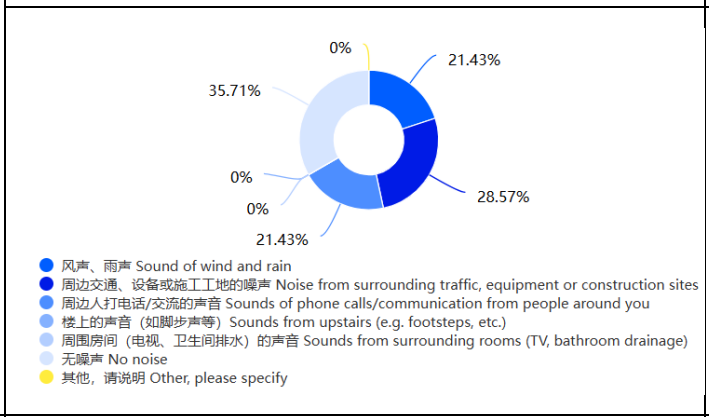
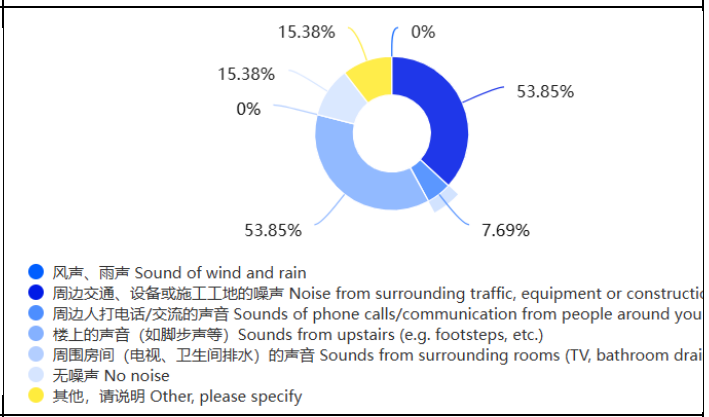
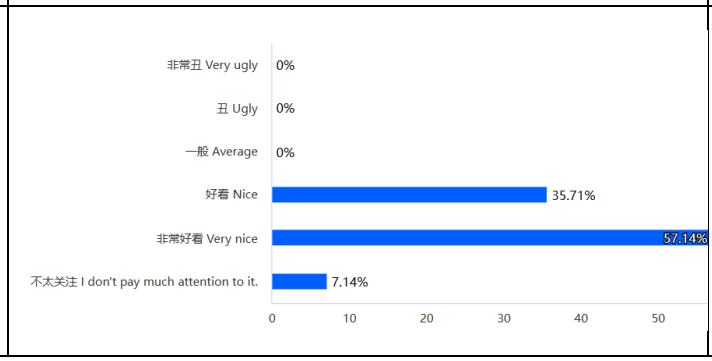
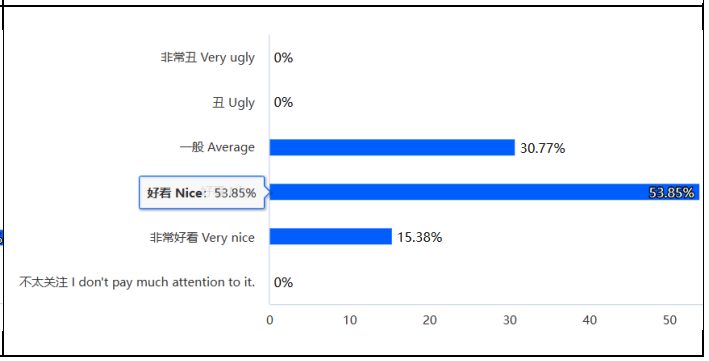
(1) Satisfaction with Indoor Environment

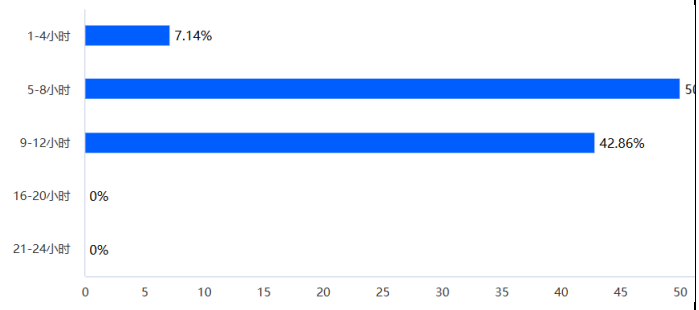
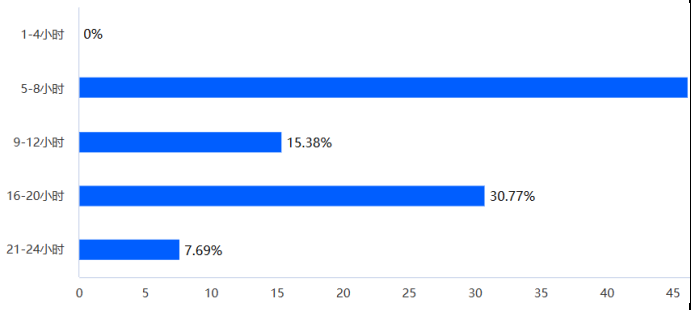
Including: floor level, temperature and humidity, air quality, accessibility facilities, artificial indoor lighting, natural lighting, natural ventilation, air/water leakage through doors and windows,

indoor greenery, noise levels, building exterior appearance, and heating season temperature.

Questions	ZEBs	Traditional Buildings
Levels		
Temperature and Humidity		
Air Quality		
Accessibility Facilities		

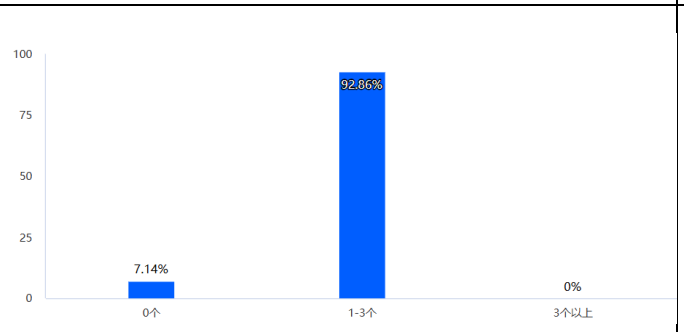
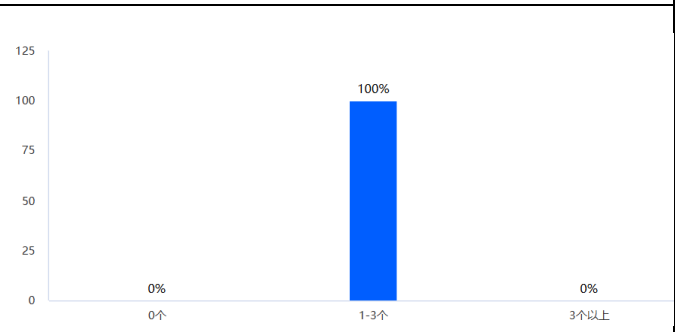
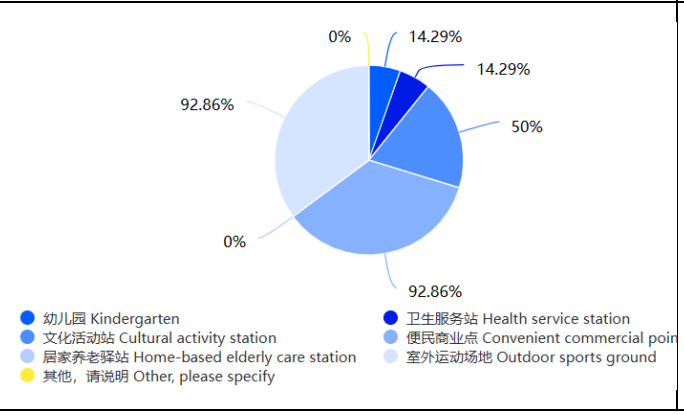
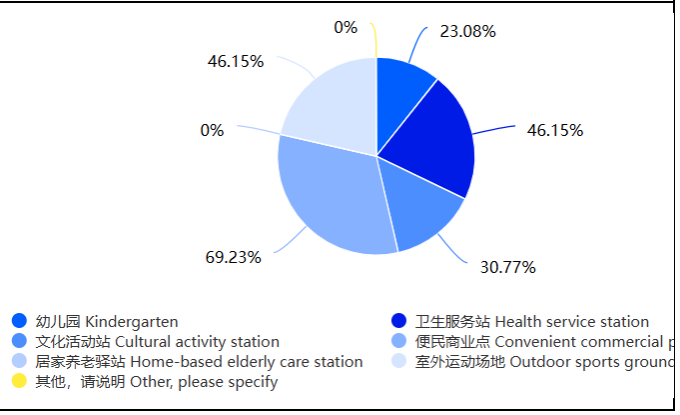
Lighting		
Natural Lighting		
Natural Ventilation		
Air/Water Leakage through Doors & Windows		

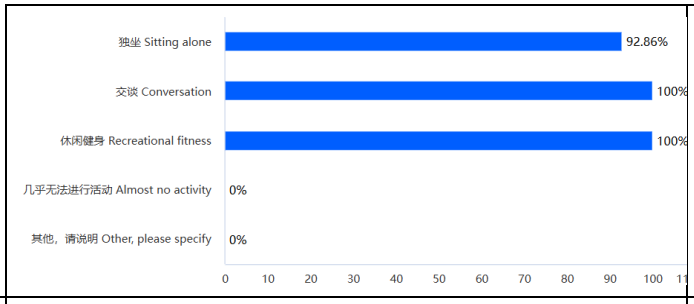
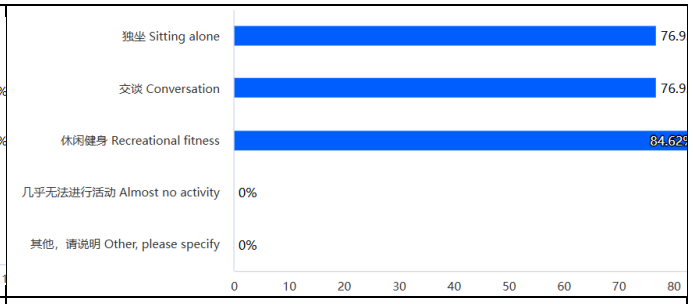
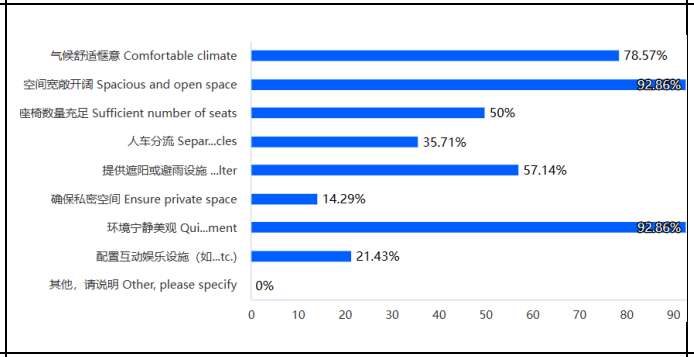
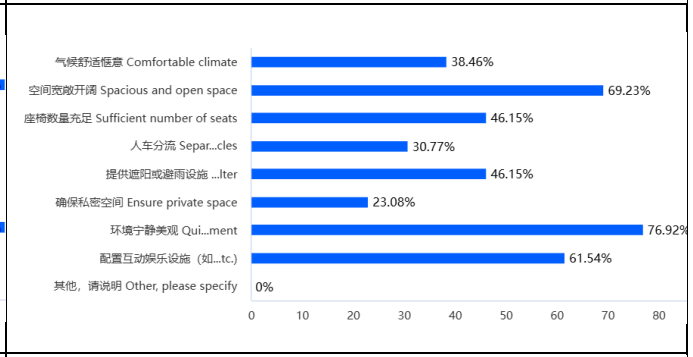
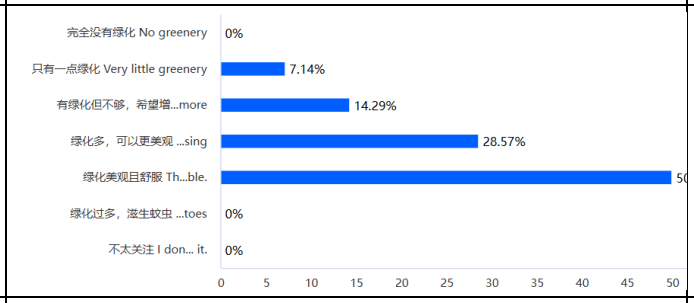
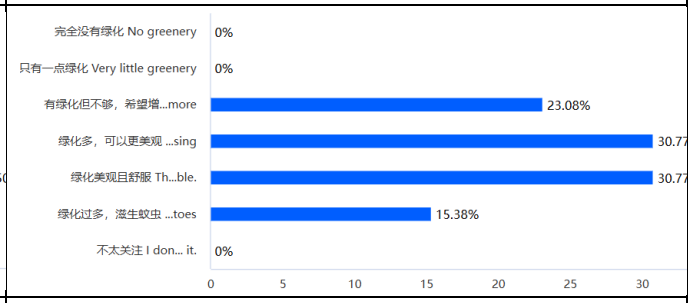
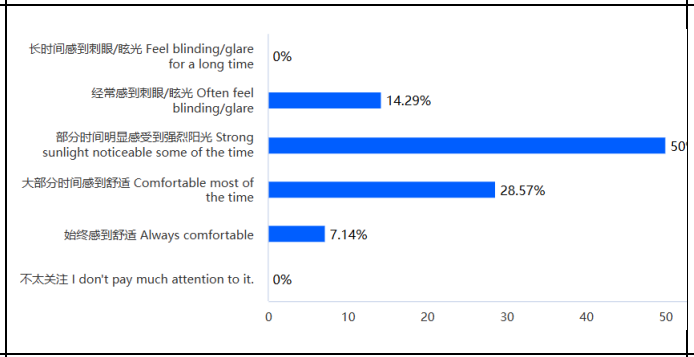
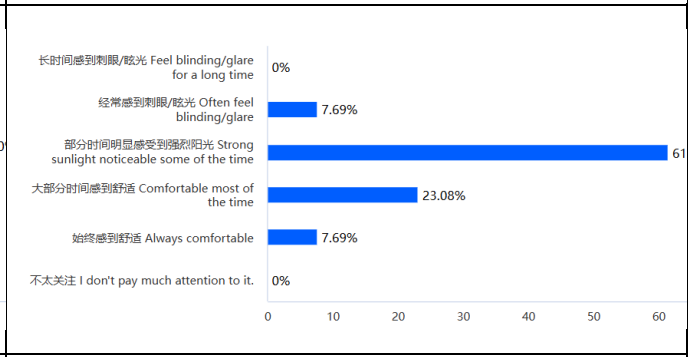
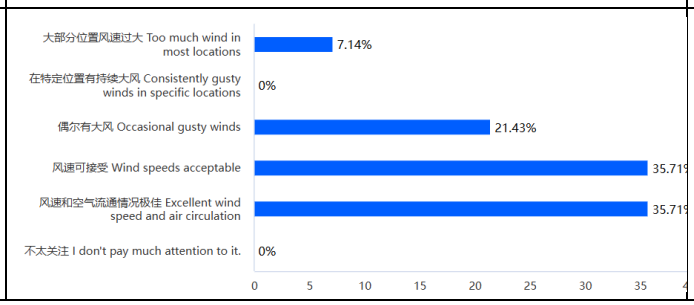
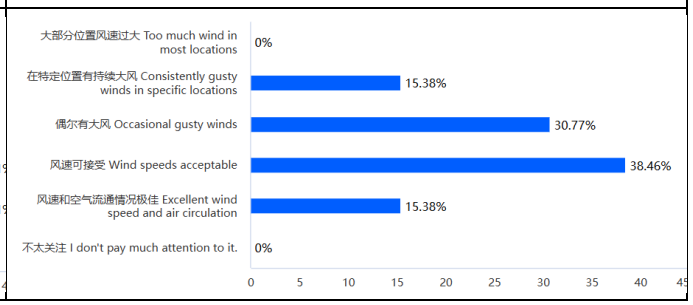
Greenery		
Indoor Noise		
		
Building Exterior Design		

Daily Average Air Conditioning Usage Duration During Summer		

(2) Relationship Between the Building and Its Surrounding Environment

Including: availability of bus stops within a 5-minute walk, service facilities, activities feasible around the building and their reasons, outdoor greenery, outdoor shading, and outdoor ventilation.

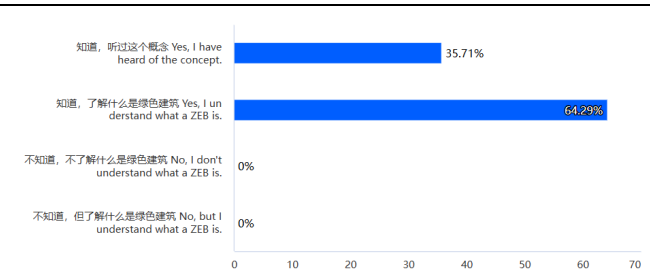
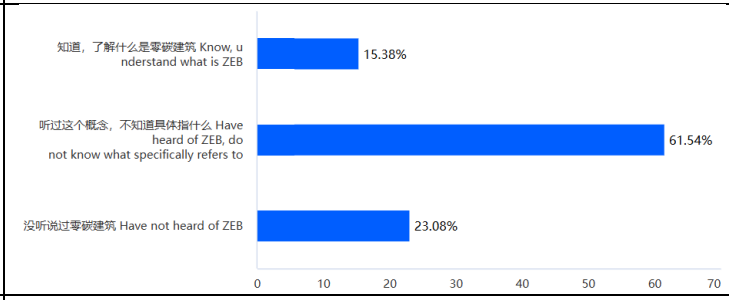
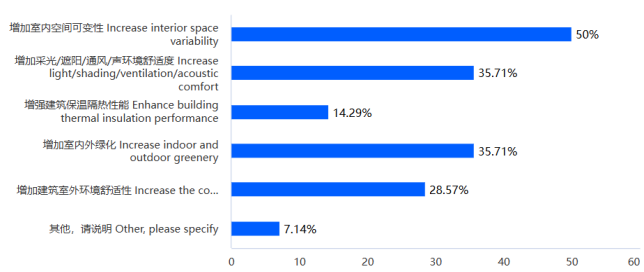
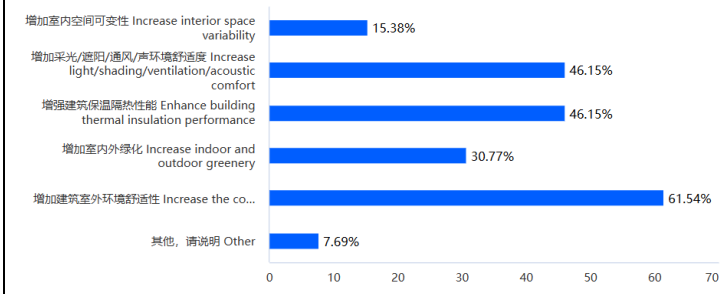
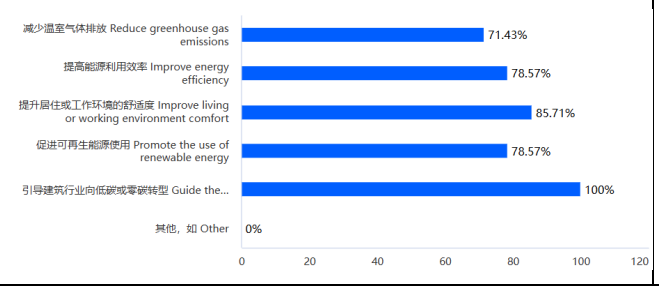
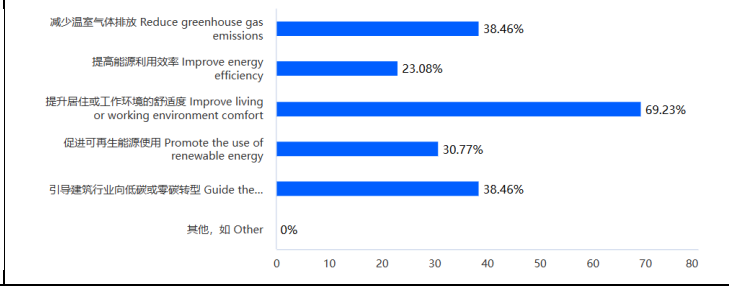
Questions	ZEBs	Traditional Buildings
Bus Stops Within 5-Minute Walk		
Service Facilities		

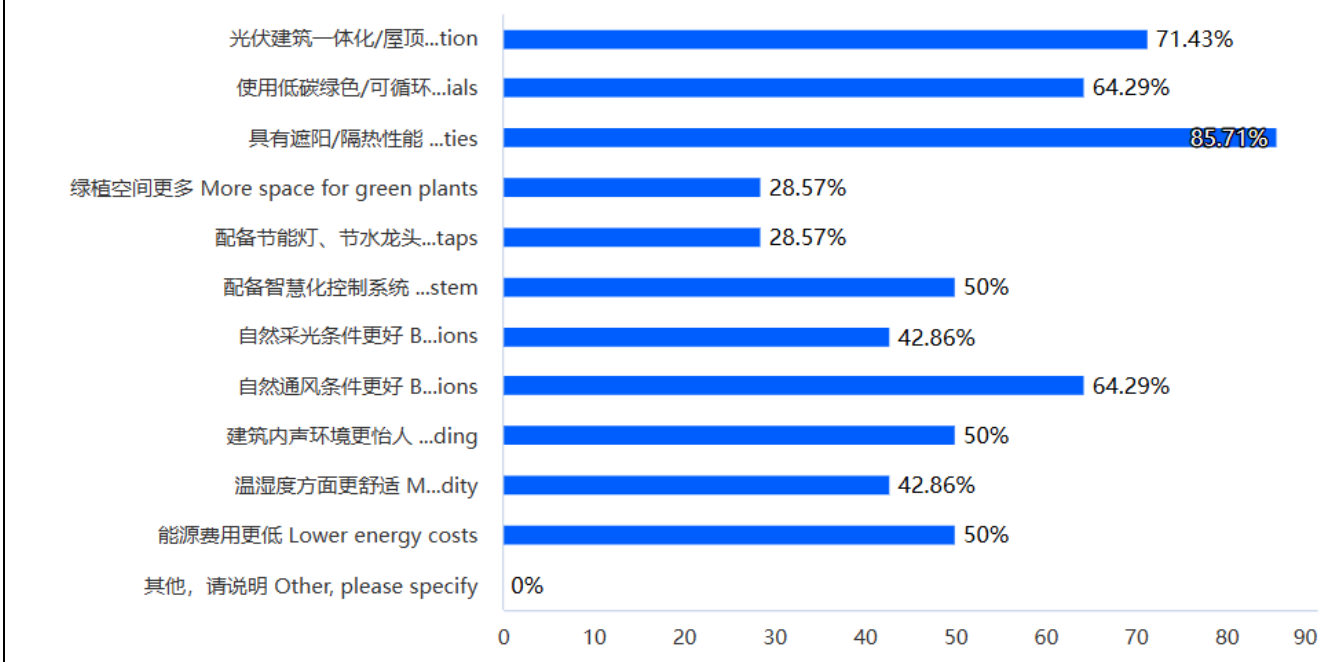
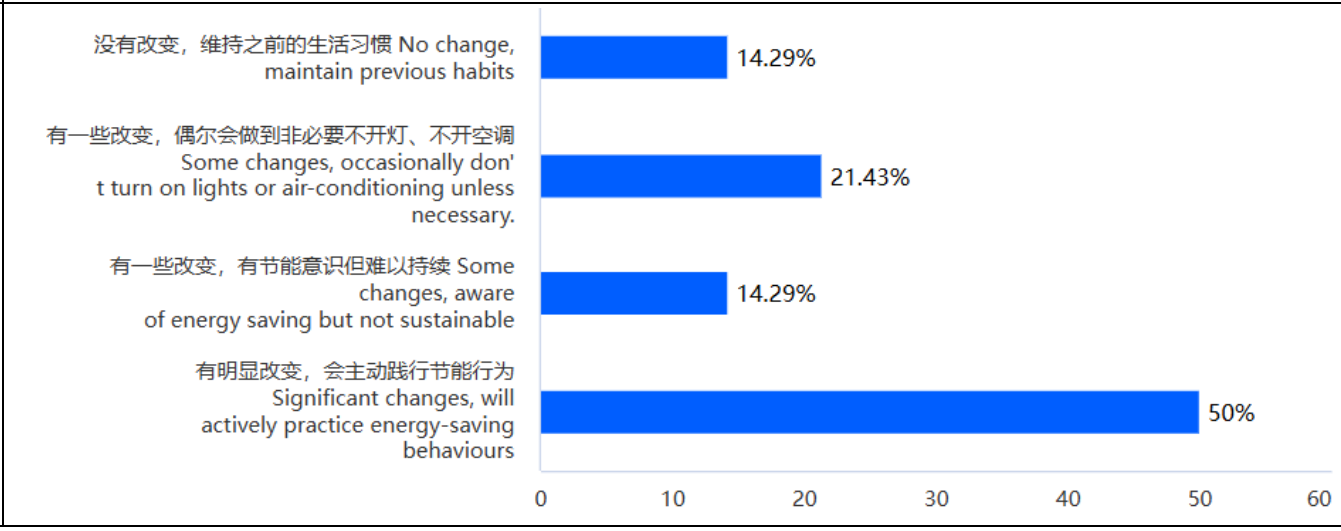
Outdoor Activities Feasible		
Reasons for Feasibility		
Outdoor Greenery		
Outdoor Shading		
Outdoor Ventilation		

(3) Understanding of ZEBs

Including: awareness of ZEBs, differences from surrounding buildings, changes to daily habits,

potential building improvements, and the significance of ZEBs.

Questions	ZEBs	Traditional Buildings
Awareness of ZEBs		
Potential Building Improvements		
Significance of ZEBs		

Differences between ZEB and Surrounding Buildings	
Changes to Daily Habits	

8. Appendix 5:

Interview Outline for Discussions with Operators and Investors

For Operators:

1. What are your specific responsibilities in building operation and management, and what training have you received?
2. What are the main components of this building's operational costs (e.g., energy costs, equipment costs, etc.)? Please consider: heating, air conditioning equipment, fresh air systems, domestic equipment, lighting, office equipment, water, gas, and equipment maintenance.
3. What types of issues do users frequently report to you?
4. What technical or managerial problems or challenges have you encountered during operation and maintenance? What future needs do you anticipate in the operational process?

Specifically for ZEBs:

5. In your view, what are the main aspects that make this building attractive to users?
6. What experiences or insights would you be willing to share with future operators of similar projects?

For Investors:

1. How do you assess the payback period and expected return on investment (ROI) for this building project?
2. What top-level policy support has this ZEB project received? How do you view the impact of such policies on investment in ZEBs?
3. What is your perspective on the market potential and growth trends for ZEB projects? What advantages and challenges do you see for ZEBs in future development?
4. Please briefly describe the external promotion and publicity efforts for this ZEB project.