Development of Green Buildings and Related Technologies in Chengdu

Nordic Sustainable Cities

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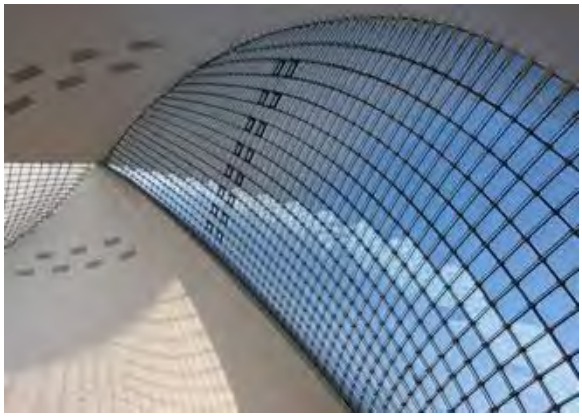
By

Nordic Innovation

Cushman&Wakefield



Nordic Innovation

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1 Research purpose and background

Cushman & Wakefield (Chengdu Office) is commissioned by The Consulate General of Denmark in Shanghai and the Innovation Centre of Denmark, to conduct research on the development of green buildings and related technologies in Chengdu. The research starts with an introduction to the green city development process in Chengdu, before then investigating the development of green buildings by reviewing related case studies and analyzing the development of green building technology and green finance. The study then goes on to summarize the technical requirements of various aspects of green buildings and concludes by looking ahead at the future development trends of green buildings.

2 History of Green City Development in Chengdu

2.1 History of Green City Development in Chengdu

Chengdu started its exploration of green city development as early as 2005 with the successful formation of a series of ecological protection-related plans. This was extended with the establishment of “The Chengdu Leading Group for Energy Conservation, Emission Reduction and Climate Change” (成都市节能减排及应对气候变化工作领导小组) in 2007. As of 2020, the exploration of green city development in Chengdu has gone through three stages. For the first and second stages, the focus has been primarily placed on ecological protection. For the third stage, an in-depth study of green city construction in Chengdu has been conducted, in terms of urban spatial layout, industrial structure and green economic development.

- **The First Stage -** to emphasize the ecological protection of key areas around the city's ecological zone. Starting from 2005, the city has successively compiled the " Land Plan for Non-Construction Area in the Central Chengdu" (《成都市中心城区非建设用地规划》) and "The Master Plan of Chengdu Ecological Ring" (《成都市环城生态区总体规划》), etc. Since then and having been ratified under legislative framework established in 2012, approximately 133 km^2 of the ecological zone around the Chengdu central city has been designated for protection. This is to prohibit the emergence of the continuous development from the central city to the ecological ring and therefore prevent any further urban sprawl and the associated ecological damage.

- **The Second Stage -** to strengthen ecological protection and establish an ecological protection mechanism in Chengdu. Commencing in 2008, a series of ecological protection plans at city level were introduced, including the "Chengdu Ecological City Construction Plan" (《成都市生态市建设规划》), the "Chengdu Ecological System Control Plan" (《成都市生态系统控制规划》) and the "Chengdu Ecological Protection Master Plan" (《成都市生态保护总体规划》). Each plan seeks to establish a foundation for reinforcing ecological protection in Chengdu.

- **The Third Stage -** to compile relevant regulations and plans, and to promote and solidify the development of green cities in Chengdu. Having started in2011, Chengdu has successively compiled a further series of ecological protection plans, including the "Chengdu Greenway System Planning" (《成都市绿道系统规划》), the "Chengdu Green Space System Planning" (《成都市绿地系统规划》), the "Chengdu Sponge City Planning" (《成都市海绵城市规划》), the "Chengdu Comprehensive Pipeline Planning" (《成都市综合管廊规划》), the "Chengdu "Livable Waterfront" Planning" (《成都市“宜居水岸”规划》), the "Chengdu Low-Carbon City Pilot Implementation Plan" (《成都低碳城市试点实施方案》) and the "Chengdu City's Implementation Plan for Promoting Green Economic Development" (《成都市推进绿色经济发展实施方案》). All of which seek to comprehensively refine and solidify the development of green cities in Chengdu.

2.2 Vision of Green City Development in Chengdu

In September 2016, the “Implementation Opinions of the Chengdu Municipal Committee of the Communist Party of China on Promoting Green Development and Building a Beautiful Model City in China” (《中共成都市委关于推进绿色发展建设美丽中国典范城市的实施意见》) was deliberated and approved. The Implementation Opinions require cities to present their organic life forms, in which population, resources, and environmental development should be coordinated to optimize the economic and ecological benefits. With the driving force of new industrialization, informatization, urbanization, agricultural modernization and green management, Chengdu should focus on strengthening ecological and environmental protection in order to promote the development of

green industries, improve environmental protection and green systems, and gradually press ahead for the modernization of the governance system and governance capabilities of the mega cities in Chengdu. By 2020, the ecological and environmental quality of Chengdu has improved significantly. The ecological carrying capacity continues to increase together with people's sense of green development, leading to significant advancement in the energy and resource-saving sectors. In order to construct a resource-saving and environmentally friendly society, efforts should be made to depict Chengdu to the rest of China as leading the way by creating a livable and green city.

Performance of Chengdu in achieving the vision of green city development by 2020

Category	Performance
Air quality	The average concentration of particulates (e.g. PM2.5) in the city is less than 50μg/m^3.
Water quality	The quality of the water in the main urban area has significantly improved and the lake system in the ecological zone around the city has reached completion. Moreover, the proportion of Chengdu river basins showing good water quality levels, such as the Minjiang River and the Tuojiang River, has reached more than 70%.
Ecological and environmental quality	The soil quality of the city has improved. The forest coverage rate and the green coverage rate of the central urban area has reached 40% and 45% respectively, while the per capita parkland area has reached 15 square meters or more.
Green commuting	The sharing rate of motorized public transport in the central city has reached more than 65%, of which rail transit accounts for more than 50%.
Urban quality and functionality	The spatial pattern metropolitan area, known as the "dual-core co-prosperity, one province and multiple cities" ("双核共兴、一城多市"), represents a network made up of city clusters. Each of these clusters form a wider network by utilizing the same infrastructure and connectivity in order to

Category	Performance
	boost and improve urban functionality.
Green economic development	The green and low-carbon circular development industry system has been initially established. The proportion of strategic emerging industries, high-end growth industries and emerging service industries has increased significantly. Meanwhile, value-added energy unit consumption, material consumption and pollutant emissions of key industries have continued to decline.
Green development system and mechanism	Progress has been made in reforming the ecological civilization system. A system of local regulations, standards and technical specifications for the ecological environment has taken shape.

2.3 Pilot Scheme on the Development of a Low-Carbon City in Chengdu

In January 2017, Chengdu was included in the third batch of the low-carbon city pilot project in China. As per the requirements, pilot cities should establish an assessment system for controlling greenhouse gas emissions whereby emission reduction tasks are allocated to the administrative regions and key enterprises in pilot cities. In addition, carbon emission indicators should be established with a solid explanation and practical assessment method in order to carry out follow-up evaluation and assessment of the corresponding emission reduction tasks allocated.

In March 2017, Chengdu officially began implementation of its national low-carbon city pilot work by issuing the "Chengdu Low-Carbon City Pilot Implementation Plan" (《成都低碳城市试点实施方案》). The Implementation Plan aims to develop Chengdu into a carbon emission trading center and a pioneer of low-carbon development. The Plan seeks to emphasize the production and living experiences in western China by providing low-carbon market-oriented services and establishing low-carbon development systems and mechanisms by 2020. Furthermore, by joining the "China Dafeng Pioneer Cities Alliance" (“中国达峰

先锋城市联盟”), the Implementation Plan aims at reaching its peak total carbon emissions as an advanced city for low-carbon development in China before 2025.

Performance of Chengdu in implementing the pilot scheme of green city development by 2020

Category	Performance
Industrial System	The added value of the tertiary industry reached a level of 53.3% by 2020. Meanwhile, an in-depth study and evaluation of fixed-asset investment projects in terms of the performance of energy-saving had been conducted. This study was used to raise the entry barriers of high-energy-consuming and high-emission industries and to adjust the level of energy consumption quotas of major goods production.
Urban System	Focus is placed on promoting and encouraging the development of green buildings, prefabricated constructions and finished buildings. The transformation of transportation modes has been encouraged by giving priority to pedestrians, non-motor vehicles and buses. By 2020, green buildings have accounted for more than 60% of new buildings. In addition, over 65% of transportation in central urban areas has been attributable to public transport, with rail transit accounting for more than 50% of public transport.
Energy System	A clean, low-carbon, safe, efficient and modern energy system has adopted by 2020, with 30.3% of the primary energy consumption having been generated by non-fossil fuels, and 57.4% of the city’s energy consumption has been contributed by clean energy.
Consumption System	The "Personal Low-Carbon Plan" and the "Low-Carbon Family" action have been launched and both advocate for a low-carbon lifestyle. Meanwhile, a pilot program for the certification of energy-saving and low-carbon products has

Category	Performance
	been established to create a catalog of energy-saving and environmentally friendly goods and services.
Carbon Sink System	The forest coverage rate of Chengdu has reached 40% and the central urban area green coverage rate has reached 45%.
General System	To build Chengdu as a “demonstration zone” for low-carbon development system and mechanism construction.

2.4 Implementation Plan of Green Finance Development in Chengdu

In March 2018, Chengdu issued the "Chengdu Implementation Plan for Promoting the Development of Green Economy" (《成都市推进绿色经济发展实施方案》).

- **9 major industrial forms:** Focusing on the development of new energy, energy conservation and environmental protection, new energy vehicles, green buildings, green logistics, green and low-carbon third-party services, green finance, urban veins, and forest health.

- **5 key industrial development zones:** Constructing 5 key industrial development zones of new energy, energy conservation and environmental protection, new energy vehicles, green finance, and forest health.

- **3 major industrial clusters:** Constructing 3 major industrial clusters of green buildings, green and low-carbon third-party services, and urban veins.

3 Green Real Estate Development Achievements in Chengdu

3.1 Current Green Building Standards in Chengdu

- **China's "Assessment Standard for Green Building" (《绿色建筑评价标准》)**: China's first "Assessment Standard for Green Building" (GB/T 50378-2006) was published in 2006. In April 2014, the latest version of "Assessment Standard for Green Building" (GB/T 50378-2014) was also released by The Ministry of Housing and Urban-Rural Development of the People's Republic of China(中华人民共和国住房和城乡建设部). Compared to the old version, the latest has made great improvements and breakthroughs. In March 2019, the Ministry of Housing and Urban-Rural Development of the People's Republic of China again issued the "Green Building Evaluation Standards"(《绿色建筑评价标准》) (GB/T 50378-2019) (hereinafter referred to as the "New Standards"). With the first edition issued in 2006 and a further 3 editions and 2 revisions released ten years later, the New Standards have generally reached an international leading level. From a technical perspective, the New Standard puts forward higher requirements:

  - The New Standard adds mandatory technical requirements for one-star, two-star, and three-star projects, including the thermal performance of building maintenance structures, requirements for water-saving appliances, sound insulation performance of residential buildings, and the reduction in concentration of urban air pollutants.

  - The New Standards have reinforced the importance of durability in buildings by implementing the SI system. The SI system is the construction system in which the support S - Skeleton and the I - Infill are separated. For the evaluation of green buildings, it advocates the emerging and rapidly developing prefabricated construction technology in China, and promotes the integrated development of interior and construction industrialization.

  - The increasing emphasis of BIM as an assessing indicator illustrates

that BIM technology, being a multi-dimensional information management technology that supports the full life cycle of construction projects, can greatly improve the quality and efficiency of projects and thus significantly reduce costs. The perception therefore is that this technology should be more widely promoted and adopted.

- The New Standards pay special attention to the actual advancement of residential industrialization. Industrialized interiors have been widely adopted in the fields of long-term rental apartments and hotels. By integrating with industrialized interiors, industry developments associated with bathroom, kitchen, fast-installed floor and wall materials has grown rapidly.

- The New Standards add a requirement for smart operations such as energy management systems, air quality monitoring, remote water transmission, water quality monitoring and smart home technology.

- The New Standards also require improvements to indoor air quality, natural lighting hours, hot and humid environments, indoor and outdoor fitness space, stair design, fitness trails construction and other related green and healthy building facets.

- **The U.S. LEED Rating System:** The U.S. LEED certification entered the Chinese market in 2003 and has been accepting project registration since 2004. It has grown rapidly since 2009 in China, becoming the second-largest country in the world to use LEED certification, second only to the United States. The LEED system provides authoritative third-party assessments for new buildings, existing buildings, interior decoration, residential, community development and other types of buildings. With the rapid growth in the field of green buildings, LEED certification has been widely recognized by many companies and has become the "standard configuration" for Grade A office buildings.

- **The U.K. BREEAM Standard:** The Building Research Establishment Environmental Assessment Method is often referred to as the Green Building Evaluation System of the British Building Research Institute. BREEAM, founded in 1990, is the world's first and widely used green building evaluation method. BREEAM is a green building evaluation system which integrates both "internationalization" and "localization". For international projects, BREEAM strictly examines the local climate, ecological environment, building materials, culture, construction specifications, construction laws and regulations, infrastructure, historical connections, politics, geography and other factors, using these to develop evaluation standards applicable to the relevant project.

- **The U.S. WELL Building Standard:** In March 2015, the Green Business Certification Inc. (GBCI) and the International WELL Building Institute (IWBI) formally introduced the WELL building standard to China. The standard focuses on the health and well-being of people in the built environment. It is a supplement to green building rating systems such as China's Green Three-Star, The U.S. LEED, and The U.K. BREEAM.

Assessment Indicator

China' "Assessment Standard for Green Building"	The U.S. LEED Rating System	The U.K. BREEAM Standard	The U.S. WELL Building Standard
Safety and Durability	Sustainable Site	Management	Air
Health and Comfort	Water Efficiency	Energy	Water
Occupant Convenience	Energy& Atmosphere	Water	Nourishment
Resources Saving	Materials& Resources	Land Use & Ecology	Light

Environment Livability	Indoor Environment Quality	Health & Wellbeing	Fitness
Promotion and Innovation	Innovation& Design Process	Materials	Comfort
		Waste	Mind
		Pollution	

Grading Mechanism

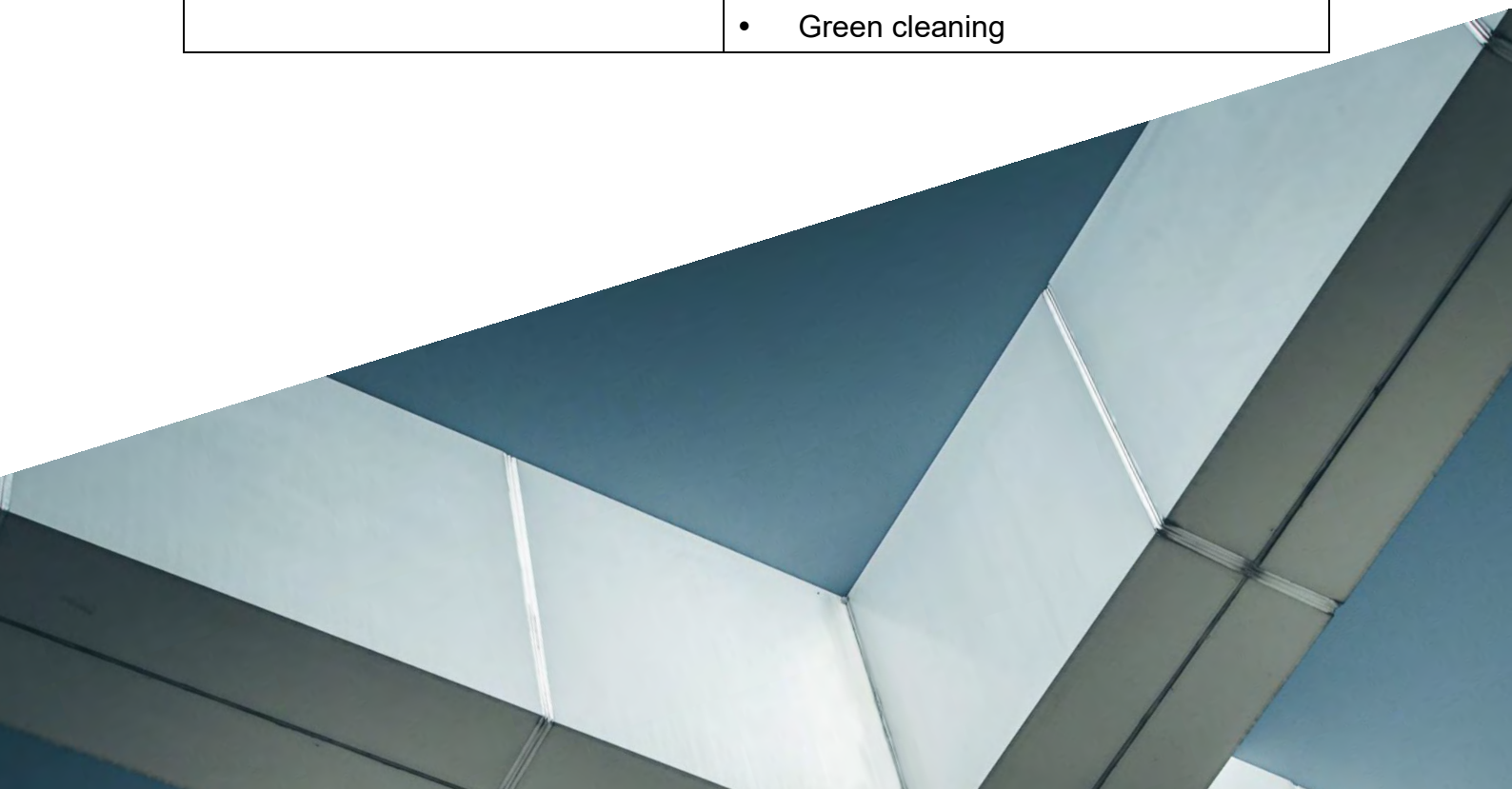
Evaluation standard	**China' "Assessment Standard for Green Building"**	**The U.S. LEED Rating System**	**The U.K. BREEAM Standard**	**The U.S. WELL Building Standard**
Grading (from the lowest to the highest)	/	Certified	Pass	/
	One-star level	Silver	Good	Silver
	Two-star level	Gold	Very Good	Gold
	Three-star level	Platinum	Excellent	Platinum
	/	/	Outstanding	/

3.2 Overview of Green Building Technology

Green buildings require comprehensive consideration regarding (i) land saving and outdoor environment, (ii) energy-saving and energy utilization, (iii) water-saving and water resource utilization, (iv) material saving and material resource utilization, (v) indoor environmental quality, and (vi) operation management. Among these, the most important incremental cost of a green building development project would be satisfying the requirement of the "energy-saving and energy utilization" sectors. Among all considerations, building energy-saving technology is currently the most important factor in determining cost.

Major application of green building technology

Consideration	Major application
Land saving and outdoor environment	• Green roof and vertical greening • Reducing the heat island effect • Green commuting
Energy saving and energy utilization	• Energy consumption monitoring and measuring system • Efficient light sources • Solar energy utilization
Water saving and water resource utilization	• Water saving appliances • Rainwater collection • Reuse of water • Water cooling towers • Conversion of dirty water
Material saving and material resource utilization	• Formaldehyde-freebuilding materials • High-performance concrete • High-strength steel
Indoor environmental quality	• Indoor air quality management • Noise control • Lighting glare control
Operation management	• Smart IoT facility management • Face recognition systems • Green cleaning



3.3 Case Studies

Tower 1 & Tower 2 of Chengdu IFS International Financial Center

Basic project information:

- Location: The intersection of Hongxing Road and Dacisi Road, Jinjiang District, Chengdu
- Transportation: situated above underground railway station
- Gross Floor Area (GFA): exceeding 0.27 million square meters, including
  - Flagship shopping center (podium): 210,000 square meters
  - Super Grade A office building (T1-T3): 290,000 square meters
  - Niccolo Hotel (T3): 230 rooms
  - IFC Haoting Service Apartment (T4): 175 sets
- Building height: T1, T2 tower - 248 meters
- Storey: T1, T2 tower - 50 storeys
  - Floors 1-7 are commercial podiums, floors 8-50 are office buildings
- Net height of ground floor: T1, T2 tower - 10 meters
- No. of elevators: 24 high-speed passenger elevators and 2 freight elevators per tower
  - Average waiting time: less than 35 seconds
  - Load capacity: 1800kg, 24 people
- Standard floor area of office building: 3000 square meters
- Standard floor height of the office building: 3.0 meters
  - The 50th floor of the transaction floor: 3.2 meters
- Settled enterprises: Most settled companies are foreign financial institutions and foreign real estate consulting companies,such as Standard Chartered Bank, ANZ Bank, Hang Seng Bank, Taiwan First Bank, KPMG, Fullerton Investments, Goodman, CBRE, Jones Lang LaSalle, King and Wood, Stryke etc.

Green certification:

- LEED platinum certification

Green strategy:

- Energy saving and environmental protection: Use of Low-E hollow glass curtain wall
- Ventilation and air conditioning system: VAV frequency conversion air volume adjustment system
- Building management system: Metasys building management system
- Security system: 24-hour comprehensive security system and CCTV central monitoring system; smart card access control system; automatic fire alarm system
- Rainwater harvesting: Roof garden
- Property management: One-stop service for Wharf butler-style property management

Yanlord Land Plaza

Basic project information:

- Location: Hongzhaobi Crossing, Section 2, Renmin Road South Road,Jinjiang District,Chengdu
- Transportation: situated above underground railway station
- Gross Floor Area (GFA): about 0.21 million square meters, including
  - Office building: 60,000 square meters
  - Shopping mall: 50,000 square meters
  - Serviced apartment: 40,000 square meters
- Building height: 180 meters
- Storey: 39 storeys
- No. of elevators: 14 imported OTIS high-speed passenger elevators
- Air conditioning: American Trane air conditioners with four-pipe VAV variable frequency variable air volume plus fresh air system
- Standard floor area: 2000 square meters
- Net height of standard floor: 2.8 meters
- Settled enterprises: Yanlord Land Plaza has attracted a large number of Fortune 500 companies and foreign consulates, such as IBM, Shell, Bayer, Novartis Pharmaceuticals, Merck, DuPont, Fuji Electric, Singapore Consulate General in Chengdu, New Zealand Consulate General in Chengdu, Chengdu Office of Thailand National Tourism Administration, etc.

Green certification:

- LEED platinum certification

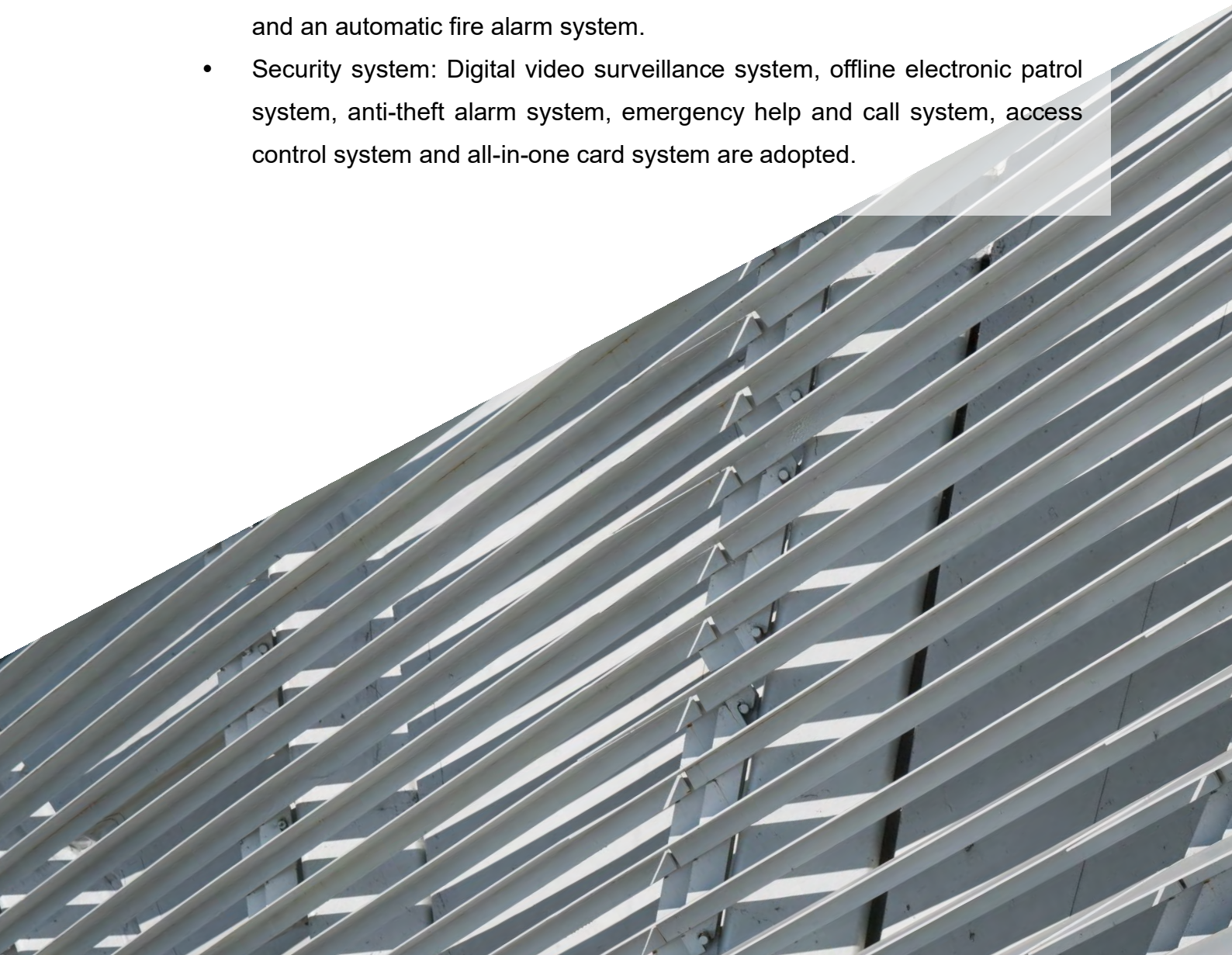
Green strategy:

- New environmentally friendly materials
  - From 1st to 5th floors: The exterior adopts 15mm ultra-white tempered glass and a patterned aluminum combined hidden frame curtain wall, partial breathing curtain wall and aluminum veneer curtain wall
  - Above the 6th floor: The exterior adopts unit glass curtain wall system, hollow Low-E tempered glass, aluminum alloy heat-insulating profile

and orange-red lacquered light guide glass fence

- The entire project: It adopts 36 energy-saving and environmentally friendly new materials such as inorganic insulation board, polymer modified bitumen waterproofing membrane, and environmentally friendly wasterproof coating.

- HVAC design: The project's cooling adopts an ice storage system to make full use of the low electricity price at night to reduce the host startup time during peak hours during the day.
- Energy-saving fresh air system: A four-pipe VAV system is installed at the end of the office area air conditioner.
- Fire system: An Indoor and outdoor fire hydrant system and automatic sprinkler system are installed with fire extinguishers equipped in the building. Both the hydrant system and the self-spraying system use the district water supply. Meanwhile, the indoor system also adopts a regional temporary high-pressure firefighting system, a centralized fire-fighting pressurization system and an automatic fire alarm system.
- Security system: Digital video surveillance system, offline electronic patrol system, anti-theft alarm system, emergency help and call system, access control system and all-in-one card system are adopted.



Chengdu International Science and Technology Energy Conservation Building

Basic project information:

- Location: CBD Core Business District, Tianfu New Town, Chengdu High-tech Zone
- Transportation: situated above underground railway station
- Gross Floor Area (GFA): about 0.15 million square meters
- Building height: Tower A - 163 meters; Tower B - 86 meters
- Number of Storeys: Tower A – 40 storeys; Tower B - 24 storeys
- Standard floor area: Tower A - 1,800 square meters; Tower B - 1,300 square meters
- Net height of standard floor: 2.7 meters
- Settled enterprises: The settled companies are mainly domestic and local companies in Chengdu, including China Energy Conservation and Environmental Protection Group Corporation, Sichuan Gaolu Traffic Information Engineering Co., Ltd, Chengdu Zhihuian New Technology Co. Ltd, Chengdu Enwei International Technology Co. Ltd, and Chengdu Bomi Technology Co. Ltd, Chengdu Siyou Biotechnology Co. Ltd, Sinopec Southwest Petroleum Engineering Co. Ltd and Sichuan Xinlan Construction Engineering Group.

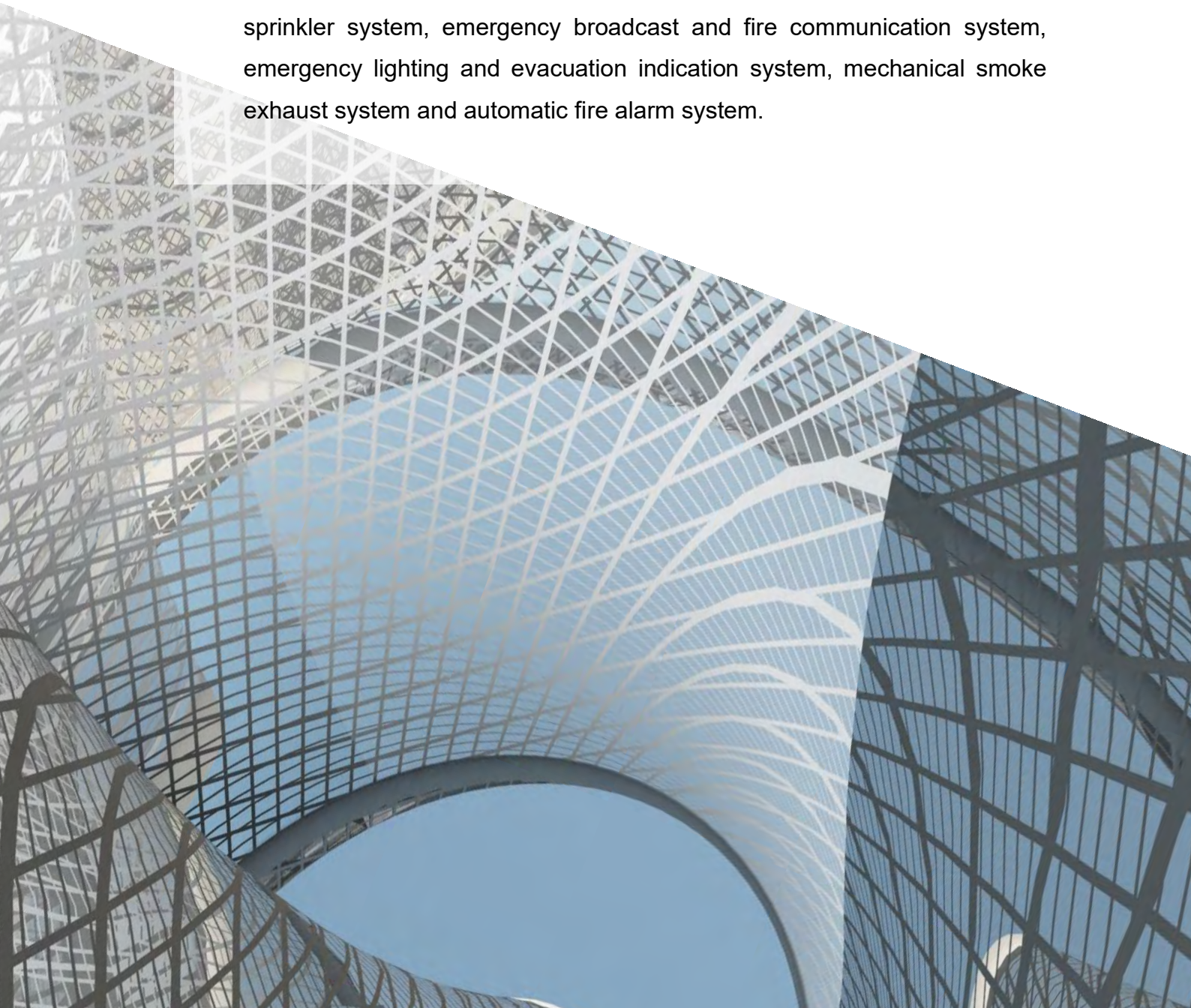
Green certification:

- China Green Building Two-Star Certification
- LEED platinum certification

Green strategy:

- Air-conditioning system: Adopt a York central air-conditioning system, with a fresh air volume of 35 cubic meters/person/hour;
- Daylight lighting system: Introduce natural light at ground floor level to illuminate the basement;
- Breeze power generation system: Convert wind energy to electricity to be used for public lighting in buildings;
- External wall moisturizing system: Adopt new moisturizing materials to stabilize indoor temperature and reduce air conditioning energy consumption;

- Photovoltaic curtain wall system: Adopt a photovoltaic curtain wall to generate electricity from solar energy;
- Building intelligent system: Adopt household-based metering of air-conditioning and electricity consumption, to monitor and reduce energy consumption;
- Solar power generation system: Install solar batteries and similar formed of equipment on the roof to convert solar energy into electricity;
- Potential energy device recovery system: Generate and support the electricity consumption of elevators by harnessing the friction created by them;
- Reclaimed water and rainwater recovery system: Reuse water resources through collection, purification and treatment;
- Fire system: Adopt an indoor and outdoor fire hydrant system, automatic sprinkler system, emergency broadcast and fire communication system, emergency lighting and evacuation indication system, mechanical smoke exhaust system and automatic fire alarm system.



3.4 Recent Trend of Green Building Development in Chengdu

3.4.1 Policy Support

In February 2018, the “Conference on Building a National Western Financial Center” (建设国家西部金融中心大会) was held in Chengdu to propose a comprehensive and modern financial industry system.The system was created to enhance the function of the western financial center and to accelerate the construction of a national central city by reflecting the development concept of Chengdu. Chengdu is expected to take the lead in 6 areas targeted. Those being the principles of “Technology Finance” (Techfin), “Rural Finance”, “Consumer Finance”, “Supply Chain Finance”, “Green Finance” and “Culture Finance”.

In October 2018, the Chengdu Municipal People’s Government issued the “Implementation Opinions on Promoting the Development of Green Finance” (《关于推动绿色金融发展的实施意见》). The Implementation Opinions seek to improve the green financial service system. These include the establishment of green finance franchise branches, business centers or green finance business units; vigorously developing green credit and services, encouraging and supporting green bond financing, supporting financing and re-financing of green enterprises, developing green insurance, establishing the Chengdu Green Finance Development Fund, expanding green investment from the Government and social capital cooperation using PPP model, enriching environmental equity financing tools and finally, consolidating the foundation for green finance development. By 2020, the proportion of green credit in Chengdu has reached 16%, with significant growth of green credit in comparison to the various other forms of loans. Green bond financing in Chengdu amounted to RMB 50 billion, and equity financing was RMB 30 billion. Chengdu A-share listed companies, National Equities Exchange and Quotations (NEEQ) listed companies and Tianfu (Sichuan) Joint Equity Exchange Center listed companies reached a combined total of 500 companies.

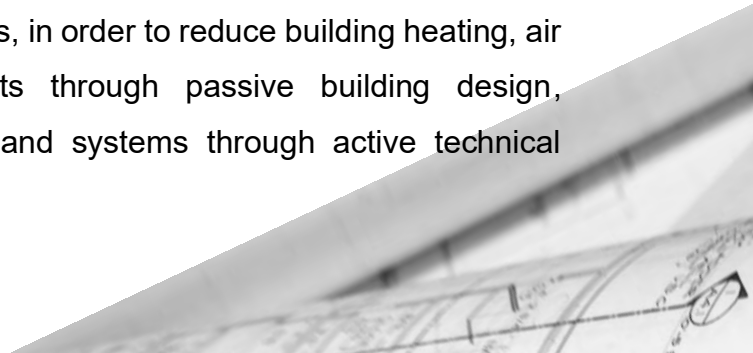
In November 2018, the Chengdu Branch of People’s Bank of China, Sichuan Provincial Financial Work Bureau, Sichuan Provincial Development and Reform

Commission, Sichuan Provincial Department of Finance, Sichuan Provincial Department of Environmental Protection, Sichuan Banking and Insurance Regulatory Bureau and Sichuan Securities Regulatory Bureau jointly issued the “Notice on Launching Pilot Green Finance Innovation” (《关于开展绿色金融创新试点的通知》), determining the Xindu District in Chengdu as one of the five pilot regions for green finance innovation in the Sichuan Province.

In December 2019, the second Chengdu Green Finance Summit Forum was held in the Xindu District of Chengdu. The Chengdu Green Finance Standards were released at the forum and the Green Certification and Evaluation Center was established. In the future, the intention is for the Certification and Evaluation Center to certify all companies, including financial institutions, into three levels: deep green, green, and non-green. On one hand, the certifying system will directly promote the development of green enterprises and projects among financial institutions and investors. On the other hand, the certification will minimize the financing costs of green enterprises and green projects, thereby objectively promoting the development of green industries.

3.4.2 Green Bonds

In May 2020, the People's Bank of China, in conjunction with the National Development and Reform Commission, the China Securities Regulatory Commission and other departments, drafted and issued the "Notice on Printing and Distributing the Catalogue of Green Bond Support Projects (2020 Edition) (Draft for Solicitation of Comments)” (《关于印发〈绿色债券支持项目目录（2020年版）〉的通知（征求意见稿）》). The Notice clearly defined building energy conservation, green buildings, comprehensive utilization of solid waste, restoration of the ecological environment of mines, resource recycling and manufacturing and the comprehensive utilization of biomass resources. To focus on the field of building energy conservation and green buildings, the Notice requires the adaptation of climate characteristics and site conditions for the construction of ultra-low energy buildings, in order to reduce building heating, air conditioning and lighting requirements through passive building design, improving building energy equipment and systems through active technical



measures. For efficient public and residential building construction, purchase and consumption, the building technical indicators are required to meet the "Near-Zero Energy Building Technical Standards"(《近零能耗建筑技术标准》). In contrast, green buildings should be designed in accordance with the relevant national green building codes and standards, and should have obtained the relevant national green building certifications. Prefabricated buildings require the use of prefabricated components on the construction site through assembly construction methods. As part of this, the manufacturing of green building materials, energy-saving wall materials, external wall insulation materials, energy-saving glass, prefabricated building parts, ready-mixed concrete, ready-mixed mortar etc. should meet the corresponding technical requirement for green building materials.

In December 2018, the first green bond in Chengdu and Sichuan Province was issued to the Chengdu Rail Transit Group Co. Ltd. The company successfully registered 7 billion green medium-term notes and issued the first phase of these in 2018. The first phase raised a total of RMB 2 billion, which were mainly used to repay the debt of its subway development projects, including the first phase of the south extension line and the third phase of the No. 1 Line. The current green medium-term notes are underwritten by CITIC Bank, with a maturity of 5 years at a coupon rate of 4.17%, representing the lowest interest rate among the 5-year medium-term notes issued in the Sichuan Province during 2018.

In May 2019, Chengdu Xingrong Environment Co. Ltd successfully issued the first green bond, "19 Xingrong G1" (“19 兴蓉 G1”), with a total issuance of RMB 800 million at a coupon rate of 4.26% and bond term of 5 years. In December 2019, they then successfully issued the second green bond, "19 Xingrong G2" (“19 兴蓉 G2”), this time at an amount of RMB 1 billion, a coupon rate of 3.58% and bond term of 5 years.

3.4.3 Green Asset Securitization

The Shanghai Stock Exchange and the Association of Interbank Dealers respectively issued relevant guidelines to encourage the issuance of green ABS,

green ABN, green CMBS etc., and clarified the arrangements for issuance specifications, basic asset and fund-raising requirements and regulatory protocol. At present, the green asset-backed securities in China could be divided into 3 categories: (i) “double-green” asset-backed securities (“双绿”资产支持证券) whereby the underlying assets are green projects directly invested in by the raising of relevant funds; (ii) “investment in green” asset-backed securities (“投向绿”资产支持证券) whereby the underlying assets are non-green projects but directly invested by relevant raised funds; and (iii) “asset green” asset-backed securities (“资产绿”资产支持证券) whereby the underlying assets are green projects but are not directly invested in by relevant fundraised.

According to research data from the Central University of Finance and Economics International Institute of Green Finance, China issued a total of 32 green asset-backed securities in 2019, which reflected a 78% increase on the 18 securities issued in the previous year. Green asset-backed securities, including green asset securitization and green asset-backed notes, both raised a total of RMB 39.203 billion - 2.5 times that of 2018. Significant breakthroughs have been achieved in the number of issuances, the scale of funds raised, the abundance of basic assets and the level of product innovation.

3.4.4 Case Study: Chengdu China Energy Conservation Building – CMBS

In November 2017, Harvest Capital China Energy Conservation Green Building Assets Supported Special Program (嘉实资本中节能绿色建筑资产支持专项计划) was successfully issued on the Shenzhen Stock Exchange with an issue size of RMB 820 million. The target asset is the Chengdu International Energy Conservation Building, a subsidiary of China Energy Conservation.

With reference to the domestic and worldwide leading green building standards, the entire building project integrates a variety of energy-saving building technologies and new energy application technologies. These include technologies that are based on the natural conditions of Chengdu – high temperature and humidity in summer months, as well as cold winters with little sunshine and wind. A comprehensive analysis and calculation of energy

attributable to the project was undertaken, providing a detailed and thorough solution for energy saving measures to the building with practical application value. Chengdu has adopted eight high-end energy-saving measures, including wind power generation systems, photovoltaic power generation systems, photovoltaic curtain wall systems, car charging station systems, healthy fresh air systems, daylight lighting systems, sun-shading and heat-insulating window technology, and building intelligent systems, each contributing to an intelligent and environmentally friendly building for the very first time.

Chengdu International Science and Technology Energy Conservation Building has won many honors for its energy-saving and environmental protection features, including the U.S. Green Building LEED Gold Certification, China green building two-star certification, Chengdu Quality Structural Engineering Award, Chengdu Renewable Energy Building Application Demonstration Project, Chengdu's first batch of "Super Grade A commercial office buildings", Chengdu's most valuable brand building, one of the Chengdu green environmental protection advocates advanced buildings, Chengdu Municipal Waste Sorting Pilot Advanced Building and the first batch of green and low-carbon demonstration units in Chengdu.

As a commercial property, the Chengdu International Technology and Energy Conservation Building integrates asset securitization to not only revitalize its existing assets, but to also meet the long-term fund requirements. Developing asset securitization empowers the building to improve its current operating level and maximize value. The asset securitization approach enables active participation from investors and establishes an effective incentive mechanism, helping high-quality properties and asset managers stand out. It also decentralizes the investment from commercial real estate investors which diversifies risk and promotes the stable development of the industry.

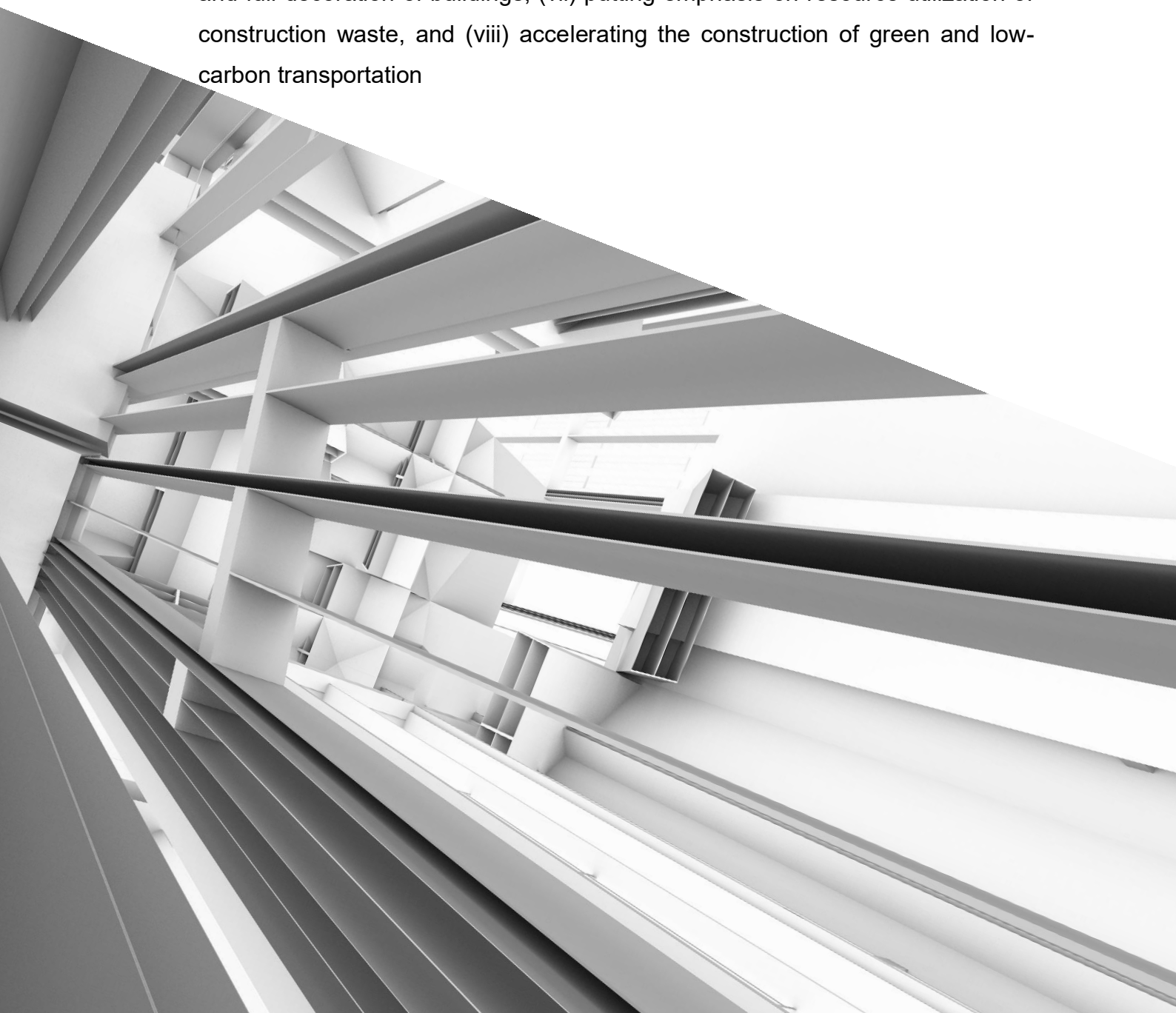
The China Energy Conservation and Environmental Protection Group has prepared for the issuance of asset securitization financing projects since July 2017. Through in-depth cooperation with Harvest Capital, the preliminary

preparations include financing transaction models, financing scales, exchange approval procedures and time nodes for each link of the issuance, providing a desirable financing structure for the development of energy-saving and green construction industries. After evaluation and investigation by various intermediary agencies, including credit rating agencies, real estate appraisal agencies, legal consultants, cash flow forecast agencies and green certification agencies, the project attracted 4 high-quality institutional investors, namely Minsheng Bank, China Merchants Bank, Industrial Bank and Shanghai Pudong Development Bank. After 4 months of preparation, the Group has successfully issued Harvest Capital's special plan for energy-saving green building asset support on the Shenzhen Stock Exchange, realizing the successful issuance of CMBS.

4 Opportunities of Green Building Projects

4.1 Green City Planning and Development

In January 2014, the Chengdu Municipal People's Government issued the "Chengdu Green Building Action Work Plan" (《成都市绿色建筑行动工作方案》). The key tasks were (i) actively participating in the planning and design of green buildings, (ii) carrying out energy-saving renovation of existing buildings, (iii) strengthening the management of energy-saving operations in buildings, (iv) vigorously promoting the application of renewable energy buildings, (v) developing green building materials and green building technologies in accordance with local conditions, (vi) effectively promoting the industrialization and full decoration of buildings, (vii) putting emphasis on resource utilization of construction waste, and (viii) accelerating the construction of green and low-carbon transportation



Technical Requirements for The Development of Green Buildings

Major application	Technical requirement
Land saving and outdoor environment	
Green roof and vertical greening	Three-dimensional greening refers to all greening other than plane greening, such as vertical greening, roof greening, tree enclosure greening, etc. The development of three-dimensional greening enriches the spatial structure and artistic effects of greening, helping to further increase the amount of greenery and reducing the heat island effect. Vacuuming, together with reducing noise and harmful gases, form the general trend of greening developments. Roof greening, especially, refers to the enhancement of the insulation performance of the vegetation on the roof while reducing the air temperature in the surrounding environment and building energy consumption. The green roof should help save rainwater, reduce the pressure on the building's sewerage system, protect the roof structure, reduce noise and filter pollutants.
Reducing the heat island effect	In urban development, the prevalence of paving to open areas and the mass of constructed buildings in place of land creates the "heat island effect". This then results in temperatures in urban areas being higher than those in the surrounding suburbs. In big cities, the average temperature difference can reach 1-3°C (1.8-5.4°F) and as much as 12°C (22°F) on a clear and windless night. Increasing solar reflectance and vegetation coverage in urban areas can reduce temperatures while also lowering air pollution and energy consumption. Long-term living in the heat island center will have varying degrees of impact on human health. Reducing the heat island effect requires increasing heat reflection, increasing green coverage, and reducing emissions and energy consumption.

Major application	Technical requirement
	Mitigation measures: • Increase heat reflection: Reduce the absorption of sunlight-change dark surfaces, black roofs and asphalt road surfaces into "cold" or light-colored surfaces. • Increase canopy coverage: When the coverage rate is greater than 30%, the heat island effect can be effectively weakened. When the coverage rate is greater than 50%, the reduction effect is extremely obvious. Where there is the construction of concentrated green spaces with a scale of more than 3 hectares and a coverage rate of more than 60%, this can effectively eliminate the heat island phenomenon.
Green commuting	As an important part of green development, green commuting has always placed most importance and concern on new energy vehicles. Under the active guidance of policies, the new energy automobile industry in China is developing rapidly. However, the market gap of charging stations is a major factor restricting the purchase of new energy vehicles. Improving the charging infrastructure system is key to the breakthrough development of new energy vehicles. The development of new energy vehicles is an important boost to achieve carbon neutrality goals and green development in China.
Energy saving and energy utilization	
Energy consumption monitor measuring system	Submetering refers to the monitoring of various energy consumption of buildings, such as water, electricity, gas, central heating, and central cooling. This is to ascertain the total energy consumption of the building and the energy consumption of different energy types and functional systems. In order to promote submetering, data collection, data transmission, data storage and data analysis should be undertaken.

Major application	Technical requirement
	The submetering system itself is not energy-saving, but the adaptation of submetering can effectively monitor and manage energy conservation, provide data support and reference for decision-making, as well as prompt relevant buildings to improve their energy-saving operations and management intensity.
Efficient light sources	By adopting high-efficiency light sources and lamps, low-loss ballasts and other energy-saving control measures, energy conservation can be effectively achieved through natural lighting or photoelectric control.
Elevator power recovery system	Generally, an elevator system includes a set of lifting devices, a power machine that supports the lifting devices during the lifting process and a device to balance the weight of the lifting mechanism. Therefore, the balancing device is heavier than an empty or partially loaded lifting device, but lighter than an almost fully or fully loaded lifting device. The difference enables the lifting device, influenced by natural forces, to raise in a partially/completely empty state; or to use this force to lower the device when it is almost fully or fully loaded. By taking advantage of gravitational forces, the lifting device is able to generate electricity. Moreover, today's elevator systems do not generate waste heat load on the building, such as Otis' ReGen. According to Otis estimates, the system can save up to 75% of energy compared to conventional elevator systems. More importantly, the saved energy can then be returned to the building's power grid, providing electricity for the benefit of other machines and equipment in the building.
Water saving and water resource utilization	
Water saving appliances	The application of water-saving appliances can effectively improve water efficiency and reduce water consumption,

Major application	Technical requirement
	especially for projects with high levels of water demand. Taking water-saving sanitary appliances as an example, the consumption rate of water-saving taps are 16.7%, toilets are 44.4%, urinals are 25.0% and showers are 20.0%. The higher the evaluation grades of sanitary appliances, the higher the rates of water-saving performance.
Rainwater collection	Rainwater harvesting is one of the best ways to efficiently use natural rainwater. Collecting rainwater is particularly important in high-density cities where the use of reinforced concrete is very common. In the urban environment, rainwater can be collected, preserved and later used to wash toilets or irrigate vegetation. The collected rainwater can even be used for safe drinking after it is filtered and purified. Rainwater collection systems can be constructed depending on their scale and applied technology. However, all systems have a dual purpose: to store rainwater and ensure that it is utilized in the most effective way. The rainwater collection system has an initial filter that uses sand to filter out dust and dirt. This water can then be used to flush toilets and irrigate plants. To reach drinking water standards, further filtration, purification or treatment is required. The collection system provides even greater advantages when applied to high-rise commercial buildings. Since rainwater is collected and stored at high level, it can efficiently supply other parts of the building through the action of gravity.
Wastewater reuse	In response to the shortage of urban water resources, reclaimed water reuse technology alleviates the water demand and reuses water according to quality. The pre-treatment phase involves mainly physical treatment, while the main treatment process primarily utilizes biological treatment, physicochemical treatment, membrane treatment, etc. Post-

Major application	Technical requirement
	treatment includes mainly filtration and disinfection. Following this cycle, reclaimed water can then be recycled and reused. Recycled water will be mainly used in watering landscape environments, firefighting, greening, roads, cleaning, flushing, building construction, etc.
Material saving and material resource	
Formaldehyde-free building materials	Formaldehyde is a major source of indoor air pollution, which can stimulate skin and mucous membranes and induce harmful effects on health. Artificial boards, paints, and coatings often contain formaldehyde. Therefore, in the selection of building materials for green buildings that are non-toxic, non-polluting, non-radioactive and beneficial to environmental protection and human health, cleaner production technology should be adapted by using less natural resources and energy and integrating large amounts of industrial or urban solid waste material. Green building materials are building materials that have been strictly tested by the national inspection agency and do not release harmful substances such as formaldehyde, benzene, ammonia and radioactivity, and do not produce environmentally polluting wastewater, waste gas, or waste residues during the production process. They are completely low-carbon and environmentally friendly materials that are the ideal choice for the construction of national green buildings.
High-performance concrete	High-performance concrete is a new type of high-tech concrete with high impermeability, volume stability, compressive strength and workability. Due to the good performance and durability of high-performance concrete, its use presents a cost saving of RMB 32-58.8 per square meter compared with the same level of high-strength concrete. If calculated on the basis of saving

Major application	Technical requirement
	RMB 40 per square meter of high-performance concrete, the annual engineering volume of 10 million square meters can save up to RMB 400 million in material costs alone.
High-strength steel	The considered use of high-performance materials is one of the critical building materials saving opportunities. The application of structural materials with good durability and material saving effects should be promoted in green buildings. For example, high-strength steel has obvious advantages in durability and material saving.
Indoor environmental quality	
Indoor air quality management	Indoor air quality mainly focuses on typical pollutants such as formaldehyde, TVOC and benzene series in the air circulating around buildings. Inhalable particulate matter such as PM2.5 and PM10, carbon monoxide in underground parking lots and carbon dioxide in buildings are also managed. In the project operation stage, indoor air quality can be observed through the real-time monitoring of professional instruments. Due to the different sources of the above indicators, simulation analysis needs to be performed separately during the design stage.
Noise control	According to a study conducted by Gensler, 53% of office workers are often distracted by others when trying to concentrate on their work. In an office setting, it is important to completely isolate quiet areas to prevent sound penetration and reduce interference. For glass walls, the minimum thickness should be circa 10 mm, with the use of frosted glass panels increasing privacy. In terms of sound insulation, the office design should incorporate the best sound insulation practices to maintain a quality experience within the office space. Sound intensity is measured in decibels (db). According to the

Major application	Technical requirement
	chosen acoustic design, the ideal decibel level is 35-40 db. The best sound intensity in an office workplace could be achieved by: • Sound absorption • Sound blocking • Soundproof coverings Sound absorption can be achieved by using sound-absorbing materials on surfaces, walls and ceilings and installing office furniture (such as high-back sofas or small workspaces). Sound insulation can be achieved by setting up screens, enclosures and walls between the noise source and the workplace. In an open office, desk enclosures are usually used to block noise from adjacent work stations. Sound coverage (or sound masking) can reduce any echoes by wrapping walls, pillars or any other hard surfaces.
Lighting glare control	The quality of indoor lighting is one of the most important factors affecting the quality of the indoor environment. Good lighting is not only conducive to improving people's work and learning efficiency, but also beneficial to people's physical and mental health, in addition to reducing various occupational diseases. Good and comfortable lighting requires an appropriate level of illuminance on the reference plane, the avoidance of glare and the use of proper color rendering. Convergent indoor light sources will produce uneven brightness levels in the field of view. The resulting glare can cause visual fatigue, visual impairment and even injury, and can lead to direct or reflected glare.
Preventive maintenance of mold and	Humidity creates favorable conditions for mold to grow, which greatly increases the risk of respiratory diseases for building users. Infiltration, condensation and internal leakage of water

Major application	Technical requirement
Legionella in buildings	into buildings risk the development of bacteria and mold growth and therefore should be monitored and managed. Legionella can multiply in circulating water systems, especially in buildings that have been vacant for a period of time. The disease caused by Legionella has a great impact on people with weaker immune functions, smokers and people over 50 years old. Implementing a control plan to prevent Legionella breeding can reduce the risk of exposure to pathogenic bacteria.
Operation management	
Green cleaning	Green cleaning refers to cleaning that promotes physical health without damaging the environment. Green cleaning is put in place to help owners and property managers create an indoor environment that is conducive to human activities. Green cleaning includes choosing the right cleaning agents, sanitary paper, tools and equipment; understanding how products can reduce the impact on cleaning staff, property users and the environment; implementing processes that reduce the negative impact of the cleaning process to users and cleaning staff; implementing a responsibility system for property users in places where green cleaning is used; providing training for those using green cleaning products; and finally establishing a feedback system with property users, cleaning staff and visitors.
Smart IoT facility management	"Internet of Things" uses IEEE 802.15.4 wireless connection technology, cloud technology and applications to streamline real-time information equipment and data. The control system of the office space transmits real-time information and data to its property owners, managers and/or employees. Current building facilities generate, summarize and analyze data by using the IoT management software, which allows a better

Major application	Technical requirement
	understanding of operators and users in terms of the management efficiency of these spaces, including the performance of energy consumption. Building control solutions aim to operate the building facilities in a smarter way and thereby improve efficiencies in energy consumption and cost reduction. There is no doubt that in the foreseeable future, the combination of mobile devices, cloud technology, software, building sensors and wireless networks will ensure the spread of the "Internet of Things" in the commercial real estate sector.
Face recognition system	Face recognition is being adopted by many smart cities and smart buildings due to its natural, non-mandatory, non-contact, concurrency and resistance to being copied. Face recognition technology is used in commercial building access control, attendance and visitor management to realize the intelligent monitoring and management of buildings. In the emerging information security application field, face recognition technology can be easily and closely integrated with traditional security technology, which greatly improves the intelligence, security and ease of use of the original systems. It also expands the application field and promotes the technological upgrading of traditional industries.

4.2 Future Prospects of The Development of Green Buildings

There are two important directions for the future development of green building technology, those being health and intelligence.

4.2.1 Health

The outbreak of COVID-19 in China has been an unprecedented event. Its influence has spread all over the country, extensively affecting the society, economy and real estate market. We expect that the spread of COVID-19 will

continue to affect China's commercial real estate market in a multitude of ways.

The outbreak of the epidemic has reshaped people's concepts of health and sustainable development. In the post-epidemic era, the enhancement of health and well-being of people in buildings and the advocation of a green lifestyle will become increasingly necessary for developers and enterprises to adopt.

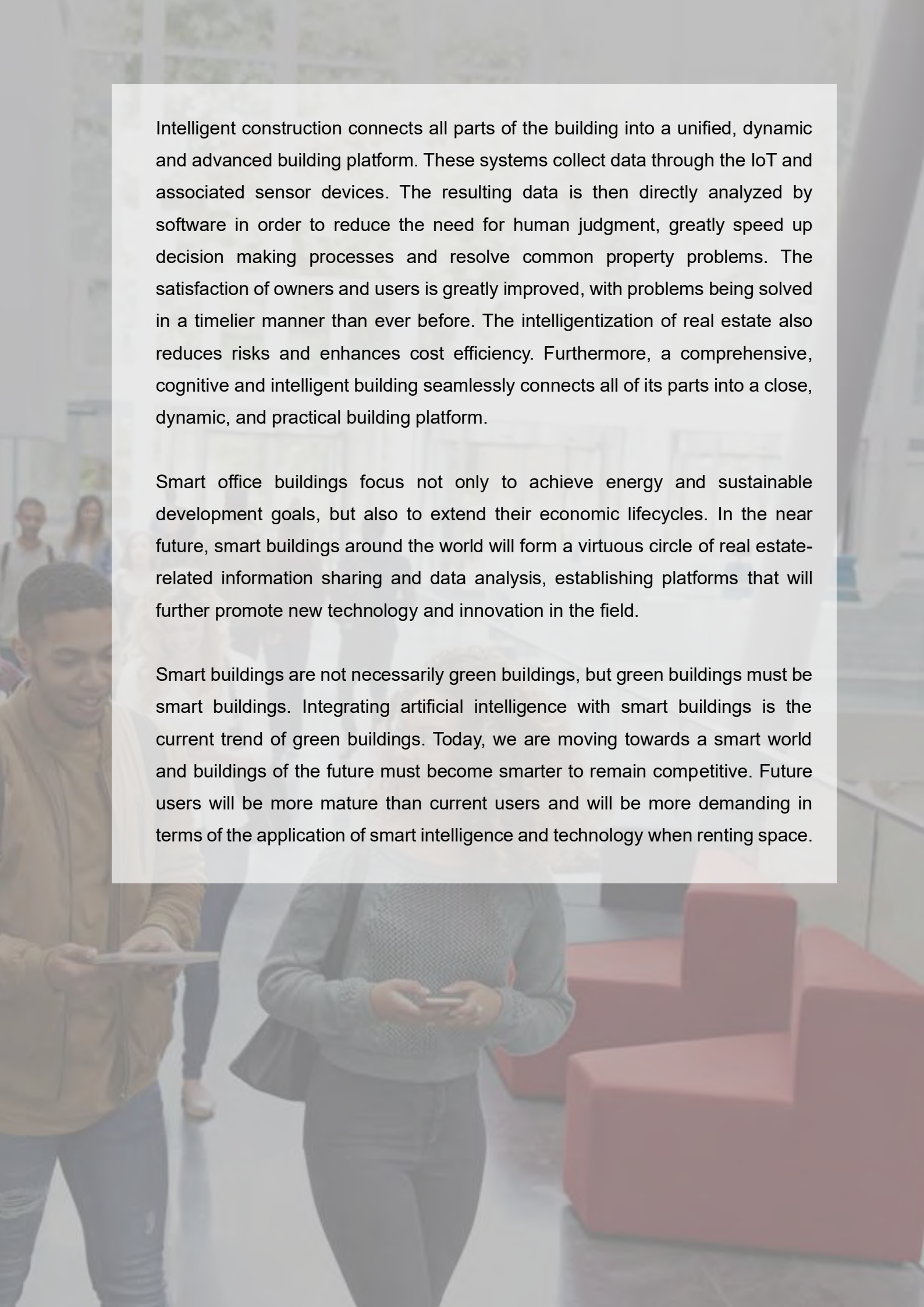
When we consider green commercial buildings and spaces, the health and well-being of users are often the primary focus, which green certified commercial buildings or spaces will continue to safeguard. Through improvement in ventilation, enhancement in natural lighting, elimination of polluting sources and the application of outdoor landscape design, green commercial buildings can help improve users' health, satisfaction and productivity and, over time, reduce employees' sick leave and absenteeism, which is undoubtedly favorable for companies that want to attract and retain employees.

4.2.2 Intelligence

The future development of smart cities is inevitable in a world that advocates urbanization and the growing economic significance of many Chinese cities. The application of technology is becoming more common while resources are becoming increasingly scarce. With the successful development of smart cities, quality of life will be improved, city services will be promoted, cost and resource consumption will be reduced and communication between citizens and the government will be enhanced.

Smart city developments will continue to be construction focus in China. New commercial real estate technologies will make cities smarter through different channels by enhancing efficiency, elevating asset value and improving sustainability.

As the built environment largely determines urban structures, the application of the latest technology promotes the shift to smart real estate and improves the efficiency of property use, asset value and environmental sustainability.



Intelligent construction connects all parts of the building into a unified, dynamic and advanced building platform. These systems collect data through the IoT and associated sensor devices. The resulting data is then directly analyzed by software in order to reduce the need for human judgment, greatly speed up decision making processes and resolve common property problems. The satisfaction of owners and users is greatly improved, with problems being solved in a timelier manner than ever before. The intelligentization of real estate also reduces risks and enhances cost efficiency. Furthermore, a comprehensive, cognitive and intelligent building seamlessly connects all of its parts into a close, dynamic, and practical building platform.

Smart office buildings focus not only to achieve energy and sustainable development goals, but also to extend their economic lifecycles. In the near future, smart buildings around the world will form a virtuous circle of real estate-related information sharing and data analysis, establishing platforms that will further promote new technology and innovation in the field.

Smart buildings are not necessarily green buildings, but green buildings must be smart buildings. Integrating artificial intelligence with smart buildings is the current trend of green buildings. Today, we are moving towards a smart world and buildings of the future must become smarter to remain competitive. Future users will be more mature than current users and will be more demanding in terms of the application of smart intelligence and technology when renting space.

5 Conclusion

It has been more than half a century since the concept of a green building was first proposed. With the development of the society and the improvement of people's living standards, the definition of a green building is constantly changing. It began with a vision of pure green development, before later expanding to cover further topics, such as energy saving and environmental protection, people’s quality of living and health, intelligence and the idea of co-sharing. The definition of a green building has been rapidly evolving and in turn, so has their function. These changes encourage people to explore and enhance the development of green buildings; optimizing user experience, enhancing economic value, promoting rational use of resources, and creating environmental benefits in building development.

This research paper has provided an introduction to the green city development in Chengdu, evaluated prominent case studies associated with green building development, illustrated the development of green building technology and green finance, summarized the technical requirements of various aspects of green buildings, and finally, looked forward to the development trend of green buildings in the future. From many practical cases, we can conclude that the development of green buildings has important social, commercial and sustainable values. A comprehensive green building development will add value in different ways, bringing benefits not only to property owners, but also users and the entire society. The six most critical value-added points are: (i) Improving health and happiness; (ii) Improving user efficiency; (iii) Reducing costs; (iv) Enhancing environmental sustainability; (v) Attracting and retaining talents; and (vi) Improving brand image.

With the future showing an increasing shift towards green city development, commercial real estate in Chengdu will need to become greener, healthier and smarter to ensure its long-lasting competitiveness. Over time, user needs will inevitably become more complex, creating an accelerating requirement for green buildings in commercial real estate.

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