China Mainland
中国大陆

ARUP

ULI BEIJING NET ZERO IMPERATIVE

Developing a Long-Term Strategy for Achieving a Net Zero Carbon CBD

SOURCE: LIU Yan

Technical Assistance Panel Report | July/August 2022

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About the Urban Land Institute

The Urban Land Institute is a global, member-driven organization comprising more than 45,000 real estate and urban development professionals dedicated to advancing the Institute's mission of shaping the future of the built environment for transformative impact in communities worldwide. ULI's interdisciplinary membership represents all aspects of the industry, including developers, property owners, investors, architects, urban planners, public officials, real estate brokers, appraisers, attorneys, engineers, financiers, and academics. Established in 1936, the Institute has a presence in the Americas, Europe, and Asia Pacific region, with members in 81 countries. ULI's extraordinary impact on land use decision-making is based on its members' sharing expertise on a variety of factors affecting the built environment, including urbanization, demographic and population changes, new economic drivers, technology advancements, and environmental concerns. Peer-to-peer learning is achieved through the knowledge shared by members at thousands of convenings each year that reinforce ULI's position as a global authority on land use and real estate. Drawing on its members' work, the Institute recognizes and shares best practices in urban design and development for the benefit of communities around the globe.

More information is available at uli.org. Follow ULI on Twitter, Facebook, LinkedIn, and Instagram.

About ULI Beijing

As the preeminent, multidisciplinary real estate forum, ULI facilitates the open exchange of ideas, information, and experience among local, national, and international industry leaders and policymakers dedicated to creating better places. ULI Beijing started in 2019, our membership grow rapidly from less thirty to over hunred now. The premier task for ULI council in Beijing is to build up collaboration relationship with the government and recruite more members from local enterprises. As the capital of China, it is our privilege to access to local think tanks, experts and scholars, benchmarking companies, design institutes and technology organizations, who have influences on decision making process in the central and municipal government. Based on researches on the international cases and other local project experience, as well as various aspects of urban development expertise, the research will result in a system of indicators for dual carbon planning that will be consistent with relevant strategies and technology, responsible parties and implementation requirements. This will help governments and other stockholders in China to identify carbon peaks, carbon-neutral targets and the best ways to achieve them.

ULI Advisory Services: National and Global Programs

Since 1947, the ULI Advisory Services program has assembled well over 700 ULI-member teams to help sponsors find creative, practical solutions for complex land use challenges. A wide variety of public, private, and nonprofit organizations have contracted for ULI's advisory services. National and international panelists are specifically recruited to form a panel of independent and objective volunteer ULI member experts with the skills needed to address the identified land use challenge. The program is designed to help break through obstacles, jump-start conversations, and solve tough challenges that need an outside, independent perspective. Three- and five-day engagements are offered to ensure thorough consideration of relevant topics.

An additional national offering is the project analysis session (PAS) offered at ULI's Fall and Spring Meetings, through which specific land use challenges are evaluated by a panel of volunteer experts selected from ULI's membership. This is a conversational format that lends itself to an open exchange of ideas among diverse industry practitioners with distinct points of view. From the streamlined two-hour session to the "deeper dive" eight-hour session, this intimate conversational format encourages creative thinking and problem solving.

Learn more at americas.uli.org/programs/advisory-services.

ULI Advisory Services identify creative, practical solutions for complex land use and development challenges.

Technical Assistance Program (TAP)

Urban Land Institute harnesses its members' technical expertise to help communities solve complex land use, development, and redevelopment challenges. Technical Assistance Panels (TAPs) provide expert, multidisciplinary, unbiased advice to local governments, public agencies, and nonprofit organizations facing complex land use and real estate issues in Beijing. Drawing from its professional membership base, ULI Beijing offers objective and responsible guidance on various land use and real estate issues ranging from site-specific projects to public policy questions. The sponsoring organization is responsible for gathering the background information necessary to understand the project and present it to the panel. TAP panelists spend two days interviewing stakeholders, evaluating the challenges, and ultimately arriving at a set of recommendations that the sponsoring organization can use to guide development going forward.

The Net Zero Imperative

Thanks to a generous gift from Owen Thomas, ULI has launched the Net Zero Imperative – a multi-year initiative to accelerate decarbonization in the built environment. Additional gifts from Lynn Thurber, Joe Azrack, Franz Colloredo-Mansfeld, and Dan Cashdan further support and bolster the NZI program's scale and impact. Work to advance the initiative includes technical assistance panels in five global cities each year, designed to help developers, building owners, cities, and other relevant constituents reduce carbon emissions associated with buildings, communities, and cities. The fundamental goal of the effort is to provide concrete ideas and strategies to real estate owners, public sector leaders, and the general public to eliminate carbon emissions from the built environment to reach net zero. Through its work, the initiative will create global resources (research, toolkits, and other tools) to help all ULI members accelerate decarbonization in their real estate operations and in their cities.

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CONTENTS

INTRODUCTION	7
About the ULI NZI Programme	8
Beijing CBD NZI Study Scope	8
About Beijing CBD	11
Regulatory Background	11
National level Policies	12
PANEL RECOMMENDATIONS	15
Calculate a Baseline	15
Collect Data	15
Set Carbon Emission Goals	17
Create Digital Platforms to Manage Data and Inform GHG Reduction Strategies	19
Implement Energy Efficient Technology	19
Embodied Carbon	22
Regulation	22
Green Finance	24
Capacity Building	26
Monitoring, certification, and disclosure	28
Building a net zero-carbon ecosystem	28
Transportation	28
URBAN LAND INSTITUTE RESOURCES	30

INTRODUCTION

About the ULI NZI Programme

Over the past five years, nearly every country has committed to achieving Paris Climate Agreement targets. So far, however, while many cities have introduced climate action plans aiming to decarbonise their built environment, few have made meaningful progress in significantly reducing greenhouse gas (GHG) emissions. With this in mind, in July 2021, ULI launched the global Net Zero Imperative (NZI), an initiative to help accelerate market transformation toward a net zero built environment, defined as buildings that are highly efficient and fully powered by on-site and/or off-site renewable energy sources.

The NZI has a global focus and includes the following key components:

- Organising ULI Technical Assistance Panels (TAPs) in various global cities to help develop a "roadmap to decarbonisation" for both public and private sector entities.
- Running on-the-ground campaigns in each of those cities to accelerate decarbonisation of the built environment.
- Building a global group that can receive technical assistance on an ongoing basis to refine on-the-ground net-zero initiatives and work together to share best practices and lessons learned.
- Creating global resources (research, toolkits, and other guidance) to help ULI members accelerate decarbonisation in their real estate operations and their cities.

More information is available here: https://ULI.org/netzeroimperative.

At this time, ULI TAPs have been organised in the following cities:

- Austin, Texas
- Beijing, China
- Kansas City, Missouri
- Los Angeles, California
- Minneapolis, Minnesota
- San Jose, California
- Shenzhen, China
- Toronto, Canada

Beijing CBD NZI Study Scope

This TAP focuses on Beijing's Chaoyang CBD. The objective is to work with the Beijing CBD Administration Committee to develop a long-term strategy for more effective engagement of stakeholders so the district can become net zero carbon, To this end, the CBD Administration Committee is currently working to create a low-carbon development goal for the CBD district. In doing so, it is looking to study international best practice for developing new buildings and also retrofitting old buildings to modern standards of energy efficiency and carbon neutrality. The Beijing CBD Administration Committee recently initiated a work plan listing some key actions to take to decarbonize the district.

The TAP process in this instance consisted of one in-person session in Beijing involving Beijing CBD Administration Committee officials and ULI panellists drawn from a variety of locally-based private sector and research organisations, a further full-day virtual session featuring the same individuals, and finally another virtual session involving panelists drawn from the USA and internationally (see page ---- for a listing of panel members). This report summarises the TAP discussions and various proposed long-term strategies for the CBD to achieve a net zero carbon environment.

22nd April 2022, Local Technical Assistance Panel

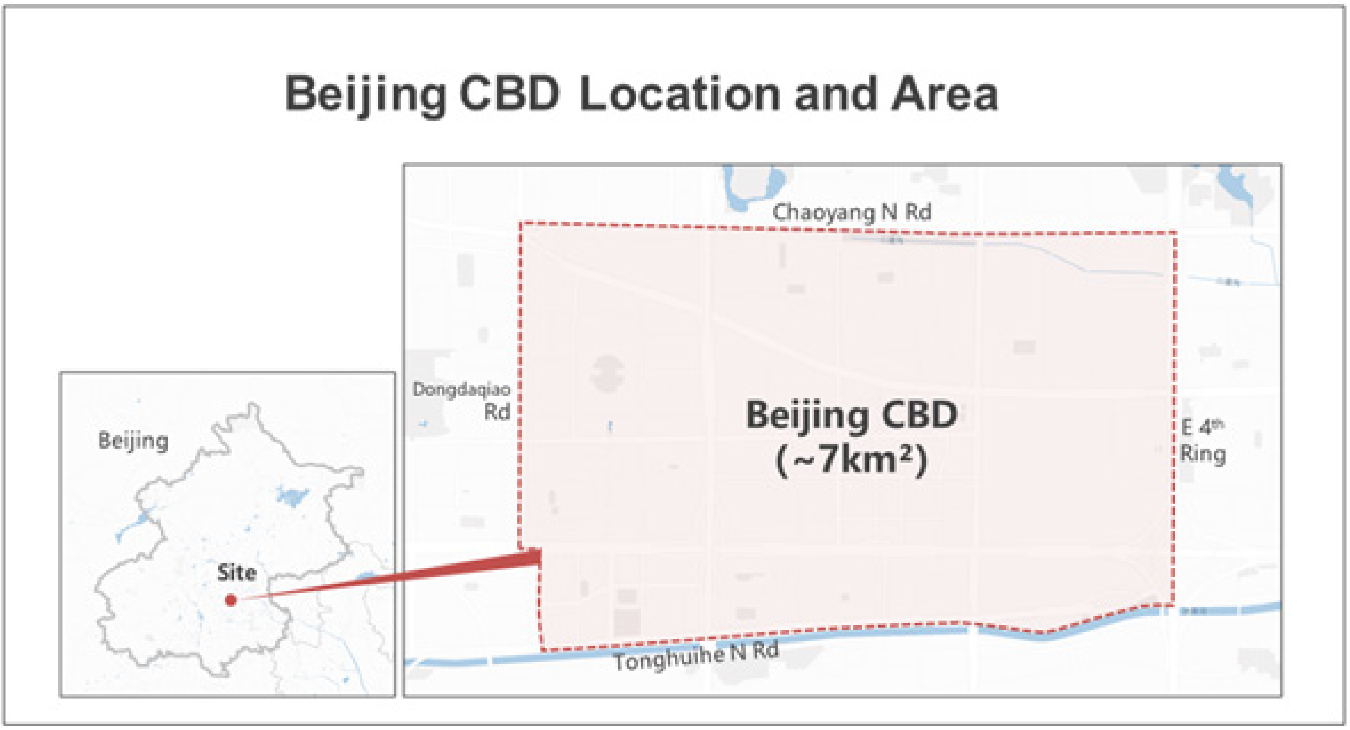
8th April 2022, "Swire Properties Carbon Reduction Strategies and Taikoo Li Sanlitun Air Conditioning Retrofit" Project Experience Sharing

8th April 2022, "Swire Properties Carbon Reduction Strategies and Taikoo Li Sanlitun Air Conditioning Retrofit" Project Tour

Questions for the Panels:

1. What is the best way to cost-effectively retrofit existing buildings in the CBD to make them net zero carbon?
2. What can the CBD do to lower its carbon footprint as fast as possible? What policies, incentives, programmes, and regulations will accelerate the rate of existing building retrofits to improve energy efficiency?
3. How best can the CBD leverage data collection and analysis as a means to accelerate the transition to net zero?
4. What green financing mechanisms should the CBD consider to improve the business case and accelerate the CBD decarbonisation process?

SOURCE: LIU Yan



SOURCE: Arup

About Beijing CBD

The Beijing CBD is in Chaoyang District. It is one of the fastest growing business hubs in the world, with construction beginning in 2000, following approval of the Beijing City Masterplan in 1993. The original 300-hectare site is located on the east side of the city between the 3rd and 4th Ring Roads, and has now been extended by an approximately 400-hectare eastward expansion that is currently under large-scale development. Most stock is therefore relatively new and of a higher standard than is found in most other Chinese CBDs.

Chaoyang is characterised by around 149 high-rise, energy-intensive towers, and is densely populated with more than 500,000 workers. Featuring many embassies, international organizations, chambers of commerce, international media, and other resources, the CBD hosts more than 4,000 foreign-invested enterprises and is the regional headquarters of 105 multinational companies.

Regulatory Background

China has been working to create a framework to reduce carbon intensity in buildings for at least two decades. In line with national and local regulations introduced over that time, the Beijing CBD has worked to reduce carbon intensity on both a district-wide and a single-building basis. Planning guidelines for the core area require each block to meet specified green building standards, and the district offers incentives for building owners to achieve green building certifications.

As a result, since 2008, all new CBD projects have applied for either domestic or international green building certification, and more than 85 percent of buildings in the CBD core area are currently LEED (Leadership in Energy and Environmental Design) certified. In December 2016, the Beijing CBD core area was awarded LEED for Neighbourhood Development Gold Level certification. In addition, the rate of green transport modes in the district is greater than 75 percent, with the CBD now a pilot zone for green transportation in the city.

That said, the carbon intensity of Chinese buildings remains high, with operational energy consumption standing at approximately 51 percent of total countrywide emissions, compared with an equivalent 35-40 percent throughout the rest of the world, according to figures published by the Lawrence Berkeley National Laboratory China Research Programme.

Given that ongoing urbanisation will continue to generate high demand for new buildings to house incoming workers, China faces both a problem and an opportunity. On the one hand, with total building floorspace likely to rise by around 40 percent to nearly 90 billion square metres between now and 2060, according to International Energy Agency (IEA) estimates, the total volume of carbon emissions from new buildings in China will continue to rise. On the other hand, given potentially long building lifespans, there is a window of opportunity for wholesale adoption of energy-efficient technologies at the development stage, when carbon remediation measures are both easier and cheaper to implement.

National level Policies

In recent years, the government has introduced increasingly strict regulations concerning carbon efficiency in buildings, including in particular:

- The **National Standard for Building Carbon Emission Calculation** ("National Standard") [GB/T51366-2019]
- The **Technical Standard for Nearly-zero Energy Buildings** ("Technical Standard") [GB/T51350-2019]
- The **Design Standard for Energy Efficiency of Public Buildings** [GB/50189-2015]
- The **General Code for Efficiency and Renewable Energy Application in Buildings** [GB/55015-2021]
- The **General Code in Building Environment** [GB55016-2021]
- The **General Code for Design of Building Water Supply and Drainage and Water Saving** [GB55020-2021]

In particular, the first two (ie, the National Standard and the Technical Standard) provide a foundation for formulating more specific carbon emission standards across buildings' lifecycles through the period to 2060.

In addition, China's 14th Five-Year plan (2021-2025) requires that:

- Building emissions should peak immediately and decline by around 90% by 2050 relative to 2015.
- Around 75% of building energy use be supplied by electricity by 2050.
- Most district heating systems in northern urban China be decarbonized by 2050.
- Embodied energy in buildings be reduced by extending building lifetimes through retrofits and/or use of higher-quality building materials.

Most recently, in a speech to the UN General Assembly on September 22, 2020, President Xi Jinping announced that China would aim to reach peak emissions before 2030 and achieve carbon neutrality by 2060. These ambitious goals are now driving a new round of regulatory and policy initiatives at both national and local levels.

Current Beijing City-level Policies

On a local level, the city of Beijing is actively planning for carbon neutrality. As a first step, city carbon emissions are targeted to fall to 50 percent of peak 2020 levels by 2035 as a result of slower economic growth, greater energy efficiency, and higher use of renewable energy resources. The second step is a long-term goal to build a near zero-carbon emission city.

November 2021, the Beijing municipal government issued the "14th Five-Year Ecological Environmental Protection Plan", running from 2021-2025. Among other things, the Plan aims to:

- Stabilise and then reduce carbon emissions by more than 10% from their peak levels (which are not defined) by 2025.

Source: Li Wentao Architecture Photography

Taikang Headquarters Building_Beijing

- Reduce carbon emissions per unit of GDP by about 18% from 2020 levels by 2025, and
- Increase renewable energy consumption as a proportion of the whole by at least 14% by 2025.

Historically, city governments in China have relied on providing subsidies to encourage developers to improve energy efficiency in their projects. In particular, Beijing has issued subsidies of up to Rmb8 million, and the Chaoyang District subsidies of up to Rmb5 million, for buildings that achieve local gold and platinum level Green Label certifications. For LEED projects, subsidies of up to Rmb2 million are provided. This is why so many commercial buildings in the CBD area apply for green label certification.

In addition, the Chaoyang District provides:

- A subsidy of up to 30 percent of total investment in new renewable energy projects
- A one-time subsidy of Rmb1,000 per kilowatt for disributed photovoltaic power generation projects
- A subsidy of up to 20 percent of total investment in energy storage technology projects

More recently, other local governments in China have begun taking more proactive steps to incentivise and compel carbon efficiency in buildings. The municipal government in Shenzhen, for example, has introduced new rules (the Regulations on Green Buildings), effective from 1st July 2022, that will introduce a stricter regulatory environment covering the entire building life cycle, applying to both developers and owners. In particular:

- New buildings in Shenzhen (over a specified size) must now meet a minimum 1-star rating under China's Green Building Evaluation standard – a level equivalent to LEED silver and stricter than otherwise required in Guangdong province or elsewhere in China. For new public buildings, an even higher 2-star standard has been set. Retrofits, meanwhile, are encouraged to meet the 1-star standard, although this is not a mandatory requirement.

- For planning and construction purposes, architects must submit design specifications to authorities in advance to demonstrate they will meet the 1-star standard. An inspection is required before completion to ensure buildings are in compliance.
- Operations and maintenance are also subject to monitoring. Residential units will be sold under contracts that specify the building's green rating, providing owners with legal recourse should the building fail to perform as indicated. Green buildings are also subject to random post-occupancy inspections by officials to ensure they meet operational performance standards. Building management companies will therefore have to learn how to operate and manange in accordance with the designated standards.
- Buildings will be subject to a baseline energy consumption standard (which has yet to be set). The rule will apply at first only to public buildings. Energy performance data will have to be submitted to a government platform and performance will be checked automatically. Buildings that fail to meet the baseline standard for a two-year period will be subject to fines set at punitive levels. Indoor air quality standards will also be set on a similar basis.
- Developers who meet high environmental standards will enjoy incentives in the form of GFA concessions, similar to a system already in place in Hong Kong. In particular, these concessions will be available for buildings that adopt high standards of insulation and shading and prefabricated façade components. In addition, buyers of residential units with 2- and 3-star ratings will be able to obtain mortgages for a higher-than-normal percentage of their purchase prices.

SOURCE: LIU Yan

PANEL RECOMMENDATIONS

Calculate a Baseline

As a starting point, the CBD should establish a carbon emissions baseline for the district's energy consumption and GHG emissions. This baseline should be compiled over a three-year period by reference to various sources of emissions, including buildings, transportation, and municipal infrastructure. By quantifying its carbon emissions, the CBD can then create a feasible carbon emissions model and reduction strategy whose progress can be tracked over time. In addition, it can help it participate more effectively in China's carbon trading market.

In 2017, the CBD Administration Committee took the lead in organizing an energy audit for a dozen buildings, providing a reference for energy diagnosis and energy-saving technology improvement. This provides a template for creating a carbon baseline on a district-wide basis.

Establishing a carbon baseline is important not only to help the CBD understand its GHG emissions, but also to provide data level guidance for future development planning and across the entire life cycle of existing assets. Only by knowing how much carbon dioxide the district emits, together with the sources of emissions, can we work out a corresponding emission reduction plan, and calculate "carbon peak" and "carbon neutral" levels.

Collect Data

For the CBD to calculate a baseline and then set verifiable net zero emissions goals, the need for accurate and adequate data is vital. Utility bills and energy audits can be used as a starting point, with individual buildings required (via incentives and penalties) to adopt appropriate data collection and management systems. Audits should not be restricted to just buildings, but should apply to the entire CBD area, given that buildings account for just 60 percent of the emissions total.

Data collection at building level

In the early stage of energy audit work, members of the international TAP suggested that all buildings over 50,000 sq feet (ie, 4,645 square metres) should complete an energy audit by the end of 2023. In Hong Kong, for example, regulations currently require all assets of more than 5,000 square metres to undergo such an audit, with verification by an independent third party. Other buildings in the CBD area should complete audits as soon as practicable, recognising that priority should be given to the largest and most energy-intensive buildings.

At the beginning, data does not have to be perfect. In the West, there has been a tendency to collect as much data as possible simply because data collection platforms allow it. However, as one international panelist observed: "It starts to get expensive and time consuming to roll out, so I always emphasize: "what can we do with 20 percent of the data to achieve 80 percent of our desired outcomes?"" A reasonable starting point would be an ASHRAE [American Society of Heating, refrigerating, and Air-Conditioning Engineers] Level 1 audit, with more complex and energy-intensive buildings pursuing an ASHRAE level 2 audit [for the standard currently used by LEED see here:

Once quality data is obtained emissions targets can be set, starting with larger buildings, in alignment with the 1-degree or 1.5-degree goal. In any event, the importance of an extensive and accurate dataset for individual buildings cannot be overstated – it is the starting point to create a baseline from which a reduction pathway can be calculated, with simple and

Source: HGEsch

CITIC Tower, Beijing CBD

clear targets to follow. For example, if a program is specified to start in 2025 or 2027, building owners will be able to respond, budget, and price leases that will then reinforce compliance with the specified targets. The process can be led by government buildings, followed by the private sector perhaps two years later.

After that, the CBD can work to ensure quality data is being collected that allows for adequate data analysis and progress tracking. Targets should be laid out in a standard unit of measurement such as GHG goal per square metre. A mechanism for ensuring certainty around regulation for developers' varying capital cycles also needs to be considered.

A data collection management system can be established for the Beijing CBD Administration Committee to improve efficiency. Reference can be made to the data collection management systems in San Francisco, Los Angeles, etc. in the USA, which have passed Building Energy Ordinances that require building owners to submit data. As an example, the State of Colorado has introduced a Building Energy Performance Standard specifying a set level of energy use per building type and area. Many cities in the US use the ENERGY STAR programme to benchmark buildings' relative energy and GHG intensity, normalised for factors such as occupancy and building use types, to help set aggressive yet reasonable goals based on building size, use type, density of occupancy, and other factors.

In addition, in US cities such as San Francisco, use of a Building Energy Ordinance that requires reporting is combined with a compliance mechanism that imposes fines for noncompliant assets. This has led to higher compliance rates and improved data acquisition. By contrast, cities such as Los Angeles and Austin, which lack enforcement mechanisms, have seen below-average compliance and data coverage in certain asset types.

All building operational carbon emission data, including electricity, natural gas, heating energy, and other types of fuel on site should be collected.

Data collection at district level

Obtaining relevant data can be a problem because it is usually owned by people (such as building tenants) who are not qualified to act on it, rather than long-term building owners who must increasingly report on building emissions to investors and global entities and are therefore motivated to use it in a more productive manner.

One way to bypass this problem, however, is for the government to require utilities (who typically possess comprehensive datasets) to provide data on electricity and other resource consumption directly to the government. Authorities can then decide to make it available however they see fit, including allowing access to building data on an aggregated basis. Although data privacy issues are a concern, utilities in the West have adopted different thresholds for approaching this issue. Some require a minimum of three different tenants in a building, or possibly two plus the owner. In addition, green leasing practices can be established that encourage landlords to provide data and work together to reduce emissions.

In any event, carbon emission thresholds must be defined, together with a standard to verify carbon emission sources and the statistical calibre used to calculate GHG emissions. Carbon emissions data from the following sectors will then be collected for evaluation:

- Buildings — this should include the gross floor area of different types of buildings, the energy usage intensity or energy consumption data, and the energy saving measures adopted.
- Transportation — this should include the district population, daily trips, modal split (including green transit rate), number of parking spaces and vehicles, amount of electricity used, number of bicycle facilities, and the number of pedestrian-friendly streets.
- Municipal infrastructure — this should include water demand and supply, waste water discharge and treatment, waste generation and disposal, streetlights, exterior wall lighting, lighting facilities in open spaces.
- Eco-space — this should include the area of green space in the district, the plantation rate, the rate of local species, and the types of plants. Depending on how the city draws its operational boundaries in calculating its net zero goal, these eco-spaces could help offset some emissions from the buildings and transport sectors through the correct cultivation of carbon sinks (ie, wetlands and fast-growing building materials such as cork and bamboo).

Set Carbon Emission Goals

Although the Beijing government already provides financial and other incentives for building owners to obtain LEED or equivalent certifications, compliance is either voluntary or set at levels too low to meet levels of carbon emission reductions that have been set by the central government. In order to ensure compliance with current net zero carbon policies, therefore, a set of standardised targets, imposed and enforced by the city government, is necessary.

In calculating these low-carbon goals, the carbon peak and carbon neutral policies at national, city, and district levels should be considered, together with the provisions of the city's 14th Five-Year Plan, the emission reduction policies of city administrative departments, energy structure, industry innovation drivers, etc. The key lies in establishing a series of quantitative sub-targets covering all essential sectors of the district. The building energy-saving target, for example, should be set based on the mid-level for each building type in the CBD, based on an annual energy audit.

Goals should time-limited and set for both individual assets and the CBD as a whole. The most obvious one is to reduce energy consumption for individual buildings. In the West, most cities set goals based on GHG intensity per square metre, requiring all buildings above a certain size to meet a GHG intensity goal by a certain date. Every five years, these GHG intensity goals become stricter, until all buildings reach net zero emissions by a target date. Cities vary as to which buildings are included or excluded from these targets, and whether or not buildings can count renewable energy or offsets towards meeting these goals. Some cities even allow buildings that exceed their goals to sell credits to those who fail to meet them (similar to a cap-and-trade program for carbon emissions at the market level).

In setting these emissions targets, we believe use of the internationally-recognised Science-Based Target initiative (SBTi) – a GHG reduction standard managed by the World Wildlife Foundation, World Resources Institute, the UN, and the CPD – is the best way to set targets for a decarbonisation roadmap.

At the same time, however, international experience suggests that the SBTi is probably more detailed than needed to establish a good climate action plan. In addition, the expert team assembled by the Science Based Target Initiative to validate SBTi goals is currently overworked and backlogged with applications.

As currently available Beijing CBD data may anyway be insufficient to achieve SBTi validation at this time, an alternative approach would be to estimate goals and set a timeframe to achieve zero-carbon levels according to international, national and Beijing policy criteria. Goals should be set at a level that is reasonably achievable in the context of the local capital cycle. Short-term, mid-term and long-term goals should be set, with a longer-term ambition of joining the SBTi framework when appropriate.

Goals should be standardised and calculated by reference to different asset types, energy consumption levels, and low-carbon development requirements. Standards should be set for both existing buildings (e.g., with carbon efficiency targets for 2025, 2030, and 2050) and newly-constructed buildings (e.g., targets for net zero new construction by 2030 and net zero – including embodied carbon – by 2050). In addition, goals should be set for:

- Energy supply (eg, greater use of renewable energy or clean grid-sourced energy)
- The transportation sector
- Municipal infrastructure (eg, upgrading bicycle lanes and parking facilities, introducing smart waste sorting systems, installing solar paving in public spaces)

The roadmap can be supplemented by carbon emission models quantitative targets, implementation strategies, management suggestions, etc.

Climate action plans and regulations in some leading cities (including New York, Washington DC, Toronto, and London) have been more proactive, publishing aggregate whole building data for every building in the CBD, as well as confirming whether those buildings comply with current GHG reduction targets. In addition, while building owners with access to energy consumption and emissions data can self-report, the CBD or a government entity can also require the local utility to report on energy consumption and GHG emissions on the buildings' behalf on an annual basis.

Buildings that exceed GHG reduction goals for a given time period should be recognized for their climate leadership, and may be good candidates for project profiles to share best practices in GHG reduction across the CBD. Buildings that do not meet GHG reduction targets should be given the opportunity to follow a prescriptive pathway of energy efficiency upgrades, supported if possible by low-cost loans for the installation of energy efficient mechanical systems, lighting, and building envelope upgrades.

Buildings that cannot cost-effectively meet GHG reduction targets would ultimately have to pay a fine for non-compliance that could be reinvested in a fund for energy efficiency upgrades, renewable energy development, or the purchase of carbon offsets.

Create Digital Platforms to Manage Data and Inform GHG Reduction Strategies

A centralised digital management platform can be used to manage and analyse operational performance of the entire district, together with distributed digital management platforms for individual buildings or portfolios of buildings. The centralised platform can be built in phases as more developers and building owners join over time. Functionally, it should be divided into 'management' and 'service' components. Digital platforms can be used for:

1. Data collection, sorting, and visualisation, especially for energy consumption and greenhouse gas emissions.
2. Benchmarking. The US Environmental Protection Agency's "ENERGY STAR Portfolio Manager", for example, allows CBDs to compare buildings based on GFA, age, number of floors, and type of occupancy.

Over time, a digital twin of the entire CBD can be created to test the most cost-effective strategies for optimising energy and greenhouse gas performance treatments.

In creating this platform, it is important to involve all stakeholders. Engagement is crucial to compile good ideas and establish a holistic and equitable pathway to decarbonisation.

Implement Energy Efficient Technology

Retrofitting the CBD can be implemented at both building and district levels, adopting internationally accepted energy-saving standards. In the West, most building portfolios would adopt the following strategies for achieving net zero over time:

- Start with no-cost strategies, including facility management and tenant engagement – the aim should be work to minimise energy consumption, especially in unused areas, and to only heat, cool,

Source: Arup

Neuron Building Management Software

light, and ventilate spaces when they are actively occupied.

- Implement cost-effective retrofits that offer a quick payback, including upgrades to LED lighting, optimising performance of your current mechanical equipment (eg, through variable speed drives for HVAC and sealing building envelope leaks) (see annexed case study: "Taikoo Li Sanlitun Air Conditioning Retrofit").
- Require older buildings to comply with Stretch Energy Code (ie, based on the International Energy Conservation Code (IECC)) by the end of the useful life of their equipment. Within the following 10 years, require major upgrades to building heating, cooling, lighting, ventilation, and building envelopes. These retrofits should also make buildings all-electric if possible, and maximize the use of on-site renewable energy and energy storage where possible.
- Over time, ensure an increasing proportion of on- and off-site energy is sourced from renewables, with all energy consumed in the CBD to be sourced renewably by 2050. In the meantime, setting a target of 10-20 percent renewables by 2030 should be possible.
- A parallel strategy to get to net zero tenants over time should be established.
- Finally, new construction should be required to achieve net zero operations on a more aggressive basis (ie, by 2030). Net zero embodied carbon in new construction should be required on a comparable timeline (ie, by 2050).

In general terms, use of green building materials, grid-connected green energy, ultra-low energy efficiency heating system, and water recycling should all be priorities.

International case studies: Scandinavia provides some good examples of a carbon efficient approach to construction (see annexed report: "Net Zero Carbon Construction, Future Ready Research"). Although they have yet to adopt a zero carbon policy in the construction process, they have incorporated projects' carbon emissions and health consequence into their regulations. In Oslo, therefore, projects cannot be built using fuel-based equipment i.e., they can only use electric equipment. This is possible because they have a robust electric transport infrastructure that facilitates transport of electricity, grid interactivity, energy storage, building information systems and more.

Denmark, meanwhile, has introduced a staged phasing in and tightening of embodied carbon targets for buildings. The policy combines both embodied carbon emissions and operational carbon emissions, including separate requirements initially for larger and smaller buildings.

Creating a "Showcase" Demonstration Project

One of the most effective ways to impact the CBD community is to designate a city block or, preferably, several adjoining blocks as a demonstration district to showcase sustainable lifestyles and Net Zero pathways. This could be combined with an "innovation district" to drive local jobs and innovation.

Processes and technologies that could be showcased by Chinese companies, working with global experts when needed, include:

a. **Regenerative urbanism** that would bring nature back into dense urban lifestyles. Human-centered biophilic design can also reduce energy, water use, and waste by applying "circular economy" principles with nature based solutions.

b. Buildings can be masterplanned to take advantage of **micro-climate analysis** and passive design strategies. To attract private sector investors, the goal is to demonstrate the "design-build-operate" of ultra-highly efficient buildings without compromising investment returns. The key energy use metric should be stated in the EUI unit "kWh/m^{2}a" in order to monitor and manage the performance of each building in the portfolio across many building types. [kWh/m2a = kilowatt hours per square metre per annum of total energy consumption of each building]. Usage of energy data should be collected on a "real time" basis to monitor performance and become key data inputs to a future digital twin (see below).

c. **District-level smart energy solutions**. A "central utility plant" approach should be used to service the needs of the district, providing heating, cooling, ventilation, hot water, EV chargers, and plug loads. Whenever possible, smart energy solutions would feature a "distributed energy approach" to locate energy supply close to where it is consumed, thereby minimising energy transmission loss. This would include:

   i. District energy with load shifting between buildings to increase energy efficiencies. Where possible, rooftop cooling towers should be avoided, and rooftops instead used to host both on-site solar and tenant amenities.

   ii. All-electric energy to prepare for carbon-neutral pathways should be considered. Electric heat pumps with geothermal heat transfer can be effective solutions and are currently being used in projects around the world. Whether this solution is financially feasible in Beijing would need to be evaluated.

   iii. A flexible microgrid that can accept alternative energy sources over time. This should start with solar photovoltaic and energy storage solutions. As technologies mature and prices become competitive, other clean energy sources such as fuel cells, hydrogen, and waste-to-energy solutions can be added to evolve the energy supply mix to 100% clean energy over time.

   iv. In a similar way to energy consumption, data on energy supply should be collected on a "real time" basis to monitor performance. This would also become a key data input for a future digital twin. GHG emissions can then be calculated and monitored transparently.

d. When metrics have been collected for both building energy consumption and energy supply, data can be monitored via a common "**digital twin**" in order to analyse energy efficiency of both buildings and smart energy solutions.

e. Once plans for a demonstration project at the scale of one or several blocks have been created, a series of workshops can be held with developers and other stakeholders to further develop the concept into a masterplan for further review. The CBD can then determine whether a "public-private partnership" can be utilised to "design, build and operate" the Net Zero Innovation District.

Building Envelope	HVAC systems	Electrical systems	P&D systems	Operation strategies
Reduce air leakage	Constant speed drive upgrade to variable speed drive for fans and pumps	Lighting fixtures upgrade to LED	Install low water flowrate fixtures	Reduce unnecessary operating hours for all energy equipment
Improve glazing thermal performance via films or coatings	Heat recovery systems	On-time motor maintenance for more efficient performance	Reduce landscape water irrigation by adopting water-saving system, low water demand plants	Adjust space temperature settings to reduce over cooling or heating
–	Central cooling or heating plant's efficiency improvement	VSD for lifts and elevators	–	Tenant education on how to maintain a low carbon habit

Source: Arup

Buildings below 1,000 square metres will initially only be required to calculate the life cycle assessment (LCA), while buildings over 1,000 square metres will also be required to meet embodied carbon equivalent limits, which include carbon and other greenhouse gases converted into equivalent values of global warming potential. The policy also includes more ambitious voluntary targets, building on the test phase of the voluntary sustainability class in 2020, which includes a requirement for LCA calculation (see annexed report: "Implementing the Paris Agreement and Reducing Greenhouse Gas Emissions Throughout the Life Cycle of Buildings"). Some existing buildings in the Beijing CBD area have already adopted energy retrofitting strategies. The following table summarises technologies frequently adopted by pioneer building operators in the CBD, and we believe more widespread adoption will improve carbon emissions performance across the district.

Embodied Carbon

Attention tends to be focused on operational carbon emissions, and with more than 50 percent of buildings that will exist in 2050 already in existence today, the CBD's first focus should be on getting these buildings to net zero cost-effectively over time.

However, another important source of building carbon emissions is contained in embodied carbon. GHG emissions from materials and the construction of new buildings can represent as much as 50 percent of a building's lifetime emissions, so a programme to measure and reduce embodied carbon, including supply and transportation of building materials and construction activities onsite, as well as reuse after the building life cycle is complete, needs also to become a near-term priority in managing new construction in the CBD. New buildings, as well as new infrastructure in the CBD, should be encouraged to include fewer heavy materials (such as steel, concrete, glass) and more carbon-friendly alternatives, such as recycled aggregates and industry by-products. Use of carbon positive or bio-based materials (such as timber, hemp fibre) can also be considered.

In 2019, a new national code, the **National Standard for Building Carbon Emission Calculation** (GB/T51366-2019) was introduced, defining a building carbon emission calculation method. Another national standard, the **General Code for Efficiency and Renewable Energy Application in Buildings** [GB/55015-2021] has been in effect since April, 2022, setting complusary requirements for carbon emission calculations for new projects

Another way to address embodied carbon is via a well-drafted carbon tax. This will indirectly support the goal of reducing embodied carbon by levying higher taxes on carbon-intensive building materials, creating financial incentives to switch to lower carbon building materials and lower waste construction management strategies.

Regulation

Once a data-collecting system is in place that can provide regulators and owners access to relevant data, it can be used as the basis for a new policy and regulatory framework. For these purposes, Energy Use Intensity (EUI) and Greenhouse (GH) gas intensity are the most important standards, because they ensure everyone is working from the same data. Although EUI is a somewhat blunt instrument, it is probably the most useful single metric to drive energy reduction or GHG intensity. That said, we also believe buildings should be normalised based on their individual uses and characteristics. The CBD should therefore set up a standard that can assist in comparing building energy consumptions of similar business types.

While an EUI-based standard will not solve all problems, if well drafted it can create a pathway for CBD buildings to meet the 1.5 degree target by a certain date by allowing them time to plan and fund necessary improvements. At the same time, regulators must be careful not to aim too high. Overly aggressive targets and fines can convince building owners to bypass rules by, for example, buying diesel

SOURCE: LIU Yan

generators, which are probably less carbon-efficient than not complying with code.

As mentioned above, the government should set targets for the CBD to achieve net zero over time, and the CBD should require gradual improvements in EUI by building type in order to manage to the overall emissions reduction goal. For new construction, building codes can be used to require measurement and reporting of their embodied carbon, and for net zero construction to be mandatory by a mid-term date (such as 2030). Embodied carbon reductions can also be imposed over time, with all new construction required to meet ever more stringent embodied carbon reduction targets, with a goal of net zero embodied carbon by 2050.

Historically, local governments in China (including in Beijing) have incentivised carbon efficient practices in buildings by offering different types of subsidies. In particular, funding can be provided to enterprises registered and taxed in the CBD, if they can achieve low carbon innovations in accordance with the "**Chaoyang District Energy Saving and Carbon Reduction Special Funds Management Measures**". Either the city or Chaoyang District is expected to issue further similar regulations to encourage carbon neutral participation.

As per international TAP members' experience, the following incentive policies are common:

- Cash rebates for purchase and installation of energy-saving heating and cooling equipment, such as boilers and HVAC units. Given the goal of achieving net zero by 2050, incentives could be progressively improved based on recipients achieving higher energy efficiency performance. They could also be only offered for the purchase of all-electric equipment to help accelerate the transition to all-electric buildings.
- Cash or tax rebates for buildings that achieve near net zero – incentives can be in the form of cash or tax rebates, or alternately anything that enhances the value of a new construction project (eg, expedited permitting, waiver of permit fees, or density, FAR, or other bonuses that maximise revenue-generating potential of new construction, as well as incentives to reduce embodied carbon through adaptive reuse of existing structures).
- A "revolving loan" or "loan guarantee" programme (see below under 'Green Finance").
- Free or subsidised energy audits to identify cost-effective retrofit opportunities.

TAP members also suggested the introduction of other potential policies, incentives, and regulations for the following purposes:

1. Existing buildings: To accelerate existing building retrofits for energy efficiency improvement.
2. Existing buildings: Building carbon emission performance standards to focus on actual performance, not design.
3. New construction buildings: Net zero energy building codes.
4. Community: To promote renewable energy generation.
5. Community: Low carbon transportation.
6. Community: Setting carbon emission standard and limits by different business types.

Green Finance

Enabling green finance will be important to allowing the Beijing CBD to scale up zero carbon activities and accelerate the net-zero transformation. In addition to government capital investment, domestic and foreign investors should also be introduced.

International experience

Experience in the US suggests that government support is needed for carbon efficiency programmes via green loans for deep retrofits. This is in recognition of the fact that few buildings can access low-cost capital, and also that many will face financing challenges. Compared to other financing mechanisms, loans have a better ROI as the capital can be reinvested once the initial goal is achieved and the loan repaid.

In the USA, a major federal stimulus program introduced in 2008 provided about $35 billion to state energy programmes. Recipients invested the funds in upgrade projects at low (1 or 2 percent) interest rates with 10-20 year paybacks. This low cost of capital made many projects possible that would not otherwise have been viable. Proceeds then went back to the originating funds (known as "revolving loan funds") to be loaned out again. This structure is preferable to a system based on outright grants or subsidies because, once deployed, such funding is lost and cannot be recycled back to the market to support new decarbonisation projects.

The US Department of Energy also has a loan guarantee program that spurs innovation in new technologies and systems to decarbonize both buildings and the overall utility sector. Guaranteed federal loans also create a financial environment conducive to the participation of private capital in deals that are guaranteed by the public sector.

An additional policy mechanism used in the USA is "property assessed" clean energy. Basically, this allows an owner to take out a mortgage that is paid back via property taxes. Depending on the asset ownership structure, it allows an investment with a payback of 20 years to become cash positive from day one by allowing the recipient of the energy savings to obtain the benefit immediately, then pay for it over time via their property taxes. If the owner sells the building, the future owner is then also able to receive the benefit of decarbonisation and also pay for it through property taxes.

SOURCE: LIU Yan

Domestic experience

The Beijing CBD has a long history of engaging in green finance within the district, and the range of such options available to it has recently been expanded by the introduction of China's national carbon emissions trading market (the China Carbon Emission Trade Exchange (CCETE)), which was launched in June 2021. The system is likely to become a critical part of China's plans to leverage market mechanisms to reach peak emissions before 2030 and carbon neutrality zero by 2060.

The carbon trading system has adopted a dual-city mechanism, with the Shanghai Environment and Energy Exchange responsible for building the trading system, and the China Hubei Emission Exchange in Wuhan dealing with the registration system and settlement bins. Eight industries have been designated to participate at the initial stage, including companies in the electricity, petroleum, chemistry, construction materials, steel, nonferrous metal, papermaking, and civil aviation sectors.

The CBD Administration Committee has created an inventory of companies in the district with carbon dioxide emissions of greater than 5,000 tons, and is currently holding talks with them to understand their current situation regarding carbon trading and carbon validation in an effort to establish a future carbon quota system in the district. The CBD Administration Committee is also working together with the China Beijing Environmental Exchange (CBEEX) regarding provision of trading credits for purchasing green electricity.

TAP members noted that emissions trading has so far gained little traction in China's property sector. A lack of carbon assessment methods for buildings, including urban areas, is a particular problem – in the absence of a recognised standard at the national level it may be impossible to trade carbon reduction credits for buildings – unlike in industry, where carbon trading has more potential. A lot of imagination and innovation will be needed before carbon assets can be easily traded within the building and construction sectors.

It is strongly recommended that the Beijing CBD proactively encourages the introduction of other green finance tools, such as green loans and green debt, especially for projects such as building retrofitting to reduce carbon emission. For some of the non-offsetting Scope 3 emissions, transition finance can also be introduced to support industry growth.

Capacity Building

Training in all aspects of the carbon reduction process is a crucial step that should be implemented as soon as (or before) CBD net zero policies are introduced. We suggest that both the CBD and City of Beijing provide training for CBD and city officials, as well as commercial building managers, on topics such as property-level technical energy-saving transformation. For this purpose, a separate body could be created to act as a hub to provide and advise on training and resources to help the CBD achieve its goals more quickly.

Creating a product catalogue/reference resource on carbon efficient products, together with an operations and installation manual for training, is also important to encourage uniformity. We recommend this be included as part of any major retrofit training programme that is created after major energy audits have been completed. As part of this, the CBD can publish a list of recommended technologies on an annual basis to encourage adoption of new tools. However, panel members considered it is less important than training facility managers to operate their buildings more efficiently.

To ensure that the CBD has support from the commercial real estate community, building a team of experts – "a CBD Expert Library" – can provide necessary feedback to overcome barriers, as well as resources and support needed to ensure compliance.

We recommend two groups be established:

a. One to advise on a climate action plan, as well as key steps (i.e., to operationalise the plan), and

b. Another to help owners with implementation (e.g., conducting energy audits and installing decarbonisation technology).

Capacity building within the municipal government structure is also important. To give some examples from international practice, San Francisco is known for a well-staffed and effective Department of the Environment that is empowered to drive legislation. Washington, D.C. has similar regulatory and compliance mechanisms that are equally effective. Other cities have divided authority between separate bodies that set goals and make and implement rules.

Cities that convene stakeholder groups to help implement regulations tend to be the most successful: they set goals and make rules together. In Washington D.C., a public-private partnership (PPP) known as the Building Performance Standards Coalition has been created to help work out how to implement policy. In particular, the Coalition:

- Sets a prescriptive pathway for carbon reduction.
- Decides how much funding is made available and how it will be distributed.
- Decides which buildings should be included or excluded and why.

SOURCE: LIU Yan

At the other end of the spectrum, the city of Los Angeles is dramatically understaffed, with just two people working in the mayor's office who are charged with handling the city's net zero framework. New York city, meanwhile, has five different agencies working together, with authority shared equally between them. Although effective, the process in New York is seen as inferior. While rules and non-compliance penalties are clear, the system lacks the element of collaboration seen in San Francisco and Washington D.C., which relies heavily on stakeholder engagement. This need for collaboration was emphasised by panelists as an important means of educating and engaging building owners and developers.

Successful cities are also tend to be those that lead by example. San Francisco, again, has established a policy that municipal buildings should be the first to reach compliance. This helps not only to build net zero expertise within the government itself, but also encourages private companies to follow the public sector example.

Monitoring, certification, and disclosure

Once a carbon emissions tracking platform is established, continuous monitoring of both single building and district carbon emissions becomes feasible. Ideally, results of monitoring should be presented in a visual format to more easily understand trends.

Monitoring carbon emission data will allow the CBD Administration Committee to track the carbon mitigation progress, benchmark Beijing CBD efforts with other CBDs, and drive further progress generally.

There are multiple ways for the Beijing CBD to disclose its carbon emission status and climate action plan: via international platforms such as CDP cities questionnaires, C40 cities questionnaires, as well as ICLEI's GreenClimateCities Program, and the Global Covenant of Mayors for Climate and Energy.

Independent validation and verification is also recommended, as it increases the credibility of the data, makes carbon emissions tradable, and provides potential revenue for the asset owners.

Building a net zero-carbon ecosystem

The CBD should work to gradually develop a net zero carbon ecosystem, with related organisations supporting the CBD Administration Committee to coordinate stakeholders and guarantee implementation of zero carbon work in the CBD. ULI can play a role in its formation. A team of experts can provide feedback on problems as they arise, as well as resources and support needed to ensure compliance. In particular, such a group could:

a. Advise on a climate action plan and help owners with low carbon activity implementation (e.g., conducting energy audits, setting targets and standards, creating roadmaps and action plans, and applying decarbonisation technology).

b. Consider how to screen and select companies in the district that embrace sustainability concepts, creating a clustering effect of low carbon industries in the CBD area

c. Help capacity building of different stakeholders in the district.

Creating zero-carbon ecosystems requires flexibility. This is crucial because building owners need multiple options depending on the asset type, the age of the building, the condition of the roof, who the tenant is, etc. For example, New York doesn't allow owners to take credit for offsite renewable deals, whereas Los Angeles allows it. There is much more value, as a building owner, investing in an 80MW offset renewables deal than there is in installing a small solar array onsite. Building owners must stay focused on the ultimate goal – decarbonizing.

Transportation

Any zero-carbon ecosystem includes a commitment to carbon efficient transportation, which, apart from buildings, is the main source of urban emissions. Although in New York and Los Angeles respectively some 80 percent and 60 percent of emissions are from buildings, transportation remains an important component. The best way for the CBD to reduce transport emissions is by discouraging single vehicle transport and creating a robust all-electric public infrastructure, including a comprehensive network of charging stations for electric vehicles. These will both optimise the energy mix and also provide alternate ways to move around the CBD – typically, via bicycles and scooters, using designated purpose-built lanes.

On a single building level, building owners (both retail and office) should also be incentivised to install electric charging infrastructure and provide parking for bicycles, scooters and other forms of green transport.

Examples of cities that have acted successfully in this regard include Santa Monica, where protected bike lanes now allow safer biking. In addition, Copenhagen – which has a culture of biking – is an example of cultural norms organically driving changes in mobility. Such changes require a shift in mentality but are quite achievable, especially in cities such as Beijing with long traditions of bicycle use.

URBAN LAND INSTITUTE RESOURCES

ULI's 10 principles for City-Level Decarbonization was developed in partnership with 20 city sustainability officers and 20 private sector real estate developers/ owners)

ULI Blueprint for Green real estate: A Guide by Real Estate Sustainability Directors, For Real Estate Sustainability Directors) is

ULI's Advisory Services panel for the Washington DC CBD - Accelerating Progress of the CBD Towards DC's Sustainability Goals made recommendations to the Downtown DC Business Improvement District (BID) on the real estate industry's role in achieving the city's sustainability goals, and on how the goals can be leveraged to generate real estate value and boost economic growth in the city's downtown.

Renewable Energy Strategies for Real Estate aims to help real estate practitioners understand the business case for renewables and develop a strategy to identify, prioritize, and execute renewable energy deals both on site and off site.

Electrify: The Movement to All-Electric Real Estate highlights the path towards electrification and what that means for commercial real estate.

Embodied Carbon in Building Materials for Real Estate report prepares the real estate market for a low-carbon materials green building future, makes the business case for why real estate should pay attention to this sustainability trend, highlights smart steps to reduce embodied carbon in development, and showcases peers already addressing the issue.

Science Based Targets: The Next Level of Carbon Reduction and Sustainability Goals in Real Estate Retrofits Over Time provides building owners insights and lessons learned from setting SBTs.

Best Practices for Achieving Zero Over Time For Building Portfolios outlines zero-over-time (ZOT) approach to set commercial building portfolios on a financially viable path to achieve net zero energy.

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TAIKOO LI SANLITUN AIR CONDITIONING RETROFIT

Located in Beijing's Chaoyang District, Taikoo Li Sanlitun (TLS) was Swire's first retail-led, mixed-use development on the Chinese mainland. Since opening in 2008, it has become one of the capital's most sought-after leisure and business hubs. Located near the embassy district and the famous Sanlitun Bar Street, TLS draws over 100,000 visitors per day.

Figure 2 – Taikoo Li Sanlitun

Consisting of two zones (South and North), TLS has a total gross floor area of over 120,000 square meters and is home to over 270 retail tenants. In November 2021, another zone, Taikoo Li West opened, featuring another 23,000 square meters.

Unusually for Swire, TLS was purchased after it was designed and mostly completed. System design was therefore inherited. Since purchasing, Swire has acted to improve energy efficiency of electrical and mechanical systems, including:

- Retro-commissioning existing HVAC systems,
- Optimising lighting controls,
- Retrofitting higher efficiency lighting,

As a result, TLS energy consumption in 2017 was 8.5 million kWh lower than in 2010 (see Figure 3). However, air-conditioning energy consumption was still higher than in other Swire malls due to the unitary water-source heat pumps (WSHP, see Figure 4) inherited from the original design. The WSHP system was designed to work efficiently under conditions of balanced heating and cooling loads, but in reality such balance seldom existed. In addition, after ten years, the AC system had also deteriorated. Swire therefore decided to replace it.

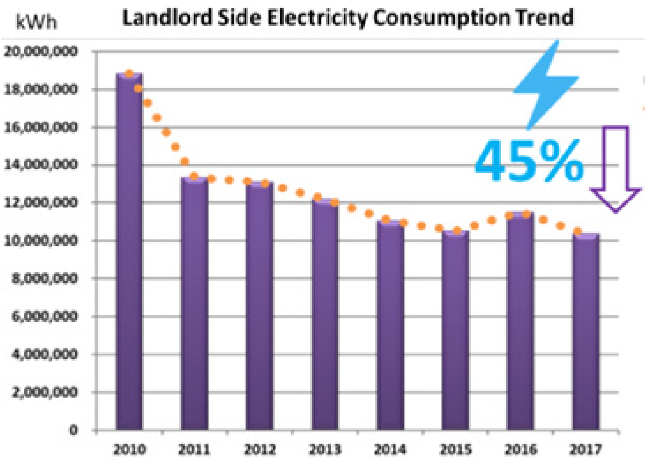

Figure 3 – Landlord Side Electricity Consumption Trend

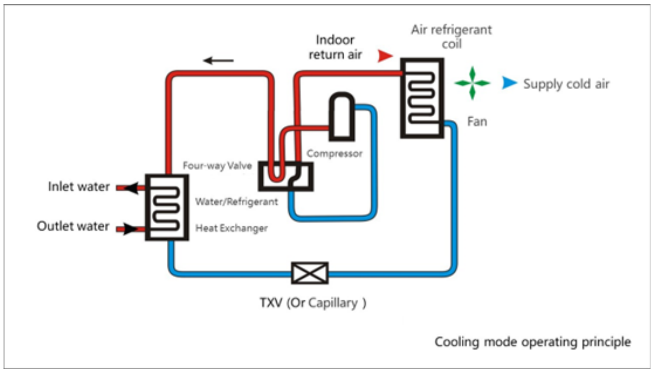

Figure 4 – Working Principle of WSHP

Adidas Pilot Project Retrofit

In 2017, Swire and Tsinghua University (THU) conducted a feasibility study to evaluate TLS energy performance under the THU-SWIRE Joint Research Centre for Building Energy Efficiency and Sustainability. Following this, a decision was made to replace the central cooling and heating plant system with fan coil units (FCUs) as AC terminals. Estimated annual energy savings were **13.4 million kWh/year**.

The pan was complicated, however, because disruption caused to tenant businesses by the retrofitting meant that work could only take place during fitting-out and renovation periods. A pilot programme was therefore planned to evaluate the feasibility of retrofit operations. At this time, a retail space let by Adidas converted its WSHPs to FCUs as part of an extensive renovation, creating an opportunity to verify the feasibility of the construction process and subsequent energy savings.

On the plant side, SWIRE worked with consultants to select chillers, pumps and (in particular) how to rout an additional pair of chilled water pipes in the back-of-house area. A modular oil-free chiller was selected. Multiple factory tests were conducted to verify performance, especially under part-load conditions. Hot-water pipes were also modified to provide high-temperature water to the FCUs.

Given limited available space, BIM was sued to create a detailed construction plan (Figure 6). To ensure businesses in the mall could continue as usual, work in adjacent areas was conducted at night, and hoarding and temporary ventilation were installed as a preventative measure. TLS also provided electrostatic filters to enhance air quality in the area.

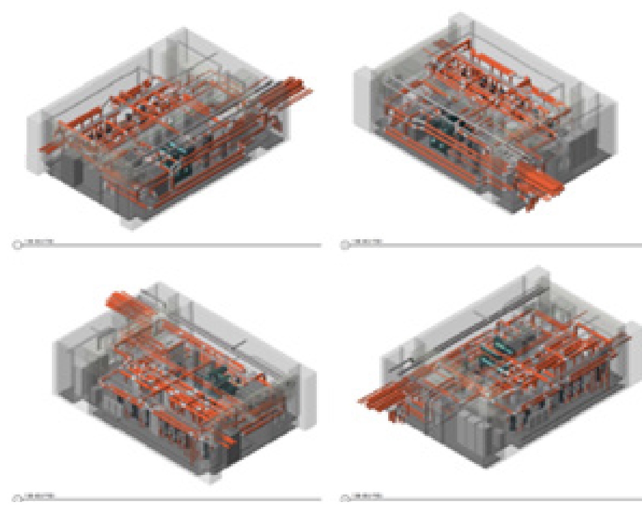

Figure 6 – BIM Model of Pipe Network

After re-opening, the new FCUs resulted in greatly reduced energy costs, with AC system electricity consumption in peak summer months falling by more than 95% (Figure 7). Year-round AC electricity consumption savings exceeded 700,000kWh.

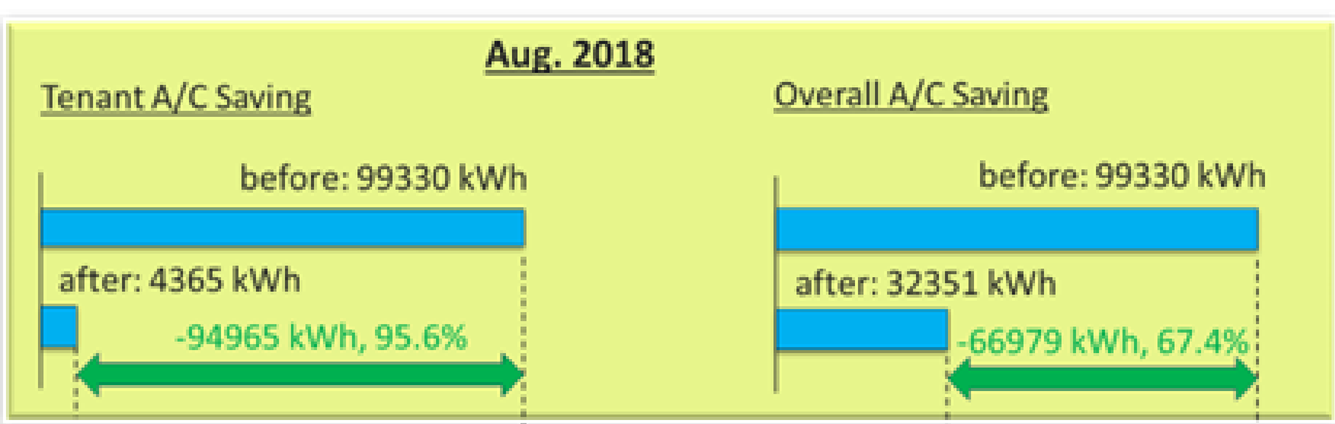

Figure 7 – Peak Summer Before After Energy Consumption Comparison

Execution of the Overall Renovation

After the Adidas retrofit, other tenants requested similar AC improvement work, whereupon TLS launched an extensive RMB150 million upgrade programme (Figure 8). After a comprehensive study, TLS decided to complete the project in phases from 2019 to 2024, allowing it to accommodate fitting-out for both new tenants and sitting tenants.

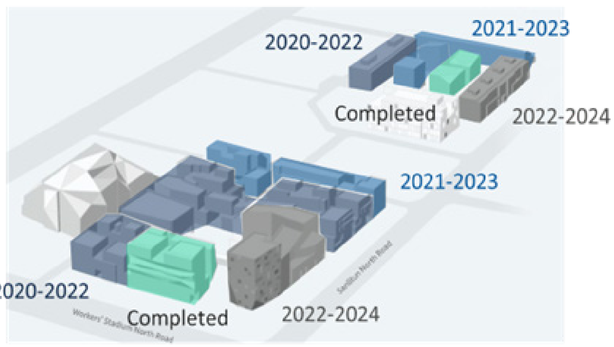

Figure 8 – Master Program

As part of this:

- Extra space was needed for plant rooms housing chillers and pumps. Given limited parking space, the location and size of the plant room had to be carefully assessed.

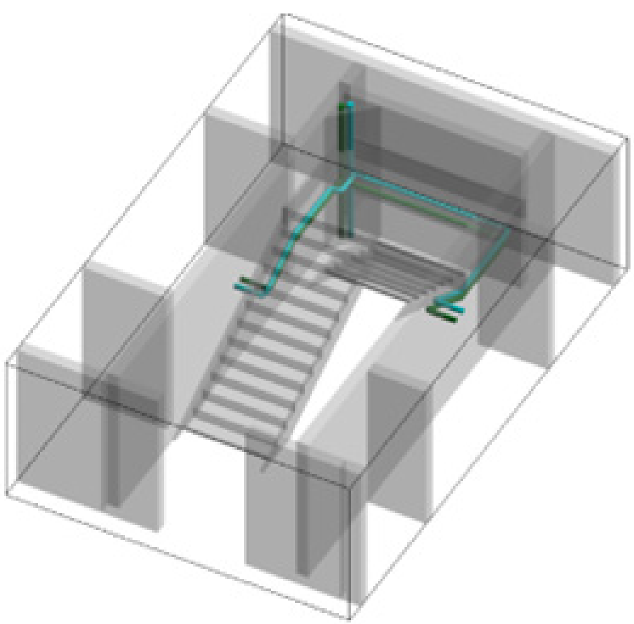

Figure 9 – Routing of Vertical Risers

- Given limited room for new water pipes, the routing of pipes in ceilings and positioning of between-floor vertical risers required detailed site investigation. Vertical risers were then placed in back-of-house areas (Figure 9) so that no front-of-house space was sacrificed.
- Substantial planning and site supervision were required in order to minimize disruption to tenant businesses.

Phase One – Cooling Tower Replacement

The building's original cooling towers operated on a closed circuit basis (a requirement of the WSHP units). However, closed circuit systems are inefficient compared to newer open circuit designs due to higher condenser water use and higher water temperatures. Efficiency problems were compounded by the aging of the existing cooling towers after over 10 years of operation.

The first phase of the renovation work involved replacing the existing cooling towers with open circuit types. A computational fluid dynamic (CFD) simulation (Figure 10) was carried out to evaluate the effect of cooling tower operations and to optimise the design. Cooling tower replacement – including tendering, procurement of equipment, and construction – had to be completed within a brief window before the start of peak cooling season in 2019. This was a challenging, especially given the business-as-usual requirement within the mall.

Because the WSHP units had to remain in operation until all tenants converted to FCUs, the original condenser water supply to WSHP units had to be kept in service until retirement of the last WSHP unit. Both chilled and condenser water therefore operated simultaneously during the transitional period. During this time, the chilled water pipes were switched to hot water pipes during the heating (winter) season, functioning as a 2-pipe system. Once the transition was completed, condenser water piping was converted to hot water for heating, making the new HVAC system a 4-pipe system.

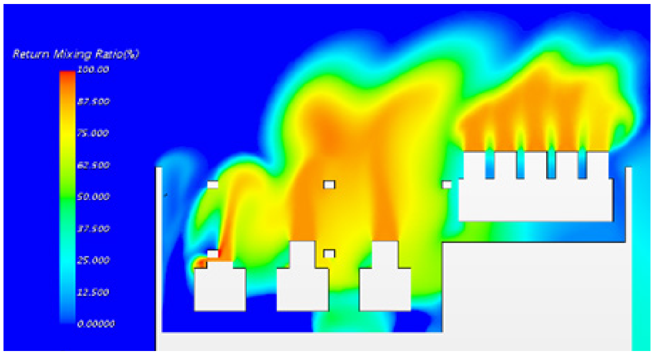

Figure 10 – CFD Simulation of Cooling Towers Operation

Installation was challenging. The building's unique architecture meant there was limited space to install a crane to lift cooling towers to the roof. In addition, despite having to work outside normal business hours at the mall, the existence of a nearby residential neighbourhood meant builders were also unable to work late. However, implementation of a strict daily timeline allowed cooling tower replacement to be completed successfully within a two-month period.

Phase Two - Chiller Installation

Installation of FCU equipment requires placement of chillers to supply cold water. As a retrofit project, a variety of factors had to be considered to determine the capacity, number, and model of chillers purchased.

First, the location of the plant room had to be chosen carefully given the extra space needed to house chillers and pumps. Limited space in the basement car park meant that the configuration of this equipment had to be carefully calculated to cater to simultaneous operation of FCUs and WSHP units during the transitional period. In particular, installation of one chiller had to be delayed until pre-existing condenser pumps could be removed.

Second, limited headroom in both the car park ramp and the underground car park space meant the chillers could be no larger than 700 tons each (Figure 11).

A comprehensive cooling load evaluation was conducted to calculate the number of chillers needed to handle various seasonal cooling loads, and also

Figure 11 - Chiller

to optimise operation of the chilled water system. Because chillers run at partial loads for 98% of the cooling season, good energy efficiency at partial loads was essential. Seven oil-free magnetic bearing centrifugal chillers, ranging between 400 tons and 700 tons, were chosen because of their high energy efficiency, quiet operation, and low maintenance requirements. Used in tandem with a few small chillers installed during the pilot stage, the chiller infrastructure was found to operate efficiently at different cooling loads.

Factory testing of the chillers verified performance levels, and the units were delivered onsite just before the first tenant converted from WSHP to FCU. The limited number of tenants using chilled water during the first few months meant that cooling loads were initially low. Notwithstanding this, energy efficiency rates remained satisfactory.

Phase Three - Piping Works

The most challenging part of the project was installation of the FCU pipe network. Because business operations had to continue as usual, an independent pair of chilled water pipes had to be installed to enable tenants and common areas to quickly switch to FCU when ready. This proved difficult because the ceiling space was already occupied by various pre-existing hardware such as ductwork, piping, cable trays, conduits, etc.

With a total of 40km of piping to install, the work has been divided into several phases according to the leasing schedule. The installation programme will need at least five years until the last tenant converts to FCU. Detailed work to map pipe routing is done at the beginning of each year based on leasing schedules, sometimes assisted by BIM modeling.

FCUs are equipped with brushless DC motors (BLDC) rather than conventional belt drives. This is partly because life-cycle analysis revealed payback for using BLDC FCUs was less than 5 years. In addition, BLDC FCUs have longer lives and lower noise levels. Finally, dust and sparking caused by brush abrasion is also eliminated, thereby improving indoor air quality.

Although electricity consumed by FCUs installed in tenants' areas are payable by tenants, TLS provided all FCUs to tenants for free during fit-out to encourage participation in the energy saving campaign.

As of April 2022, approximately 35 percent of TLS tenants had converted from WSHP to FCU. Upgrading work for the remaining tenants continues, with completion expected by the end of 2024. In addition, around half the work in public areas has now been completed. In addition, an online indoor air quality monitoring system has been installed for real time air quality assessment, which should also provide scope to explore further energy-saving options.

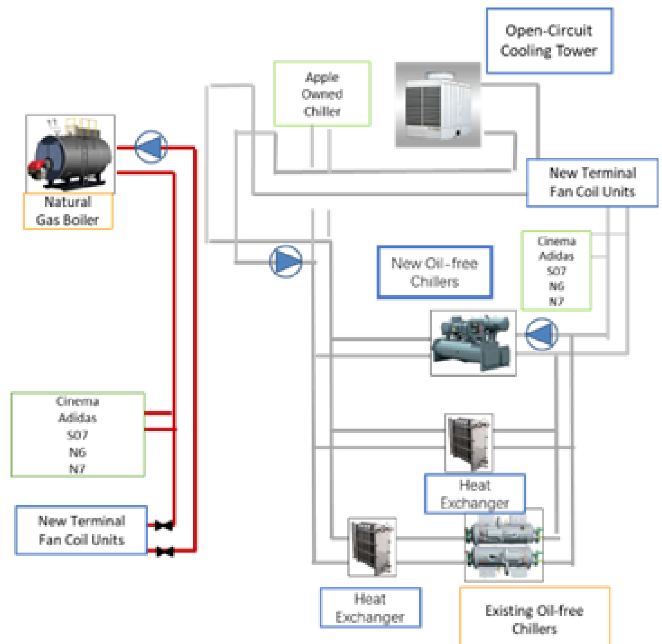

Figure 12 – Sketch of New AC System

Figure 13 – BIM Model of Plant Piping Network