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Case 6: Shenzhen

International Low Carbon City (ILCC)

Abstract

Shenzhen is taking the lead in demonstrating innovation in sustainable urban transformation and future-orientated city planning through its ambitious International Low Carbon City (ILCC). This initiative aims to transform the previously manufacturing-based and carbon-intensive economy and built environment of Pingdi into a model of low-carbon, post-industrial urban revitalisation. ILCC maintains a focus on preserving and refurbishing existing buildings to the latest environmental standards whilst also pursuing new construction of cutting-edge, low-carbon buildings and urban infrastructure. As such, this initiative marks a significant shift from large-scale demolition and new construction centred modes of urban development. Also involving extensive collaborations with the Dutch government and other international partners, futuristic green buildings and economic transformation is pursued whilst taking the utmost care to preserve the natural environment and cultural identity of the area.

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1. Programme context

Citywide reduction target(s)

To meet China's new 13th five-year working programme to control GHG emissions, by the year 2020, the City of Shenzhen aims to reduce its CO_2 emissions by 10% relative to every RMB 10,000 of GDP (1 RMB = US $0.151 as of 20 August, 2016) compared to 2015 levels, and at least 45% compared to 2005 levels. As a specific goal for the built environment, also by 2020, the city aims to ensure that 100% of all new buildings comply with national green building standards.

Built environment context and programme background

Designated as China's first Special Economic Zone (SEZ)[1] in 1980, the southern city of Shenzhen, in Guangdong province, has since experienced skyrocketing economic growth. The adoption of flexible economic and social policies has transformed it from a small town with a total population of less than 30,000 to one of the most developed cities in the country. Its population now exceeds ten million. However some unofficial estimates put the population possibly as much as 15 million. These favourable policies attracted both Chinese and foreign investments and, in less than thirty years, the city has become home to the headquarters of China's most reputable high-tech companies. Shenzhen now enjoys a prosperous economic output, ranking fourth among 659 Chinese cities, behind Beijing, Shanghai and Guangzhou. Shenzhen's overall GDP grew by a yearly average of 17.9% from 2001 to 2014. As of 2014, per capita GDP was RMB 64,664. The city, once only 10.65 km^2 in area, has also experienced a huge expansion. Initially, the rapid development of the city was exclusively centred around the designated SEZ area of 327 km^2. However, non-SEZ areas were also included in the city masterplan to embrace forecast growth in population and industrial development. Currently, the total area of Shenzhen has now approached nearly 2,020 km^2.

Shenzhen has not only played a significant role in China's economic reform, but has also taken a leading role in environmental responsibility and tackling climate change. To this end, it has created several innovative policies. One pioneering measure was the country's first local law on GHG management, titled "Provisions of Shenzhen Special Economic Zone's GHG Emissions Management". These provisions set the legal foundation for carbon finance and trading, facilitating the launch of China's first emissions trading pilot scheme, operating since 2013. Buildings complying to green standards occupy an area of 16.36 million m^2, which

[1] Special Economic Zones (SEZ) in China are supported by the national government. Although they vary in function and scope, SEZs enjoy special preferential reform treatment such as trade policies, taxation, land use and others. They were launched as part of China's opening-up policy and market-orientated reforms. Some SEZs became experimentation zones for high-tech innovation whilst others aimed at attracting international investments and boosting the economy.

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is the largest in the country. Shenzhen also boasts the lowest carbon emission per RMB 10,000 of GDP among major cities in China.

In 2010, Shenzhen was selected by the National Development and Reform Commission (NDRC) as one of the first eight cities to become a “low-carbon city pilot” (LCCP). Later expanding to encompass a total of 36 cities across China, LCCP’s are expected to lead the transition to a low-carbon economy by designing and implementing innovative policies to spur low carbon development, that can be applied nationally. Selected cities are encouraged to focus on lowering energy consumption in six main categories: industry, traffic, buildings, energy production, lifestyles and land use. As a flagship initiative from this context, Shenzhen launched a comprehensive and ambitious project called the “Shenzhen International Low Carbon City” (henceforth ILCC) in the Pingdi sub-district of the northeastern part of the Longgang district. Pingdi is located about 40 km from the main urban area in Shenzhen. It is situated near the provincial borders of Shenzhen, Dongguan and Huizhou, which are less than a two-hour drive away. It is also within easy reach of Guanzhou and Hong Kong’s downtown. Surrounded by mountains, and with three rivers flowing through its heart (Dingshan, Longgang and Huangsha), it also enjoys a lush, natural environment.

Pingdi was once a poor and highly underdeveloped district of some 170,000 residents that escaped the benefits of Shenzhen’s dramatic rise to prosperity. In contrast to central Shenzhen, Pingdi’s environment was characterised by scores of relatively low-value houses, energy intensive old factories and a scattered layout. In recent years, traditional heavy industries such as mining and quarrying and light manufacturing industries such as plastics, textiles, furniture and tobacco etc. created serious air and water pollution. In 2012, per capita GDP in Pingdi was one-fifth the average level of Shenzhen whilst carbon emissions per unit of GDP were 2.5 times higher, and energy consumption double. An abundance of land and natural resources and a waning, carbon-intensive economy therefore represented an ideal location for Shenzhen to reduce CO_2 emissions and energy consumption whilst demonstrating a new model of sustainable, urban renewal.

2. Programme overview

Overall goals and start year

Shenzhen’s ILCC was officially launched in 2012. It aims at catalysing the transformation of a previously economically insignificant and polluting urban district into a model of low-carbon development, high-output and high-technology industry, environmental sustainability and sustainable lifestyles.

ILCC project takes a new path in development. The project pursues urban transformation and low-carbon innovation through the integration of efforts to preserve existing buildings and heritage with construction of cutting-edge new buildings and infrastructure. This marks a radical departure from the “demolish and build from scratch” mentality that drove much of Chinese urban development over the recent decades. It also aims at creating new forms of mixed-use developments and creative forms of low-carbon businesses and services. Buildings will be designed to enable young entrepreneurs to reduce start-up costs by using spaces for both residential and commercial purposes. Additionally, ILCC promotes preservation of the rich, natural environment and traditional culture. Approximately 70% of the eco-city will be set aside for green spaces and natural environment zones. These will assure heat dissipation and natural ventilation, clean air quality and natural flood and waterlogging control.

Skyline of Shenzhen

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Table 1: **Various key indicators and low-carbon targets**

Category	Indicator	Unit	Target value in 2025
Low-carbon output	Carbon emissions intensity relative to GDP	t-CO_2 per RMB 10,000	<0.32
	Carbon emissions per capita	t-CO_2 per capita per year	≤5
Low-carbon Industry	Proportion of emerging industries in GDP	%	≥80
	Proportion of R&D input relative to GDP	%	≥5
	Per capita annual GDP growth rate	%	≥7.5
Green buildings	Proportion of new buildings meeting national green building standard	%	50% 1-star 30% 2-star 20% 3-star
	Proportion of existing buildings meeting national green building standard	%	50% 1-star
	Coverage of energy consumption monitoring	%	100
	Utilisation of renewable energy in buildings	%	≥5
Low-carbon Transportation	Participation rate of green travel	%	≥80
	Proportion of electric vehicles in motor vehicles	%	≥81
Optimisation of energy structure	Cleanliness of electric power	t-CO_2 /MWh	0.694
Green spaces	Ratio of green space	%	Planning area ≥ 73.5% Built-up area ≥ 35%
Resource use and recycling	Recycle rate of industrial water	%	≥90
	Utilisation of non-traditional water resources	%	≥20
	Resource recovery rate of solid waste disposal	%	≥70
Environmental quality improvements	Good air quality days	days/year	≥350
	Heat island intensity	°c	≤1.0
Low-carbon management	Coverage of carbon emission monitoring system	%	100

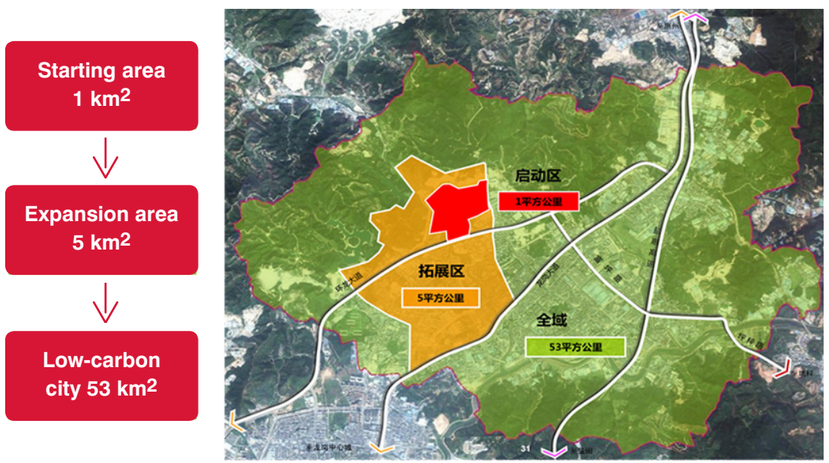
Source: **Based on materials from City of Shenzhen**

As shown in Table 1, a comprehensive set of quantitative goals has been set to guide development in ILCC, and also to allow subsequent monitoring of progress. Firstly, by 2025 carbon emissions relative to each RMB 10,000 of GDP will be reduced to less than 0.32 tonnes of CO_2 (henceforth t-CO_2). Secondly, also by 2025, per capita CO_2 emissions will be reduced to 5 t-CO_2 (comparable to average E.U. national standards in the same year). Both of these goals are highly ambitious, and represent a vast improvement from current levels. For reference, unofficial estimates place current per capita emissions in Pingdi in the range of approximately 9 t-CO_2. Additionally, carbon intensity in Pingdi in 2011 was 2.21 t-CO_2 per RMB 10,000 of GDP, which is around double that of Shenzhen.

Programme target and scope

When completed, ILCC will cover an impressive total area of 53.4 km^2. The present population of the Pingdi area is approximately 170,000. This is expected to grow significantly, to around 420,000 in 2020 (including both residents and commuters working in the eco-city). As shown in Figure 1, development will be rolled out on three scales. Initial development will centre on a pilot zone of 1 km^2 around the Gaoqiao Dingshan River, to be fully established by 2020. In parallel, development is also taking place in an expanded zone of 5 km^2 around the Gaoqiao, Pingshan and Dingshan riverbanks, to be completed by 2025. Finally, the third development scale covers the entire Pingshan community. This is expected to materialise at some point after 2025, with significant progress made over the next decade. For the entire development, land for construction will cover only 17.5 km^2 and the remaining 35.9 km^2 dedicated to water, green spaces and forest areas.

Figure 1: **Layout of ILCC showing the pilot (red), extension (orange) and comprehensive (green) zones.**



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The logic of realising the ILCC in phases and zones is three-fold. First, to draw lessons from the pilot zone in terms of effective technologies, economic development strategies and policy approaches. Second, to grant sufficient time for improving the performance of existing buildings and the local economy and enhancing the quality of the currently polluted environment. Third, the controlled and phased-out development model also aims to allow the City of Shenzhen to construct the required infrastructure (energy, water, transport, waste treatment etc.) at a pace matching that of development in the area.

Programme structure and function

ILCC is essentially a City of Shenzhen driven initiative, with extensive private sector involvement in both design and construction of individual projects. Essentially, the City of Shenzhen is responsible for setting the overall vision, goals and layout of ILCC through a masterplan, and then creating the regulatory and zoning framework to guide development. The city is also largely responsible for investing in the supporting infrastructure (metro, roads, water, energy etc.) and managing allocation of land to the private sector. The city of Shenzhen is also charged with measuring progress to the various goals. The private sector is largely responsible for investment and implementation of the majority of construction projects. The city however, is playing a significant role in attracting new enterprises and construction projects to Pingdi as well as creating incentives and subsidies to encourage existing industries to implement retrofitting (see *Incentives and support mechanisms*).

General layout

The spatial layout of ILCC follows a grouping method where mixed-use urban forms are clustered following the principle of “one axis and one belt; one core and three sub-centres”. As shown in Figure 2, the entire ILCC will be threaded and united by a single axis (shown in red) that marks an extension of the original city of Pingdi. This will be mainly achieved through an extension of the current Line 3 of the Shenzhen metro (creating seven new stations over 9.4 km), a major reconstruction of existing Pingdi Road, and the addition of trunk roads, highways and expressways. All vital elements of the city will centre around a single belt (shown in dark green) following the north-south flow of the Dingshan River. Within this area will be found public buildings and spaces like the convention centre, innovation park and landscape architecture etc. The core of the city will consist of three interconnected areas (shown as dark, red circles) that comprise of three key functions, each built around a separate metro or railway station. In the first, a Low Carbon Exhibition Centre will demonstrate green technologies and be used for holding conferences etc. The second will be a low-carbon service centre dedicated for commercial use (i.e. low-carbon businesses and finance, shopping and entertainment) and public services. The third will be a low-carbon living centre for leisure, recreation and culture. Three sub-centres (shown as circles along the main red axis) will serve as sub-centres in three zones that comprise a mixture of industries, services and residential areas.

Figure 2: **Spatial planning for ILCC**

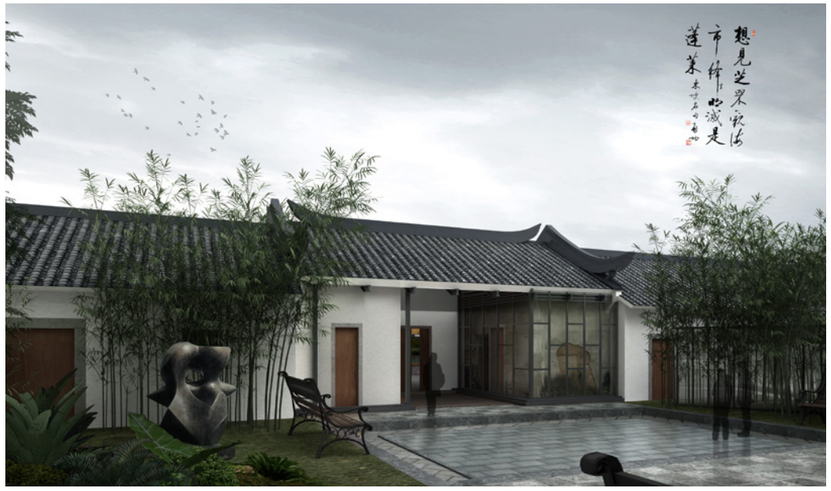
Overview of key projects

Based upon the vision, goals and spatial planning outlined in the masterplan for ILCC, the City of Shenzhen has started implementing approximately ten major infrastructure and construction projects around the pilot zone and expansion area. The following sections shed more light on the chief components and characteristics of this initial progress.

- **Urban renewal and industrial transformation:** A chief feature of the pilot zone is the preservation of existing buildings whilst renovating and upgrading them to meet strict green building standards (see Table 1). Large demolitions are avoided. Industrial premises such as warehouses or factories are thus being transformed into modern, high-tech buildings that can provide additional and mixed-use spaces for leisure, R&D, offices, residential and commercial purposes (e.g. hotels, R&D and exhibition centres etc.). Another flagship retrofitting project aims at improving the environmental performance of traditional Hakka courtyard-style houses (see photo Refurbished traditional Hakka houses) whilst preserving their traditional spatial layout, form and appearance. Retrofit measures include repairing deteriorated surfaces and structures, upgrading lighting, ventilation and fire protection performance, whilst at the same time, introducing novel space uses such as tea houses and cultural exhibition centres.

- **New green buildings:** All new buildings will be designed to meet the latest green design methods, incorporating advanced building technologies to attain

Refurbished traditional Hakka houses



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high environmental performance. Iconic demonstration green buildings will also be established. One key new building project involved construction of the ILCC Exhibition Centre in 2013. This serves as a site for demonstration and exchange of low-carbon technologies, holding of low-carbon international meetings and other services. The centre exceeds the national green building 3-star standards, with energy consumption around 50% less than a comparable, conventionally designed exhibition centre. It occupies a gross floor area (GFA) of 35,000 m^2 and a building area of 25,000 m^2. It boasts almost 100 unique, low-carbon features and technologies. These include vertical gardens, rainwater collection, membrane sewage treatment and water recycling, ecological building materials, advanced insulation and natural cooling features, solar photovoltaic electricity production and a smart micro-grid. Materials from the older structures on site were also recycled to make road aggregate, seats and flower pools.

• **Low carbon infrastructure:** Upgrades are currently being carried out to overhaul existing, or create new, low-carbon and ecologically responsible infrastructure for the city. These include treatment and recycling networks and plants for water, sewerage and storm water, energy distribution systems, solid waste treatment, transport and permeable pavements. Energy infrastructure upgrades include a high voltage electricity transmission corridor, renewable energy installations such as solar and wind and construction of a distributed energy centre. The latter will provide electricity and district hot water and cooling to commercial, public and residential premises from renewable sources and through a smart grid. Natural gas will be used as a base to support renewable energy sources including solar, wind and biogas from sewerage sludge and wastewater. The centre will also feature battery storage. A low-carbon comprehensive transportation system will be introduced in ILCC. This includes advanced networks of roads, highways, metro, tramway and bus lines and pedestrian pathways. It will encourage public transit and be designed to effectively connect key clusters and blocks in the city.

• **Industrial park for advanced low-carbon industries:** This will be built on an area of 3 km^2 with a total investment of around RMB 20 billion. The park will host a demonstration and R&D zone for both domestic and international enterprises in the low-carbon technology manufacturing and energy saving sector. Featured technologies will include solar, biomass, biogas, energy storage, waste, water and materials recycling, green building technologies, robotics and high-end equipment manufacturing, medicine, health and biotechnology. As well as being home to the abovementioned distributed energy centre, this park will also see construction of the world's largest and most advanced waste incinerator; the Shenzhen East Waste-to-Energy Plant. Scheduled to open in 2020, this will be a 267,000 m^2 facility capable of incinerating 5,000 tonnes of trash per day (around a third of Shenzhen's daily output). Recyclable materials will be recuperated first, and then heat captured to provide electricity to the city. It is estimated that the facility will save up to 750,000 t-CO_2 per year and constitute the largest carbon saving project in Pingdi. Designed by Danish architects who won an international design competition, the entire site will be built to green building standards and feature a solar array of 44,000 m^2, making up 65% of roof space. Pollution control standards for waste incineration exhaust emissions will be in the vicinity of two to eight times higher than those in the E.U.

• **R&D research clusters:** ILCC aims to become a knowledge city, hosting national and international research institutions and R&D facilities that contribute to low carbon technologies, innovation and other research areas related to future-orientated urban development. Some research institutes currently under planning or construction include the Aerospace Science and Technology South Centre, Shenzhen Institute of Building Research, China Academy of Functional Material (CAFM) and the Sino-U.S. Low-Carbon Building and Community Innovation Experiment Centre (a collaboration with the Lawrence Berkeley National Laboratory in the U.S.).

• **Natural environment enhancement:** In addition to preserving existing green and blue resources, a central feature of ILCC will be efforts to remediate previously polluted sites. One key project is the Dingshan River Water Quality Improvement Project. This features several measures to improve water quality and aquatic ecosystems such as construction of a sewage collection pipe network, water treatment plant with a capacity of 25,000 m^3 per day and flood control trenches. The project will also encompass environmental improvement and vegetation enhancing measures to improve the embankments and restore natural wetlands. This restoration project will extend 6.7 km and include the creation of an urban waterfront, public spaces and parklands.

Data collection and utilisation

Given the comprehensive set of low-carbon development goals laid out in Table 1, data collection and monitoring of progress will form a central part of the governance

and evaluation framework for ILCC. The monitoring system infrastructure itself is still under development. Yet it is envisioned that once completed, results for each of the indicators will be publically viewable online, and in real-time. Big data collection and analysis will thus play a large role in monitoring the various environmental, economic and societal impacts of the city. Energy and emissions related indicators will encompass the full life-cycle of construction and manufacturing. The entire set of indicators will also allow government officials to objectively gauge the merits of various project proposals and requests from industry to relocate to the eco-city. In addition, with ambitions to make real-time results from the monitoring platform highly visible around the city, this system will also serve as a powerful educational tool for industry and citizens alike.

Unique and innovative features

Urban renewal and industrial transformation

ILCC integrates preservation and reformation of existing buildings with advanced, new construction projects. The development model avoids large-scale demolition of old industrial establishments and housing (which requires relocation of residents). It instead works with citizens and building owners to upgrade buildings to attain new levels of environmental performance. In parallel, by reforming buildings and industrial facilities to achieve novel and re-imagined building uses (e.g. combined commercial, residential and cultural etc.), ILCC is also serving to restructure and revitalise the local economy. Previously polluting, old factories, warehouses and residences are being transformed to futuristic green buildings and spaces that generate a higher economic output relative to floor area and carbon emissions. The result is a dynamic and mixed-use urban landscape that puts citizens and lifestyles at the centre. Young entrepreneurs and start-ups will have the chance to use their spaces for both residential and commercial purposes. Transition to an energy-intensive industrial infrastructure to a new low-carbon technology and service orientated economy also serves to provide new employment and further reduce pollution and carbon emissions.

Building a whole new city while preserving the natural environment

The guiding vision and various projects comprising ILCC strive to balance progress in technological and built environment innovation with ecological health, and harmony of human and natural systems. As mentioned, a distinguishing feature of the eco-city will be the overwhelming presence of natural spaces. These will make up more than 70% of the total area, whilst construction is confined to the remaining 30% or 17.5 km^2. Furthermore, these green zones will comprise of existing natural forest, river and mountain areas on the one hand, with manmade or enhanced environments such as wetlands, urban forests, parklands and building vegetation (green walls and roofs) on the other hand. This preserved and enhanced natural environment will deliver multiple benefits such as climate control (i.e. reduced heat-island effect), air purification, beautification and recreation.

Incentive and support mechanisms

City planners in ILCC exploit various incentive mechanisms to encourage private sector developers and enterprises to pursue low-carbon construction and technological innovation. Since many existing households and factories have low environmental performance, the City of Shenzhen offers various incentives to incite owners to upgrade their facilities. Firstly, it provide subsidies of RMB 20-40/m^2 for refurbishment projects. Secondly, being a nationally supported low-carbon pilot city, larger refurbishment projects of industrial buildings can benefit from financial subsidies offered by NRDC. These help reduce expenses incurred in implementing retrofits to conserve energy and reduce CO_2 emissions, and equally, can also be given to selected new building projects. Third, new, small enterprises may apply to a low-interest loan programme from private, local and foreign banks (including German development banks and the World Bank) to aid with capital raising for initial business start-up. Fourth, since Pingdi has been integrated into the SEZ of Shenzhen, companies operating in the pilot city are able to enjoy special tax benefits.

ILCC also spurs green building and technical innovation by carefully screening business development and construction plans of private enterprises wishing to relocate or start up in the eco-city. This is done by using specific criteria created by researchers at the Harbin Institute of Technology that include GHG emissions, environmental impact, development potential and relevance of industry type to the overall goals of the city. This selective screening strategy has the advantage of assuring that existing or new enterprises settling down in Pingdi are committed to low-carbon innovation and environmental sustainability, and therefore, well-positioned to play an active role in the transition to a low-carbon, technology-driven economy. This selective admittance of industry also serves to drive uptake of 2-star rated building certifications. For existing buildings, typical costs of upgrading buildings to achieve this rating are around RMB 100/m^2. Obtainment of this certification fits well with the mission of new and relocating enterprises. In addition, such entities are also well-positioned to appreciate the business case of investing in building certification, since this ultimately leads to higher energy efficiency and reduced running costs.

Links to other city policies or programmes

ILCC is one of the centre-pins by which Shenzhen will achieve its transition to a low-carbon and technology driven economy. Due to the breadth and scale of the development currently unfolding, Pingdi will contribute significantly to the progress Shenzhen is currently making towards various targets for the year 2020. These include, for example, reducing CO_2 emissions relative to every unit of GDP, increasing overall GDP and the proportion spent on R&D or created from low-carbon industry, percentage of green spaces and buildings obtaining green certification, coverage of public transport and proportion of energy derived from renewables, to name a few.

View of Low Carbon Exhibition Centre (architectural rendering)

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3. Design and implementation

Design phase

Timeline and inputs

Development of the idea of establishing a low-carbon pilot city in Shenzhen unfolded over around two years, from 2010 to 2012. As mentioned, in 2010 Shenzhen was officially nominated by NRDC to become one of the first national low-carbon pilot cities in China. This gave the City of Shenzhen the responsibility of trialling various policies and initiatives to reduce carbon emissions and achieve a new model of low-carbon, urban development that could be shared with other cities across China. This designation as a national low-carbon pilot city sparked a series of exchanges and collaborations between the City of Shenzhen, the Embassy of the Kingdom of the Netherlands, and Dutch research institutions such as Delft University of Technology and Harbin Institute of Technology Shenzhen Graduate School on areas like urban planning, infrastructure and sustainable city development etc. Also, research by local institutions on establishing a zone for industrial cooperation between the three provinces of Shenzhen, Dongguan and Huizhou was conducted. In parallel, 2010 also witnessed an international conference called the "International Conference on Next Generation Infrastructure Systems for Eco-cities". The event was attended by hundreds of experts from around the world, and culminated in the suggestion that an "ecological knowledge city" be established in Pingdi.

In 2011, further research was conducted on establishing this ecological knowledge city. As part of this, officials from Shenzhen and from the Netherlands shared several meetings and official visits, that eventually lead to the formal decision to establish a "Sino-Dutch Low Carbon City". This name later was changed to "International Low Carbon City". In 2012, cooperation between the two sides was raised to the national level between China and the European Union. In the "High-Level Conference on China-EU Urbanization Partnership"[2] attended by Prime Minister Li Kequiang and the Mayor of Shenzhen, ILCC was officially launched as one of eight pioneering eco-cities projects by China. These all involved collaborations with E.U. countries and Singapore.

In 2013, the official masterplan titled "Shenzhen International Low Carbon City Pilot Zone Planning Research (Detailed Blueprint)" was approved by the City of Shenzhen and Longggan District Government. This masterplan was a collaboration between various academic players in Harbin Institute of Technology, the Next Generation Infrastructures Foundation (affiliated with Delft University of Technology) and the Dynamic City Foundation, a Dutch-owned architecture institute in Beijing. This 150-page report was based upon research into the geographical, economic, environmental and infrastructure attributes of the target area. It included all the details on the land functions, spatial plan and project guidelines of the new eco-city, in addition to images showing the appearance of the futuristic, green and knowledge city. After adoption of this masterplan, input of foreign architectural firms was then integrated into the design of individual large construction and infrastructure projects through international design competitions.

Implementation phase

Timeline and inputs

Construction in ILCC began in late 2012. Ground breaking on the new exhibition centre, one of the centrepieces of the initial pilot zone, took place in early 2013. For detailed information on the timeline and implementation progress, refer back to sections 'Programme target and scope' and 'Programme structure and function'.

Key collaborations

To design and implement the ILCC project, the City of Shenzhen attached great importance to establishing partnerships to draw upon international expertise in eco-cities, urban planning, energy and other areas, and combine this with Chinese expertise. Collaboration across government, private sector firms, NGOs

[2] The Sino-Euro partnership on urbanisation was launched in Brussels in May 2012 offering a framework for cooperation between European and Chinese cities on sustainable urban development projects in China. Twelve agreements have already been signed and a yearly Sino-Euro forum was established for exchanges between leaders and stakeholders from both sides on advanced forms of sustainable urbanisation.

and development organisations—local, national and international— is thereby the motor by which ILCC is unfolding. Moving into construction and business development, countless alliances have been forged between public agencies in Shenzhen and domestic or foreign private enterprises, international organisations and research institutes. Some notable examples include:

- Joint establishment of Sino-U.S. Low-Carbon Building and Community Innovation Centre by Lawrence Berkeley National Laboratory in the U.S. and Shenzhen Institute of Building Research. This will be a base for R&D in low-carbon construction technologies, energy efficiency testing, human resource training and new business development. The RMB 480 million facility will attain 70,000 m2 of GFA and encompass testing facilitates, offices, incubator spaces and apartments.

- An annual international low-carbon forum is held in the exhibition centre in ILCC. This annual event gathers experts, scholars and companies to exchange information and exhibit the latest green technologies and sustainable building methods, thus becoming a driver for more innovation in the city. Shenzhen relies heavily on this forum, first launched in 2013 as a promotion platform for ILCC. It aims to attract international attention of businesses and research institutions and serve as a feedback platform for international views on the progress of the eco-city.

- Other collaborations with international organisations have included the United Nations Development Programme, World Bank, Asian Development Bank, Global Environment Facility, World Wildlife Fund, C40 Cities Climate Leadership Group and R20 Regions of Climate Action.
Compromising/adjustments

Compromising or adjustments

After completing the pilot zone and majority of the extension zone in 2025, Shenzhen plans to replicate lessons learned there on the remaining area. In addition, the various quantitative targets set for the eco-city have all been designed to be highly ambitious, and therefore, difficult to achieve. It is possible that some of these could be adjusted according to the outcomes of development progress over the next several years.

View of innovative green buildings surrounded by rich environment of Pingdi

Credit: Provided by Shenzhen Municipal Government. Copyright © 2016

4. Outcomes and impacts

Environmental impacts

As suggested by Table 1, the environmental accomplishments of ILCC will be vast. With various projects realised so far, the Pingdi area has witnessed substantial improvements to the built and natural environment. Carbon emissions intensity per unit of GDP have already dropped by 22% in Pingdi, from 2.21 t-CO_2 in 2011 to 1.72 t-CO_2 in 2014. This is largely the result of the industrial transformation, as many new low-carbon enterprises move into locations around the pilot zone. Vastly greater reductions are anticipated for the future, since Shenzhen officials are limiting to limit carbon intensity to 0.32 t-CO_2 per RMB 10,000 , or 5 t-CO_2 per capita, by 2025. Additionally, renewable energy will make up 30% of ILCC's energy supply, decreasing coal usage and boosting air quality. This will result in a low-carbon electricity mix of 0.694 t-CO_2/MWh. Expectations are also that a combination of low-carbon power, green spaces and vegetation in building roofs and walls will ensure that at least 350 days per year exceed the good air quality index, whilst at the same time, heat island intensity is mitigated to below 1°C. As mentioned already, water quality in river systems will also be significantly improved, as ecological sewerage and treatment networks, recycling up to 90% of industrial water discharge, and vegetation-based flood control measures, are implemented.

Environmental impacts are already prominent in the building stock, and poised to grow. So far, around 100,000 m^2 of buildings has been retrofitted, as ILCC aims to achieve a 1-star rating for 50% of existing buildings, and for new

buildings, 50% as 1-star, 30% as 2-star and 20% as 3-star. The aforementioned exhibition centre, for instance, has already attained a 3-star rating. Further environmental improvements will include the transport system. Improved walkways, comprehensive public transit (metro, buses and streetcars) and measures to encourage bicycle use—in addition to an 80% electric vehicle share of road transport by 2025—will reduce citizens travel-related carbon footprint whilst promoting exercise and healthy lifestyles.

Social impacts

Pingdi was once was a poor, crowded and polluted district with a low quality of life. Its population of some 170,000 low-income farm workers and built environment was marked by heavily polluting and low output factories, deteriorated traditional houses and chronic urban sprawl. This scene is now in the process of transforming into a highly livable, dense and mixed-use, futuristic and ecologically-centered city that will draw global attention. Population will grow to over 420,000 by 2020 and increase further in the years beyond. It is predicted that around 50,000 high-paying new job opportunities will be created by 2020 as a result of the economic and environmental reformation. Mixed-use urban forms, combining commercial, residential and industrial premises into tightly compact pockets, surrounded by dense green zones will promote sustainable lifestyles among the citizens, reducing transit times and need for travel. Live monitoring of emissions and educational efforts from public agencies will make citizens aware of their activities and how they are affecting the environment.

ILCC will thus become a role model for other Chinese cities struggling with pollution and problems of urbanisation, and other cities around the world. Pingdi will demonstrate that high levels of environmental quality can be attained with existing built environmental heritage. On the planning side, this is through a combination of visionary and long-term masterplans, ambitious targets, explicit guiding principles and progress indicators, and on the implementation side, a combination of retrofitting and new construction driven by public-private and international collaboration. This marks a radical new form of urban development for China, which until recently, has not typically pursued international collaboration or preservation of existing buildings and heritage.

Market impacts

Although ILCC concerns the physical transformation of the built and natural environment in Pingdi, it is equally an economic transformation project. It's chief accomplishment will be the transition from carbon-intensive and low output forms of industry (mostly traditional manufacturing with low economic output relative to floor area) to low-emission and high output types of new industries. As shown in Table 1, by 2025 it anticipated that new, low-carbon industries will make up in excess of 80% of local GDP. Initial indicators demonstrate that early progress is being made. Firstly, ILCC has attracted many new businesses and industries. In the last two years, 40 high-tech companies with a total output of RMB 9.6 billion have settled in the eco-city. Secondly, industrial output in Pingdi grew strongly between 2011 and 2014, from RMB 11.5 billion to RMB 23.4 billion. This translates to an annual growth rate of 27%. Third, indications show that in the same period between 2011 and 2014, rental yields of factories doubled from around RMB 7/m^2 to around RMB 14/m^2 whilst fixed asset investment doubled. Fourth, state asset investments in the eco-city also grew for this period, from RMB 1.91 billion in 2011 to RMB 4.25 billion in 2014. This equates to an annual growth rate of around 30%. Pingdi is therefore poised to become a leading-edge centre of international significance for sustainable urban development. This will bring global attention to exploit lessons from this transformation experience in other cities around the world, thus providing unique business opportunities for Chinese companies.

5. Lessons learned for replication

Strengths and drivers

Balance of national government support with city-led decision making power

Support from the national government (i.e. NRDC) and substantial state asset investments are significantly driving progress in ILCC. Following the decision to select Pingdi as one of eight national pioneering low-carbon eco-city projects, a city-level branch of NRDC was set up in Shenzhen to serve as the official body guiding ILCC, and also, establish networks with external parties. National governmental interest in ILCC not only contributed to the increase of state asset investment, it also instilled confidence in the business sector to get involved, equally facilitating governmental cooperation with the Dutch side. On the other hand, designation as a pilot city also emphasised a bottom-up approach. The City of Shenzhen was given authority from NRDC to adopt policies and approaches that best fit its local conditions. Thus, synergy attained from the commitment of the national government, together with rule-making and goal-setting power given to the City of Shenzhen, has played and will continue to play an important driving role in realising the establishment of ILCC.

Gradual improvement strategy, with rigorous monitoring

One factor also helping ILCC achieve its ambitious goals is the strategy of focusing efforts and investments in controlled phases and development zones, of which the results are carefully monitored. By focusing on fully establishing the pilot zone of 1 km^2 and much of the 5 km^2 extension area by 2025, results will be concentrated and highly visible. ILCC will consequently be well-positioned to extract lessons from these initial development sites and apply them to the remaining area. Use of the low-carbon index and its comprehensive set of indicators will allow objective, quantitative monitoring of environmental, economic and societal performance as the eco-city unfolds. As shown in Table 1, not only will these serve to measure progress, they are also serving as yardsticks of sustainability against which various project proposals can be evaluated. In addition, they also send an explicit vision and set of guiding principles for urban planners and new industries regarding the

types of environmental performance required by the individual components for the entire city.

International and local collaborations

Driven by public-private partnerships, both local and international, ILCC is constantly injected with expertise and emerging technologies from around China and the globe. This gives a chance for cutting-edge ideas from outside to find their way into the emerging eco-city. These drive innovation and progress in a fashion that might not have been possible with domestic policy and industry know-how alone. ILCC also emphasises the international identity of Pingdi and Shenzhen. Significant efforts are being made to increase use of English through language education, international schools and signage etc. This further facilitates the migration or engagement of foreign firms, urban designers and engineers. The financial resources of Shenzhen and the commitment of the national government to driving green development then allow these experts to contribute to achieving a level of innovation and socio-environmental impacts that would not have been possible in their home country.

Challenges, limitations and countermeasures

Promoting low carbon industries as a mainstream business model

The concept of an eco-city and low-carbon economy is still new to the local industry, still heavily influenced by its recent and traditional manufacturing based past. Despite support from the national and local government and appeal as a general idea, propagating the concept of a low-carbon economy to foster viable business models and achieve significant investment levels in a non-mature, still emerging market is proving highly challenging. This is especially so given that the mind-set of industry is slow to change, with many key players still unable to see the financial sense in establishing high-capital and high-risk ventures and building projects in an uncertain market. The main strategy used to overcome these barriers are subsidies for retrofitting and low-interest loans for smaller start-ups. However even these are sometimes not sufficient enough to entice retrofitting of older, industrial premises and reformation of business models, since many owners perceive little immediate benefit from doing so.

Technological innovation dependent on subsidies

The pursuit of advanced technological innovation is hugely dependent on governmental support and investments. Since many technologies are new, unproven or still emerging, the cost of production and installation is still high. As such, government officials face the challenge of having to not only promote diffusion of these technologies, but also support industry so that low-carbon technologies can be produced at lower costs. Achieving this will require time and continued, large, public and private investments in R&D. It will also necessitate a spirt of risk taking and innovation, which is still in the process of emerging.

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Also essential is trust and intimate cooperation between Chinese and foreign firms. However concerns over protection of intellectual property appear to be challenging progress in this area. This highlights the need for institutional and private sector measures to protect the intellectual property fruits that arise from increased R&D spending and blue-sky innovation activities.

Restrictions imposed by natural environment setting

ILCC is located in a rich, natural environment. Half of the existing land comprises of vegetation, mountains and forests of which 40% is a natural reserve. However, full development of the entire eco-city in the coming years will require some encroachment upon these natural areas. This poses fundamental challenges to the overall goal of preserving natural spaces across the entire city, and creating additional greenery to attain a green land surface area of around 70% overall, and 35% in the central urban areas. To tackle this challenge, the City of Shenzhen has a set ecological protection lines around the city where development is restricted. Integration of dense, mixed-use urban development principles with careful, phased-out development and city-led planning are also serving to contain sprawl and preserve natural spaces.

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