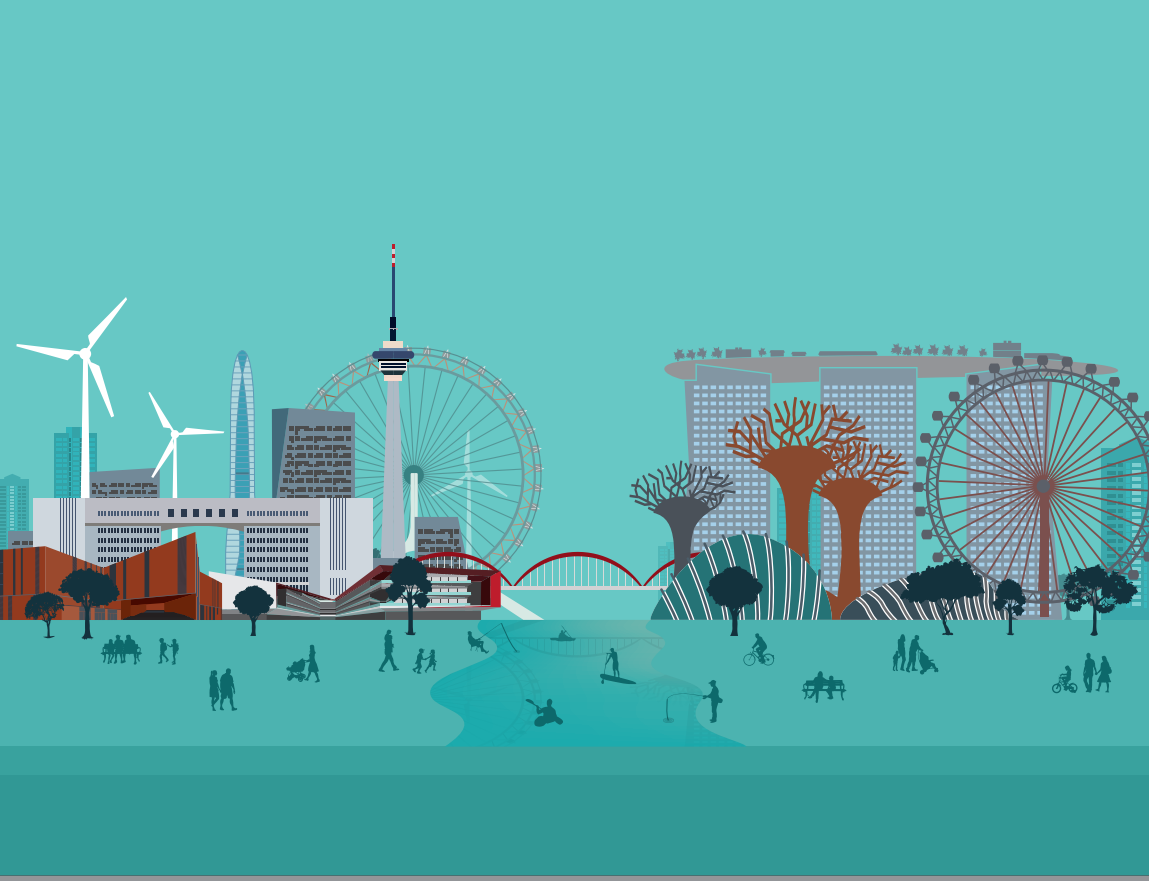

A Partnership for a Smart and Sustainable Future

The China-Singapore Tianjin Eco-City

中新天津生态城
CHINA-SINGAPORE TIANJIN ECO-CITY

中国生态城市研究院
CHINA ECO-CITY ACADEMY

CENTRE for LiveableCities SINGAPORE
A division of AND SINGAPORE

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CENTRE for LiveableCities SINGAPORE

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Set up in 2008 by the Ministry of National Development and the then-Ministry of the Environment and Water Resources, the Centre for Liveable Cities (CLC) has its mission "to distil, create and share knowledge on liveable and sustainable cities". The CLC's work spans four main areas—Research, Capability Development, Knowledge Platforms, and Advisory. Through these activities, the CLC hopes to provide urban leaders and practitioners with the knowledge and support needed to make our cities better.

中新天津生态城
CHINA-SINGAPORE TIANJIN ECO-CITY

The China-Singapore Tianjin Eco-City Administrative Committee (ECAC) was set up by the Tianjin Municipal People's Government to oversee the planning and development of the project.

中国生态城市研究院
CHINA ECO-CITY ACADEMY

China Eco-City Academy (CECA) is a State-level research institution focused on green, smart and liveable development of cities, approved by the State Council of the People's Republic of China, and jointly established by the Chinese Society For Urban Studies (CSUS) and the China-Singapore Tianjin Eco-City (TEC). CECA's key mission is to support the planning, design, construction, operation and management of eco-cities in China, and be a think-tank for the TEC, a flagship Government-to-Government project between Singapore and China. CECA brings together an authoritative team of experts, locally and internationally, to provide solutions for China's and international eco-city development.

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A Partnership for a Smart and Sustainable Future

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中国生态城市研究院
CHINA ECO-CITY ACADEMY

"The idea is to create, jointly with China, a city which is socially harmonious, environmentally friendly, resource efficient, and which can serve as a model for other Chinese cities... I am confident that the Eco-City will become a second iconic project in our bilateral cooperation."

Lee Hsien Loong

Prime Minister of Singapore (2007)

"我们的愿景是与中国共同创造一座社会和谐、环境友好、资源节约的城市，为其它城市提供一个可持续发展的样本…我有信心生态城将成为我们两国之间友好合作的第二个亮点。"

新加坡总理李显龙 2007 年

"The Tianjin Eco-City should take care of the balance between pursuing advanced and high-end solutions and being practicable and scalable, and provide a good answer to the challenge of achieving harmony between people and people, people and the economy, and people and the environment, so as to be a model for a resource-efficient and environmentally-friendly city."

Xi Jinping

President of the People's Republic of China (2013)

"生态城要兼顾好先进性、高端化和能复制、可推广两个方面，在体现人与人、人与经济活动、人与环境和谐共存等方面作出有说服力的回答，为建设资源节约型、环境友好型社会提供示范。"

中国国家主席习近平 2013 年

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FOREWORD

Sim Ann

Senior Minister of State for National Development and Foreign Affairs, Singapore

Singapore is pleased to have contributed to the successful development of the Sino-Singapore Tianjin Eco-City (TEC), the second flagship Government-to-Government project between Singapore and China. It signifies the deepening bilateral cooperation between both countries, and has helped both sides learn about smart and sustainable development from each other. As climate change is an existential threat that affects all of us, we hope that TEC's experience can serve as a contribution towards better understanding of green growth and sustainable development among policymakers, both in Singapore and China, as well as countries around the world.

The TEC has made good progress over the years and continues to make headway in its development through the strong partnership between Singapore and China on smart and sustainable urban development. Our leaders, officials and experts from the public and private sectors have collaborated to bring together expertise and experience from Singapore and China to develop TEC and achieve its vision of people living in harmony with one another, with economic activities, and with the environment.

To achieve this vision, Singapore had worked with China to introduce innovative initiatives including developing a comprehensive Key Performance Indicator (KPI) Framework to guide the TEC in its planning and development. At the time, there was little agreement on what defined an eco-city, and how to measure success. Singapore treasures our partnership with China in being joint early movers in this space.

From a site which comprised abandoned saltpans, barren land and polluted waterbodies, the TEC has transformed into a green, liveable and smart city to live, work and play in. The sharing of best practices and experiences from Singapore and China in the TEC, such as its sponge city development and integrated water management, have allowed open spaces and parks to be developed in the TEC without the occurrences of floods. Urban management and the quality of public services have also been enhanced through TEC's smart city developments such as its one-stop online services platform.

We will continue to deepen efforts in positioning the TEC as a forerunner in eco-development and meet the evolving needs of residents. To this end, Singapore and China have worked together to upgrade the KPI targets for TEC to ensure it remains a leading eco-city in China. We have also worked together on a new Master Plan for zero-waste initiatives in the TEC.

Both countries envisage the TEC as a model that other cities in China and beyond can refer to in their own sustainable development journey. To this end, the TEC was designated as China's National Green Development Demonstration Zone in 2013. The TEC regularly hosts visits from Chinese cities interested in its development experience. In addition, TEC's experience in water rehabilitation has been replicated in the Xiong'An New Area's Baiyangdian (白洋淀) Lake Basin, Hunan Province Zhuzhou City's Qingshuitang (清水塘) and Zhejiang Province's Yuhuan City. Furthermore, TEC became a pilot programme for International Standards Organisation (ISO) standards for the management and implementation of sustainable cities and communities in 2017.

I would like to thank the Chinese leaders and senior officials for their continued support and collaboration in the TEC and forging a close partnership between our two countries in positioning the TEC as a leading smart and eco-city at the forefront of smart and sustainable development. I hope readers will find this book a useful reference in learning more about TEC's development experience.

FOREWORD

Huang Yan

Vice Minister for Housing and Urban-Rural Development, People's Republic of China

The China-Singapore Tianjin Eco-City: An Eco-City of the World and the Future

As the world's largest developing country, China is undergoing the most extensive and rapid urbanisation in history. By the end of 2019, 60.6% of its permanent population had become urban dwellers, up from 10.6% at the end of 1949. Facing exponential growth in the number of cities, urban population, built-up areas and urban housing development, China has been proactively drawing from the experience of both domestic and international eco-cities. By rolling out extensive programmes to implement green-city development across the nation, China has seen significant improvements in its ecological and environmental indicators, including those for urban resources, natural environment and supporting amenities. In particular, the China-Singapore Tianjin Eco-City (TEC) has become one of China's most important and successful projects in eco-city development, and has attracted both domestic and international attention.

In November 2007, the governments of China and Singapore made the decision to build an eco-city in the Tianjin Binhai New Area and signed the *Framework Agreement on the Development of an Eco-City in the People's Republic of China*. The following September, leaders of the two governments officiated the ground-breaking ceremony for the TEC in the Tianjin Binhai New Area. After nearly 13 years of hard work, the once-barren 30 km^2 block along the Ji Canal has taken on an impressive new look; in place of a saline-alkali expanse, a beautiful and vibrant international city stands there today.

The TEC draws on many of Singapore's experiences in developing liveable cities and explores various ways to advance its own development. The TEC has established a framework for the planning and development of an eco-city based on Key Performance Indicators (KPI) to systematically examine and evaluate the TEC's performance. The TEC's master plan is formulated to provide a clear blueprint to guide the various aspects of development. Rehabilitation works carried out on the saline-alkali barren site and the lessons learnt from the process have been distilled into a restoration solution that is being implemented in various regions of China.

Following the rehabilitation, an open eco-space comprising "One Island, Three Waters and Six Eco-Corridors" was formed to house a green ecosystem. Building on local conditions unique to the site, the TEC set up a rainwater harvesting system to collect and recycle rainwater, creating a new model for building a sponge city on saline-alkali land. High-quality green buildings and demonstration projects for low-energy or zero-energy buildings were built to achieve the goals of reducing demand for land, energy, water and building materials and, most importantly, to protect the environment.

The TEC promotes the use of renewable energy by comprehensively utilising energy from solar, wind, geothermal and biomass sources, effectively reducing urban carbon emissions. The TEC was designated a Zero-Waste pilot city. Waste sorting and recycling are encouraged in the TEC, and a waste disposal system that features reduction at source, classified collection, closed transportation and concentrated disposal was established. To improve urban governance and capabilities in delivering public services, the TEC is charting new frontiers in smart city development, building a city information modelling (CIM) platform. To enhance the sense of belonging and unity among people, the TEC has stepped up its conservation efforts in protecting its local cultural and historic sites, such as the ancient canal first built during the Three Kingdoms (AD 220-280) period, and a commanding podium for calvary units from the Qing Dynasty (1644-1911). Such efforts enhance the TEC as a cultural city as well as an eco-city that has retained its historical memories and characteristics of its region.

To build liveable communities, the TEC has established a three-tier residential model based on a system of "eco-cell – eco-neighbourhood – eco-district", featuring a 500-metre-radius living circle. The TEC has attracted 100,000 residents to live and work there. This experience provides a useful reference for urban development in Chinese cities, as many practices from the TEC have now been adopted as the criteria for assessing the development of green and ecological cities in China.

Throughout its development, the Chinese and Singapore governments worked closely together to ensure a greener and more sustainable future for the TEC. A Joint Steering Council (JSC) meeting is held annually to enable senior leaders from both countries to gather and make decisions that guide major developments in the TEC. Led by the Ministry of Housing and Urban-Rural Development of the People's Republic of China and the Ministry of National Development of the Republic of Singapore, the JSC manages and supports the development of the TEC closely, to strategically position and integrate its development in the wider "Beijing–Tianjin–Hebei" region. In addition to the high-level council meeting, the two ministries communicate actively and convene regular coordination meetings every year to solve problems, enhance mutual understanding and expand bilateral cooperation to create a win-win situation. The close cooperation between the two ministries will offer valuable experience for future international cooperation in eco-city development. This book, based on *The China-Singapore Tianjin Eco-City: A Typical Model for the Ecological City (Chinese Edition)*, summarises the experience in planning, constructing, and managing an eco-city, and can serve as a reference for professionals from China and abroad working on eco-city development.

China's President Xi Jinping proposed at the 75th General Assembly of the United Nations that China would strive to reach its peak in carbon dioxide emission by 2030 and achieve carbon neutrality by 2060. At the Climate Ambition Summit on 12 December 2020, he made these solemn commitments, "By 2030, China's carbon dioxide emission per unit of GDP will drop by more than 65% of that of 2005, and the consumption of non-fossil energy will account for about 25% of the primary energy consumption." These commitments not only place higher requirements for the development of China's ecological cities, but also have become the major task and guideline for China's new urbanisation campaign.

In the face of more stringent requirements in the new development era, the TEC has embarked on a new journey guided by the concept and goals of building a liveable, green, resilient, smart and cultural city. We look forward to more prevalent implementation of advanced green concepts and technologies to reduce carbon emission in cities all over the world.

PREFACE

The Tianjin Eco-City (TEC) is the second flagship Government-to-Government project between Singapore and China. The project was mooted by then-Singapore Senior Minister Goh Chok Tong and then-Chinese Premier Wen Jiabao in April 2007, against the backdrop of rapid urbanisation and increasing global attention on the importance of sustainable development. On 18 November 2007, Singapore Prime Minister Lee Hsien Loong and then-Chinese Premier Wen Jiabao signed the Framework Agreement for Singapore and China to jointly develop the Sino-Singapore Tianjin Eco-City project. More recently, on 20 September 2018, Singapore and China signed a Memorandum of Understanding on promoting the replication of the Eco-City's development experience.

With a total land area of 30 km^2, the TEC was planned to house a population of 350,000. The Master Plan for the Eco-City was jointly developed by the Singapore planning team led by the Urban Redevelopment Authority (URA), and the Chinese planning team from the China Academy of Urban Planning and Design and the Tianjin Urban Planning and Design Institute. The joint effort to develop the TEC demonstrated the determination of both Singapore and China to tackle the challenges of addressing climate change, strengthening environmental protection, conserving resources and energy, and building a harmonious society.

"A Partnership for a Smart and Sustainable Future: The China-Singapore Tianjin Eco-City" is a collaborative project between the Centre for Liveable Cities (CLC), Singapore, and the China-Singapore Tianjin Eco-City Administrative Committee (ECAC), China. It documents the shared journey undertaken by both countries to develop a model for sustainable urban development based on the principles of social harmony, environmental sustainability and resource conservation. This publication seeks to distil and share key insights from a decade of the TEC's development experience.

It is heartening to note that the collaboration has been and continues to be strongly supported, with the active participation of senior officials from both sides. This publication is a testament to the longstanding ties and strong partnership fostered between Singapore and China.

The joint research and editorial team of the CLC and the ECAC have worked closely together, having interviewed and gathered inputs from pioneers and colleagues who were deeply involved in the TEC, to tap on their insights and expertise. As a knowledge centre under Singapore's Ministry of National Development, the CLC seeks to share knowledge on the best practices and lessons in urban governance and to promote the development of sustainable and liveable cities. This collaboration has deepened mutual knowledge-sharing between Singapore and China, and we look forward to sharing this publication with other international cities.

This book consists of five chapters. The first four chapters focus on the development journey of the TEC, and the final chapter synthesises the key insights, vision and perspectives from the TEC experience.

Chapter 1 sets out the ambitious yet pragmatic vision for the TEC, which is underpinned by the concepts of "three harmonies and three abilities" (三和三能). The three harmonies refer to people living in harmony with the environment, economy and society. At the same time, the TEC would serve as a viable model for sustainable development that is practicable, scalable and replicable in other cities. As the second strategic Government-to-Government project between China and Singapore, the development of the TEC would be anchored around a comprehensive governance framework embedded at the strategic planning and implementation levels.

The starting point for the TEC, as explained in Chapter 2, underscored its groundbreaking approach to sustainable development. Unlike other typical urban developments in China, the TEC began with a holistic Key Performance Indicators (KPI) Framework, which reflected the concepts of "three harmonies and three abilities". This KPI Framework

signalled the TEC's push towards more ambitious standards in environmental, economic and social developments than what had been the norm throughout China. There was a corresponding shift to integrate its KPI Framework into the master planning process. This translated into a strategic focus on protecting the TEC's green and blue environmental assets and networks, developing a compact city favouring greener travel modes, and an "eco-cell – eco-neighbourhood – eco-district" model based on Singapore's public housing development experience. The result has been a highly liveable and endearing living and working environment.

One of the TEC's most critical tasks was restoring the natural environment and strengthening its blue—green networks after four decades of industrial pollution. Chapter 3 elaborates on the TEC's pioneering efforts to rehabilitate a former wastewater pond at the heart of the site and enable greenery to supplant previously barren lands. The TEC has also implemented measures to ensure that its limited resources of water and energy are used sustainably, and any waste generated is reused and recycled responsibly. Crucially, non-traditional water sources such as recycled water provide 60% of its water needs, allowing the TEC to be water resilient in a water-scarce region. In transport, the TEC has made greener travel modes a priority, such as by introducing greenways to encourage active mobility. All buildings in the TEC are certified green buildings, further shrinking the city's carbon footprint.

The development of a vibrant economy and active communities to sustain the TEC are described in Chapter 4. To make the city attractive to residents, public facilities and amenities were built ahead of demand and distributed based on the concept of "15-minute neighbourhoods". In education and healthcare, the TEC introduced innovations such as experiential learning through classroom simulations and an integrated neighbourhood health service management system. Community centres and residents' centres promote bonding among residents as they are encouraged to step up and take stewardship of their communities. In line with its vision, the TEC focused on developing with low-emissions growth despite facing considerable challenges. Five industrial parks in the TEC cater to the creative industries, information technology, environmental technology, and services such as tourism and healthcare. Technological innovation lies at the heart of the TEC's strategies to attract talent, nurture innovative capabilities and grow the R&D ecosystem.

So, what lies ahead for the TEC? Chapter 5 sheds light on how the TEC continues to push the envelope of sustainable development and, more recently, smart city development. Its KPI Framework has been upgraded to set higher targets in environmental and social development, and incorporate smart-city development to further improve urban management. A new Master Plan for a Zero-Waste City is in the works, which seeks to support innovation in advanced waste management technologies and establish a resilient circular economy. With the TEC's start-up area largely completed, the focus is turning to its city centre. Designed in collaboration with Singapore, the city centre is envisioned as a "Green Smart Hub"—packed with green and smart infrastructure. Undergirding all this is the TEC's software as represented by its governance system, and the community vibrancy and cohesiveness that makes it stand out amid other emerging eco-cities.

Smart and sustainable are the important drivers for the TEC's ecological, economic and social developments. To realise its vision of being a practicable, replicable and scalable model for sustainable development, the TEC continues to innovate and adapt to ever-changing needs. With the commemoration of its 10th year anniversary on 28 September 2018, the TEC continues to transform itself in the face of current and future challenges to achieve higher targets in environmental, social and smart-city developments.

We sincerely hope that this publication will provide interesting insights on sustainable development and be a valuable reference for other cities looking to become smarter, greener and more liveable.

Centre for Liveable Cities
Singapore

Tianjin Eco-City Administrative Committee
People's Republic of China

CHAPTER 1

Tianjin Eco-City: A Practicable, Scalable and Replicable Model for Sustainable Development

The site of the TEC was once barren land and polluted waterbodies (left); since 2007, it has been transformed into a vibrant and liveable eco-city (right). Image courtesy of Sino-Singapore Tianjin Eco-City Investment and Development Co., Ltd. (SSTEC)

Cities and Sustainable Development

Since the initial discussions between Singapore and China in 2007, the Sino-Singapore Tianjin Eco-City project (中新天津生态城, TEC) has made substantial progress over the past decade. Today, its start-up area—a mixed-use district of 8 km^2 with residential developments, industrial parks, community centres, schools and a hospital—has been completed, and houses a population of 100,000 people alongside more than 9,800 companies with a registered capital of greater than RMB 414 billion.[1] Who could have imagined that this was built on what was once barren land?

Birth of the Second China-Singapore Bilateral Project

The year Singapore and China initiated the eco-city project was the same year that China's then-Premier Wen Jiabao warned that the Chinese economy was threatened by the "Four Uns"—becoming unstable, unbalanced, uncoordinated, and unsustainable (不稳定、不平衡、不协调、不可持续). China had undergone an important phase of rapid urbanisation and industrialisation in its development. While China's per capita resource utilisation was still low relative to its level of economic development and population size at the time, its

energy consumption and carbon emissions were expected to rise as the economy developed. China was also facing water shortages in many of its cities, a problem exacerbated by water pollution in urban areas. Confronted by the twin challenges of resource constraints and environmental pollution, the Chinese government thus placed greater emphasis on sustainable development.

It was against this backdrop that the idea of jointly developing an eco-city in China was first proposed in April 2007 during discussions between Singapore's then-Senior Minister, Goh Chok Tong and China's then-Premier, Wen Jiabao.

"When I saw Premier Wen Jiabao in 2007, I broached the subject of an Eco-City. He listened attentively. China at that time was emphasising the environment, green development, urbanisation without too much pollution. We had the expertise in Singapore. I was able to align our experience with China's interest of wanting to have a clean environment for its urbanisation. Premier Wen agreed on the spot and we birthed the Tianjin Eco-City."

Goh Chok Tong, Emeritus Senior Minister of Singapore

The collaborative effort to develop the TEC demonstrated the determination of both countries in tackling the immense challenges of addressing climate change, strengthening environmental protection, conserving resources and energy, and building a harmonious society. Amidst global concerns about the effects of urbanisation on climate change, this bilateral project aimed to provide a model for sustainable development for other cities in China and elsewhere.

"Singapore is strongly committed to this global research effort. We are investing considerable sums to develop clean technologies like solar and water. We are also partnering China to build an eco-city in Tianjin, to testbed and demonstrate environmentally sustainable and economically viable approaches for urban development, which can be replicated in other Chinese cities.[2]"

Lee Hsien Loong, Prime Minister of Singapore

Testing New Ground, Collaborating on Urbanisation Challenges

Following the development of the Suzhou Industrial Park (苏州工业园) in February 1994, the first strategic Government-to-Government project (G-to-G) between Singapore and China, the TEC became their second strategic G-to-G project with an emphasis on sustainable development.

Leading with Vision and Pragmatism

With sustainable development in mind, the vision for the TEC project was ambitious yet outlined with pragmatism. The TEC project would not be merely an experimental showpiece but a demonstration project that strived to push boundaries. Drawing on its urban development experience and taking into consideration China's developmental needs, Singapore proposed that the vision for the TEC initiative focus on "three harmonies and three abilities" (三和三能). The "three harmonies" referred to people living in inclusive and harmonious communities; people living in harmony with economic activities; and people living in harmony with the environment. The "three abilities" referred to the TEC model being practicable, replicable and scalable. Being practicable meant that instead of focusing on cutting-edge technologies, the technologies and systems adopted for the TEC had to be affordable and commercially viable. Being replicable meant that the technologies and systems implemented in the TEC could be adopted in other Chinese cities or cities elsewhere. Being scalable meant that the technologies and systems developed for the start-up phase of the TEC could be adopted on a larger scale in bigger cities.

The thinking behind this vision was then translated into the following approaches for action. First, the project was to emphasise environmental sustainability, resource conservation and recycling. Second, it had to conform with the relevant Chinese laws, regulations and national policies. Third, the project was to enhance the capacity for innovation, and the technologies developed to be appropriate to the Chinese context and protected by a robust intellectual property rights regime. Fourth, the project was to maintain a clear separation between the public and private sectors by clearly defining the roles and responsibilities of local government agencies and the private sector, while adopting a market-oriented approach in the provision of public amenities and facilities in the TEC.

In addition, during another meeting between then-Premier Wen and then-Senior Minister Goh in September 2007, the Chinese government proposed two conditions that the TEC project had to meet. The first condition was that the site of the TEC was not to occupy any arable land, and the second was for it to be located in a water-scarce area. This positioned the TEC as a potential example of sustainable urban development in the context of significant resource constraints. In turn, the Singapore government suggested additional factors that would be essential to the success of the project, such as locating the TEC close to an existing city centre so that it could attract residents and investments, as well as being plugged into well-developed transport infrastructure and networks. Based on these parameters, four possible sites for the project were identified in the western and eastern regions of China: Baotou (Inner Mongolia), Tangshan (Hebei), Tianjin and Urumqi (Xinjiang).

Following several field visits to the proposed sites and reviews of site selection reports from the municipal governments of Baotou, Tangshan, Tianjin and Urumqi in 2007, Tianjin was eventually chosen to host the TEC. The proposed site in the Tianjin Binhai New Area (天津滨海新区, TBNA) comprised abandoned salt farms, polluted water bodies and abandoned alkali fields—essentially, an area saddled with a degraded environment, fragile ecosystem, no arable land and little water. If an eco-city could be developed in an area that presented such inherent challenges due to its poor initial conditions, it would be a convincing demonstration of the approach taken and highlight possibilities for future projects. Although natural resources were severely limited, the location of the site along the Beijing-Tianjin corridor did mean that it would be supported by a favourable transportation network and energy infrastructure. So the selection of this site was strategically considered at multiple levels.

BOX STORY

Geographical Features and History of the TEC Site

Occupying an area of about 30 km², the TEC site has clear advantages in terms of accessibility and location. The site sits on the west of the Bohai Bay Region (渤海湾区) covering Beijing, Tianjin and part of Hebei Province, which has been identified as China's next growth engine after the Pearl River Delta and Yangtze River Delta. Tianjin's gross domestic product (GDP) was the sixth highest in China in 2009, after Shanghai, Beijing, Guangzhou, Shenzhen and Suzhou. The TEC falls within the strategically important TBNA and is close to the Tianjin Economic-Technological Development Area (天津经济技术开发区, TEDA) and Tianjin Port (天津港). Located 45 km from Tianjin's city centre and 150 km from Beijing's city centre, the TEC is accessible via several highways and high-speed railways, including the Beijing-Tianjin-Tangshan Highway, Tianjin-Binhai Highway, Jingjintang Expressway, and Jingjin Highway.

Distance and typical travel times between the TEC and surrounding areas. Image courtesy of Sino-Singapore Tianjin Eco-City Investment and Development Co., Ltd. (SSTEC)

Much of the low-lying terrain of the TEC site was originally salt pans.

The TEC lies north-east of the North China Plain. In terms of its climate conditions, the annual average temperature of the area is 11.9°C, annual average precipitation is 572.7 mm, annual average relative humidity is 66%, and annual average sunshine is 3,100.2 hours. Its main landforms are silt-mud beaches, coastal plains, uneven flat grounds and flood plains. The terrain is on average less than 5 m above sea level.

The area was the cradle of China's sea-salt industry and home to its first large-scale salt pan. Winding through the city, the Ji Canal (蓟运河) was an ancient canal used during the period of the Three Kingdoms in the third century. The original name of the Ji Canal River (运粮河, meaning "transporting grain") appears in ancient records dating back to the Liao dynasty. During the Yuan and Ming dynasties, vast quantities of building materials were transported via this river directly from northeast China and the surrounding seas to Jizhou. During the Yuan dynasty, the Ji Canal River conveyed 90,000 to 96,000 tons of military food supplies to the border regions each year. In the early Qing dynasty, Du Lide, a prime minister who was from the city of Liangcheng near the Ji Canal River, acquired fertile land downstream on behalf of the Ministry of Works to produce reed,

salt, whitebait and other tributary goods for the imperial court. In the 1950s, China built the Bayi salt pan which occupied an area of 10 km².

Originally filled with salt pans, the area has a high level of soil salinity, scarce water resources, and a severely deteriorated ecosystem. Its main water bodies, the Ji Canal River and Hangu sewage reservoir, were also badly polluted.

The TEC site had high levels of soil salinity, making it difficult for vegetation to grow.

The site was also water scarce, and the ecosystem was badly degraded.

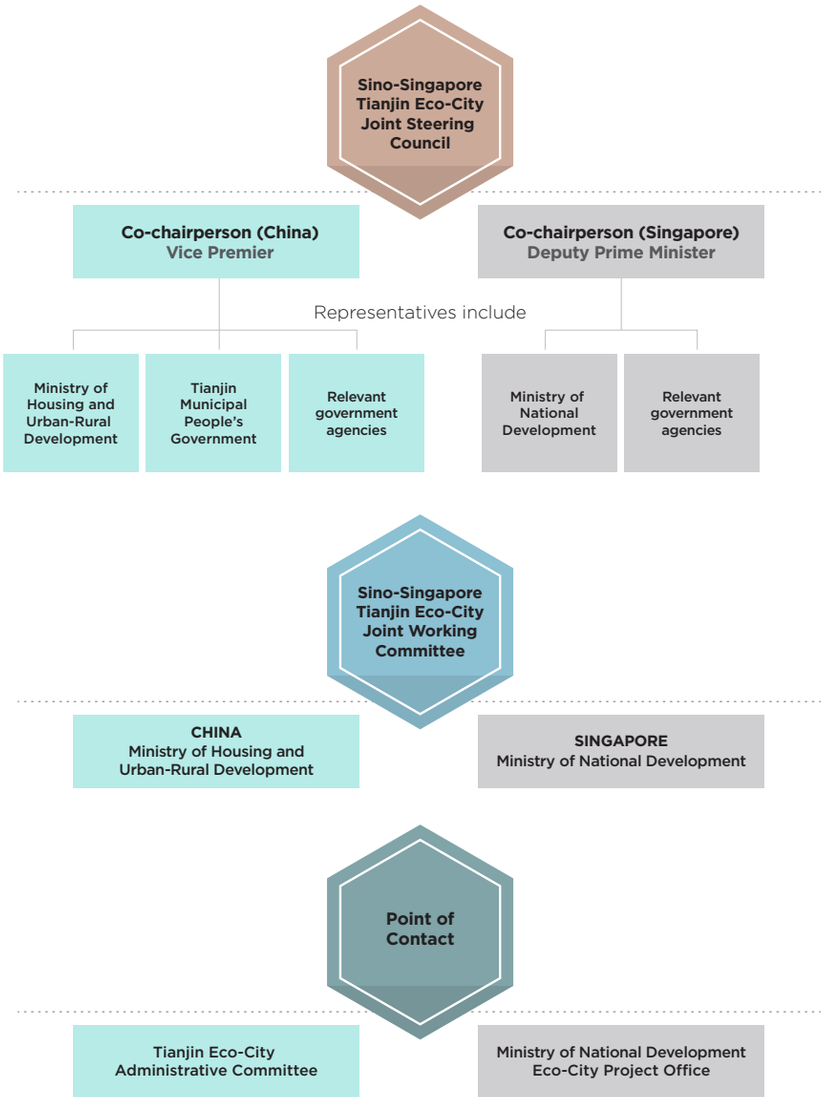
Establishing Sound Governance and Institutions, and Fostering Close Partnership

To implement the TEC initiative, a number of agreements were inked between Singapore and China. The strategic intent and objectives of the TEC project were captured in a Framework Agreement signed by Singapore's Prime Minister Lee Hsien Loong and China's then-Premier Wen Jiabao in November 2007. It stated that the development of the TEC would demonstrate the commitment of both countries in tackling climate change, strengthening environmental protection, conserving resources and energy, building a harmonious society, and that the TEC would serve as a model of sustainable development for other cities in China. This was accompanied by a Supplementary Agreement which was signed by Singapore's then-Minister for National Development, Mah Bow Tan, and China's then-Minister for Housing and Urban-Rural Development, Wang Guang Tao. This agreement laid out the development objectives of the TEC and formally announced the selection of TBNA as the site of the TEC. Supplementary Agreement II was signed the following year in July 2008, which formalised the roles and responsibilities of the implementation unit—the China-Singapore Tianjin Eco-City Administrative Committee (ECAC).

To realise the vision of the TEC project, Singapore and China took reference from the Suzhou Industrial Park project and instituted a multi-level cooperative mechanism that covered a wide range of domains to enhance the viability and sustainability of the project:

Joint Steering Council (JSC): The mechanisms for bilateral cooperation for the TEC project were set up at three levels. Both governments agreed to establish an independent Joint Steering Council (JSC) for the TEC project led by the co-chairs of the highest-level forum—the Joint Council for Bilateral Collaboration—between the two countries. The first JSC co-chairs were Singapore's then-Deputy Prime Minister, Wong Kan Seng, and China's then-Vice Premier, Wang Qishan. Comprising high-ranking representatives from the relevant ministries and government agencies of both countries, the JSC would determine the direction, scope and policies of the TEC project.

Cooperative Mechanism



Multi-level cooperative mechanism of the TEC.

The Joint Steering Council met several times over the years; its ninth meeting was held in Beijing in February 2017.

Joint Working Committee (JWC): A Tianjin Eco-City Joint Working Committee (JWC) reporting to the JSC was also set up. It was co-chaired by Singapore's Ministry of National Development (MND) and China's Ministry of Housing and Urban-Rural Development (MHURD), and also included the Tianjin Municipal People's Government (TMPG). The JWC would conduct detailed study and planning for the TEC project, addressing issues relating to its development and construction including the TEC's development goals, key performance indicators, cooperation modes, implementation and performance monitoring, and dispute resolution. The JWC would also review relevant regulatory documents drafted by the Chinese local administration, which would then be ratified by the TMPG and relevant national government departments.

Eco-City Administrative Committee (ECAC): The TMPG formed the ECAC in January 2008, which served as its implementation arm. While the TMPG and the relevant government departments were expected to formulate conducive policies to support the development of the TEC, the ECAC was responsible for their implementation. The ECAC thus functioned as a single point of contact for policies, regulations, public services, and engagement with enterprises in relation to the TEC. Its responsibilities included the development of basic infrastructure such as public utilities, public transport, recycled water, sewerage and solid waste management, and public greenery. It was also given the authority to enter into commercial agreements with joint ventures established by Singaporean and Chinese consortiums for the development of the TEC.

To facilitate the sharing of knowledge and joint discussion on specific issues, several working-level sub-committees were also formed between Singapore government agencies and the ECAC. Spearheaded by the MND on the Singapore side, statutory boards such as the Building and Construction Authority (BCA), Housing & Development Board (HDB), International Enterprise Singapore (now known as Enterprise Singapore), Land Transport Authority (LTA), National Environment Agency (NEA), National Parks Board (NParks), PUB, Singapore's National Water Agency, and Urban Redevelopment Authority (URA), were brought in to engage their respective counterparts in the ECAC.

Joint Venture Company: To carry out the development of the TEC, a 50-50 joint venture company, the Sino-Singapore Tianjin Eco-City Investment and Development Co., Ltd. (SSTEC), was formed by Singaporean and Chinese consortiums in July 2009 with a registered capital of RMB 4 billion. As the master developer of the TEC, the SSTEC was responsible for developing residential, commercial and industrial real estate, and was also involved in infrastructure development such as construction of the road network, drainage network, water recycling network and sewer network. The Chairman of SSTEC's Board would be a member of the Standing Committee of the Tianjin Municipal People's Committee and Party Secretary of the TBNA Committee, while the Chief Executive Officer would be appointed by Singapore. The Singapore consortium was led by Keppel Corporation, while the Chinese consortium—the Tianjin Eco-City Investment and Development Company (TECID)—was led by Tianjin TEDA Investment Holdings Co. Ltd, with other major shareholders including China Development Bank. Neither of the governments made direct equity investments in the TEC.

From 25 to 29 October 2007, Singapore's then-Minister for National Development Mah Bow Tan, Deputy Secretary Chionh Chye Khye and other officials visited Tianjin city, and discussed in detail issues such as the various forms of cooperation, land costs, taxes, pollution control, municipal infrastructure and the construction of public welfare service facilities. After several rounds of talks, both sides reached an agreement on the management system, developmental model, mode of land transfer, land price, infrastructure construction, public facilities construction, environmental governance,

supporting policies, construction schedule and other key issues, securing a foundation for the signing of a future commercial agreement between both parties and accelerating the pace of development and construction work.

Overcoming Challenges, Reimagining Possibilities

Some ten years on after the TEC project began, its barren land and polluted waters have been transformed into a green, vibrant and highly liveable city for residents and businesses. Several challenges had to be overcome along the way. It was through determination and perseverance, reinforced by close collaboration between partners in Singapore and China, that brought the TEC to where it is today.

Created through bold ideas and a pragmatic mindset, the TEC demonstrates the collaborative spirit and determination of Singapore and China in developing a model of sustainable urban development based on the principles of social harmony, environmental sustainability and resource conservation. The TEC serves as a testing ground for new concepts, approaches and technologies in sustainable urban development. In being practicable, replicable and scalable, the TEC aims to become a sustainable development model for other cities.

The following chapters will elaborate on the TEC's development through the years and seek to share the TEC's experience with other cities.

CHAPTER 2

Laying a Sound Foundation

Creating a new eco-city on a greenfield site offered an unprecedented opportunity for Singapore and China. When the Sino-Singapore Tianjin Eco-City (TEC) project was first conceived in 2007, there were several other so-called "eco-cities" taking shape in China, but with little agreement on what constituted sustainable, comprehensive and integrated eco-city development, and how it should be evaluated. While the Ministry of Environmental Protection (now known as Ministry of Ecology and Environment) and the Ministry of Housing and Urban-Rural Development (MHURD) had set certain standards, these were focused primarily on energy and resource use efficiency, and urban infrastructure construction. Most eco-city initiatives at the time were aimed at sector-specific interventions, such as targets for wastewater treatment and building energy efficiency, but lacked an integrated approach in addressing environmental challenges.

This prompted Singapore and China to jointly formulate a Key Performance Indicators (KPI) Framework which clearly defined the eco-city standards for the TEC, based on its overarching concept of "three harmonies and three abilities". Under the KPI Framework, targets were set to advance breakthroughs in areas such as land use, water usage efficiency, energy efficiency, carbon emissions reduction, ecology and liveability. Besides serving as a distinctive calling card for the TEC in the international arena, the KPI Framework also provided a benchmark and reference for other eco-cities. This approach of using a KPI Framework to guide urban development has since been replicated in other Chinese cities.

With regard to urban planning and management practices, a corresponding shift was needed to integrate ecological principles and resource management dimensions into the formulation, implementation, and evaluation of the urban development process. Urban planning of the TEC thus took a markedly refreshing approach. In contrast to the prevailing methodology of most Chinese cities, the TEC's master planning process was guided by a KPI Framework which placed strategic focus on protecting its green (vegetation) and blue (water) environmental assets, and adopted an integrated master planning approach that cut across different disciplines. As a city built from scratch, there was an opportunity to apply best practices in land use and spatial design principles, and to integrate and optimise land use planning with infrastructure system design.[3]

Both the KPI Framework and master plan for the TEC were endorsed by the Joint Working Committee in January and April 2008 respectively, before the TEC broke ground in September 2008.

KPI Framework to Guide Development

The planning and development of the TEC was guided by a set of indicators under a KPI Framework which set targets and measured the city's progress in environmental, economic and social developments. This reflected the TEC's strategic objectives of people living in harmony with the economy, society and environment, as well as its objectives in coordinated development.

Formulated in 2008 by experts from Singapore and China, the KPI Framework selection was based on certain principles. To ensure that the TEC's indicators had a demonstrative effect, Chinese and Singaporean experts were consulted and prevailing best international practices studied. The national standards in Singapore and China were also considered and, where appropriate, the higher of the two standards was adopted for the TEC. The local conditions in Tianjin and the existing conditions of the TEC site were also taken into account when formulating the KPI Framework and its targets.

Scientific and measurable: The KPIs should have a clear scientific basis and be measurable. The KPIs should be of practical use, i.e. data for the KPIs had to be obtainable and statistically significant, as well as measurable or could be derived from scientific methods.

Qualitative and quantitative: The TEC's indicators should be quantifiable as far as possible. However, recognising that some KPIs were difficult to quantify at that time, the KPI Framework also adopted some qualitative KPIs.

Comparable yet customised: On one hand, the indicators should, as far as possible, be applicable for use in China and internationally to allow for meaningful comparison with other cities. On the other hand, the KPI Framework should also take into account the TEC's local context.

Achievable, actionable and forward-looking: Taking into account the pace of socio-economic development of the TEC, the KPIs should be actionable in the short term, and yet, forward-looking enough to have a demonstrative effect.

The KPI Framework initially comprised 22 quantitative indicators and four qualitative indicators, covering four aspects critical to sustainable development—environmental sustainability, social harmony, resource efficiency, and regional coordination and economic integration.

KPI Framework for the TEC in 2008

Quantitative KPIs

Objective	KPI Area	KPI	Target	Timeframe for achieving target
Healthy ecological environment 生态环境健康	Good natural environment 自然环境良好	Ambient air quality 区内环境空气质量	Number of days per year in which ambient air quality in the urban areas meets or exceeds China's National Ambient Air Quality Grade II standard ≥ 310 days (i.e. 85% of 365 days) Number of days per year in which SO^2 and NOx content in the ambient air should not exceed the limits stipulated for China's National Ambient Air Quality Grade I standard ≥155 days (i.e. 50% of 310 days)	Immediate
		Quality of waterbodies within the TEC 区内地表水环境质量	100% meeting Grade IV surface water quality standard of China's National Standard	By 2020
Healthy ecological environment 生态环境健康	Good natural environment 自然环境良好	Carbon emission per unit GDP 单位 GDP 碳排放强度	≤ 150 tonne-C per US$1 million	Immediate
		Quality of tap water 水喉水达标率	100% attaining drinking water (potable) standards	Immediate
		Noise pollution levels 功能区噪声达标率	100% meeting stipulated noise standards	Immediate
		Net loss of natural wetlands 自然湿地净损失	≤ 0	Immediate
	Healthy balance in the urban environment 人工环境协调	Native vegetation index 本地植物指数	≥ 70%	Immediate
		Proportion of green buildings to total buildings 绿色建筑比例	100%	Immediate
		Per capita public green space 人均公共绿地	≥ 12 m^2 per person	By 2013
Harmonious development of society 社会和谐进步	Good lifestyle habits 生活模式健康	Per capita daily water consumption 日人均生活耗水量	≤ 120 L per day per capita	By 2013
		Per capita daily domestic waste generation 日人均垃圾产生量	≤ 0.8 kg per day per capita	By 2013
		Proportion of green trips to total trips 绿色出行所占比例	90%	By 2020

Objective	KPI Area	KPI	Target	Timeframe for achieving target
Harmonious development of society 社会和谐进步	Comprehensive infrastructure 基础设施完善	Overall recycling rate 垃圾回收利用率	≥ 60%	By 2013
		Access to free recreational and sports facilities within 500 m in residential areas 步行 500 米范围内有免费文体设施的居住区比例	100%	By 2013
		Waste treatment from hazardous to non-hazardous 危废与生活垃圾无害化处理率	100%	Immediate
		Barrier-free accessibility 无障碍设施率	100%	Immediate
		Services network coverage 市政管网普及率	100%	By 2013
	Sound management mechanism 管理机制健全	Proportion of public housing to total housing 经济适用房、廉租房占本区住宅总量的比例	20%	By 2013
Dynamic economy 经济蓬勃高效	Sustainable economic development 经济发展持续	Utilisation of renewable energy 可再生能源使用率	≥ 20%	By 2020
		Utilisation of water from non-traditional sources 非传统水资源利用率	≥ 50%	By 2020

Objective	KPI Area	KPI	Target	Timeframe for achieving target
Dynamic economy 经济蓬勃高效	Promote technological innovation 科技创新活跃	Number of R&D scientists and engineers per 10,000 workforce 每万劳动力中 R&D 科学家和工程师全时当量	≥ 50 man-years	By 2020
	Overall balanced employment 就业综合平衡	Employment-housing equilibrium index 就业住房平衡指数	Ratio of number of local residents who are employed locally, to total number of employable local residents ≥ 50%	By 2020

Guiding KPIs

Objective	KPI Area	KPI	KPI description
Integrated regional coordination 区域协调融合	Coordinated natural ecology 自然生态协调	Healthy ecological safety, advocating green consumption, low-carbon operations 生态安全健康、绿色消费、低碳运行	To maintain an integrated regional ecology, strengthen ecological safety and establish a sound regional ecological security system within the TEC, from the perspective of the optimum utilisation of regional resources and energy, and the capacity of the environment.
	Coordinated regional policies 区域政策协调	Advancing innovative policies, together with anti-pollution policies in place 创新政策先行、联合治污政策到位	To actively participate in and promote regional cooperation and implement the principle of uniformity of public services. Regional policies should ensure regional policy coherence. Establish a sound regional policy system to ensure the improvement of the surrounding areas.
	Social and cultural coordination 社会文化协调	Giving prominence to the river estuarine cultural character 河口文化特征突出	Urban planning and architectural designs should preserve history and cultural heritage; manifest unique aspects while protecting ethnic, cultural and scenic resources. Planning and design should also ensure workplace safety and social order.

Objective	KPI Area	KPI	KPI description
Integrated regional coordination 区域协调融合	Regional coordinated economy 区域经济协调	Complementing economic development 循环产业互补	Sound market mechanism to overcome the limitations of administrative divisions, drive the orderly development of the surrounding region, promote a reasonable division of functions at the regional level, as well as an orderly market, and relatively balanced economic development and living standards.

Compared to the prevailing standards in China then, the TEC's KPIs were more encompassing, and often more ambitious. For example, the TEC aimed to keep its carbon emissions far lower—at 150 tonne-C per US$1 million or lower—than the rest of China which had a national average of 750 tonne-C per US$1 million in 2004.[4] Compared to China's prevailing national target where the share of renewable energy was to be at least 15%, the TEC aimed to achieve 20%. While for Singapore, where only new buildings with a gross floor area greater than 2,000 m^2 were required to meet green building standards from 2008 onwards, in the TEC, all buildings were to be green buildings. The water consumption and domestic waste generation targets set for the TEC were more stringent than for other major cities in China, particularly in its requirement for the share of non-traditional water sources to be at least 50%. In terms of green trips involving public transport and active mobility such as walking and non-motorised transport, few cities in developed or developing countries had exceeded 70% share, while the TEC aimed to achieve 90%.

Urban Planning: Translating the KPI Framework on the Ground

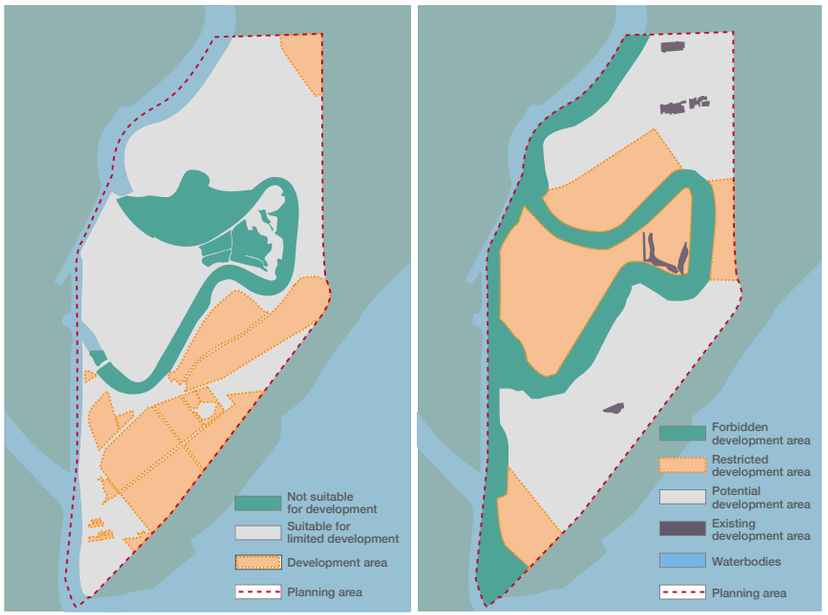
The TEC's master plan was the blueprint to guide the eco-city's overall urban development to achieve its KPIs. Jointly formulated in 2008 by the China Academy of Urban Planning and Design, Tianjin Urban Planning and Design Institute, and Singapore's Urban Redevelopment Authority (URA), the master plan guided the development of the TEC by demarcating sites where development was to be prohibited, restricted or permitted. Through the master plan, the location, concentration, distribution, and even demand for key urban services, such as transport, energy, water, and waste services could be determined. This had a direct and extensive impact on a city's resource efficiency and carbon emissions.

The TEC was planned to be a compact city, with a good mix of land use to encourage greener travel modes like active mobility and public transport. It was to feature extensive green and blue networks of vegetation and waterways to create an endearing living and working environment. The TEC's master plan won the Survey and Design (First Grade) Award from China's MHURD in 2009.

Pioneering a New Approach to Urban Planning in China

Unlike typical urban development projects in China which usually started with a master plan and feasibility study, the TEC pioneered the approach of developing a KPI Framework before a master plan was drawn up. The TEC's master plan first considered the requirements needed to achieve the 26 indicators under its KPI Framework and then translated these into detailed plans in respective functional areas such as land use, transport and energy use. The TEC also conducted detailed studies to support the master plan, covering areas such as strategic positioning for the TEC, population projection, circular economy, green transport system, green building, housing, green waste management and disaster prevention.

Ahead of a national campaign in China to promote integrated master planning, the TEC implemented an integrated approach to planning in formulating its master plan in 2008. Integrated master planning in the TEC not only took into account land use, economic and social development, but also prioritised ecological and environmental protection of the eco-city's key flora and waterbodies, such as its natural wetlands. Planners had marked out these areas for conservation based on their ecological sensitivity and suitability for development, and established buffer zones to ensure their protection before any development plans were made.



Ecological suitability for development (left) and spatial control (right) maps to safeguard ecological conservation areas.

Key Features of the Master Plan

The first master plan covered the initial 30 km^2 of the TEC for a population of up to 350,000.[5] The master plan envisaged its implementation from south to north of the site over three phases, establishing the TEC's basic spatial structure which included its basic infrastructure, public facilities and transport network connecting it to the surrounding regions. The first phase centred on the start-up area in the south of the TEC. The second phase would focus on the central district. The third phase would focus on the Eco-Island district, the northern and north-eastern districts.

One Axis, Three Centres, Five Districts
The TEC was planned to be compact with a good mix of land use. A transit-oriented development approach was taken, so development plans in areas around transport nodes were of higher density.

The spatial layout of the TEC can be visualised as "One Axis, Three Centres, Five Districts" (一轴, 三心, 五片). The "One Axis" refers to an eco-valley—a 50 to 80 m-wide green belt that cuts across the TEC providing a scenic trail for pedestrians and cyclists, and connecting the five districts within the TEC. The functional axis would integrate transport, landscape, leisure, tourism and disaster prevention.

The "Three Centres" refer to the main city centre and the two smaller sub-centres in the south and north respectively. The city centre provides office, retail, cultural and entertainment, tourism and leisure spaces, while the two sub-centres provide education, healthcare, culture and sports, business, financial and postal services.

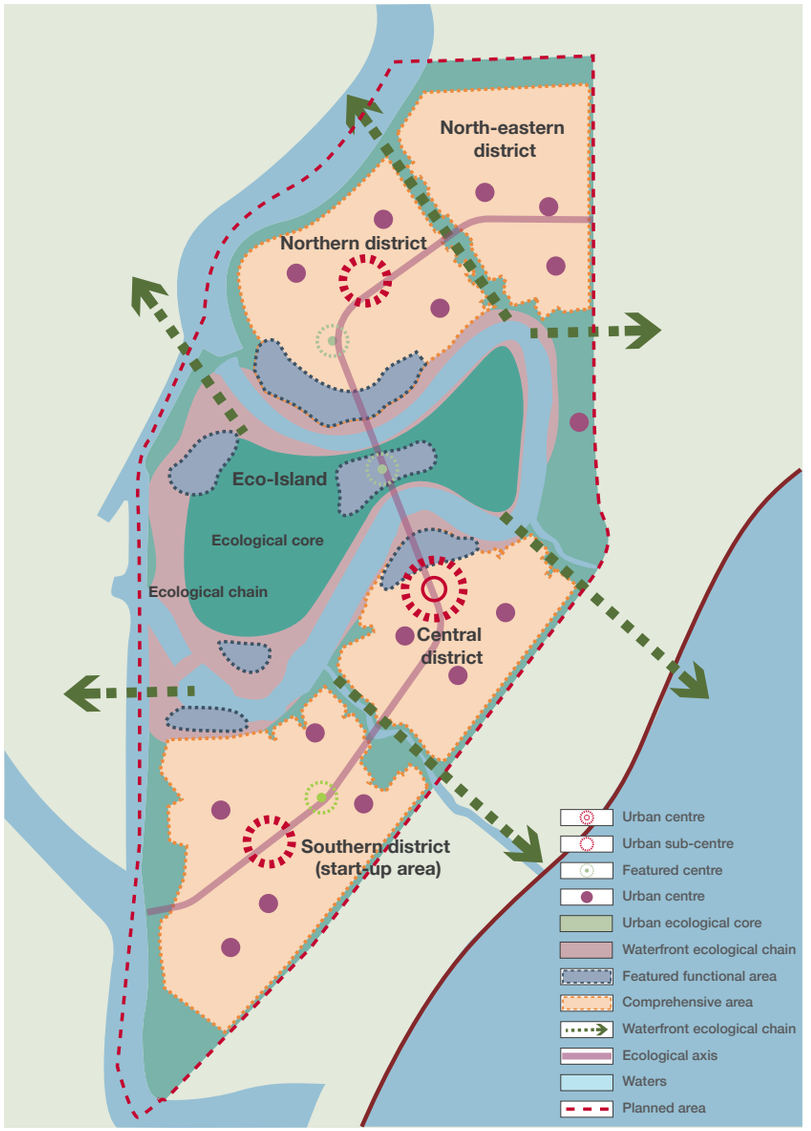
The "Five Districts" refer to a core area of greenery and waterbodies which surrounds the Eco-Island, as well as four self-contained eco-districts distributed across the TEC in the south, central, north and north-east.

Eco-Cell, Eco-Neighbourhood, Eco-District
Taking reference from Singapore's experience in public housing town development which is based on a three-tier "community–neighbourhood–town" hierarchical planning system, the TEC adopted a similar approach based on "eco-cell – eco-neighbourhood – eco-district" (生态细胞—生态社区—生态片区) system.

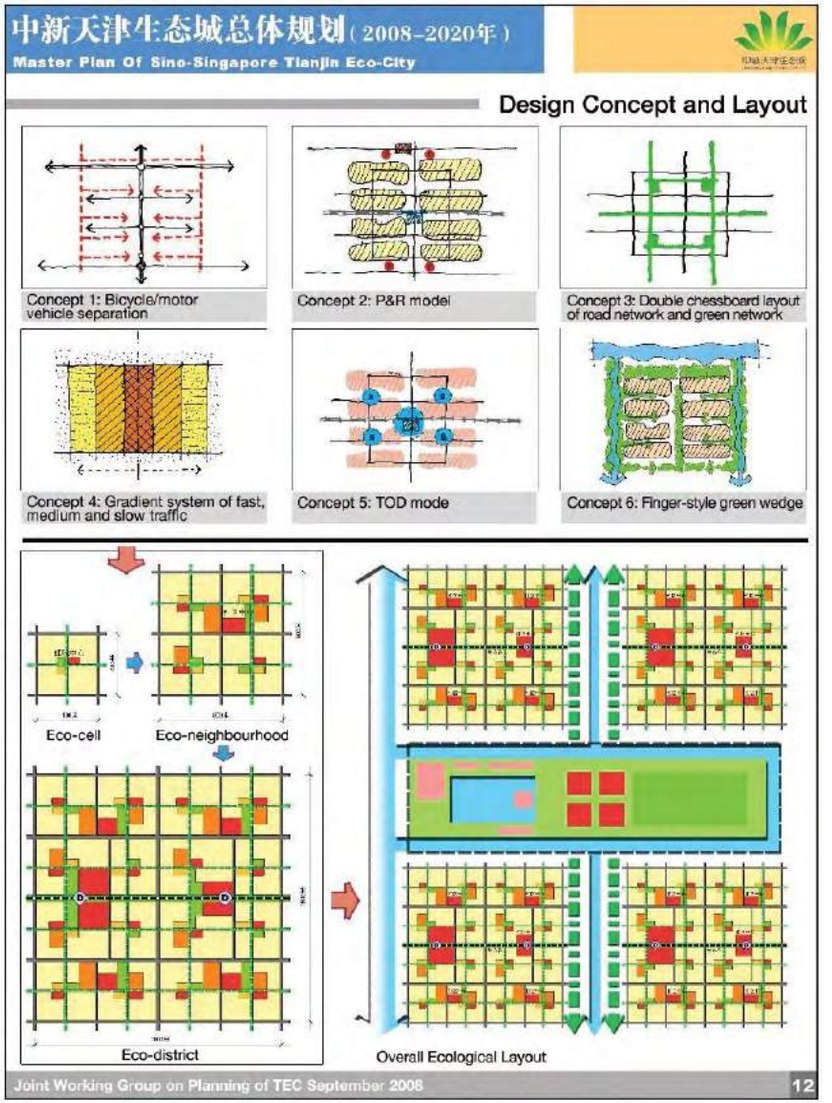
Eco-cells—each of about 400 m by 400 m—are the basic building blocks of the TEC's master plan in ensuring walkability and easy access to amenities. As 400 m is generally considered a threshold for a comfortable walking distance, within which the eco-cell system encourages active mobility through walking and non-motorised green transport. Each eco-cell houses about 3,000 households or 8,000 residents and has a one-stop community centre with a service radius of 200 m to 300 m, providing public services and day-to-day amenities including leisure and sports activities for families and the elderly. Such shared public areas and amenities provide platforms and spaces to encourage social interaction and bonding within the community.

Four to five eco-cells make up an eco-neighbourhood, with a size of about 800 m by 800 m and a population of about 10,000 to 15,000 households or 30,000 people. This is similar to Singapore's neighbourhood centres, where centralised facilities and community clubs serve

the needs of residents within a 400 m to 500 m radius in each neighbourhood. The neighbourhood centres would provide a comprehensive range of public services and community facilities for leisure, sports, medical services, dining and entertainment—all in one stop.



"One Axis, Three Centres, Five Districts" spatial layout of the TEC.



Schematic layout of the eco-cell, eco-neighbourhood and eco-district for housing development.

An eco-district comprises four to five eco-neighbourhoods. The TEC contains four eco-districts which are flexibly configured according to site conditions and contain not only a variety of housing types, but also commercial and amenity centres. Compared to eco-neighbourhoods, eco-districts surround a commercial core which offers more comprehensive public amenities, large-scale commercial complexes, as well as high-end business and recreational facilities. Thus, each self-contained eco-district possesses integral functions of housing, business, commerce and recreation to serve the communities and provide jobs near residential areas. This hierarchy of centres encourages walking and the use of non-motorised transport by making a variety of services and destinations available within 300 m to 500 m.

Prioritising Green Travel

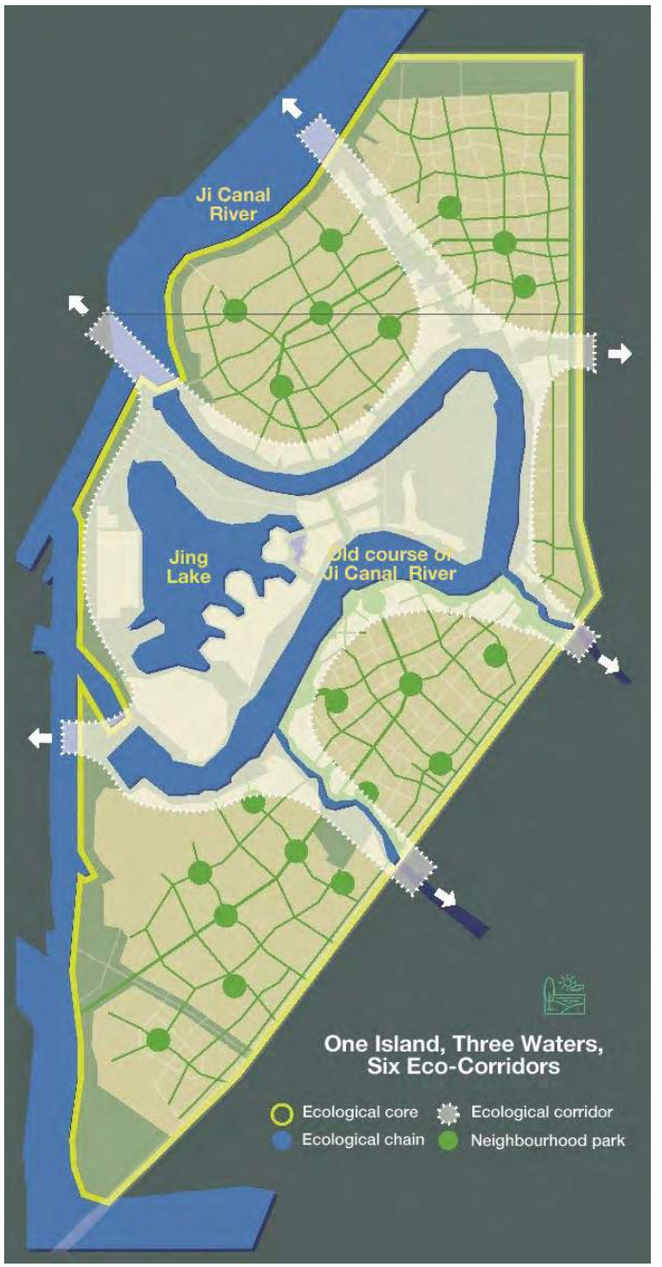
As green transport is a key feature of the TEC, the transport network was planned to prioritise pedestrians, non-motorised transport and public transport. The aim was to increase trips via public transport and non-motorised modes of transport within the city. The TEC's road network deviates from China's traditional four-tiered road hierarchy. Instead, roads in the TEC are divided into two categories: the two-way, six-lane major arterial roads, and the two-way, four-lane secondary arterial roads. To encourage active mobility, the TEC implemented an extensive cycling network along the eco-cells which separated pedestrian from vehicular traffic. At the same time, the spatial layout encourages walking and reinforces the use of green transport options.

One Island, Three Waters, Six Eco-Corridors

Extensive green and blue networks were planned throughout the TEC to create an endearing environment for living, working, learning and playing. The green and blue networks are arranged in a "One Island, Three Waters, Six Eco-Corridors" (一岛, 三水, 六廊) configuration.

"One Island" refers to the Eco-Island in the central ecological core that serves as the green lung of the TEC.

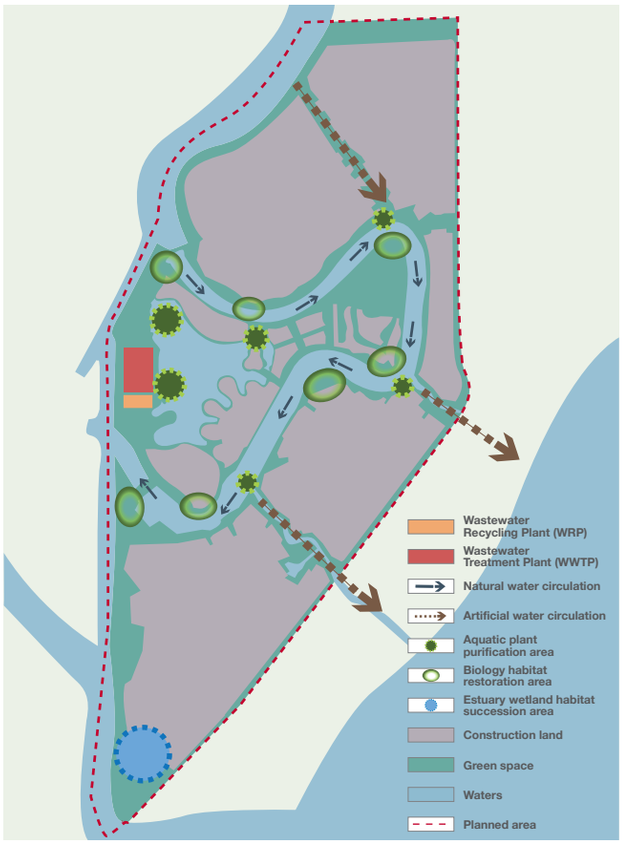
"Three Waters" comprise three waterbodies, namely Jing Lake, a rehabilitated former wastewater pond, Ji Canal River, and its old course.



The "One Island, Three Waters, Six Eco-Corridors" configuration created extensive green and blue networks throughout the TEC.

"Six Eco-Corridors" connect the conserved ecological core to the larger eco-system of surrounding rivers and sea. The waterbodies are linked to promote better water circulation and create an attractive waterfront environment. These green and blue networks allow for better water circulation to enhance the ecology, facilitate the movement of fauna across green spaces to enhance biodiversity, and provide an attractive environment for residents.

Emphasising Resource Conservation
The master plan also set aside space for infrastructure and utilities to raise resource efficiency in the TEC. For example, the water system plan covered wastewater recycling and laid out water circulation pathways to strengthen ecological rehabilitation of the waterbodies.



The TEC's water system plan supported the rehabilitation of its waterbodies.

A Product of Sound Master Planning and a Robust KPI System

Good planning ensures that well-defined strategies are formulated, appropriate technologies are identified and necessary resources are set aside to support sustainable development. It also avoids mistakes that are difficult and costly to rectify once physical developments are in place. For example, the safeguarding of ecologically sensitive areas upfront and the creation of buffer zones cushion the impacts of urban development, preventing irreversible damage to natural habitats. This in turn supports the TEC in achieving the indicators related to "Healthy Ecological Environment". There was zero net loss of natural wetlands in the TEC, and residents enjoyed the benefits of green buildings and green public spaces.

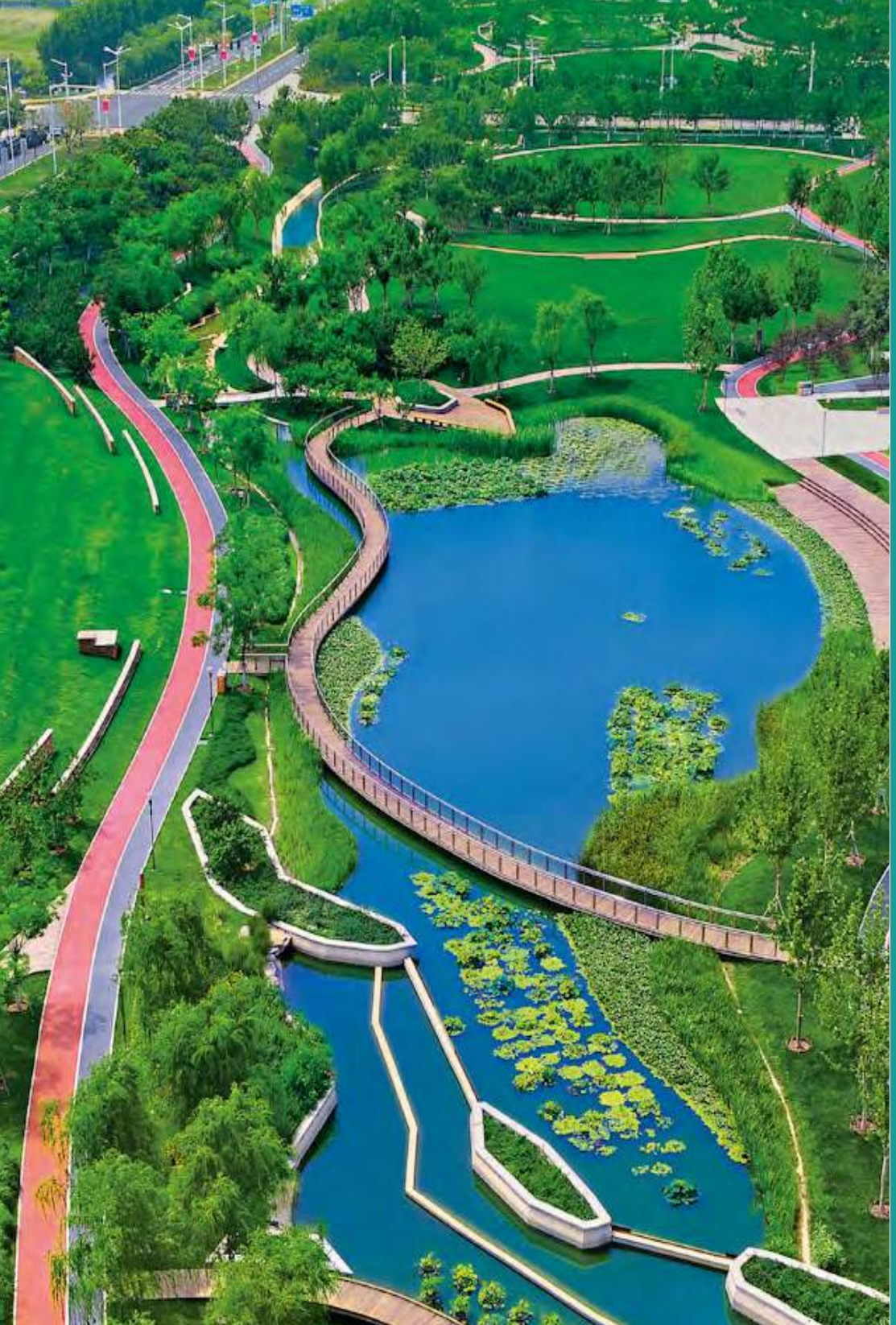
Over the last decade, the TEC has made good progress as measured by its KPI Framework. Indicators related to "Harmonious Development of Society" had performed well. These include per capita daily water consumption, waste recycling rate, and proportion of barrier-free accessibility facilities. This demonstrates the advantages of the TEC in terms of infrastructure and indicates that residents are adopting greener and more sustainable lifestyles.

For indicators pertaining to "Dynamic Economy", the utilisation of non-traditional water resources in the TEC was nearly 60%, better than the target of at least 50%. The number of man-years contributed by research and development (R&D) scientists and engineers per 10,000 workers reached 230 man-years in 2018, surpassing the target of 50 man-years. The strong presence of R&D scientists and engineers show the headway that TEC has made in attracting talent.

The experience of the TEC demonstrates the importance of holistic planning and upstream design in urban development for sustainable development and the creation of a liveable environment. Putting in place a holistic KPI Framework to guide its integrated master planning process ensured that competing priorities between people, the environment, and the economy could be resolved upfront.

The TEC's implementation of a sound foundation through the KPI Framework and integrated master planning approach serves as an example to other cities navigating their own sustainable development paths. To this end, the TEC became an ISO 37101 pilot programme on sustainable development in communities and a case study for the ISO 37104 implementation guide in 2017.

Notwithstanding the TEC's progress in the first decade, there are new competing priorities in its next phase of development as China continues to evolve. The TEC's KPI Framework and master plan have to be updated and refined to address these new challenges and leverage new opportunities (see Chapter 5).



CHAPTER 3

Creating an Environmentally Sustainable Eco-City

In the early stages of the Sino-Singapore Tianjin Eco-City (TEC) project, one of the most critical tasks was to reverse decades' worth of industrial pollution in the area. The natural environment of the site had to be rehabilitated, before the "blue—green" networks—interrelated water and greenery systems—could be strengthened and the natural heritage preserved ultimately.

The concept of blue—green networks refers to the connections between surface water systems (rivers, wetlands, stormwater drains and canals) and vegetated spaces (roadside trees, parks, greenways and recreation zones) within urban areas. Such networks attempt to mimic a natural water cycle while providing amenity through a combination of water management and greening. Beyond creating an aesthetically pleasing physical environment and promoting the well-being of urban residents, blue—green infrastructure protects the hydrological and ecological values of urban landscapes and is increasingly critical in making cities more resilient to the problems of climate change and environmental degradation. With accelerating urbanisation and the increasing loss of habitats and biodiversity, blue—green planning is fast becoming a crucial component of sustainable urban development. Activating the TEC's blue and green assets will not only reinforce the outcomes of water pollution rehabilitation efforts and soil remediation measures, but will also create new public spaces for the eco-city.

In addition, the TEC has taken other steps to embed green urban systems that boost resilience and adaptation to the effects of climate change and other environmental challenges. These steps focused the TEC's efforts on environmental rehabilitation and management, resource conservation, and the implementation of green transport and building systems.

At the same time, implementing green urban systems had not just been about deploying the latest technologies. It was equally, if not more, about involving the community so that such measures could be sustained over the longer term. This process has been complex and demanding, but it has ultimately been a rewarding one for the TEC.

Activating Blue and Green Assets

Building on the foundations of the TEC's Key Performance Indicators (KPI) Framework and master plan, the first task of building the eco-city had been to rehabilitate the waterbodies and soil so that the blue and green layout of the master plan could be implemented. Concurrently, green urban systems were put in place to meet the targets set in the KPI Framework and achieve the TEC's "three harmonies" vision, specifically harmony between people and the environment.

Prioritising waterbody and soil rehabilitation is particularly relevant in northern China. The region suffers from water scarcity due to a combination of factors—the climate is generally drier than the south, and has an evaporation rate that exceeds the annual precipitation rate, which further exacerbates the issue. The region is also home to large populations with high water demand and has long suffered widespread water pollution. In fact, the water supply in northern China had to be supplemented through a massive south-to-north water diversion project.

In particular, the Tianjin Binhai New Area (天津滨海新区, TBNA), where the TEC was to be situated, has a semi-moist continental monsoon climate with cold but sunny winters and hot and rainy summers. Although the region generally receives low rainfall, the TBNA can experience heavy storms in the summer months of July and August, which often cause severe flooding. The TBNA also lies adjacent to Bohai Bay, where seawater intrusion from the sea has been observed since the 1960s due to the region's low rainfall and excessive extraction of ground water. The resulting saline soil conditions make it challenging to carry out substantive greening in the coastal areas.

Moreover, the TBNA has been a major hub for heavy industries, such as chemicals, for decades. For instance, prior to the 1920s, China imported all alkaline chemicals used in various industrial applications. This changed when Asia's biggest alkali plant was established in the TBNA. One of the main water bodies in the heart of the TEC site had been serving as a wastewater pond for the heavy industries, receiving effluents from nearby chemical plants for some 40 years. Before 2008, the 2.6 km^2 wastewater pond contained 2.15 million m^3 of polluted water—

enough to fill 860 Olympic-sized swimming pools—and 3.85 million m^3 of sediment contaminated by heavy metals. Based on China's classification of surface water quality, the water quality was below Grade V which meant that the water was not capable of self-purification and could not support aquatic plant life.

Restoring the Blue Assets

To undo the accumulated environmental degradation of its water bodies, the TEC applied various remediation measures. Furthermore, there was a need to reconnect the blue and green spaces of the site to allow its wetland ecosystem to thrive again. The site is part of the Yellow Sea/Bohai Bay (黄海/渤海湾) coastal wetlands, which serve as important stopovers for migratory birds, and includes the mudflats around the TEC site which are part of its natural heritage. Under the integrated approach of the TEC's master plan, environmental protection was prioritised by identifying and marking out upfront a central core of water bodies, ecological wetlands and green areas to be protected and conserved before any urban development could take place.

Rehabilitating the Water Bodies
As there were neither precedents nor established standards for the management of polluted water bodies in China at the time, a team comprising members from several research institutes was formed to rehabilitate the wastewater pond. The team tested various remediation techniques such as mechanical dehydration, natural drying and bio-treatment, before developing a proprietary method for rehabilitating severely polluted water bodies. This method was applied to the wastewater pond, later renamed Jing Lake (静湖). The project also helped mitigate the pollutive impact of the wastewater pond in the surrounding areas and downstream water bodies.

Today, the rehabilitated Jing Lake is compliant with China's national environmental standards and is inspected regularly. The TEC has in place a comprehensive management and maintenance regime, including a taskforce to enforce upstream pollution control as well as an international advisory panel to regularly review monitoring plans and share best practices in water quality management. The wastewater

pond rehabilitation project has since received several accolades in China, and the method has since been replicated in other parts of the country.

BOX STORY

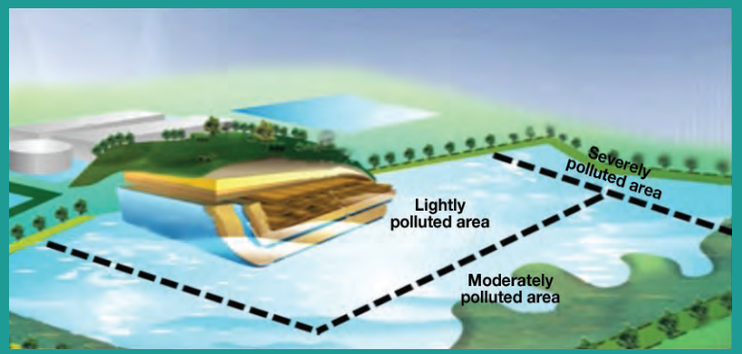
Rehabilitating the Wastewater Pond

The wastewater pond was divided into three segments—lightly polluted, moderately polluted, or severely polluted. First, the pond was drained of its wastewater, with the discharged water treated in a wastewater treatment plant within the TEC before being discharged back into the pond.

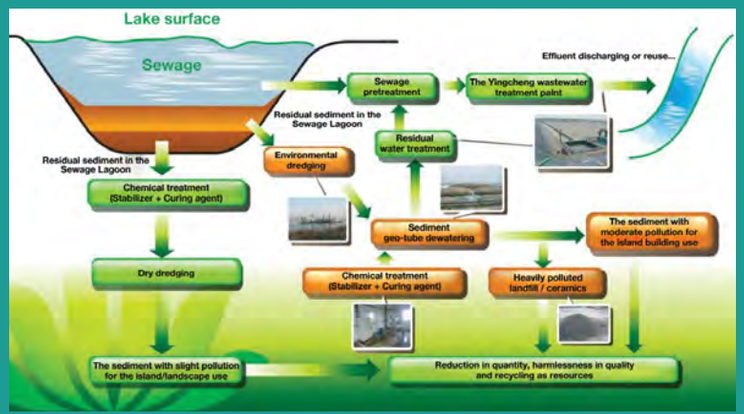
Next, the contaminated bed sludge was treated and reused. Sludge dredged from severely polluted parts of the pond bed was dewatered, then treated with stabilisers and flocculants before being properly disposed or recycled into ceramic products. Sludge dredged from moderately polluted areas was placed into specially designed geo-tube geotextile bags, dewatered, and then treated with stabilisers and curing agents. These bags were then used in the subsequent construction of Jing Lake. The lightly polluted sludge was also treated and recycled into subgrade soil.

Following the treatment of the wastewater and contaminated sediments, the soil at the bottom of the pond was then excavated and used in constructing Jing Lake.

The polluted wastewater pond (left) at the heart of the TEC was rehabilitated and renamed Jing Lake (right).



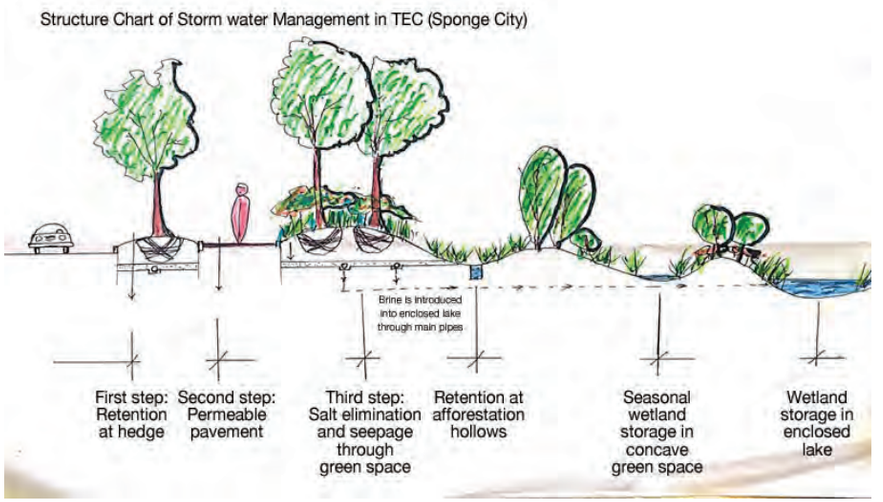
The wastewater pond was segregated into three segments—lightly polluted, moderately polluted, and severely polluted—for treatment.



Roadmap of the rehabilitation process for the wastewater pond.

Integrating Sponge-City Measures

In the process of rehabilitating the water bodies, the TEC also improved the resilience of its water systems against climate change and summer-time flood risks by adopting the "sponge-city" (海绵城市) approach. The development of sponge cities in China is a relatively new concept in urban stormwater management. Like a sponge, the land in a sponge city is able to absorb, store, filter and purify rainwater to be released and used when needed. A sponge city is thus better able to adapt to environmental changes and cope with flooding.



The "sponge-city" approach was applied to stormwater management and flood control in the TEC. © Chi Fenglong.

In applying sponge-city principles to its urban storm water management, the TEC also adapted Singapore's approach in integrated water management to enhance its water management system, notably improving its drainage system, harvesting rainwater and integrating sponge-city measures into its urban design. The TEC was included in the second batch of pilot sponge cities under China's Ministry of Housing and Urban-Rural Development (MHURD) in April 2016. As a result of these measures, the TEC has not experienced any flooding since its inception.

Sponge-city measures were incorporated through the introduction of green belts, permeable paving, green spaces, seepage wells, seasonal rainwater wetlands and brackish wetlands. Open public green spaces, sunken green belts, rain gardens, bioswales and rainwater storage tanks were built to drain and store rainwater. Planting was carried out along both banks of the rivers in the TEC. Other measures included minimising the use of hard paving, which is impervious to surface runoff, as well as using plants to help reduce river pollutants and create more pleasant waterfront spaces.

Sponge-city features, such as roof gardens, were incorporated into the architectural designs of office and school buildings to retain, store and purify rainwater. These roof gardens also served as recreational spaces for office workers and students.

Alongside the rehabilitation of the wastewater pond, the old course of the Ji Canal River (蓟运河故道) was also dredged. The channels of the river were excavated to create linkages such as Huifeng Creek (惠风溪). These not only served as blue and green spaces for the TEC, but also played an important role in stormwater management. Through design, the terrain in various spaces was also raised to allow rainwater to drain into water bodies by a combination of gravity flow and mechanical pumping. By adopting an early warning system, the water levels of the rivers and lakes could be suitably lowered through pumping to allow more rainwater to be stored before an impending storm.

With annual evaporation far greater than annual rainfall, and an annual irrigation demand totalling 18.5 million m^3, the TEC faced the risk of a serious water shortage. To address the shortfall, the TEC's rainwater harvesting capacity was expanded. The rainwater harvesting system was constructed by leveraging the area's undulating landforms, creating sunken areas that enable rainfall to filter through the subsoil. The rainwater collected was used for landscape irrigation. Collection facilities were also integrated into public spaces to maximise rainfall collection. At present, almost 3 million m^3 of rainwater is collected annually, meeting about 16% of the TEC's landscape irrigation needs. Residential project developers were also encouraged to provide small-scale and easy-to-maintain rainwater harvesting facilities, such as rainwater tanks, to make it convenient for residents to use rainwater.

BOX STORY

Gan Lu Creek's Sponge-City Measures

Gan Lu Creek (甘露溪) is an important ecological corridor and recreational area for residents in the TEC. Measuring 750 m long and 120 m wide, it covers an area of 89,000 m^2. Surrounded by green spaces, the waterscape system occupies 10,600 m^2 and divides the creek into two parcels, one in the east and the other in the west. It features a stepped terrain forming a basin-like landform which channels rainwater flowing from green spaces, gardens and public squares into the centre of the site. The runoff is then channelled into the river systems. The project was designed to attain an annual runoff control rate of 85% and annual suspended solid removal rate of 60%.

The TEC's stormwater management approach features rainwater retention at source, flow management and control, and outflow treatment. Rainwater retention at source includes sunken green belts, permeable pavements and intercepting rainwater inlets. Public squares, parking lots and garden paths covering some 16,000 m^2 are paved with permeable concrete. Intercepting rainwater inlets are used on roads within parks to reduce pollution at source. The collection of rainwater from municipal roads has also been piloted. Flow management and control measures include a vegetation buffer zone surrounding the waterscape system, which has helped to reduce the speed of surface runoff through vegetation interception and soil seepage. Rainwater is purified as it flows towards the waterscape system and can be used for ecological water replenishment. Finally, a stepped waterfall system and wetland provide outflow treatment and support the TEC's water circulation system, thereby improving the system's self-cleaning capacity.

As the soil in the TEC areas were highly salinised and alkalised, plants with saline- and alkali-tolerance, such as Chinese tamarisk (*Tamarix chinensis*), seepweed (*Suaeda salsa*) and narrowleaf cattail (*Typha angustifolia*) were planted. Careful attention was put into designing the optimal planting arrangement to encourage the survival rates of the vegetation and achieve the desired landscaping effect.

Chinese tamarisk (Tamarix chinensis)

Common cordgrass (Spartina anglica 'hub')

Crabapple (Malus micromalus cv. 'ruby')

Seepweed (Suaeda salsa)

Saline- and alkali-tolerant plants were introduced into Gan Lu Creek.

Restoring the Green Assets

Many of China's coastal regions face difficulties in rehabilitating saline soils as part of their greening efforts. In the case of the TEC, two-thirds of the site was originally saline land affected by seawater intrusion from the Bohai Sea. The distribution of plants in the area is inversely correlated with the level of soil salinity—areas with lower salinity had a higher concentration of plants than areas with higher salinity, while some areas had no vegetation at all. Soil remediation of the site was particularly challenging, as the level of ground saline water was high and the soil had low content levels of organic matter, nutrients and nitrogen.

Innovation in Soil Remediation

Conventional methods of soil remediation in the past relied mainly on importing soil to green coastal areas. Similar to its approach to the rehabilitation of polluted water bodies, the TEC developed an innovative new process for soil rehabilitation and coupled this process with the use of saline-tolerant plants to green the eco-city. The objective was to reduce soil salinity as much as possible and enhance the self-regulating capacity of the soil. The soil remediation process developed by the TEC involved digging up non-arable saline soil, mixing it and topping up with imported soil, and washing the soil using methods such as leaching before backfilling the mix. For its imported soil, the TEC imported slightly saline soil to minimise the impact on ecosystems in other areas. The new method was applied to landscaping areas in the TEC, transforming the areas into ecological oases.

Greening with Local Salt-Tolerant Species

Some salt-tolerant plants grow in the low marine plain of the TEC site. Hence for the greening of the TEC, particular attention was paid to the selection of local species of salt- and alkali-tolerant plants, such as Sea Aster (*Tripolium vulgare*) and Sword-leaf dogbane (*Apocynum venetum*). The variety of plants in the TEC was gradually increased as the salinity of the soil was reduced. The combination of trees and shrubs was also carefully considered. Accompanying evergreens with deciduous species were selected to prevent the winter landscape from looking too bare. Annual herbs that complete their lifecycle in a single growing season were interspersed with perennial shrubs for optimal greening, landscaping effect and diversity of species. This planting arrangement also enhanced the visual continuity of the landscape.

Plants could hardly grow in the saline-alkali soils of the TEC in the past (left); through soil remediation, the TEC has extended its green cover (right).

Connecting the TEC's Blue—Green Networks

The TEC's environmental rehabilitation initiatives have transformed polluted water bodies and saline wasteland into beautiful rivers, streams and lush green landscapes. Today, they have become parks and open spaces for the TEC's residents to enjoy.

Planning for the TEC's green and blue assets integrates natural and man-made ecologies based on the "matrix–corridor–patch" layout, where an ecological core was established around Jing Lake, forming the primary public open space in the TEC.

The ecological core comprises a spatial matrix of a wedge-shaped green corridor, a riverside landscape belt, and an eco-valley. A "green vein" serves as a corridor linking various functional areas, such as landscaped areas and recreational areas, while various gardens and street parks provide green patches.

The TEC's wetland ecosystem, including a natural habitat for native birds, has also been preserved. This approach strengthened the connection between the ecological core and peripheral ecological systems around the eco-city, making the TEC an environmentally-friendly and ecologically viable city. Many of the features have become popular spots for cultural, recreational, entertainment and sports activities for the residents. The China-Singapore Friendship Garden (中新天津友好花园) which is being constructed is yet another green space that will serve as the TEC's "urban living room".

An artist's impression of the China-Singapore Friendship Garden.

Managing the Sustainable Use of Natural Resources

Environmental rehabilitation, remediation and the eventual ecological conservation in the TEC's blue—green layout were undoubtedly crucial first steps. Next, the TEC had to implement sustainable urban systems to ensure that limited natural resources, especially water and energy, were used efficiently. At the same time, the waste generated within the TEC could become a resource.

An integral part of the TEC's environmental mission was to enhance resource conservation, strengthen water and energy usage efficiency, and implement a system of circular development. This was done through a two-pronged approach—by conserving the TEC's limited natural resources, and by expanding alternative resources. As a greenfield development, the TEC could provide an opportunity to test new approaches in the management of natural resources, particularly in developing green transport and green buildings—two sectors which are typically the largest users of energy and water in a city.

While technology and good policies played an important part, it was equally important to create public awareness and acceptance of the value of sustainable development. Behavioural changes, such as recycling habits, green commuting choices, and energy conservation practices, had to be fostered collectively to support the TEC's "three harmonies" vision.

Managing Water Sustainably

Water shortage is a key factor in limiting urban development. Many developing cities face water crises from time to time. Natural water resources in and around the TEC were already rather limited. Moreover, most of its surrounding water bodies had been badly polluted, making it a challenge to meet the TEC's relatively large water needs. By 2017, the average daily water consumption in the TEC reached 18,300 m^3 per day, with a large proportion used for municipal greening and construction. Without the development of new water sources, the TEC would have had to depend largely on external

water sources, such as channelling water from the Luan River (滦河), groundwater from Yuelong (岳龙), or desalinated seawater. To combat this, the TEC adopted a two-pronged approach to water sustainability. First, it aimed to reduce the overall water consumption in the TEC. Second, the TEC expanded its water resources by tapping on non-traditional water sources.

Promoting Water Conservation
To prevent wastage in the water distribution process to end-users, the TEC implemented measures to cut the leakage rate for the municipal water supply pipeline to below 7%, and for buildings to below 3%. This is lower than the leakage rate in most other Chinese cities. The TEC also applied a quality-based water utilisation scheme. For example, non-potable water recycled from domestic wastewater was to be used for landscape irrigation and road cleaning. Other water conservation measures included using drought-tolerant plants for municipal greening, adopting more water-efficient sprinkler irrigation and drip irrigation methods, and promoting the use of recycled water and rainwater where possible.

The TEC also issued water conservation guidelines aimed at modifying the water usage patterns of industries, which were traditionally major water consumers, to improve their water management. For domestic water use, the TEC put in place a three-tiered monitoring system that would monitor household water usage by individual units, by block and by precinct. Various water conservation measures were also implemented in public housing.

Water conservation measures for public housing

Outdoor landscaping	A bioretention system using plants and pebbles, similar to Singapore's ABC (Active, Beautiful, Clean) Waters Programme, was constructed along the active mobility network and neighbourhood gardens for recycling and purification of rainwater.
Irrigation of municipal greenery	Planting arrangements were adjusted to increase the efficiency of plant watering. Water-efficient irrigation methods were adopted and the amount of irrigation adjusted according to weather conditions. Recycled and treated domestic wastewater is used for irrigation.
Household water use	Non-potable water from non-traditional water sources such as recycled water or rainwater is used for toilet flushing, vehicle washing, outdoor sprinkling and municipal greening. The use of water-efficient appliances is encouraged.
Water distribution and metering	The materials used for underground pipelines and fittings were carefully selected to reduce the risk of leakages. High-precision water meters are used, while building automation systems connected to unit water meters detect leakages.

Developing Non-Traditional Water Sources
The TEC set a target of 50% water utilisation to come from non-traditional water resources. Taking reference from Singapore's Four National Taps framework, the TEC developed its own framework of traditional water supply (municipal water supply and rainwater harvesting) and non-traditional water supply (seawater desalination, wastewater treatment and reclaimed water). Notable differences in the prevailing conditions between Tianjin and Singapore necessitated adaptations of Singapore's experiences to suit the TEC's local needs and conditions. As the average precipitation in Tianjin is much lower than in Singapore due to differences in climate conditions, there is a higher need for ecological water replenishment.

To produce potable water from seawater, the TEC developed the Freshwater from the Sea Project at the Beijiang Power and Desalination Plant (天津北疆电厂), located 10 km away from the TEC. The plant has a daily production capacity of 300,000 m^3. Two freshwater booster pumping stations and a direct desalinated water pipe network would draw desalinated water from the plant to the TEC.

To treat wastewater, the Tianjin Eco-City Wastewater Treatment Plant was put into operation in October 2010. The plant has a treatment capacity of 100,000 m^3 per day, the volume of approximately 40 Olympic-sized swimming pools. It was further upgraded in 2013, and the effluent water quality standard raised from Grade I-B to Grade I-A, meeting the requirements for the water to be used for recreational purposes. Some of the treated water is used to supplement landscape irrigation needs, while the rest is channelled towards water recycling.

Referencing Singapore's experience in developing NEWater, water recycling capabilities were built into the Tianjin Eco-City Wastewater Treatment Plant. By the end of 2017, the plant had a production capacity of 21,000 m^3 of recycled water per day, equivalent to more than the volume of eight Olympic-sized pools. Water supplied from this plant is mainly distributed for

non-potable uses such as construction, municipal sprinkling, greening and for partial use in public buildings, industry and warehousing uses. This has alleviated the demand on the TEC's municipal water supply.

By the end of 2017, the wastewater treatment rate had reached 100% and the water utilisation rate from non-traditional sources was at 61.7%. The surface water quality of the water bodies in the TEC had also improved to Grade IV standard, as per China's classification of water areas for recreational and industrial use which has no direct human contact.

BOX STORY

Singapore's Four National Taps

As a small island city-state, Singapore faces a particular water vulnerability, having for many years been largely dependent on Malaysia for its water supply. To safeguard its national water security and improve its water self-sufficiency, the Singapore government prioritised water in its national agenda and launched a "Four National Taps" strategy. It established a water management framework integrating four water sources—water from local catchments, imported water supply, high-grade reclaimed water known as NEWater, and seawater desalination.

Catchment Water (Rainwater Collection)
Singapore's 17 reservoirs and its stormwater catchment system cover approximately two-thirds of the island nation. The Marina Barrage, completed in 2008, is one of the world's largest water supply projects using an urbanised catchment. The Singapore government prioritises the protection of catchment areas through robust and detailed measures, including regulation of land use, acquisition of land, resettlement of squatters and strict pollution control. Through careful land use planning and strict enforcement against incompatible uses, the government has been able to maintain the quality of water in catchment areas.

Imported Water
Singapore established two water supply agreements to import water from neighbouring Malaysia in the 1960s. The first Water Agreement expired in 2011, while the second Water Agreement was signed in 1962 and expires in 2061. It entitles Singapore to draw up to 250 million gallons of raw water per day from the Johor River. The water from the Johor River is treated at the Johor River Waterworks.

Reclaimed Water
Singapore's NEWater is water recycled from treated used water, and further purified using advanced membrane technology and ultraviolet disinfection. During dry periods, a small quantity of NEWater is introduced into reservoirs to be blended with raw water, which is then transported to the waterworks where it is treated to drinking water standards and serves as an indirect potable water supply. The rest of the NEWater is supplied to industrial users, such as wafer fabrication plants.

Seawater Desalination
As an island surrounded by the sea, desalination has become another important component of Singapore's water management framework. Like NEWater, desalinated water is a weather-resilient water source that helps Singapore better cope with the threat of climate change.

Water is precious and vital to our survival. Getting clean drinking water to our homes is far more intricate than a mere turn of the tap. 50 years ago, Singapore had only two water sources – imported water and local catchment water. Today, we have four sources, or what we call Singapore's "Four National Taps". However, our water supply remains vulnerable to factors such as climate change.

The 3Cs of our 4 taps

2 Imported water

Challenges
The Linggiu Reservoir, which regulates the flow of the Johor River, fell to a historic low of 20% of its capacity in Oct 2016.

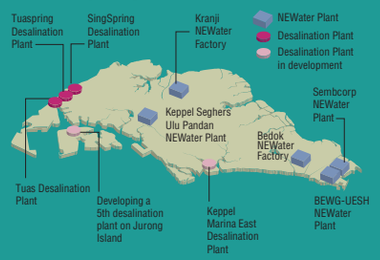
Capacity
Under the 1962 Water Agreement Singapore signed with Malaysia, Singapore has the exclusive right to draw up to 250 million gallons of water from the Johor River each day.

3 NEWater

Challenges
NEWater is ultra-clean and safe to drink. It has passed over 150,000 scientific tests, meeting and surpassing all international drinking water standards and guidelines. However, this requires the use of advanced membrane and ultraviolet disinfection technologies, which makes producing NEWater from treated used water costly.

Capacity
Singapore has 5 NEWater plants that can meet up to 40% of total demand today. NEWater is expected to meet up to 55% of total demand by 2060.

Current and upcoming NEWater and desalination plants



4 Desalinated water

Challenges
Desalination is the most energy-intensive of our four taps. This makes desalinated water the most costly to produce.

Capacity
We have three desalination plants which can meet up to 30% of total demand today. Two new plants will be built by 2020. Desalinated water is expected to meet up to 30% of total demand by 2060.

1 Water from Local catchments

Challenges
Two-thirds of Singapore's land area is already water catchment to collect rainfall for storage in our reservoirs. Increasing the catchment area is costly and challenging given our urban density.

Urban stormwater is harder to purify compared to pristine freshwater sources and Singapore is one of the few countries in the world to harvest on a large scale urban stormwater for consumption.

Capacity
Singapore has 17 reservoirs to store collected rainwater.

Our 17 reservoirs

Two water collection systems –
Separate systems for collecting rainwater and used water to prevent cross-contamination.

Challenges
Capacity
Cost

Cost

In 2015, it cost $1.3 billion to operate our water system, almost three times more than in 2000.

To meet increasing demand, PUB has to continue investing in our water infrastructure by building new plants, upgrading existing ones and expanding potable and used water networks.

From 2000 to 2015, $7 billion was invested in water infrastructure. In the next five years (2017 - 2021), PUB will invest a further $4 billion in water infrastructure.

Our future water supply will come largely from costlier water sources, namely NEWater and desalinated water. These are weather-independent sources that will strengthen the resilience of our water supply against the effects of dry weather caused by climate change.

Singapore's four national taps.
Image courtesy of PUB, Singapore's National Water Agency, updated as of September 2020

Managing Energy Sustainably

Similar to its approach to water, the TEC implemented a two-pronged approach to energy management by focusing on energy conservation and developing renewable energy, such as solar, wind, geothermal and biomass.

Promoting Energy Conservation
Through the master plan of the TEC, housing, industry and public services were planned such that commuting for work, shopping and leisure, and their corresponding energy consumption could be reduced. This was further supported by a green transport model that prioritised active mobility and public transport.

To lower the energy consumption of buildings, the TEC introduced a green building regime and an energy conservation programme to reduce heating requirements. The TEC also implemented metered heating charges for its residential sector. This resulted in more than 80% of residents conserving energy and cutting heating costs. To reduce industrial energy consumption, the TEC focused on developing service industries that had high economic output, but low energy and resource utilisation, low emissions and promoted waste recycling.

Developing New Renewable Energy Sources
The target was for the TEC to achieve at least 20% renewable energy utilisation. As a result of implementing various initiatives, renewable energy accounted for 15% of energy use in the TEC as of 2020.

Tianjin's key renewable energy advantage is the availability of geothermal resources. Renewable energy technologies that draw heat from the ground and seawater have been adopted to make full use of the various geothermal resources available. As of 2020, TEC has completed 31 geothermal heat pump projects, which serve 1 million m^2 of buildings. This has become the TEC's main source of renewable energy.

Although the lack of space within the TEC poses a challenge for harnessing renewable energy such as solar and wind power, the TEC has tapped into solar energy, and piloted energy generation through biomass and wind power. The TEC's renewable energy master plan has set a target for solar power capacity to reach 45.4 MW. By the end of 2017, photovoltaic (PV) projects had been set up in various sites in the TEC, such as along major traffic arteries or on the rooftops of buildings. This resulted in the generation of an additional 14.3 million kWh in 2017. Solar water heating systems can also be found in all residential buildings as well on the rooftops of industrial parks across the TEC.

Other renewable energy projects include a wind farm that had been set up at the mouth of the Ji Canal River. Further methods to augment the electricity grid have also been implemented, including the use of multiple renewable sources of energy for public infrastructure. For example, nearly 800 street lamps powered by wind and solar energy have been used across 12 km of roads, saving 500,000 kWh a year.

Implementing Smart Energy Management
The TEC has been a site for the State Grid Corporation of China, which has piloted innovative energy solutions such as the setting up of a platform to integrate flows of energy, information and finance, adopting a plug-and-play distribution generation, and the allocation of multiple energy resources and smart power. One of these projects is the development of an integrated energy information platform for the TEC's industrial parks, which aids in centralising the management and control of four combined cooling, heat and power (CCHP) stations in the industrial parks. This has helped increase the overall energy efficiency and utilisation of distributed energy in the industrial parks by over 10%.

The TEC also pioneered the development of an energy management platform, integrating the management of renewable energy and conventional energy as well as energy supply and consumption. The platform automates information collection, as well as monitors, manages and deploys energy data and includes an early warning system. This has helped balance energy supply and demand, and promote energy conservation.

Managing Waste Sustainably

For waste to become resource, infrastructure needs to be in place to support waste sorting and recycling, and consumers have to make waste segregation a daily habit.

Infrastructure to Support Waste Segregation and Recycling

The TEC has been designated as one of the pilot sites for a national new urban district waste segregation. As of 2020, 19 residential areas have been selected for pilot projects on waste reduction and segregation in partnership with estate management companies. Using designated facilities in these areas, domestic waste was classified into five categories: recyclable, toxic, unrecyclable, kitchen waste and bulky waste.

Promoting Waste Sorting and Recycling

Carrying out waste sorting after waste collection is costly and impractical. Moreover, to avoid contamination, recyclables have to be cleaned before disposal at recycling bins. Hence, consumer support is critical for recycling efforts to be successful. Community activities are important in shaping residents' behaviour in relation to waste management. One example the TEC adopted was the use of community surveys conducted by volunteer groups to raise public awareness about waste segregation and to identify problems encountered by residents.

Private enterprises, law enforcement units, volunteers and facilities managers have also been involved. Many have conducted promotional activities to encourage more eco-friendly lifestyles such as the need for waste segregation. To this end, the exhibitions in the TEC's Urban Solid Waste Management Exhibition Hall have been promoting the importance of waste segregation, allowing residents to better understand waste management issues including toxic waste, waste segregation and waste disposal technology.

Smart city technologies can also influence user behaviour. In the TEC, a smart waste-recycling platform has been set up to improve waste management behaviour. Using the platform, residents can earn and accumulate points by properly segregating their domestic waste. These points can then be used in exchange for items at a designated store. By the end of 2017, the TEC had set up 25 smart terminals for waste segregation with more than 60% of residents participating.

Through these efforts, the TEC has reached a recycling rate of 67%, exceeding the 60% target under the KPI Framework. The TEC has also managed to keep domestic waste generation at 0.69 kg per day per capita, below the target of less than 0.8 kg per day per capita.

The TEC provides waste segregation and collection facilities to encourage residents to segregate their waste.

Setting Green Transport Systems in Motion

Cities are not static. The movement of people, services and goods requires the support of transport infrastructure and systems. The TEC is well-located and easily accessible from Tianjin central area, TBNA, Tianjin Airport and Tianjin Binhai Station, which connects to Beijing via high-speed rail.

However, transportation contributes to about 14% of global greenhouse gas emissions, making this sector a key battleground in the fight against climate change. Cities can solve these challenges through innovative ways, such as by taking an integrated and long-term approach to urban planning and implementing green transport infrastructure and systems. Moreover, green urban transport is not new in China, where the first subway line was built as early as 1969 in Beijing. In 1984, Tianjin was the third city in China to implement a subway system.

Two key approaches in the TEC's green transport plans are transit-oriented development (TOD), and its active mobility system.

Transit-Oriented Development

Although the concept of TOD as a planning approach gained prominence in the 1990s, the approach had already been adopted successfully in cities such as Singapore. The TOD model advocates more intensive development around transit nodes. This suited the TEC, which had set a target for 90% of all trips within the city to be green or low carbon.

The TEC's transport infrastructure, including its public transport systems and road networks, is part of the overarching Integrated Transport Plan. This complements the self-sufficiency of amenities in the "eco-cell – eco-neighbourhood – eco-district" urban planning system (see Chapter 2), reducing the need for people to travel long distances on a regular basis.

Public Transport

The TEC had planned for a full suite of public transport including a Mass Rapid Transit (MRT) system and a fleet of clean energy buses to encourage green trips. The MRT is a heavier investment which typically takes a longer time to implement. As the intended primary mode of transport connection to other parts of the TBNA, the MRT is expected to be completed by the mid-2020s. In the meantime, the TEC is served by buses, with travel information made available through 60 smart electronic station boards and a mobile bus app—"Traffic in TEC".

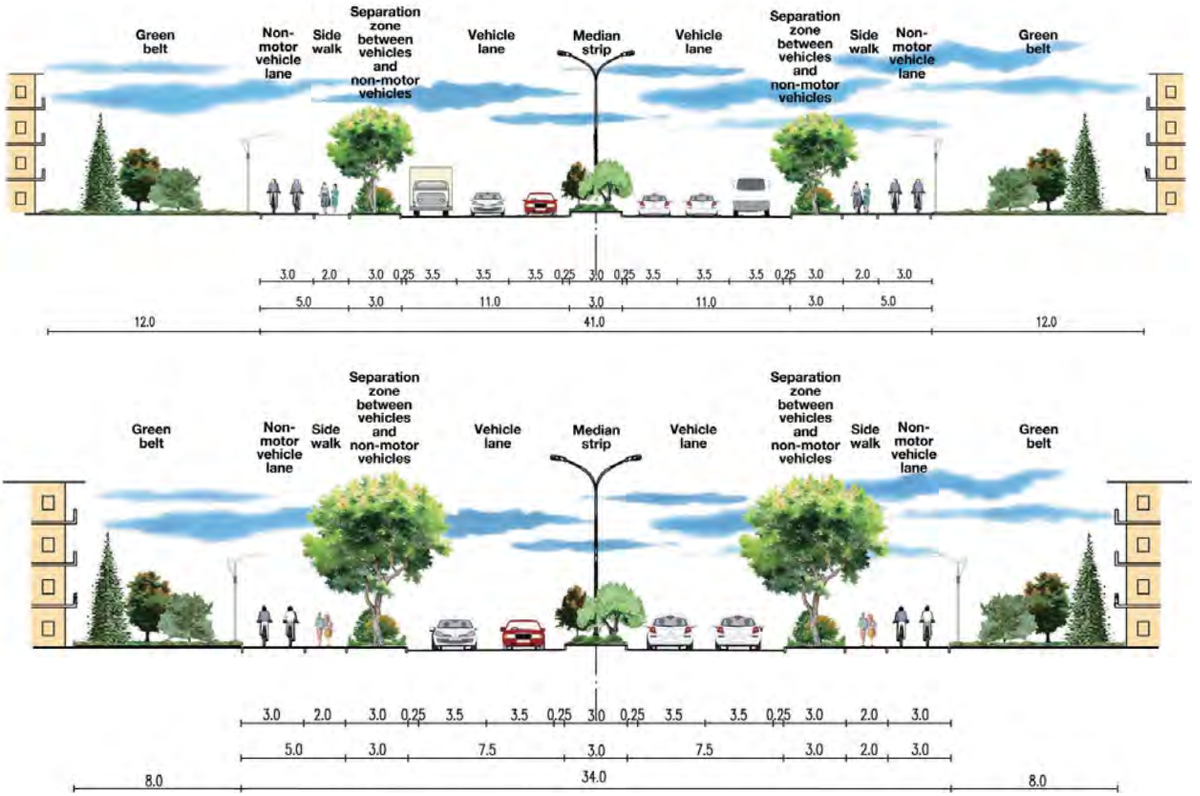
Clean energy buses offer green travel options in the TEC.

In line with the TOD model, developments near rail transit stations have higher plot ratios. The TEC's residential and employment areas are planned to be concentrated within a radius of 800 m around the rail transit stations, conveniently connecting the residents and workers in the TEC to other parts of Tianjin.

High-Density Road Network

One of the features of the TOD approach in the TEC is its dense network of roads. This is in contrast to the conventional practice in many cities in China at the time, which had encouraged the building of wide roads and expressways.

The TEC has a dense road network with a 400 m by 400 m grid spacing, accommodating both motor vehicles and greenways for pedestrians and non-motorised vehicles. This road hierarchy has been an innovative improvement from the traditional four-level model of expressways, and the primary and secondary trunk roads and distributors in China. Land take of roads in TEC is 15%, making it close to cities like Singapore, London, Tokyo, New York and Barcelona where the ratios are between 10% and 25%. In contrast, many cities in China favour wide roads and big street blocks, and generally have a land take of roads below 10%.



The primary roads (top) and secondary trunk roads (above) accommodate both motor vehicles and greenways for pedestrians and non-motorised vehicles in the TEC.

A high-density road network provides a safe, convenient and highly accessible active mobility system for pedestrians and non-motorised transport alongside motor vehicles. Pedestrians can make shorter street crossings, which makes walking more convenient. The road network also helps disperse traffic flow and lower the incidences of traffic jams. It also raises the economic value of the land. Areas around traffic junctions provide attractive spaces for small businesses serving neighbourhoods, allowing for flexibility in urban typology and more efficient land use.

Active Mobility System

The TEC's active mobility system prioritises walking and cycling over public transport systems such as bus, rail and taxi, where practical. This is in tandem with the TOD approach. As part of the active mobility system, the TEC has designated separate paths, known as greenways, for non-motorised transport within the TEC. This extensive network connects community, business, recreation and other urban nodes to form a comprehensive green transport system.

These greenways are independent from motorised corridors. With the exception of emergency vehicles, motor vehicles are prohibited on the greenways. Greenways, which are divided into recreational and commuting greenways, are located on both sides of motor vehicle lanes as well as in neighbourhoods and parks. Greenways make travel by active mobility safer, enhance the urban and road landscape, and provide pedestrian and non-motorised vehicle lanes with shade.

A greenway with barriers to prevent motor vehicles from entering.

To improve non-motorised user experience, barriers were installed along greenways to prevent motor vehicles from entering or occupying sidewalks. The intersections between greenways and roads were made accessible for the elderly, families with young children and people with disabilities. Pedestrian refuge islands were also installed at the intersection of municipal roads. Such features in the TEC exceed China's prevailing national standards.

Pedestrian refuge islands make traffic crossing safer and easier.

As of 2020, the proportion of green trips to total trips in the TEC was about 72%, far higher than the average in China. The completion of the MRT line is expected to bring about further improvements.

Shaping a City of Green Buildings

As part of the urban fabric of cities, buildings cannot be viewed in isolation; instead, they should be seen as a microcosm of the city. As the primary spaces of human activity and as major consumers of water, energy and materials, buildings require resource efficiency if the overall goal of sustainable development is to be achieved.

Green buildings play an important part in the TEC. Besides being energy and resource efficient, green buildings can also provide good indoor environmental quality, contributing to economic competitiveness and the health of end users. The TEC was able to make green buildings mandatory because it was a new district built from scratch. It is currently the only district in China fully comprising green buildings and has been designated as a "Green-Building Base" by the then-Ministry of Construction (now known as MHURD) in recognition of its achievements in green buildings.

The TEC's success with green buildings stems not only from having appropriate government support in place; it is also the result of pioneering systematic green-building solutions in China. Drawing from experiences in Singapore and China, the TEC had developed a comprehensive green-building management system with standards covering the entire building life cycle from planning, design, construction to operation. Such a system had lowered the incremental costs of green buildings, making it easier for developers to adopt and for designers to incorporate green designs. The TEC also tested and promoted various new green-building initiatives and technologies, such as piloting passive housing projects, prefabricated construction and carbon emission optimisation across the entire building life cycle.

Developing Green Building Guidelines and Standards

In developing its green building standards, the TEC took a holistic approach in combining mandatory standards, a point-based evaluation system, incentives and technological research. In 2009, taking reference from China's national standards and from international standards such as Singapore's Green Mark system, the TEC established the first complete green-building management system in China. This system set out specific requirements for various stakeholders, including government agencies and planners, architects, contractors, building operators and consultants. Notably, this approach of scoring green buildings and facilitating performance-based design gave developers more flexibility in developing green buildings while encouraging energy conservation and renewable energy utilisation.

Under this system, the TEC piloted China's first quantitative standard for building energy utilisation, targeted at urban energy conservation and emissions reduction. The standard provided the basis for the evaluation of energy use and management through the design, construction and operation of individual buildings. This helped to ensure that the TEC's energy conservation and emissions reduction targets would be met.

Given the difficult environmental conditions of the original site, the TEC imposed higher requirements than what was generally required. For example, specific requirements for land improvement were included to address the characteristics

of the saline land on which the TEC was to be built. Higher requirements were also set for the utilisation of non-traditional water sources due to the lack of water resources. In addition, the TEC specified measures in its green-building management system on how to protect the environment and conserve resources (materials, water and energy) during construction to promote green construction.

The TEC also partnered with several national scientific research and design institutes to establish the TEC Green Building Research Institute to provide independent third-party review and assessment of green buildings for the TEC's regulatory approvals.

BOX STORY

Global Benchmarks for Green Building Evaluation

Three-Star Rating System for Green Buildings (China)
Set by the MHURD, China's green-building evaluation system has indicators in six areas: land conservation and outdoor environment, energy conservation and utilisation, water conservation and utilisation, material conservation and utilisation, indoor environment quality, operation management (residential buildings) and comprehensive full life cycle performance (public buildings). The indicators are divided into three categories: regulatory (mandatory), general, and preferential (higher standards but optional). An indicator may have a range of regulatory, general or preferential targets. Green buildings are further classified into three grades: one-star, two-star or three-star.

Green Mark System (Singapore)
Launched in 2005, the Building and Construction Authority (BCA) Green Mark scheme is an internationally recognised green building rating system tailored for the tropical climate. The scheme comprises distinct rating tools that, together, rate the built environment for its environmental performance holistically. These include rating new buildings, existing buildings, user-centric spaces and "beyond buildings", such as districts, parks, rapid transit system and infrastructure. It has four ratings—certified, gold, gold plus, and platinum.

The Green Mark scheme sets parameters and establishes indicators to guide the design, construction and operation of buildings towards increased energy effectiveness and enhanced environmental performance. Developed in consultation with key stakeholders, the scheme provides a largely performance-based and flexible framework of assessment to encourage positive environmental outcomes. It comprises a full suite of sustainability indicators with specific outcome requirements, along with minimum standards of performance in key areas to ensure that fundamental environmental issues are addressed. More recently, the BCA Green Mark for Super Low Energy Buildings was introduced to give additional recognition for projects that achieve best-in-class energy efficiency, beyond the energy efficiency standard set for the Green Mark Platinum rating.

LEED System (USA)
The Leadership in Energy and Environmental Design (LEED) evaluation system, developed by the US Green Building Council in 1996, is a third-party green building certification programme and a globally recognised standard for the design, construction and operation of high-performance green buildings and neighbourhoods. By promoting a whole-building approach to sustainability, LEED recognises performance in location and planning, sustainable site development, water savings, energy efficiency, materials selection, waste reduction, indoor environment quality, innovative strategies and attention to priority regional issues. Each area consists of several prerequisites and optional scoring indicators. A building is LEED-certified if it meets the mandatory prerequisites. The scoring indicators, which can be adjusted according to the project, are used to tabulate scores to determine whether a building is certified silver, gold or platinum.

CASBEE System (Japan)
The Japan Sustainable Building Consortium, established in 2001, developed the Comprehensive Assessment System for Building

Environmental Efficiency (CASBEE). CASBEE aims to assess and grade a building's environmental efficiency. The CASBEE system is unique in that it separates construction projects into internal and external spaces using a hypothetical boundary. The internal space is evaluated based on improvements in living amenities for the building users, and the external space is evaluated based on the negative aspects of environmental impact.

Under this system, buildings are assessed based on two criteria: building environmental quality and performance (Q), and building environmental loadings (L). The higher the Q value and the lower the L value, the more sustainable a building is assessed to be. During evaluation, four tools geared towards various aspects of the building market—predesign, new construction, existing building and renovation—are used. CASBEE gives buildings grades according to the ratio between Q and L, ranging from a poor grade (C) to excellent (S).

Managing the Full Building Life Cycle

Green buildings in the TEC take into account environmental protection and the conservation of resources such as land, energy, water and materials. It also considers local conditions such as climate, level of economic and social development, and building types.

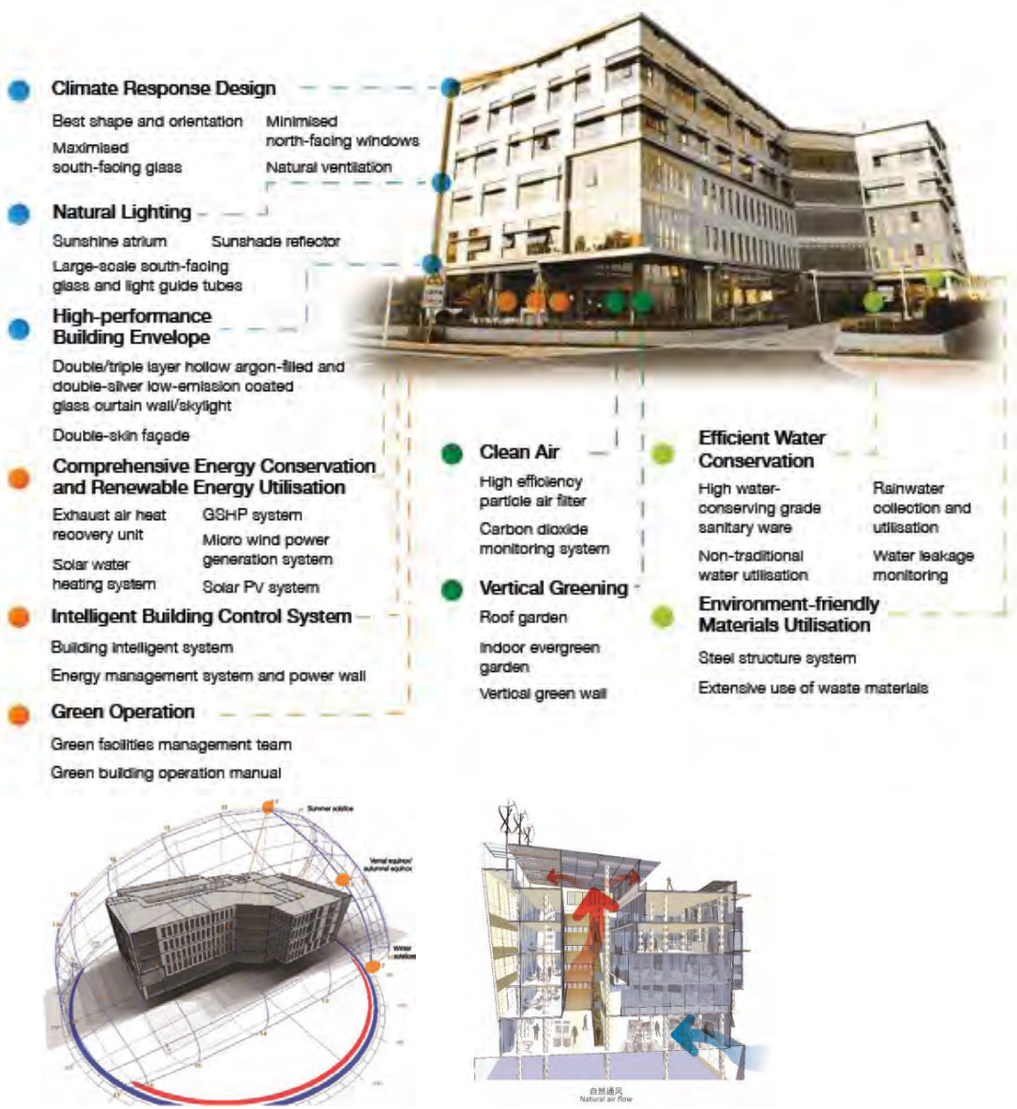
The TEC has adopted and localised technologies such as passive design to ensure cost-effectiveness. The incremental cost of constructing green buildings relative to conventional buildings in the TEC is thus made more manageable. There are no incremental costs for a one-star green building, while the incremental cost for green buildings with two-star and three-star ratings range from RMB 20 to 50 per m^2 and RMB 50 to 300 per m^2 respectively. In comparison, the incremental costs for green buildings elsewhere in China can be as high as double that of the TEC.

Green Buildings in the TEC

Low-Carbon Living Lab

Located in the TEC Eco-Business Park, the Low-Carbon Living Lab is a green office building developed by Sino-Singapore Tianjin Eco-City Investment and Development Co., Ltd. (SSTEC), with support from Singapore's BCA, International Enterprise Singapore (now known as Enterprise Singapore), Ministry of National Development, Singapore, and Tianjin Eco-City Administrative Committee (ECAC). It has a steel structure and built-up area of 13,000 m^2, including one basement level and five floors of 9,899 m^2.

Green building features as well as energy-conservation and renewable energy technologies are tested and demonstrated at the Low-Carbon Living Lab.



Key features of the Low-Carbon Living Lab.

The Low-Carbon Living Lab aims to achieve low-carbon construction and operation by adopting a full life-cycle operation and management model, and implementing environmental technologies such as clean energy, rainwater collection, recycled construction materials and vertical greenery. The project has also been positioned as a "living lab" to test and demonstrate green building features as well as the application of energy-conservation and renewable energy technologies, while providing users and visitors with an educational experience. The building has received several awards, including China's first BCA Green Mark Certified Platinum rating, the Three-star Green Building Design Label, the TEC Green Building Evaluation Standard Platinum Award and the Three-star Green Building Operation Label.

Features of the Low-Carbon Living Lab

Climate-responsive design	The building shape and orientation are optimised to create the appropriate external microclimate environment. Using natural ventilation, the building's annual energy consumption is lower than buildings of comparable size and capacity. The openings on the north-facing walls are designed to be as small as possible to shield against winter winds and reduce heat loss.
High-performance building envelope	High-performance double- or triple-layer hollow argon-filled and double-silver low-emission coated glass are applied to skylights. Curtain walls reflect outdoor solar heat in summer and prevent indoor heat loss in winter. The building's "double skin" design allows building users in the north-facing units to enjoy natural ventilation and lighting without losing too much heat by keeping the windows open. The space between the double layers serves as an indoor green space for the building's occupants.
Natural lighting	To maximise natural lighting, 50% of the building's glass panels are south-facing and 20% are on the roof skylight. Light guide tubes and sunshade reflectors are installed to draw natural light into the building while blocking solar radiant heat. Such design elements not only maximise natural lighting but expand the viewing range.
Water and energy	By adopting water-efficient sanitary fittings, the building's water conservation rate exceeds the TEC's green building standards by 40%. Rainwater collection and utilisation systems provide 5% of the building's water needs. Energy recovered from exhaust air heat recovery units are equivalent to 4% of the building's energy consumption, enough to power 30 average households in China for a year. Renewable energy systems suited to the site conditions and building shape are installed, including ground source heat pumps (GSHP), solar water heating, solar PVs and micro wind power generation systems. Such renewable energy systems provide 12% of the energy used by the building.
Ventilation	Fresh air ventilation systems are equipped with high-efficiency air filters, which filter out more than 90% of PM2.5 pollutants (atmospheric particulate matter [PM] with a diameter of less than 2.5 micrometres). Return air systems are equipped with carbon dioxide concentration detectors to monitor indoor air quality.
Recycled building materials	By adopting a steel structure, the utilisation rate of recycled materials is 30%, which is triple the requirements under the TEC's green building standards.

Vertical greening	Growing indoor evergreen gardens and setting up green walls help filter indoor air and create a green core within the building, allowing its occupants to enjoy indoor greenery throughout the year.
Intelligent building management	An energy management system was installed to track the building's energy consumption, water consumption and renewable energy operations in real time. The system also uses information from rooftop weather stations to optimise the building's energy efficiency in different seasons. The SSTEC formed a dedicated green-facility management team to ensure that green building operations and management have been carried out efficiently throughout the building's entire life cycle.

Public Housing Exhibition Centre

The Public Housing Exhibition Centre was the first net-zero energy building in Tianjin. In other words, the building's energy consumption for its built-up area of 3,467 m^2 is fully supported by the renewable energy generated on-site, and the building uses no other energy sources such as coal, oil, or power grid. This net-zero energy consumption was achieved by implementing a solar power PV system and, more importantly, by adopting energy conservation measures. Integrated energy conservation and emission-reduction technologies and solutions were also implemented, such as roof solar PV power generation, chimney-based ventilation systems, natural lighting from light guide tubes and GSHP heating and cooling.

Overall, the Exhibition Centre has achieved up to 70% overall building energy conservation, 66.8% non-traditional water resource utilisation, 100% renewable energy utilisation and 10.3% of recycled building materials in its construction.

The Public Housing Exhibition Centre was the first net-zero energy building in Tianjin.

Features of the Public Housing Exhibition Centre

Optimising solar power generation	The diamond-shaped building structure is designed to have optimal exposure to sunlight. The roof is covered with 2,600 m^2 of solar panels. Unlike most buildings in China, the Exhibition Centre is not south-facing. Instead, it is oriented 15 degrees towards the southeast to be aligned with Tianjin's local sunshine hours and intensity. This ensures that the Exhibition Centre's solar panels can absorb the optimal amount of sunlight. As the intensity of sunlight varies throughout the day, several underground power cells are installed to store excess electricity and release it when needed. The solar panels generate approximately 240 MWh hours of electricity per year, exceeding the Exhibition Centre's annual electricity consumption of about 210 MWh hours per year.
Natural lighting and ventilation	The facade of the two-storey building features creative use of glass windows rather than reinforced steel or concrete walls. As the Exhibition Centre's central hall has high ceilings, a series of windows along the upper sections have been installed to provide the central hall with natural lighting and can be opened to improve ventilation. The building also features a chimney-based ventilation system connected to outdoor air intake wells through an underground pipe network. Fresh air enters the Exhibition Centre via the outdoor air intake well and pipe network, which then passes through the windows and offices' indoor windows for internal ventilation. This system conserves electricity by rendering air-conditioning unnecessary when the outdoor temperature is comfortable.
Automatic adjustment of indoor lighting	The Exhibition Centre does not contain any lighting or air-conditioning switches or regulators. Instead, an intelligent lighting system automatically adjusts the indoor lighting required based on the amount of natural lighting present. Light guide tubes are designed to make direct use of natural light. The light emitted from rooftop spotlights is generated through refraction and reflection of sunlight. Even with few installed lights, there is adequate lighting in the large central hall.
Heat insulation	The use of low-emission glass, coated with an additional layer of film, improves transparency and heat insulation. The inclined window design moderates the indoor temperature loss by allowing the sun to shine directly on the windowsill made of glossy material designed to reflect light, rather than heat. In summer, no additional heat is absorbed when the air conditioning is running, while in winter, heat does not dissipate excessively.
GSHP heating and cooling system	A capillary network radiant heating system is installed in the Exhibition Centre. The ultra-thin, small-load capillary networks on the roof are effective in improving heat transfer and contributes to the building's energy efficiency.

Creating Sustainable Blue—Green Networks

The TEC demonstrates that the pursuit of economic and urban development need not be at the cost of environmental sustainability and ecological protection. With long term vision and planning, both aspects can progress in tandem.
The investments made in the research and development of environmental technologies have generated significant returns for the TEC. The blue assets of the city have been restored, while the TEC's green cover—the area covered by vegetation—has reached 50%. Sustainable green buildings anchor the urban fabric of the eco-city. Living standards for the TEC's residents have improved, while real estate values surrounding Jing Lake have risen.

In the TEC, innovative and cost-effective technologies suited to local conditions for the rehabilitation of polluted water bodies and the remediation of polluted land and saline soils have been developed. Many of these technologies, such as water pollution treatment and soil rehabilitation, have received accolades domestically and have been awarded national patents. They have come to set a new environmental benchmark in China, where the Ministry of Ecology and Environment has recommended that the scientific method for the management and evaluation of wastewater ponds used in the TEC be adopted in other parts of the nation. The method has since been replicated in other parts of China, such as Xiong'an New Area (雄安新区) in Hebei province.

The sustainable environment nurtured in the TEC is reflected not only by the "hardware", represented by the physical assets, but also in the "software" of new knowledge and systems that enhance the eco-features of the TEC, and the "heartware" demonstrated in the eco-mindsets and green lifestyles of its residents. The natural heritage and sustainable environment that the TEC has to offer has made the city more attractive to investors and talented individuals alike.

CHAPTER 4

Creating a Liveable and Vibrant Eco-City

Through hard work and close cooperation between Singapore and China, the Sino-Singapore Tianjin Eco-City (TEC) project overcame the initial environmental challenges of the site to create a green and beautiful habitat. Beyond being environmentally sustainable and enhancing resource conservation, the success of the TEC is also measured by the vibrancy of its communities and economy. New cities face the challenge of attracting activity and buzz, as they usually have a small initial resident population, modest business sector, limited job opportunities, and few supporting facilities and amenities. Similarly, the next test facing the TEC was its ability to attract people and socio-economic activities in a harmonious and sustainable manner.

To address these challenges, the TEC pursued three key strategies. First, it created "15-minute neighbourhoods" in which residents could meet their day-to-day needs within a short walk from their home. Second, it gave due attention to the provision of public amenities and services in order to provide a harmonious and vibrant city life for residents. Lastly, the TEC focused on building a competitive green economy to increase its appeal to residents, investors, companies and visitors.

In a little over a decade since these three strategies were adopted, the TEC has attracted some 100,000 residents and 9,800 enterprises, setting a firm foundation for the growth of a vibrant city. These efforts have ensured that the TEC is not only environmentally sustainable, but also liveable and economically vibrant, bringing to life the "three harmonies" vision that underpinned the TEC's development.

Nurturing a Vibrant Community, Creating "15-Minute Neighbourhoods"

Having access to adequate public amenities and services is a crucial factor in strengthening the social fabric of a city. To this end, public amenities were conscientiously planned and distributed within the TEC to ensure that all residents could meet their day-to-day needs within a 15-minute walk from their home. Public amenities were also built ahead of demand to attract potential residents.

The planning for public amenities was based on three principles. First, public amenities were developed in advance to attract people to move into the TEC. Second, the TEC adopted a people-centric approach by developing public amenities that catered to the diverse interests and needs of residents. Third, public amenities such as primary and middle schools were run by reputable institutions such as Nankai University.

Referencing Singapore's experience in township planning, the TEC adopted a similar approach based on an "eco-cell – eco-neighbourhood – eco-district" layout to distribute public amenities. Within each eco-neighbourhood is a centrally located neighbourhood centre, with a built-up area of 15,000 to 20,000 m^2, integrated with medical services, cultural and sports facilities, office space, community management and commercial services. These neighbourhood centres provide convenient one-stop services to about 30,000 residents within a radius of 500 m or within a 15-minute walk. Within each eco-cell is a 200 m^2 neighbourhood home that serves as an office for the neighbourhood committee as well as a space for residents to relax and interact. Each neighbourhood home also provides services such as childcare and self-service health screening.

The TEC also prioritises education and healthcare services. To make schools accessible to everyone, the education facilities range from pre-school to secondary-education levels. Kindergartens, primary schools and secondary schools are located within a radius of 400 m, 800 m, and 1,500 m of residential areas respectively. The master plan for the TEC included 32 kindergartens, 19 primary schools and eight secondary schools. By the end of 2020, 15 kindergartens, seven primary schools and four secondary schools had been built. In healthcare, the TEC implemented a three-tier service model; each neighbourhood is serviced by a clinic, while large general hospitals serve as regional medical centres.

A New Model for Community and Eldercare Services

Neighbourhood centres located within the eco-neighbourhoods function as the main providers of community services in the TEC. Adapting this model from Singapore's integrated community clubs, the neighbourhood centres not only provide convenient one-stop services, but also promote community bonding as a common space for residents to gather.

The First (top left), Second (top right) and Third (above) Neighbourhood Centres provide community services to residents in the TEC.

These neighbourhood centres differ from China's traditional community committees or sub-district offices in terms of geographical scope and target population. Firstly, the planning and development of these centres were characterised by integrated planning, controlled land use and development aligned to the demographic needs of the area. The catchment area of these centres was estimated based on the upper bound of travel times, while the layout was planned according to the size of the population being served. Secondly, these centres were conceived as integrated community spaces embodying the concept of "big community and big cluster". This is in contrast to the smaller, hyper-localised scales of traditional community centres in China. Thirdly, these centres were fitted to provide 12 basic services: banking, supermarket, grocers, postal service, food and beverage services, laundry services, hair and cosmetic services, pharmaceutical services, stationery, repair services, community activities and primary healthcare services. Both commercial and public services are offered at these centres. Lastly, a standardised development and operation model was implemented. Professional developers and operators were engaged throughout the project lifecycle, from development and construction to the operation and management of non-public amenities.

The TEC began operating an elderly day-care centre in the Second Neighbourhood Centre in 2017, to provide high quality eldercare services for its residents and to comply with the operating standards set by the Tianjin Municipal People's Government (TMPG). The centre has been well-received by residents and visitors for its conducive environment, high-quality services and affordable pricing. Since then, another facility, Zhongfu Tianhe Smart Elderly Care Service Demonstration Zone (中福天河智慧养老服务示范区) has also commenced operations. The TEC plans to cultivate and bolster its "silver economy" by developing and promoting its own eldercare service standards and operating model.

Providing High-Quality Education

Between 2012 and 2020, the population of children in the TEC had increased substantially. To meet their educational needs, the TEC implemented an educational roadmap to bring together well-established academic institutions and well-known preschools to the TEC.

With regard to public education, the TEC brought in highly regarded schools such as Tianjin Binhai Foreign Languages School (天津滨海外语学校) and the TEC Nankai High School (天津生态城南开中学). To promote more diversified, high-quality educational offerings, the TEC also partnered with various well-known private educational institutions in Tianjin. For example, Cathay Future Primary School (天津华夏未来中新生态城小学), which focuses on high-quality arts and sports education, was set up in 2016.

TEC Nankai High School (top) and Cathay Future Primary School (left) are some of the highly regarded schools set up in the TEC.

Schools in the TEC are well equipped with modern educational and teaching facilities. The buildings incorporate environmental technologies such as solar water heating and geothermal heat pump air-conditioning to improve energy conservation. The TEC also pioneered the use of experiential learning through classroom simulations for subjects such as biology, history, science and pottery; this approach has since been replicated in other parts of Tianjin.

Schools in the TEC pioneered the use of experiential learning through classroom simulations.

Integrated Healthcare Services

The TEC currently adopts a three-tier healthcare system of "general hospital - neighbourhood clinic - general practitioner". At the hospital level, the China-Singapore Eco-city Hospital of Tianjin Medical University (天津医科大学中新生态城医院), a top-tier general hospital which started operations in 2016, provides high-quality medical care. Furthermore, each eco-neighbourhood is served by a neighbourhood clinic with the target provision of one doctor per 1,000 residents. A comprehensive range of basic medical and public health services are available to the residents, supported by a centralised system for residents' health records, giving residents and their healthcare providers a holistic picture of their health status. To provide better access, general practitioners (GPs) are able to provide house call and telemedicine services, such that a team of GPs can serve between 300 to 500 households.

The China-Singapore Eco-City Hospital of Tianjin Medical University started operating in 2016.

Beyond healthcare facilities, the TEC also promotes the adoption of healthy lifestyles through organising fitness campaigns and monitoring the residents' health awareness. Health promotion activities are organised through multi-sector cooperation. Neighbourhoods, schools and families are organised into smaller units to motivate residents to participate in health promotion. The TEC also developed a self-service health management app called LOHAS (乐活), which is centred on the idea of residents taking responsibility for one's own health. The TEC also held a China-Singapore Tianjin Eco-City Eco Run in 2018, in conjunction with its tenth anniversary.

The China-Singapore Tianjin Eco-City Eco Run was held in conjunction with the TEC's tenth anniversary in 2018. Image courtesy of Sino-Singapore Tianjin Eco-City Investment and Development Co., Ltd. (SSTEC)

Enhancing Public Services and Community Relations

Certain public services in the TEC are undertaken by about 100 social organisations set up with the support of the Tianjin Eco-City Administrative Committee (ECAC). These services include childcare and healthcare services, as well as provide support for the women, elderly and vulnerable groups. The ECAC encourages these organisations to deepen their capabilities through measures such as hiring professional social workers and innovating how public services are delivered.

The TEC also places strong emphasis on developing civil communities and neighbourhoods where residents look out for one another. Community groups, such as the Eco-City Volunteer Association, organise activities to encourage residents to engage in a green lifestyle. Various community initiatives have also since been introduced, such as lifestyle markets and competitions, which are held regularly to encourage community participation. Such cultural activities have enhanced the residents' sense of belonging and community spirit.

Another key element in the provision of public services and community building is the mechanism for community engagement with residents. To this end, the ECAC set up three feedback channels for residents—a neighbourhood committee, a resident liaison office and an online public sentiment system—to help resolve issues through mediation, administrative orders or by legal proceedings. The aim of these channels is to strengthen the daily operations of the ECAC and build a self-reliant community within the TEC.

A key policy instrument in promoting social harmony has been the TEC's public housing programme. Drawing on the experiences of Singapore's public housing programme and other affordable housing projects in China, the TEC has developed its own public housing programme to provide affordable housing for lower income households working in the TEC. The first two phases of public housing development have since been launched in 2013 and 2018 respectively.

BOX STORY

From Eyesore Landfill to Neighbourhood Garden

The north-eastern corner of Kunyuyuan (鲲玉园) Housing Estate in the TEC was once a landfill. An unsanitary and disorderly area with little greenery, it was considered an eyesore. Some members of the Kunyuyuan Housing Estate Owners' Committee had proposed to turn the area into a community garden, which would enhance the environment and create a community platform for residents who enjoyed gardening.

The "Neighbourhood Garden" project was timely as the TEC was just starting to promote community projects.

The Owners' Committee organised several meetings between the homeowners and the property management team to decide how the project should be implemented. Efforts were made to raise awareness regarding the project and to secure residents' participation. With the support of the Social Affairs Bureau of the ECAC, the Neighbourhood Committee, as well as estate management companies and residents, the landfill began its transformation.

Following careful planning, the infrastructure and facilities of the neighbourhood garden were completed by August 2016. A voluntary service team comprising over 30 members was formed to supervise and manage the greening efforts. The role of the service team was to ensure that the project would be self-managed by the residents and self-sustainable over the long run. Support for the garden among the residents was evident. Members of the neighbourhood garden grew vegetables such as spinach, coriander, garlic, pak choi, canola, pepper, lettuce and crown daisy. The service team members bought anti-frost plastic film for thermal insulation at their own cost, while others purchased seeds, plastic pots and fertilisers for the garden.

What began as a source of unhappiness among the residents was transformed into a neighbourhood garden through multi-party collaboration. Today, the garden has become a highlight of the community, creating a pleasant living environment for the residents. The project has not only improved the relationships among neighbours, it has also strengthened community bonds. Most of the garden service team members are retirees from different households, and over time, friendships have been forged while caring for the garden. On festive occasions, the service team members invite other residents to share the fruits of their labour.

Building a Competitive Green Economy

A competitive economy is one of the key desired outcomes of a liveable city. The TEC has invested much into the development of a competitive green economy, which is crucial for generating good employment opportunities and providing the engine for low-emissions growth. The TEC has been deliberate in the types of industries to develop. Specifically, the intent has been that industries in the TEC should be non-pollutive as well as resource efficient and should ideally highlight the eco-features of the city.

However, the TEC faced various challenges in its industrial development journey. First, as a new city with a small resident population, most businesses did not see the TEC as a viable or attractive market. Second, the TEC's high eco-standards were viewed by some as restrictive and potentially requiring higher upfront cost compared to the abundant supply of industrial and commercial space in the surrounding Tianjin Binhai New Area with less restrictions. Third, the TEC is situated near large metropolises such as Beijing and Tianjin, which had resulted in stiff competition for resources and talent.

The TEC thus had to work doubly hard to raise its appeal to investors and businesses in green industries. They did so through two thrusts—by creating a conducive business environment and by developing a hub for technological innovation.

Creating a Conducive Business Environment

The ECAC, Tianjin Eco-City Investment and Development Co. Ltd. (TECID) and its subsidiaries—the joint venture company Sino-Singapore Tianjin Eco-City Investment and Development Co., Ltd. (SSTEC), as well as Singapore's economic agency, International Enterprise Singapore (now known as Enterprise Singapore)—have played key roles in attracting investments into the TEC from within China, Singapore and elsewhere internationally.

"One-Stop Shop" Services for Investors
A conducive business environment is a critical ingredient for industrial development. To this end, the TEC's investment promotion teams had worked together to provide "one-stop shop" services for investors to offer seamless access to government services and support. The TEC offers customised solutions and relevant policy support based on the specific needs of

each enterprise. A monitoring system is in place to ensure that enterprises receive timely assistance to help overcome bottlenecks and improve operating efficiency. In addition, various trade shows and marketing activities are also organised.

Fine-tuning Policy Support
The ECAC constantly fine-tunes its investment promotion policies and processes, and has formulated industrial promotion initiatives and targeted policies for specific industries such as animation and green energy. The ECAC also provides preferential policies in terms of financing, office space and manpower for industries such as the financial, creative and service outsourcing sectors, and continues to support enterprises through the provision of office space, transportation services and public housing.

Over the years, both the governments of Singapore and China have supported the TEC's industrial development through various initiatives. For example, the Singapore government had encouraged Singaporean companies to set up branches in the TEC, while support from the Chinese government came in various forms. For example, the Ministry of Culture and Tourism of China and Tianjin Municipal People's Government worked together to build the National Animation Industry Park, while the National Movie & Industry Park was developed with support from the National Radio and Television Administration.

Developing Industrial Parks to Support Growth
The TEC planned and built five industrial parks—National Animation Industry Park (国家动漫产业园), National Movie & Industry Park (中国天津3D影视创意园), Eco-Business Park (生态科技园), Eco-Information Park (生态信息园) and Eco-Innovation Park (生态创业园)—to meet the infrastructure and business needs of enterprises in industries such as culture and creativity, information technology, energy conservation and environmental protection, research and development (R&D), and modern services.

The Eco-Innovation Park is targeted at the information technology industry. Image courtesy of Sino-Singapore Tianjin Eco-City Investment and Development Co., Ltd. (SSTEC)

BOX STORY

The National Animation Industry Park and the Eco-Business Park

Jointly developed by China's Ministry of Culture and Tourism and Tianjin Municipal People's Government, the National Animation Industry Park was established to cultivate and support the production of original animation, television and film products in China. Spanning an area of 1 km^2 with a built-up area of 770,000 m^2. it is the country's first national comprehensive demonstration park for the animation industry.

The industrial park supports animation enterprises in several ways. Equipped with an advanced public technology service platform linked up to China's supercomputer—Tianhe-I (天河一号)—the industrial park boasts one of the world's largest and fastest animation rendering clusters, providing technical support to enterprises both within and outside the park. In addition to providing free workspace to support start-ups, the industrial park also provides equipment such as tablet PCs and workstations. More established enterprises also receive assistance in scaling up their operations, including support in acquiring permits to produce and distribute radio and television programmes for movie production.

Facilities of the public technology service platform at the National Animation Industry Park.

Another industrial park located in the TEC is the Eco-Business Park, which comprises three clusters—electronics and infocomm, biomedical sciences and green industries. With a built-up area of 40,000 m^2, notable tenants include the Tsinghua University Institute for Electronics and Information Technology, Hylanda Incubator and Momo Technology.

The Eco-Business Park focuses on electronics and infocomm, biomedical sciences and green industries.

Developing a Hub for Technological Innovation

Innovation is a key driver of the development of a modern, knowledge-intensive economy that the TEC seeks to build. To develop a hub for technological innovation, the TEC had focused on attracting and cultivating the right talent, nurturing innovation capability and strengthening financial support to technology-intensive companies, developing innovation platforms and incubators, and growing the research and development (R&D) ecosystem.

Attracting and Cultivating Talent

Given the strategic importance of attracting the right talent to the TEC, policies and measures to attract talent were formulated based on the requirements of key industries, including specific policies for postdoctoral programmes and special funds for talent development. Complementary policies on housing subsidies, rent subsidies, household registration of talents, education for their children and employment for their spouses were also introduced.

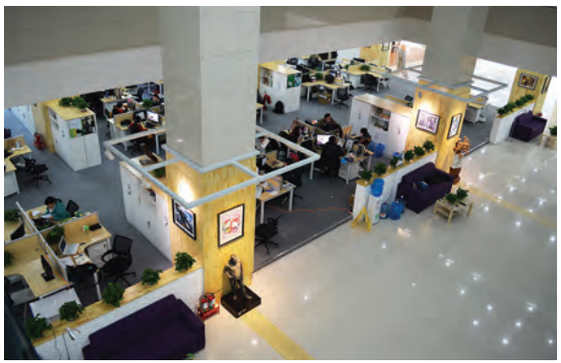
Postdoctoral programmes were oriented towards encouraging collaborations between universities and enterprises. For example, Dynamiker Biotechnology (Tianjin) Co., Ltd. set up an academic expert programme and a postdoctoral programme. It worked with Nankai University (南开大学) to train talents, including foreign students. By the end of 2020, there were 15 postdoctoral programmes in the TEC with 44 postdoctoral fellows.

Nurturing Innovation Capability and Strengthening Financial Support to Technology Intensive Companies

To enhance the capability of enterprises to innovate and create a vibrant and entrepreneurial climate, the TEC set out various measures to promote technological innovation. Under its "Young Giant" (小巨人) enterprise development programme, the TEC identified and offered financial support for R&D projects in science and technology to promising technology-based small- and medium-sized enterprises (SME) and high-tech companies. The TEC also funded promising companies to support them in planning their technological development and improving their corporate governance. Further support was extended to developing technology R&D platforms through collaborations between enterprises and research institutions, key laboratories and engineering centres.

Under the National Fund for Technology Transfer and Commercialisation, the TEC had set up a national-level fund of RMB 285 million targeted at technology transfer and commercialisation. The TEC also established intellectual property awards.

Developing Innovation Platforms and Incubators
The TEC developed innovation platforms and incubators targeted at various industries, such as cultural and creative, internet technology, hardware R&D and big data. One example is the ThinkBig Incubator for Cultural and Creative Industries, which serves as a national cultural and creative co-working space focusing on microfilm, film, TV and animation, game, industrial design and intelligent hardware. The ThinkBig Incubator has nurtured promising stars in the industry, such as Nice Boat Animation, which has produced works such as Da Hu Fa (大护法, The Guardian), a top-grossing Chinese animated film in 2017.



ThinkBig Incubator for Cultural and Creative Industries serves as a national cultural and creative co-working space.

Other examples include the TusStar Incubator and Beihang StarsUp Technology. TusStar Incubator is backed by Tsinghua University's strong scientific research capabilities and industry linkages. TusStar promotes independent innovation by offering a four-in-one incubation model that encompasses incubation service, entrepreneurship training, angel investment and an open platform. TusStar also set up an investment fund and micro-equity fund in the TEC. Beihang StarsUp Technology, which is a wholly owned subsidiary of Beihang Investment,

offers high-quality co-working spaces with specialised resources and hardware for R&D, as well as access to equity investment which is supported by Beihang University and Beihang Investment. It also helps start-ups connect with well-established incubators overseas such as in the United States, Europe and Israel.

Other incubators in the TEC include TusStar Incubator (top and above left) which is backed by Tsinghua University, and Beihang StarsUp Technology (top and above right) which is linked to Beihang University.

Growing the Research Ecosystem
The TEC has brought together various stakeholders and resources from the government, industry, universities, research institutes and end users to create an ecosystem for innovation in science and technology. Enterprises provide funding and manufacturing technology, while universities contribute technology R&D expertise, and research institutes focus on technology transfer and commercialisation, all within an ecosystem supported by government policies. The TEC has also committed funds to support technology incubation and commercialisation, such as the RMB 241 million Qingyan Fund.

The TEC has also supported the formation of research institutes, working with universities and research entities to build shared technology platforms. One example is the establishment of the Tsinghua University Institute for Electronics and Information Technology (IEIT) in 2015. With the backing of Tsinghua University, the IEIT focuses on technology and product R&D, technology transfer and commercialisation, and high-tech business incubation. In 2017, the TEC and IEIT co-founded the Sci-tech Park (清华大学天津电子信息研究院科技产业园) to develop an end-to-end ecosystem, from scientific research to technology transfer and commercialisation in the field of electronics and information technology. Another example is the Beihang Intelligent Driving Institute (北航天津智能驾驶研究院) in Tianjin, which was established with support from various organisations including China's only national association in intelligent technology—the Chinese Association for Artificial Intelligence (CAAI). The institute's focus areas include technological innovation, the development of industry standards, talent development and business incubation for autonomous driving technology.

In addition to the above initiatives, the TEC actively organises events to promote technological innovation and offers itself as a testbed and platform for the development of cutting-edge technology. For example, in 2018, the TEC hosted a series of drone events during the 2nd World Intelligence Congress to promote R&D in drone technology. Another example is the pilot project for fifth generation (5G) mobile communication technology jointly launched by the TEC and China Mobile, a leading telecommunications operator in China.

As part of the 2nd World Intelligence Congress in 2018, the TEC hosted the World Intelligent Drone Industry Development Forum.

The TEC also hosted drone events such as the World Intelligent Drone Exhibition (top), World Intelligent Drone Race (second from top) and World Intelligent Drone Carnival (above).

Liveable Communities and a Vibrant Economy

By the end of 2019, the TEC had become home to a relatively youthful population, comprising mostly young families drawn to its liveable environment and educational resources. Public amenity projects that have been built include three Neighbourhood Centres, 21 Residents' Centres, 10 schools and 15 kindergartens with over 18,000 students. The TEC has also enhanced its public services and community relations by establishing channels for government-community engagement and encouraging residents to have a deeper involvement in community life. There are promising signs of active participation in neighbourhood community activities with support from the ECAC, such as the initiation of neighbourhood garden projects. The prioritisation, careful planning and effective implementation of public amenities in the TEC has laid a strong foundation for a liveable and vibrant city.

The green economy of the TEC has also had a positive start. Economic development in the TEC has been largely led by the private sector, which accounts for some 73% of the city's economic output. The TEC has also attracted a growing talent pool to support and drive the development of a sustainable and competitive green economy. By the end of 2019, there were some 54,000 registered employees among the population in the TEC, of which more than 20,000 have at least a college-level education. While this has provided a strong start for the initial stages of economic development, more effort is needed to further address manpower gaps in some industries and to attract the right talents to cultivate greater innovation and entrepreneurship in the TEC.

More than 1,600 digital technology companies are registered in the TEC, including Meituan, Didi and Momo Technology. The big data industry is also taking off in the TEC, with companies like Hylanda and Tencent focusing on areas such as data mining and analysis, and data storage. The TEC was also one of the first cities in China to venture into the e-sports industry by launching professional e-sports competitions and building top-notch e-sports venues, including one in the National Animation Industry Park which has been billed as North China's top e-sports venue.

There is also a thriving cultural and creative industry comprising three clusters—film, television and animation; book publishing; and advertising media. Over 2,000 such enterprises have been set up in the TEC including Thinkingdom Media—the first private publishing enterprise in China to be listed on the mainboard of the Shanghai Stock Exchange. The TEC is also home to many leading private publishing enterprises. More than 10,000 new media copyrights have been registered with the TEC Copyright Exchange since it was founded in 2015. The TEC also hosts leading Chinese and foreign enterprises in the advertising media industry.

At the same time, the TEC is developing modern services industries in finance and healthcare. There are more than 600 financial enterprises in the TEC, while the bio-pharmaceutical industry counts several Chinese and foreign biopharmaceutical companies such as Dynamiker Biotechnology and Jecho Biopharmaceuticals in its fold.

With its unique natural coastal assets, the tourism industry is another bright spot in the growing economy of the TEC. There are currently 56 tourist projects at various stages of development, forming a series of tourist attractions. They include the National Maritime Museum (国家海洋博物馆), Tianjin Binhai Aircraft Carrier Theme Park (天津滨海航母舰主题公园), Relict Gull Park (遗鸥园), Tianjin Fantawild Adventure Theme Park (天津方特欢乐世界主题公园), Tianjin Aqua Magic (欢乐水魔方) and Binhai Carp Gate (滨海鲤鱼门). In early 2016, the TEC was included in the first batch of National Global Tourism Demonstration Zones announced by the China National Tourism Administration. TEC held the first Eco-City International Tourism Festival in 2018, and its tourist attractions welcomed more than 6.5 million visitors in 2019.

CHAPTER 5

Making the Eco-City: Distilling Insights, Looking Ahead

Overcoming Challenges, Breaking New Ground

Since the Sino-Singapore Tianjin Eco-City (TEC) project first broke ground in 2008, the city has undergone a remarkable transformation in little more than a decade. From a barren wasteland of saltpans and polluted waterbodies along China's Bohai Bay, the TEC is today a liveable and environmentally sustainable city framed by lush greenery and sparkling blue waterscapes.

The biodiversity of the area has been restored and protected, including its wetlands and bird habitats, and the replanting of local plant species have created an extensive green and blue environment. The wastewater pond at the centre of the TEC has been rehabilitated and is now brimming with life. Its saline-alkali soils have been remediated with added topsoil to sustain city-wide greening. To date, the buildings in the TEC are certified green buildings, with the TEC tapping renewable energy sources such as solar, geothermal and wind. Despite its initial water scarcity, the TEC has developed a diversified and sustainable water supply with a sponge-city infrastructure that is resilient against flood risks. Green transport, such as public transportation and active mobility, is actively promoted and encouraged. These initiatives have helped reduce the TEC's energy consumption and carbon footprint.

Beyond the "hardware" mentioned above, the TEC has also focused on the "heartware" for its residents. The TEC was planned and designed to promote social harmony and community bonding. People living and working in the TEC have convenient access to a comprehensive range of public amenities, including neighbourhood centres, residents' centres, hospitals and health centres, schools and kindergartens, fitness centres and public parks, all of which are close to their homes and workplaces. Residents are encouraged to lead environmentally-friendly lifestyles and participate in community life.

The development of the 8 km^2 start-up area, where much of the TEC's development has taken place in the past decade, is complete and the population of TEC is now reaching a critical mass. Attracted by its high-quality living environment, comprehensive range of amenities and vibrant economic opportunities, over 100,000 people now live or work in the TEC, up from 20,000 in 2014. There are more than 9,800 registered companies in the TEC with a total registered capital exceeding RMB 414 billion in industries such as coastal tourism, culture and creativity, smart and information technology, as well as health and wellness. Tourist attractions such as Huaqiang Fantawild Adventure Theme Park (天津方特欢乐世界主题公园) and MICE (meetings, incentives, conferences and exhibitions) activities in the TEC are also attracting new visitors. The upcoming mass rapid transit (MRT) line will further enhance the TEC's connectivity with the surrounding region.

Drawing Insights From a Decade of Development Experience

Climate change, sustainable development and social harmony—the drivers behind the TEC project—are the defining global challenges of our time. The past decade has seen exceptional weather changes, melting polar ice caps and accelerating sea level rise. Global in scope and unprecedented in scale, the reality of climate change is taking hold in socio-economic development, health, displacement, food security, and land and marine ecosystems. Cities, which are major consumers of resources such as energy and water, as well as producers of carbon emissions, have a key role to play in combating climate change. In the coming decades, 90% of urban expansion will take place in developing countries.[6] At the same time, the urban social fabric is under strain from global and local social divides fuelled by growing inequality, lack of economic opportunities and gaps in the provision of public services.

A successful eco-city project rooted in the principles of environmental sustainability, resource conservation and social harmony, can provide a blueprint to help address these challenges. The TEC started with a vision to build a thriving city that is "environmentally friendly, resource efficient and socially harmonious—a model of sustainable development", underpinned by the "three harmonies" and "three abilities". The "three harmonies" demonstrate the viability of a better model of urban development. It is built on the principles of people living in harmony with the environment (environmental sustainability), people living in harmony with economic activities (economic vibrancy) and people living in harmony

with other people (social harmony). The "three abilities" reflect the TEC's aim to be a model of sustainable development that is practicable, replicable and scalable so that it can be adopted by other cities in China and the rest of the world.

Achieving this vision for the TEC required adopting a radical new approach in urban, environmental and social development, starting with the master plan.[7] To ensure that it made good progress towards its vision, the TEC pioneered a planning and development approach that was guided from the outset by a clear Key Performance Indicators (KPIs) Framework. Encompassing four aspects of resource utilisation, environmental sustainability, social harmony and regional coordination, the KPI Framework set targets and measured the city's progress in the areas of environmental, economic and social developments. From an initial set of 22 quantitative and four qualitative indicators, the TEC has since upgraded its set of KPIs which now comprises 30 quantitative and six qualitative indicators, with higher targets in the areas of environmental, social and smart-city developments. In addition, some indicators under the original KPI Framework have been removed since they have been achieved and are now deemed as a basic requirement for many cities in China.

New Quantitative KPIs

Objective	KPI Area	KPI in Upgraded Framework	Target	Timeframe for achieving target
Healthy ecological environment 生态环境健康	Good natural environment 自然环境良好	Ecological shoreline retention rate 生态岸线保有率	100%	2023
	Healthy balance in the urban environment 城市环境宜居	Access to parks and green spaces within 5-minute walk 步行5分钟可达公园绿地居住区比例	100%	2035
		Urban heat island effect intensity 城市热岛效应强度	≤ 2.5°C	2035
Harmonious development of society 社会和谐发展	Good lifestyle habits 生活方式健康	Proportion of active social groups to total social groups 居民社团活跃度	≥ 80%	2035 (2028: ≥ 50%)
		Residents' life satisfaction level 居民生活满意度	≥ 80%	2035

Objective	KPI Area	KPI in Upgraded Framework	Target	Timeframe for achieving target
Harmonious development of society 社会和谐发展	Good lifestyle habits 生活方式健康	Residents' health literacy level 居民健康素养水平	≥ 45%	2035
	Comprehensive infrastructure 基础设施完善	Annual runoff control rate 年径流总量控制率	≥ 80%	2035
	Sound management mechanism 管理机制健全	Wastewater reuse rate 污水集中处理设施出水回用率	100%	2023
		Social security coverage 社会保障覆盖率	100%	2023
Green and low carbon economy 经济绿色低碳	Promotion of technology innovation 科技创新驱动	Company innovation activity rate 企业创新活跃度	≥75%	2035
New Qualitative KPIs				
Integrated regional coordination 区域协调融合	Cityscape shaping 城市风貌塑造	Enhance urban design and create a distinctive Eco-City 加强城市设计，打造生态特色风貌	To regularly develop surveys and evaluations on urban landscape features and ensure implementation of planning and design.	
	Industry collaboration optimisation 产业协调优化	Develop business-to-business (B2B) service industry 生产性服务业提质	To upgrade the economic structure of the TEC and integrate with the growth of other immediate and potential markets.	

The TEC has to continuously innovate to succeed. Many new technologies and solutions for urban and environmental issues have been piloted in the TEC. Some of these include pioneer techniques to rehabilitate and manage polluted waterbodies, as well as new methods of remediating non-arable saline-alkali soil. These innovations have transformed the area into a green ecological oasis. In urban planning, the TEC has adopted the "eco-cell – eco-neighbourhood – eco-district" concept to ensure that amenities and public facilities are well distributed, and to encourage green travel. Departing from the traditional approach in China, the TEC implemented a three-level community service centre system across respective catchment areas, to serve as the main provider of community services and offer convenient one-stop services. The TEC also broke away from conventional approaches with regard to transportation planning in China, by introducing greenways, which are well-suited for active mobility. In addition, the TEC also adopted smart energy management

and developed non-traditional water resources, such as seawater desalination and wastewater recycling.

The development of the TEC has been made possible with the unwavering commitment of the governments of Singapore and China at all levels as well as the support of consortiums from the two countries. As a strategic partnership between Singapore and China, the TEC serves as an important platform for the leaders and officials of both countries to engage and learn from each other, by exploring new collaborations and ideas and sharing best practices in sustainable urbanisation. At the same time, while Singapore has shared lessons from its development experience with China, the TEC has also provided fresh perspectives on Singapore's urban planning.

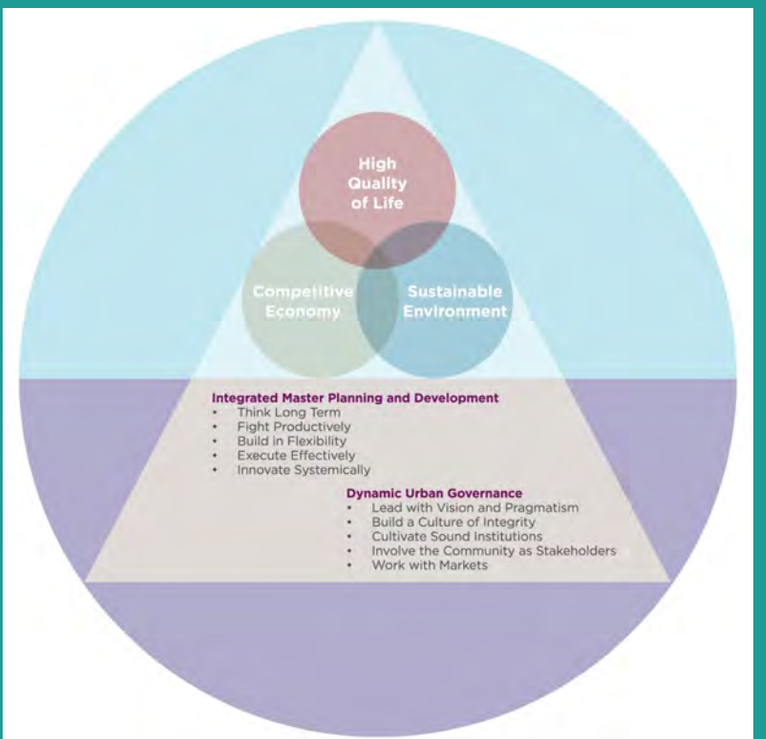
The experience in developing the TEC has produced invaluable learning points which continue to attract keen interest from city leaders in China and abroad. The TEC was launched at a time when China was paying greater attention to environmental issues and sustainable development. These issues have since become a fundamental priority in China's other development projects. The TEC has hosted numerous study visits by mayors and officials of other Chinese cities, offering a first-hand experience of its urban systems and innovations. Companies involved in the development of the TEC have also taken on environmental projects in other parts of China. For example, the Tianjin Eco-City Environment Protection Co. Ltd is now involved in rehabilitating polluted waterbodies in other parts of the country, drawing from its experience in the rehabilitation of the TEC's Jing Lake. The TEC Green Building Research Institute also provides green building-related technical advisory and consultancy services to other Chinese cities.

The achievements of the TEC have been recognised in China and beyond. In 2018, the TEC was selected as China's first "Happiest Ecological City" by the China Happiness City Forum, in recognition of the new urban development model pioneered by the TEC. In the international arena, the TEC was awarded the 2018 Green Solutions Awards "Sustainable City Grand Prize" by Construction21—a media portal focused on sustainable construction. The award highlights the TEC's high quality of life, ecological protection measures, use of technological innovation for environmental protection, energy conservation and emissions reduction, green buildings and circular economy.

BOX STORY

The Eco-City and the Singapore Liveability Framework

Through the study of Singapore's urban transformation, the Centre for Liveable Cities (CLC) has been distilling general principles and desired outcomes undergirding Singapore's approach to sustainable development. Derived from Singapore's urban development experience, the Singapore Liveability Framework is a useful guide for developing sustainable and liveable cities. Some of the general principles under Integrated Master Planning and Development, and Dynamic Urban Governance are reflected in the development of the TEC.



Singapore Liveability Framework

Integrated Master Planning and Development

Think Long Term
To ensure that development can truly be sustainable, the master planning, design and management of the TEC had to be implemented with a long-term perspective. From the early stages of planning the TEC, it was the integration of land use, spatial and transport planning that enabled the implementation of walkable eco-cells and eco-neighbourhoods within the city. Today, the actualisation of these sustainability-driven concepts enables the TEC to thrive while maintaining a low carbon footprint.

Build in Flexibility
Plans guiding the TEC's development are regularly reviewed to help the city adapt and respond effectively to changes in its surrounding regions or shifts in its positioning. For example, to respond to changes in its internal and external environment and sharpen the TEC's positioning within the Beijing-Tianjin-Hebei region, a master plan review was initiated in 2016. Similarly, the KPI Framework, which had guided and tracked the planning and development of the TEC, has also been updated to include additional indicators and higher targets in environmental, social and smart-city developments.

Execute Effectively
After the integrated master plan was developed, the TEC set out various five-year action plans to guide the execution of its master plan. Each action plan identified key implementation projects, set out development timelines, and aligned the various work plans of local authorities to execute the master plan. This has helped to ensure that the required budget, manpower and other resources are set aside for a smooth implementation.

Innovate Systemically
The process of planning and developing the TEC was marked by conscious efforts to inject practical and effective innovations to create a better city. The adoption of the KPI Framework was an innovation in urban planning in China. Setting clear targets and measures, and regular monitoring of the TEC's progress in the areas of environmental, economic and social developments, has ensured that the development of the TEC adheres to its vision. In dealing with its environmental challenges in water and on land, the TEC has also devised innovative methods which not only improved the area's environment and ecology, but also created "blue—green networks" of new public spaces for the TEC.

Dynamic Urban Governance

Lead with Vision and Pragmatism
From the onset, the governments of Singapore and China had worked closely together to formulate a clear and coherent vision for the TEC that was shared by both sides. At the same time, this vision was grounded in pragmatism, as reflected by the "three abilities", which required the TEC to be practicable, replicable and scalable. The TEC was not intended to be a showpiece, but a feasible model of development that would be of use to other cities in China and beyond.

Involve the Community as Stakeholders
While regulatory enforcement is needed, building community stewardship of the environment is a more sustainable approach over the longer term. As polluted waterbodies were rehabilitated into scenic lakes and greenery took root in the saline wasteland, mindsets were changed and the environment was recognised as an asset to be protected and nurtured. For example, residents in Kunyuyuan Housing Estate (鲲玉园) were empowered and encouraged to take the initiative to transform a landfill into a neighbourhood garden that became a shared community space, which in the process helped to strengthen neighbourly bonds.

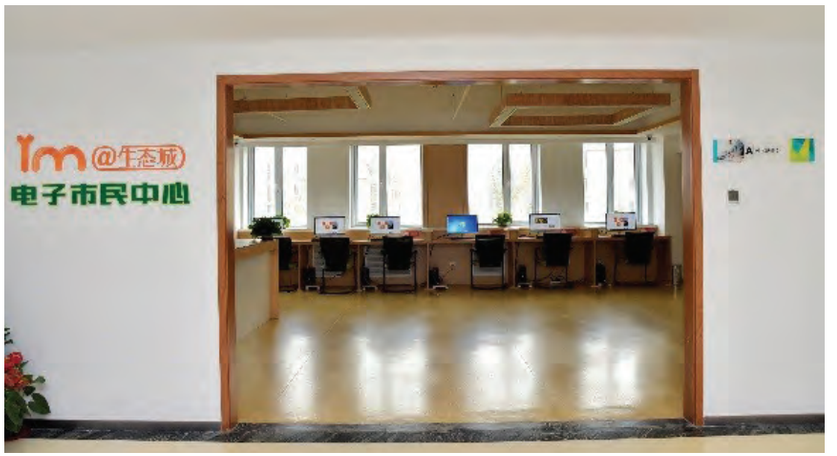
Work with Markets
While the TEC project was initiated at a Government-to-Government level between Singapore and China, both governments recognised that the involvement of the market-oriented enterprises was essential to instil financial discipline for the long-term viability of the TEC. From residential projects, commercial and industrial developments to public amenities and facilities, a large part of the design and development of the city had been led by such enterprises under the guidance of the TEC's master plan. In some instances, the private sector was involved in providing high-quality social services such as education.

Making the Eco-City a Smart City

One key focus area for the future is leveraging and incorporating smart city features to improve urban management. In 2013, the TEC was included in the first batch of pilots for the development of smart cities in China. Its development was guided by a smart city master plan and smart transport master plan that drew from Singapore's experiences.

Taking a coordinated infrastructure development approach, the TEC built a shared communications network for the delivery of various services, such as a residential communications network, local authority and enterprise communication networks, cable TV network, and urban integrated services network. The TEC also set up a shared video surveillance platform to serve multiple purposes such as security, safety and supervision, urban management, public works, social services and public transport. A green data centre was built, laying the foundation for the implementation of cloud services and the development of the TEC's big data industry.

Today, businesses in the TEC can conveniently access an online regulatory approval platform using various channels such as SMS, websites and hotlines. For residents, the TEC has a one-stop online service platform providing information and services related to health, food, lifestyle, travel, entertainment and education. There is also an E-Citizens Centre where those who need assistance with the one-stop online service platform can visit. A Single Sign-On (SSO) system modelled on Singapore's SingPass system has also been implemented for seamless access to various government services.



The Second Neighbourhood E-Citizens Centre where those who need assistance with the one-stop online service platform can visit.

Constructed in 2018, the Smart City Operations Centre (智慧城市管理中心, SCOC) is the TEC's flagship smart-city project. The SCOC serves as a "city brain" to integrate, monitor, analyse and manage city-wide public utilities infrastructure, public services and emergency management. Tapping into an integrated network of sensors, including some 400 smart street lampposts with sensors and CCTV cameras, the city-wide data generated by the TEC's daily operations are integrated and analysed at the SCOC to improve the quality and efficiency of city management.

Constructed in 2018, the TEC's Smart City Operations Centre serves as a "city brain".

The TEC has also piloted smart solutions such as autonomous public buses and smart carparks, as well as real-time energy consumption monitoring for public buildings to identify ways to improve energy efficiency. An example is JD.com—a leading e-commerce company in China—which is conducting trials on autonomous courier vehicles and an unmanned supermarket in the TEC.

Such smart city initiatives are paying off. For example, in the area of water management, the SCOC uses a combination of geographic information system (GIS), drone scanning and robot surveillance data to identify areas of water leakage in its pipe network and leverages the Internet-of-Things (IoT) for maintenance planning. This has helped the TEC to conserve water and save more than 50% of manpower in maintenance work. As a result, the Tianjin Municipal People's Government has showcased the TEC as a model for smart city development in Tianjin. The TEC is also the smart city showcase site for the World Intelligence Congress.

Staying at the Forefront of Sustainable Urban Development

The TEC continues to push the boundaries of sustainable urban and smart city development. The upgraded KPI Framework includes more stringent targets and new indicators, such as curbing urban heat island intensity, real-time monitoring of administrative database, access to parks and green spaces, and monitoring of residents' physical activity levels for health. It will guide the TEC towards achieving higher targets in environmental, social and smart-city developments.

At the same time, the TEC has reviewed its urban master plan to take into account the city's position as the coastal recreational hub for the Beijing-Tianjin-Hebei region. In its next phase of development, the TEC will focus on the central district and city centre which will be the heart of commercial, leisure and recreational activities to support its future growth.

An artist's impression of the TEC's central district.
Image courtesy of Sino-Singapore Tianjin Eco-City Investment and Development Co., Ltd. (SSTEC)

Bounded by the Ji Canal River and Central Avenue, the city centre is envisioned as a "Green Smart Hub"—a smart low-carbon central business district with green and smart infrastructure. Designed in collaboration with urban planners from Singapore, the city centre will feature ideas and elements adapted from Singapore. Open plazas will be embellished with greenery and water features, while sky gardens and terraces have been proposed for tall buildings. An iconic skyline will see building heights gradually taper from the gateway towers adjacent to the MRT station towards the waterfront. The China-Singapore Friendship Garden and China-Singapore Friendship Library will serve as major nodes of attraction in the city centre. Mixed-use districts with live-in populations will be developed to make the city centre lively and vibrant. Smart bus stops, as well as plans to introduce driverless vehicles and bicycles, will make commuting easier.

Opened to the public in November 2018, the China-Singapore Friendship Library is set to be a major attraction in the TEC's city centre.

The TEC is also developing a new master plan for a zero-waste city, implementing policies to support innovation and test-bedding of advanced waste management technologies, such as on-site plastics and organic waste recycling into resources for use. Adopting the circular economy approach to address waste management, resource constraints and climate change, the TEC is among China's first batch of 16 zero-waste pilot cities launched nationwide in June 2019. It is also the only pilot city to involve international collaboration.

Other initiatives include City Information Modelling (CIM)—a live digital model of the city—which is being introduced in the TEC to serve as a foundation for other smart applications. This will enhance data-driven and collaborative urban planning, as well as make administrative and public services more efficient and convenient for businesses and residents. A green urban mobility plan is also in the works to achieve the higher target of 95% low-carbon trips in the TEC.

These initiatives will keep the TEC at the forefront of eco-city development, amid the rise of other green and eco-friendly projects in China and other countries. Good infrastructure and hardware of the city, though important, are only the means to an end. It is the software of the TEC—its governance system, community vibrancy and cohesiveness—that will make it stand out. In the next phase of the TEC's development, the TEC will be focussing on strengthening its people-centric strategies and aspects, such as place-making and destination marketing, to highlight the TEC as a choice location for talent, tourism and business.

Replicating the TEC model in other Chinese cities and elsewhere will take on increasing importance. Singapore and China intend to promote the replication of the TEC's development experience and expand the impact of the bilateral cooperation in the TEC to other urban areas in China, including the larger Tianjin Binhai New Area, and to countries participating in the Belt and Road Initiative. To date, the TEC's experience in water rehabilitation has been replicated in the Xiong'An New Area's Baiyangdian Lake (白洋淀湖) basin. Both countries have also been working on joint research and training of Chinese public servants on sustainable urban development, based on the TEC's development experience.

To advocate replication of similar developments that enable sustainable urban living, Singaporean and Chinese partners have come together to jointly promote, publicise and export the project's experience and eco-solutions through the Global Institute for Sustainable Urban Development. The Global Institute is a non-profit entity jointly set up to conduct research and promote standardisation, participate in international events, offer consultancy and provide training to other cities, including those along the Belt and Road Initiative. The founding members of the Institute include Keppel Corporation, the joint venture company Sino-Singapore Tianjin Eco-City Investment and Development Co., Ltd. (SSTEC), the ECAC and its Green Building Research Institute (GBRI), and a Chinese eco-city development consultancy.

This cooperation brings the TEC a step closer to realising its vision of becoming a practicable, replicable and scalable model for sustainable development. As its vision takes root, the TEC will continue to innovate and adapt to changing needs, and seek to scale even greater heights.

Epilogue

A Partnership for a Smart and Sustainable Future: The China-Singapore Tianjin Eco-City is a joint effort by the Centre for Liveable Cities (CLC), Singapore and the China-Singapore Tianjin Eco-City Administrative Committee (ECAC). The aim is to document and distil the development journey of the Tianjin Eco-City (TEC), and distil insights from the TEC's development experience to be shared with Chinese cities and beyond. In preparing for this publication and ensuring a comprehensive coverage of the TEC's development, considerable efforts were undertaken by the CLC and the ECAC to interview and gather inputs from those involved in the TEC, where possible.

This publication chronicles the story of the TEC through five chapters. The first four chapters cover the development journey of the TEC, while the concluding chapter synthesises the key insights derived from the entire TEC experience. We hope that the contents will serve as a useful and practicable reference for other cities seeking to develop smart, sustainable and liveable cities.

We would like to express our gratitude to Sim Ann, Senior Minister of State, Ministry of Foreign Affairs and Ministry of National Development, Singapore and Huang Yan, Vice Minister of the Ministry of Housing and Urban-Rural Development, People's Republic of China, for their support for this publication. We would also like to extend special thanks to leaders from Singapore, Tianjin and the ECAC for their guidance. We are grateful to the Singapore and Chinese pioneers involved in the TEC, experts and colleagues from the CLC and other Singapore agencies, as well as from the ECAC, especially Mah Bow Tan, Lim Chee Onn, Khor Pow Hwa, Tay Kim Poh, Tay Lim Heng, Chionh Chye Khye, Tan Siong Leng, Loh Ah Tuan, Lim Chin Chong and Wong Kai Yeng for their invaluable inputs.

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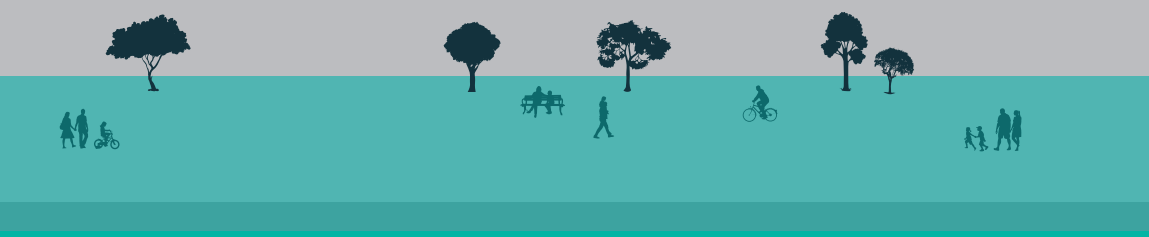
Endnotes

[1] Figures are correct as of 8 December 2020.
[2] Prime Minister's Office, Singapore, "Speech by Mr Lee Hsien Loong, Prime Minister, at the UNFCCC Conference in Bali, 12 December 2007, 11.15AM", Singapore Government Media Release, 12 December 2007, https://www.nas.gov.sg/archivesonline/data/pdfdoc/20071212988.htm
[3] The World Bank, *Sino-Singapore Tianjin Eco-City: A Case Study of an Emerging Eco-City in China* (Washington D.C.: World Bank, 2009), 21.
[4] The World Bank, *Sino-Singapore Tianjin Eco-City: A Case Study of an Emerging Eco-City in China* (Washington D.C.: World Bank, 2009), 28. https://openknowledge.worldbank.org/handle/10986/28143
[5] The initial area of the Eco-City, along with the jurisdiction of ECAC, was eventually expanded in 2014 with the inclusion of the neighboring tourism district.
[6] "Goal 11: Sustainable Cities and Communities", United Nations Development Programme, 24 March 2020, https://www.undp.org/content/undp/en/home/sustainable-development-goals/goal-11-sustainable-cities-and-communities.html
[7] Lim Yan Liang, "Tianjin Eco-city: Lessons from Singapore on social and sustainable development", *The Straits Times*, 30 June 2018, https://www.straitstimes.com/asia/lessons-from-singapore-on-social-and-sustainable-development

A Partnership for a Smart and Sustainable Future

The China-Singapore Tianjin Eco-City



Overcoming considerable odds, the China-Singapore Tianjin Eco-City (TEC) is the result of a vision shared by Singapore and China to create a viable model for sustainable development, signalling a deepening partnership between the two countries. Bringing together expertise and experience from Singapore and China, the TEC has been developed based on the concepts of "*three harmonies*" and "*three abilities*". It reflects the vision of people living in harmony with other people, with economic activities, and with the environment. At the same time, the TEC has been designed to be practicable, replicable and scalable to serve as a demonstration of what can be achieved. This book, a collaboration between Singapore's Centre for Liveable Cities and the Eco-City Administrative Committee, traces the TEC's transformation from an inhospitable wasteland into a socially harmonious, environmentally friendly and resource-efficient city.

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