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## Sino–Singapore Tianjin Eco–City:

# A Case Study of an Emerging Eco-City in China




THE WORLD BANK

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Technical Assistance (TA) Report
November 2009

# Foreword

China is experiencing rapid and large scale urbanization—and the resulting local and global urban environmental challenges are unprecedented. The Chinese Government has fully recognized these challenges and is aiming to promote more sustainable urbanization in line with the objectives of the 11th Five Year Plan, which calls for "building a resource-conserving and environmentally friendly society". Various initiatives are being pursued to support this objective, both at the national and local levels. At the local level, cities have responded by developing "eco-cities", which aim to promote a more sustainable urbanization model. More than one hundred eco-city initiatives have been launched in recent years. One such initiative is the Sino-Singapore Tianjin Eco-City.

Tianjin Municipality has requested that the World Bank support the Sino-Singapore Tianjin Eco-City through a Global Environmental Facility (GEF) grant that is currently under preparation. This Technical Assistance (TA) report was launched in conjunction with the GEF preparation process. The objectives of this report are to create a detailed knowledge base on Sino-Singapore Tianjin Eco-City, and to provide policy advice on key issues and challenges, especially those related to the GEF project, early during the project's design and implementation. Contextualizing the Sino-Singapore Tianjin Eco-City in the wider ecological urban development initiatives in China and broadening the Bank's engagement beyond the GEF project was assessed to be important given the project's complexity, and its potential to provide lessons learned for China's sustainable urban development challenges.

The report was prepared during the early development stages of the Sino-Singapore Tianjin Eco-City, mainly between September 2008 and June 2009, after the master plan was developed but before many of the detailed sector plans and feasibility studies were available. It therefore provides an initial overview of some of the key issues and challenges faced by the eco-city, many of which need to be further analyzed during the detailed sector planning and feasibility study review process. Given the scope of the project, the analysis presented necessarily had to vary in coverage, with some topics covered in greater depth than others.

# Acknowledgements

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The project was managed by Axel Baeumler and a core team including Mansha Chen, Arish Dastur, Hinako Maruyama, and Hiroaki Suzuki. Chapter one was written by Mansha Chen. Chapter two was authored by Arish Dastur based on inputs from Belinda Yuen and Mansha Chen. Chapter three was authored by Yabei Zhang based on inputs from Liu Feng, Bernd Kalkum, Bill Nesmiths, and Arto Nuorkivi. Richard Filewood (McCormick Rankin Cagney) wrote chapter four with inputs from George Darido. Chapter five was written by Khairy Al-Jamal with inputs from Sing Cho. Chapter six was written by Charles Peterson; chapter seven by Monali Randale, Nat Pinnoi, and Charles Peterson; and chapter eight by Axel Baeumler. Annex two is based on findings from a stocktaking study on Chinese eco-cities conducted by the Chinese Academy of Urban Planning. Dean Thompson edited the final report.

Others who contributed to the report included Bob Taylor, Stephen Karam, Neeraj Prasad, and Sam Zimmerman, who served as peer reviewers. World Bank management provided valuable guidance throughout the process, particularly Christian Delvoie, Ede Ijjasz, and Keshav Varma.

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## Tables

## Boxes

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# Selected Abbreviations And Acronyms

| | |
|---|---|
| ACEEE | American Council for an Energy Efficient Economy |
| AP | Acidification Potential |
| AusAID | Australian Agency for International Development |
| BETC | Business Energy Tax Credit |
| BHNA | Binhai New Area |
| BRT | Bus Rapid Transit |
| CAGECE | Companhia de Água e Esgoto do Ceara |
| CAPEX | Capital Expenditure |
| CDM | Clean Development Mechanism |
| CFL | Compact Florescent Light Bulbs |
| CHP | Combined Heat & Power |
| CNCCP | China National Climate Change Program |
| CNG | Compressed Natural Gas |
| CNY | Chinese Yuan |
| Co. | Company |
| DH | District Heating |
| DHW | Domestic Hot Water |
| EMAS | Eco-Management and Audit Scheme |
| EP | Eutrophication Potential |
| ESCO | Energy Service Companies |
| EU | European Union |
| GBEC | Green Building Evaluation Committee |
| GBES | Green Building Evaluation Standard |
| GEF | Global Environment Facility |
| GHG | Greenhouse Gas |
| GWh | Gigawatts |
| GWP | Global Warming Potential |
| HVAC | Heating, Ventilation, Air Conditioning |
| ITS | Intelligent Transport System |
| IPCC | Intergovernmental Panel on Climate Change |
| JV | Joint Venture |
| km | Kilometer |
| KPI | Key Performance Indicator |
| l | Liter |
| LCC | Life Cycle Costing |
| LCE | Lower Carbon Emission |
| lcpd | Liters Per Day |
| LED | Light Emitting Diode |
| LEED | Leadership in Energy and Environmental Design |
| LFG | Landfill Gas |
| LNG | Liquefied Natural Gas |
| LRT | Light Rail Transit |
| LTD | Limited |
| m | Meter |
| MEP | Ministry of Environmental Protection |
| mg | milligram |
| MLNR | Ministry of Land and Natural Resources |
| mn | Millions |
| MoHURD | Ministry of Housing and Urban-Rural Development |
| MW | Megawatts |
| NDRC | National Development and Reform Committee |
| NGO | Non-Governmental Association |

| | |
|---|---|
| NMT | Non-Motorized Transport |
| NRE | Non-Renewable Energy |
| OD | Origin Destination |
| OPEX | Operational Expenditures |
| POCP | Photochemical Ozone Creation Production |
| PT | Public Transport |
| PUB | Public Utility Board |
| PV | Photovoltaic |
| R&D | Research and Development |
| RETC | Residential Energy Tax Credit |
| RMB | Chinese Renminbi |
| RW | Radioactive Waste |
| SCE | Standard Coal Equivalent |
| SEER | Seasonal Energy Efficiency Ratio |
| $SO_2$ | Sulfur Dioxide |
| SSTEC | Sino-Singapore Tianjin Eco-City |
| SSTECAC | Sino-Singapore Tianjin Eco-City Administrative Committee |
| STEC | Singapore Tianjin Eco-City Investment Holdings Ltd. |
| TA | Technical Assistance |
| TBNA | Tianjin Binhai New Area |
| $tCO_2$ | Tons Carbon Dioxide |
| TDM | Travel Demand Management |
| TECID | Tianjin Eco-City Investment and Development Company |
| TEDA | Tianjin Economic-Technological Development Area |
| TFTZ | Tianjin Free Trade Zone |
| TOD | Transit Oriented Development |
| TPD | Tons Per Day |
| UAFW | Unaccounted for Water |
| UK | United Kingdom |
| UN | United Nations |
| UNFCCC | United Nations Framework Convention on Climate Change |
| USD | United States Dollars |
| WWTP | Wastewater Treatment Plant |

# Executive Summary

## Introduction

***Urbanization and Environmental Pressures.*** China is experiencing the largest scale of urbanization in history—at an unprecedented pace. Over the past three decades, the share of China's population living in cities more than doubled, reaching 44.9 percent in 2007. Urbanization is projected to rise to about 64 percent by 2025, which translates to slightly over 350 million more people living in urban areas. The annual population increase in China's cities over the next 20 years is forecasted to be about 17.7 million—the equivalent of adding one global megacity, such as New York City, each year. As China's rapid urbanization takes shape, the country is facing severe challenges related to resource conservation and environmental sustainability. These challenges impact all major areas: water pollution, waste management, air pollution, energy demand, and land utilization, including the conversion of agricultural land to urban use. Indeed, the latest estimates suggest that China has overtaken the United States as the world's largest emitter of greenhouse gases (GHGs). A large part of global GHG emissions can be attributed to cities, which are estimated to contribute about 80 percent of total emissions worldwide. With the predicted continuation of urban-led economic growth, much is at stake in China's urban ecological footprint—not just for China, but globally.

***Ecological Urban Development.*** The Government of China has recognized the importance of "sound urbanization" and expressed the intention to pursue a "new pattern for urban development which is resource-conserving, environmentally friendly, economically efficient, and socially harmonious". This intention is aligned with China's 11$^{th}$ Five-Year Plan, which calls for "building a resource-conserving and environment-friendly society". Although the goal of adopting sustainable urban planning has gained momentum, there is relatively little policy guidance at the national level on what constitutes "ecological urban development" in a comprehensive and integrated manner. There are many city-level environmental targets and initiatives mandated for implementation at the local level, such as targets for wastewater treatment, building energy efficiency, and land use (among others). However, most initiatives focus on sector specific interventions and provide only limited guidance on a more integrated approach to tackling environmental challenges at the city level. There is a clear gap, therefore, in terms of guiding China's continued urban development along a more sustainable environmental trajectory.

***"Eco-City" Standards.*** One attempt to provide such guidance relates to China's "eco-cities" initiatives. The Ministry of Environmental Protection (MEP) and the Ministry of Housing and Urban-Rural Development (MoHURD) both developed national standards for "eco-cities" with the intention of advancing the environmental agendas in cities. Reflecting its respective ministerial mandates MoHURD's standards focus largely on urban infrastructure construction while MEP's standards, being somewhat broader in scope, include targets on energy and resource use efficiency. However, both sets of standards leave significant gaps in assessing environmental sustainability in a more comprehensive manner—including in important areas such as land use, renewable energy, and GHG emissions. Despite their limitations, the eco-city standards of MEP and MoHURD provide an initial basis for introducing ecological development concepts, though they cannot serve as objective benchmarks and reference points for assessing ecological urban development. MEP and MoHURD update their respective indicators regularly and annually announce selected "eco-cities".

***Local Eco-City Initiatives.*** Despite the lack of clear national guidance on sustainable ecological urban development, many local governments have begun to develop eco-cities on their own or together with international partners. It is estimated that eco-city initiatives are being developed in at least a hundred cities across China. Some of the cities correspond to MEP and MoHURD's eco-city standards, ranging from small and medium cities, such as Rongcheng, to large ones, including Shenzhen. More recently, there has been a trend to develop eco-cities through international cooperation, such as the Sino-United Kingdom Chongming Dongtan Eco-City, Tangshan Caofeidian International Eco-City, and Sino-Singapore Tianjin Eco-City (SSTEC). MoHURD has also encouraged cities and towns that were heavily hit by the Wenchuan Earthquake to support reconstruction aligned with eco-city principles.

## Sino-Singapore Tianjin Eco-City

***Project Origin.*** Following earlier cooperation between China and Singapore on the Suzhou Industrial Park in China, in November 2007 the two countries signed a Framework Agreement to collaborate on the SSTEC project. The agreement elevated the project to the level of inter-government cooperation. This entailed endorsement from the Prime Minister, and has enabled SSTEC to gain momentum from strong political commitment while benefiting from Singapore's extensive knowledge and experience in areas such as integrated urban planning and water resource management. The master plan for SSTEC was completed and approved in 2008, and the corresponding control plans are being finalized. The development work of Phase I of the project has begun and is expected to be completed between 2011 and 2013. The SSTEC project was selected after a competitive selection process among four candidate cities: Tianjin, Tangshan, Baotou, and Urumqi.

***Project Objectives.*** SSTEC is envisioned as an "economically sustainable, socially harmonious, environmentally friendly and resource-conserving" city which will become a "model eco and low carbon city replicable by other cities in China". It aims to achieve this vision by taking an integrated approach to planning a new urban area in an environmentally sustainable manner. According to the master plan, SSTEC promotes integrating land use and urban transport and balancing employment and housing supply. SSTEC promotes the "use of clean/renewable energy and reuse/recycle of resources through innovative technologies and environmentally friendly policies and investments across various sectors", including water, energy, land, and transport, among others. Global climate change and social equity issues are also incorporated into the master plan by explicitly including GHG reduction and affordable housing targets.

***Project Implementation.*** The Chinese local authority responsible for the overall implementation and coordination of the project is the Sino-Singapore Tianjin Eco-City Administrative Committee (SSTECAC). SSTECAC was set up especially for the project and is responsible for all government administrative functions. In addition, SSTEC's organizational structure reflects its nature as a bilateral project between China and Singapore (see Figure E.1). In terms of project implementation, the Chinese side takes responsibility for land acquisition and the construction of basic infrastructure, the transportation network, and public buildings. A Joint Venture Company, owned by Chinese and Singaporean counterparts, is responsible for developing parts of residential and commercial real estate, and some infrastructure. SSTEC's organizational structure is a complex partnership which involves multiple private and public sector participants from the two countries. It is governed by the SSTEC Framework Agreement, a Commercial Agreement between all major parties, and the SSTECAC Management Regulation.

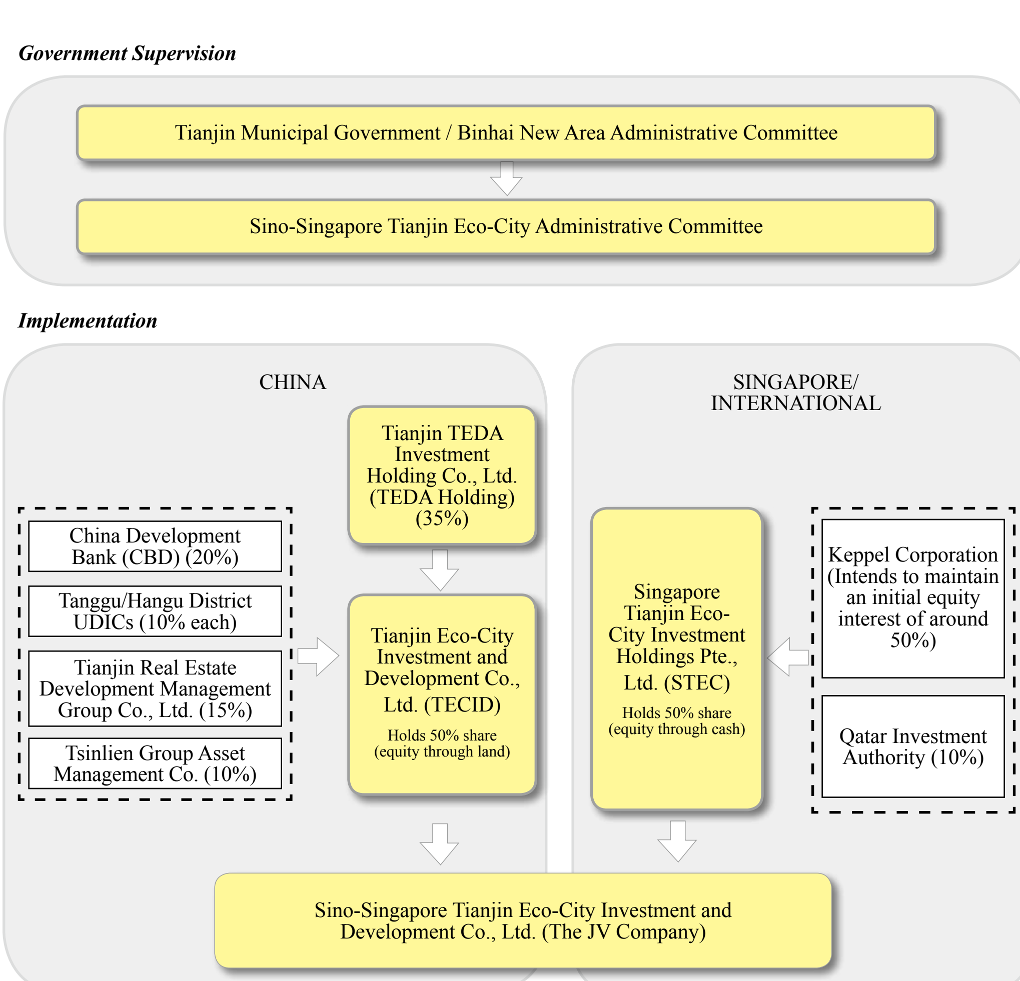
***Request for World Bank Support.*** In this context, Tianjin Municipality requested World Bank support and submitted a request for a Global Environment Facility (GEF) grant. The intended objective of the GEF project is to assist SSTEC in establishing an enabling policy, regulatory, and institutional framework for implementing the SSTEC project. The GEF will include specific Technical Assistance (TA) components supporting project implementation, "green transport" and "green buildings"; and financial assistance to demonstrate energy efficient technologies in the building sector. The GEF is in the early stages of preparation, with project approval expected during 2010.

***Objective of this TA report.*** The purpose of this report is to review the SSTEC project from a comprehensive perspective with a view to achieving the following principal objectives: (i) create a detailed knowledge base on the project; (ii) provide policy advice on key issues, especially those related to the GEF project; (iii) estimate SSTEC's GHG emission reduction potential;[1] and (iv) contextualize the project among the broader ecological urban development initiatives in China. Broadening the World Bank's engagement beyond the GEF was assessed as important given the project's complexity, and its potential to shed light on China's sustainable urban development challenges.[2]

## Main Findings and Messages

***Choosing a Strategic Location.*** SSTEC is located in the northern part of the Tianjin Binhai New Area (TBNA), at the intersection of the Beijing-Tianjin urban development axis and the Bohai rim coastal industrial zone. The project is 45 km from the Tianjin city center, 150 km from Beijing, and 50 km from Tangshan. Under the extension of the new Beijing-Tianjin High Speed Rail to TBNA, and other planned

Figure E.1: Institutional Overview



trunk transport infrastructure connecting Hangu and Tanggu, SSTEC will be able to join Beijing's one-hour economic zone. As such, SSTEC is located in one of the major growth poles in northern China. TBNA has been the powerhouse of Tianjin's economic and demographic growth, producing 44 percent of Tianjin's Gross Domestic Product (GDP) with only 10 percent of its population. Over recent years, TBNA has been experiencing one of the fastest growth rates among cities in China, with annual GDP growth of 20.6 percent from 1994 to 2005.

***Responding to Tianjin's Demographic Context.*** Reflecting fast-paced economic growth, TBNA is also undergoing the fastest population growth in Tianjin Municipality, attracting nearly 50 percent of Tianjin's new urban population. The Metropolitan Planning Area of Tianjin can be categorized into four zones: the urban districts, essentially the city center; TBNA, which is the coastal area about 40 km from the city center and the location of SSTEC; suburban clusters; and other rural areas. Although the annual average growth rate for the urban districts is likely to be only 0.2 percent over the next decade, the annual average growth rate for the TBNA where SSTEC is located is projected to be 5.5 percent. While the city center will absorb 197,000 people between 2000 and 2020, TBNA will absorb 1.65 million people in just 15 years (between 2005 and 2020).

***Responding to Overall Land Shortage.*** One of the key features of the project involves the selection of the site, which was part of the binding selection criteria. Unlike common practices of urban sprawl and green field development that can often encroach on farmland, SSTEC makes good use of unused land by converting non-arable wasteland into an eco-city. Land conditions in SSTEC are relatively poor: one-third of its land is saline, one-third is wasteland, and one-third is water area. By selecting for development 34.2 km$^2$ of non-arable land, deserted salt pans, and polluted water bodies, the project contributes substantially to the efficient revitalization and use of scarce land and water resources. At the same time, the site selection will obviate urbanization development pressures on an equivalent 34.2 km$^2$ of potentially agriculturally productive land, thereby contributing economic, social, and ecological benefits in a context where agricultural land is increasingly lost to urbanization. In addition, the number of existing residents on this site is comparatively small relative to the project size.

***Setting Key Performance Indicators (KPIs).*** To guide the implementation of the project, a set of binding 'Key Performance Indicators' (KPIs) were developed, including 22 quantitative indicators and four qualitative indicators. Quantitative indicators are categorized into three broad areas: ecological and healthy environment; social harmony and progress; and dynamic and efficient economy. Qualitative indicators focus mainly on regional coordination and economic integration. Compared to the existing eco-city standards developed by MEP and MoHURD, SSTEC's KPIs are broader in scope, and, in part, more ambitious. Some KPIs refer to existing national standards, for example, stipulating access to quality tap water, maintaining the quality of water bodies, and ambient air quality, etc. Other KPIs imply shifts toward a potentially more ecological urban development pattern. The KPIs that fall into this category are likely to determine the "ecological content" of the project, and include the following targets to be achieved by 2020:

- KPI 5: Carbon emissions per unit of GDP: ≤150 tons C per one million US$ GDP
- KPI 7: Proportion of Green Buildings: 100 percent
- KPI 11: Per capita domestic waste generation: ≤ 0.8 kg per day per capita (by 2013)
- KPI 12: Proportion of Green Trips: 90 percent (30 percent by 2013)
- KPI 13: Overall solid waste recycling rate: 60 percent
- KPI 19: Renewable energy usage: 20 percent
- KPI 20: Water supply from non-conventional sources: at least 50 percent

***Achieving the KPIs.*** Fulfilling the targets set by the KPIs would represent an advance over China's current urban development model. For example, though a "green transport" KPI of 90 percent (defined as the share of walking, cycling, and riding public transport) may appear attainable by today's standards given China's traditionally high share of non-motorized transport, motorization is likely to be significantly higher by 2020, rendering the achievement of the target a substantial advance over likely prevailing benchmarks. Only a few cities in developed and developing countries have "green transport" shares 70 percent or higher. Similarly, ensuring that 100 percent of buildings are "green buildings" that comply with standards higher than the associated national Green Building Standard would also differentiate SSTEC from other urban development projects, especially because compliance with building codes is low (though it needs to be noted that in some key areas the basic Green Building Standard only refers to the existing Tianjin building code). Other KPIs may be easily achievable, such as receiving at least 50 percent of water supply from non-conventional sources, in light of the fact that Singapore, one of the world's leaders in water reclamation, is a core partner in the project. However, achieving this and the other KPIs, while implying advances in urban development, also presents important financial implications and significant risks, as elaborated below.

***Key Sector Issues.*** In Chapters III-VII of this report, each of the key sectors is analyzed from the perspective of identifying possible roadblocks to achieving the most critical KPIs. Given that the project is only in the early stages of development, detailed sector plans are currently being developed, and nearly no feasibility studies are available. As such, the sector analyses focus on key strategic issues. The key emerging messages are as follows.

*i.* ***Spatial and Urban Design.*** The overall spatial density in SSTEC is relatively high at about 10,000 persons per km$^2$. This is somewhat lower than the projected density in Tianjin's core city, which is anticipated to be 12,500 persons per km$^2$ by 2020, but almost double the projection for Binhai's core urban area. At an aggregate level, such densities provide a sufficient economic demand base to more efficiently provide infrastructure services, such as public transportation or district heating. The overall urban form and density gradient fully support transit-oriented development, with 100 percent of the population living within 400m of some form of public transportation (i.e., metro, light rail, or bus). However, much of the eventual success of introducing a higher share of walking, cycling, and public transportation depends on the micro-level urban design. Good urban design can contribute to creating the conditions for walk-able and vibrant neighborhoods that reinforce the public transport system, pedestrian modes, and bicycle use. Though SSTEC's urban design has some notable features, including plans that mixed used communities will provide citizens with easy access to various destinations within 300-500m walking distance, some risk is posed by SSTEC's decision to use the relatively large 400 by 400 meter block design typical of new urban development in China (though the blocks are further subdivided by accesss roads). Using this block design as the basis for the city's layout may not create the envisaged walk-able communities, especially if these blocks are separated by large roads.

*ii.* ***Transport Sector.*** The transport sector plan adopts a transit-oriented development model based on a broadly supportive urban plan. The regional transport linkages are fully established, particularly through the planned regional metro and other public transport connections. However, it is unclear whether the ambitious "green transport" target of 90 percent can actually be achieved. First, as noted above, the road network is designed in a manner that is likely to create unintended barriers for walk-able communities; moreover, large roads separate individual communities. The current assumption that only 30 percent of trips are conducted by walking and cycling may in fact reflect such thinking. As a result, the major contribution to green transport in SSTEC will need to come from public transport, which is projected to account for 55-60 percent of total trips. Whether this is achievable will depend on public transport infrastructure and the level of eventual motorization in SSTEC. Given that SSTEC is designed to be a community with a somewhat higher income distribution, with implied higher motorization rates, this may constitute a significant challenge. Strong polices to counterbalance the use of private motor cars need to be in place, including strict parking strategies. A good first step is that the building code restrict parking in buildings to 70 percent of the existing Tianjin city code. However, this may not be enough, as every residential household will still have one parking space. In this context, it is worthwhile noting that the share of public transport in the Tianjin Economic-Technological Development Area (TEDA) is currently only 15 percent, and, internationally, public transport shares of more than 50 percent have been achieved only in a few cities.

iii. ***Energy Sector.*** Energy supply is largely exogenous to the eco-city, as it is provided by two combined heat and power plants (CHP) outside the eco-city. More directly under the eco-city's control is energy demand, which is largely driven by the building sector. As such, it is a good objective to set a target to achieve 100 percent "Green Buildings". As indicated above, SSTEC's Green Building Standard is higher than the national Green Building Standard. However, building standards for energy efficiency, which strongly influence energy consumption, follow Tianjin's existing building codes (Tianjin is a national leader in building energy efficiency). The challenge therefore is how to ensure that all the basic building standard requirements are met, and then incentivize developers and owners to exceed minimum requirements. To what extent this will be achieved will depend on policy and incentive mechanisms, which are currently largely undefined. Energy commissioning is a systematic approach that ensures that energy-related systems perform according to requirements; reduce energy use along multiple channels, and lower operating costs. Energy commissioning also results in fewer contractor callbacks, better building documentation, and performance verification. Energy commissioning is strongly recommended to be included in the SSTEC's Green Building Standard. In addition to the energy efficiency requirement for building envelopes and central heating, SSTEC may consider mandatory energy performance requirements for major energy-uses, such as air conditioning. The heating/cooling sector follows conventional Chinese design standards, with many options for reducing ecological footprints unexploited, such as using lower temperatures for the supply and return of water for district heating, moving from group to building sub-station designs, and using the district heating system for cooling and domestic hot water. In renewable energy, the main challenge is that there are few sources in Tianjin except for geothermal heat which, together with solar energy for hot water and street lighting, will provide the bulk of renewable energy. Reaching the renewable energy target could therefore become a challenge.

iv. ***Water Sector.*** The key distinguishing feature of the water sector relates to the very high share of non-conventional water sources, including from reclaimed and desalinated water sources. The KPI of 50 percent of water from non-conventional sources would put SSTEC into the same category as Singapore, a world leader in this area. As Tianjin is located in an area with extreme water shortages, the use of non-conventional sources should form a core element of a sustainable water strategy. However, given that water reclamation is capital expensive and has high operating costs, detailed assessments of the costs and benefits of adopted solutions will need to be carried out, including justifying the required dual-pipeline networks for reclaimed water in buildings. The justification for using desalinated water will also need to be carefully considered in light of multiple existing water supply options, and the small contribution desalinated water would make to the overall water supply. The wastewater sector is being supported by an existing World Bank project—Hangu Yingcheng's wastewater treatment plant is financed by the World Bank. Given its coastal location, and Tianjin's projected exposure to rising sea levels, the storm water and drainage system will also need to be designed to reflect the future impact of climate change.

*v.* ***Solid Waste Sector.*** In the solid waste sector, the key challenges relate to achieving a comparatively low per capita solid waste generation rate and a high recycling rate. Achieving a recycling rate of 60 percent may be particularly hard to achieve by employing only formal measures (there have been discussions about eliminating informal recycling by waste pickers, which plays a large role in China's sold waste sector). If successful, SSTEC would be among cities with the highest recycling rates—for comparison, Singapore's current recycling rate is 51 percent. Though the proposed pneumatic collection system is an innovative proposal, there are concerns that without a detailed cost benefit analysis, this solution may not be the most cost-effective way of achieving SSTEC's stated environmental objectives. Solid waste disposal solutions, either incineration or land-filling, have not yet been finalized. However, if land-filling were to be adopted, landfills should adhere to advanced standards, such as those at the existing Shuangku landfill (see also the GHG section below).

***Focus on Technological Solutions.*** One striking feature of the current plans for SSTEC is that they strongly emphasize adopting technological solutions to achieve the project's environmental objectives. While this can, in part, be rationalized in the context of the early stages of project implementation, there is some concern that unless the technological solutions are fully complemented with operational strategies for reducing the ecological footprint, the environmental targets may not be met—or met at unnecessarily high costs. For example, in other cities, such as Yokohama, Japan, significant reductions in solid waste generation were achieved, in part, through environmental campaigns to enhance awareness among residents, and not through infrastructure-focused investment solutions. More generally, demand management measures across all sectors (energy, water, transport, etc.), including supportive pricing strategies will need to be important aspects of this project. The possible impact of demand-side management strategies should be assessed early, as this may lead to "downsizing" of infrastructure investments. Moreover, it is important to retain a flexible approach to technology choices in light of the many new technology options that will emerge during the project's implementation.

***External Influence on the KPIs.*** A number of issues that will influence the eco-city's development are outside the direct control of SSTEC. Appreciating SSTEC's strategic role requires that many of its proposals should not be viewed in isolation, but as part of a larger regional network and economic context. If accomplishing some of SSTEC's KPIs simply entails relocating or displacing certain polluting industries or land uses outside its formal jurisdictional boundary, then environmental impacts at the regional scale do not change. At the same time, regional economic and developmental dynamics, many of which is beyond the control of SSTEC, can impact the viability of certain proposals of the project. For instance, the unfolding effects of the current economic downturn on trade and business at the regional scale might impact land values and the financial underpinning of SSTEC's development. In addition, certain basic parameters that drive the development of SSTEC, such as the underlying economic structure, are hard to predict and likely to evolve. These more exogenous factors have to be considered in any assessment of the KPIs, and pose risks to the success of various project elements.

***Need for Additional Indicators.*** Altogether, the initial analysis of the sector plans points to critical challenges that need to be addressed if some of the ambitious targets embedded in the KPIs are to be met. There is clearly a need to complement the current strategy that focuses heavily on technology-driven solutions with a more explicit and prominent focus on the operational dimensions of the project. An explicit accounting for regional inter-linkages and acknowledgement of exogenous factors that will influence the project will be necessary. It is recommended that such dimensions are incorporated by introducing additional, secondary indicators—as a means to complement SSTEC's primary KPIs. Chapters III-VII suggest the inclusion of such indicators.

***GHG Emission Reductions.*** SSTEC aims to become "a model eco and low carbon city replicable by other cities in China". The target of producing only 150 tons of GHG emissions per million US$ GDP is very ambitious, compared to a current national average of 750 tons. Though in principle ambitious, this target will be less practical when applied to a relatively small city, such as SSTEC, because it aggregates many economic and energy characteristics that are better captured at a regional or national level. Comparisons of this indicator should be applied carefully and may be more meaningful to cities and regions having similar economic structures and climate conditions. To provide a more complete picture, an additional indicator, such as carbon emissions per capita, can be useful, particularly to capture the effect of population density.

***Carbon Finance Potential.*** Generating less GHG emissions is important, but emission reductions also offer potential financial benefits through carbon finance programs. Tianjin Municipality already has good experience in accessing carbon finance for environmental improvement projects through the Clean Development Mechanism (CDM), as evidenced by Tianjin's methane capture project at the Shuangkou Landfill. However, SSTEC may be able to tap carbon finance at a much larger scale. As a result, this study analyzed SSTEC's potential for GHG emission reductions and carbon finance in a more comprehensive manner. Specifically, the study applied, on a pilot basis, the emerging "city-wide" carbon finance methodology. The Bank's Carbon Finance Unit is currently developing this new methodology—in light of the evolution of the CDM approaches toward capturing carbon finance more programmatically.[3]

The SSTEC project has many elements that could lower GHG emissions, including in the energy sector (building efficiency and renewable energy, including solar street lighting and water heating, etc.), transport (changes in mode shares, clean fuels, etc.), and waste treatment (sludge management, methane capture, etc.). To qualify for carbon finance, SSTEC's biggest challenge will be to ensure that each planned reduction activity is "additional" to a "business-as-usual" scenario, as only then can carbon finance be obtained. As can be seen in Table E.1, applying the emerging city-wide methodology to SSTEC yields an indicative GHG emission reduction potential of about one million tons of $CO_2$/year.

Table E.1: Summary of Estimated GHG Emission Reductions

| Sector | SSTEC Potential Interventions | GHG ER |
|---|---|---|
| ($tCO_{2e}$/yr) | Landfill gas capture, anaerobic digestion, incineration, improved waste collection | 158,300 |
| Transport | Transit-oriented development, promotion of clean vehicle technologies | 610,474 |
| Energy | Green buildings, energy efficient public services, solar and geothermal energy use | 267,409 |
| Estimated Total | | 1,036,183 |

The GHG emission reductions could translate into a financial benefit estimated at US$10 million/year based on an assumed carbon price of US$10/ton. However, the review of sector plans suggests that areas exist where the potential for GHG reductions is not fully exploited, such as, inter alia, moving from a group substation to a building substation design for the district heating system, which could reduce GHG emissions by an estimated 10 percent.

## Implementation Challenges

***Building on Strong Foundations.*** SSTEC's implementation builds on strong foundations. The project is guided by a clear vision and supported by strong leadership at both local and national levels. It has established dedicated administrative capacity and implementation has commenced. However, to ensure that project implementation proceeds effectively, significant challenges have to be overcome. SSTEC is a large project with an untested, innovative vision. It aims to build a new city in a more ecological way, and is on a tight implementation schedule. Such a project presents significant risks that need to be managed actively to ensure that the original project vision can be implemented effectively. The example of Dongtan, another eco-city project in China, is the most recent example of a longer list of projects that encountered significant implementation challenges. Specific recommendations on how some of the risks related to the energy, transport, water and waste sectors can be managed are provided in Chapters III-VII. The key cross-cutting challenges are as follows.

***Integrated Urban Planning.*** Building a city from scratch presents an opportunity to apply the best land use practices and spatial design principles, and to integrate and optimize land use planning with infrastructure system design. The process needs to begin prior to, and continue through, the development and implementation of the master plan. All critical infrastructure service providers need to work together with urban planners to devise solutions that optimize the urban system. SSTEC has put in place some of the basic building blocks that offer the potential for efficiency gains from integrated planning. Above all, it has established a conducive institutional structure that allows for cross-sectoral collaboration: it has set up a dedicated and integrated administrative capacity (SSTECAC) and established a cross-sector infrastructure construction company (TECID) (see Figure E.1). This will permit, in principle, the benefits of integration to be realized. However, achieving integrated planning is difficult, and only a few cities have accomplished it. One city is Stockholm, as evidenced by its well-known "Hammarby Model", which led to significant environmental benefits. The review of SSTEC's evolving sector plans suggests that, in some instances, opportunities for more integrated approaches have not yet been fully exploited, with sector plans largely developed along sector silos.

***Phased Approach and the Importance of "Learning".*** SSTEC's three phase implementation, a strong point of the project, provides policy makers with the opportunity to achieve a balance between long term planning and adaptation to changing circumstances. As SSTEC continues to take shape and evolve, the three phases provide an opportunity to revisit certain weakness and enhance strong points—thereby adopting a "learning" approach to constructing a new city. To ensure that the project makes the most of this phased approach, sufficient flexibility and capacity for adaptation will need to be maintained during implementation. In other words, the master plan should not just be a static blueprint. Continuous assessment of lessons learned from the early phases of implementation relative to the long term objectives, as encapsulated by the KPIs, will be useful. A comprehensive evaluation at the midpoint of construction during Phase I based on an explicit evaluation framework should also be considered.

***'New Town' Planning.*** 'New town' planning often presents risks of building "too much too fast" based on hard to predict demographic and economic projections, and future real estate valuations. The building of costly infrastructure, the negotiation of large land transactions, and the instantaneous construction of a city from scratch, are financially risky for all parties involved. The successes of such ventures are contingent on many uncontrollable variables that are hard to capture and 'model' in projections. It is therefore recommended that SSTEC examine in detail how to avoid the risks and mistakes associated with new town development, and make sure the "phased" approach to developing SSTEC ensures good adaptive and risk management strategies. This is not only important from a financial risk management point of view, but also from an urban design perspective. In this context, the review can draw from the many noted experiences of "failed new towns", especially in Japan and post-war Europe.

***Commercial versus Public Interests.*** The project is a complex partnership between private and public entities that cuts across multiple jurisdictional boundaries, both national and international. Commercial pressures relating to economic and real estate development will be strong. How to balance commercial interests with public interests so that the overarching ecological objective of the project is not lost will constitute an ongoing challenge and will require careful decision making. At the outset, the objectives could be mutually reinforcing. However, once implementation obstacles arise, trade-offs will become more difficult. For example, if the evolving economic structure of SSTEC does not generate sufficient local employment opportunities, what will this mean for the green transportation KPI, given the need for more commuting trips in and out of the eco-city? How to balance commercial and public interests in the project is likely the principal challenge of this project.

***Project Cost and Financing.*** Given the magnitude of the project, financial sustainability will also be a critical challenge. Good investment planning is therefore required, including by rigorously applying life-cycle cost benefit analysis to guide the investment decision-making process. Though the application of life cycle cost analysis is rare in China (but standard procedure elsewhere), it is especially important for SSTEC given the project's size and the fact that the costs and benefits of its environmental investments are distributed differently over time and entities. However, the initial review of the draft sector plans suggests that cost benefit analysis is not consistently implemented. Moreover, there are instances where potentially higher cost alternatives are being contemplated that, in aggregate, could impact the project's financial viability. Examples include the proposed district heating system and the preference of Light Rail (LR) over a Bus-Rapid Transport (BRT) system. Beyond the evaluation of investments in terms of costs effectiveness and cost/benefits, it is important that SSTEC develops a comprehensive strategy to ensure that all its investments are financed on a sustainable, long term basis.

***Affordability and Social Inclusion.*** The overall costs of the project will, of course, impact affordability and, in turn, SSTEC's likely social composition. It is important to note that unless SSTEC is developed in a socially inclusive manner, it will unlikely become a vibrant urban community. This will strongly compromise one of SSTEC's overall project objectives, namely the building of a "harmonious city". The affordable housing KPI is a step in the right direction to ensure a balanced social development, though the extent to which it will be effective will depend, inter alia, on the specific thresholds sales and rental prices adopted. Overall, it is important to ensure that SSTEC remains affordable to a wide spectrum of citizens and promotes social diversity to avoid the risk of becoming an "eco-enclave".

***Project Risk Management.*** SSTEC's establishment of specific KPIs that will be monitored and publicly disclosed is an excellent starting point, but the usefulness of the KPIs could be strengthened if linked to an explicit risk management framework. Such a risk management framework, if applied as a management tool, could help to identify roadblocks and challenges related to project implementation early in the project. As mentioned above, an important element of the project is its phased development, which allows for continuous learning and improvement, based on a monitoring and evaluation system building on the KPIs. The credibility of the KPIs, beyond their public disclosure, could also be strengthened if, at a later stage, they are linked to or form the basis of an independent eco-audit of the SSTEC project. Such an independent eco-audit could be a first in China, and further contribute to advancing the objective of developing a pilot project of sustainable urban development in China. Introducing an independent eco-audit might also help to mitigate the risk of being perceived as 'eco-branding' the SSTEC project.

## Conclusion and Structure of the Report

Overall, the SSTEC project presents an interesting example of a new urban development pattern—one that aims to develop on a more ecological trajectory compared to prevailing standards. Analyzing the project enabled a better understanding of the practical challenges of undertaking such urban ecological development in China. The project has many strong points; above all, it clearly articulates a vision of developing a city in a more sustainable ecological manner from the outset. In some areas, the project's targets are ambitious, and if achieved, would indeed point towards greater urban environmental sustainability. In other areas, the targets are less ambitious and follow prevailing practices in China. However, achieving the targets will require that many issues, including those identified in this report, are successfully addressed during project implementation.

This report developed a 'snapshot' picture of the SSTEC project at mid-year 2009, after the master plan was developed but before many of the specific details were analyzed through the feasibility study and detailed design processes. Achieving the appropriate solutions will require this detailed analysis, and will need to be based on relevant good Chinese and international practices, and lessons learned in the early stages of project implementation. This report is therefore one step in a continuous process to adapt SSTEC's plans to the challenges and changing needs of the project. For the Bank, the next step is to support SSTECAC by preparing a GEF project through which a sub-set of the issues identified in this report can be analyzed in greater detail.

The report is organized in nine chapters.

1. Chapter I provides the broader context on challenges of urban environmental management in China, and summarizes the emerging policy responses, including various eco-city initiatives.
2. Chapter II analyzes the project from a cross-cutting urban perspective, with a focus on spatial and urban planning issues.
3. Chapters III through VI analyze the key sectors, specifically transport, energy, water and wastewater, and solid waste.
4. Chapter VII estimates the GHG emission reduction potential of the project by applying the emerging "city-wide" carbon finance methodology.
5. Chapter VIII provides an overview of the key institutional, financial, and risk management challenges for the project.
6. Chapter IX offers a summary and conclusion.

Table E.2: Summary Recommendations

| | |
|---|---|
| **Urban Planning and Spatial Development** | |
| | • Spatial Structure and Urban Design: Consider dividing some of SSTEC's 400m by 400m blocks into smaller units to create vibrant neighborhoods and add spatial variety through good urban design.<br>• Integrated Urban Planning: Ensure integrated planning across all infrastructure sectors; optimize and synchronize land use planning with infrastructure system design to realize cross-sectoral synergies and enhance resource use efficiency.<br>• Phased Development: Develop a detailed strategy on how to capitalize on SSTEC's phased development schedule; this strategy should capture the benefits of incremental planning, introduce a "learning" approach to developing the project, and reduce risks. |
| **Energy Sector** | |
| Technical | • Green Buildings: (i) As the Green Building Evaluation Standard (GBES) largely incorporates existing national and local building standards and regulations, especially in energy efficiency, provide appropriate incentives for buildings to be built at a higher (silver, gold, platinum) standard, rather than just the pre-requisite level. (ii) Introduce specific energy performance requirements for key end-users in buildings; such requirements could cover, inter alia, lighting, major appliances, air-conditioning, and water heating. (iii) Introduce commissioning of energy systems in buildings; and (iv) Consider introducing a GBES accreditation program similar to the Leadership in Energy and Environmental Design (LEED) program in the United States.<br>• Heating/Cooling System: As the current proposed district heating system essentially reflects conventional Chinese design concepts, improve the district heating system by considering: (i) Using a low temperature regime for supply/return water in district heating; (ii) Using building-level sub-stations instead of group sub-stations; (iii) Using the district heating system for domestic hot water; and (vi) Using CHP plants for base loads and meet peak load demand by heat only boilers.<br>• Renewable Energy: Examine renewable energy options to choose more cost-effective options based on lifetime costs, particularly for photovoltaic powered public lighting systems. Also, consider installing centralized solar systems in public buildings, and determine the optimal share of district heating-supplied hot water relative to solar hot water. |
| Policy | • Institutions, Policies, and Regulations: Explore an institutional setup that will effectively and continuously address the evolving needs and issues of sustainable urban energy planning and management—in terms of both operating and regulating the energy system (particular with respect to the GBES).<br>• Enhance and Incentivize Sustainable Energy Actions: Adopt a broader set of policies to further incentivize sustainable energy actions among citizens, businesses, and organizations. This might include a smart pricing and billing system for electricity use, and grants, low-interest loans, line of credits, rebates, bonuses for density, and technical assistance to motivate people to go green. Behavior-based energy efficiency programs should be developed and implemented. |
| **Transport Sector** | |
| Technical | • Further Data Analysis: Given its importance to the overall transportation plan, review the veracity of the travel demand model. In particular, verify the base data from as many diverse sources as possible. Appropriately consider other relevant comparators, particularly new development areas with similar demographics as those planned for SSTEC.<br>• Road Design and Urban Form: Enhance the livability and mobility in the eco-city by considering developing more but narrower roads, thereby subdividing the planned 400m by 400m blocks and better promoting non-motorized travel.<br>• Detailed Review of Capacities in Transport Infrastructure: Analyze how specific infrastructure commitments (e.g., road design and public transport investments) relate to the travel demand model. Undertake a detailed review of capacities in roads, infrastructure, public transport, city parking, and other relevant areas against the modeled modal split forecasts.<br>• Review LRT and BRT Options: Develop a detailed business case for the LRT over the BRT option. This should review, in parallel, both technologies' designs, capital costs, recurrent costs, capacities, and operational impacts to determine the optimal technical and most cost effective solution. |

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| Policy | • Develop 'Phasing-In' Policy: Develop a policy for phasing in 'green' public transport concurrent to SSTEC's development through 2020, focusing particularly on investment costs and projected cost recovery needs during the development stages.<br>• Travel Demand Management (TDM): Develop a policy for phasing in TDM strategies across all its dimensions to ensure high-level coordination of the competing imperatives of fulfilling SSTEC's targets while ensuring commercial and residential property sales.<br>• Institutional Arrangements: Introduce institutional arrangements that support adequate transport policy as well as regulation and enforcement of TDM strategies and public transport initiatives. This might involve establishing a new agency, operating businesses, and regulatory strategies.<br>• Develop Secondary Indicators: Develop indicators that better capture the constituent parts of the green transport KPI, including measurements of the share of public transport and walking/cycling. To allow for precise KPI measurement, clarify how mode shares of trips are apportioned. Consider additional indicators for operational issues, such as cost recovery and affordability. |
| Water Secto | |
| Technical | • Design of Water Distribution System: Optimize the designs of distribution systems (water and reclaimed water) to minimize total costs and energy consumption.<br>• Dual Water Supply System: Conduct a costs benefit analysis on the proposed dual water supply system using reclaimed water for domestic uses, as it may not be cost effective.<br>• Desalinated Water: Reexamine the need for desalinated water and assess the optimal operation of the Bejiang power plant as a cogeneration plant.<br>• Unaccounted-for Water: Reassess the UFW target of 10 percent as it is relatively high, especially for a new city.<br>• Industrial Wastewater: Consider pre-treatment of industrial wastewater, which will result in lower treatment costs.<br>• Sludge Disposal: Revisit sludge disposal plans as an eco-city's approach should more closely align to current good practices like digestion and composting; such processes are widely applied in developed and developing countries, and the technologies are well proven.<br>• Energy Efficiency: Improve energy efficiency in various system operations. Consider implementing leak control programs, and equipping networks with telemetry systems to facilitate pump scheduling, pressure control, and burst control.<br>• Wastewater and Strom Water System: Design the wastewater and storm water system to anticipate the likely impacts of climate change and rising sea levels. |
| Policy | • Water Conservation: Apply water conservation practices and programs that address both the supply and demand for water. Consider appropriate tariff structures that promote water demand management while ensuring cost recovery, conservation, and equity.<br>• Public Involvement: Strengthen public awareness and participation; public involvement is crucial to the success of demand management and conservation programs.<br>• Regulatory Oversight: Establish appropriate regulatory oversight. Absent an independent regulator, SSTECAC will need to establish a regulatory unit to monitor regulatory compliance to ensure the realization of the KPIs and other emerging service standards.<br>• Operating Company for Water Sector Services: Consider using one operating company for all water sector services, including enforcement of onsite water treatment and reuse.<br>• Coordinated Construction: Closely coordinate contractors' construction of different systems to ensure synergistic and, when possible, simultaneous system installation.<br>• Develop Secondary Indicators: To complement the water sector KPIs, consider other indicators focused on operational issues, including energy consumption and cost recovery. |
| Solid Waste Sector | |
| Technical | • Waste Reduction: Consider comprehensive waste reduction strategies, including establishing collection points to gather food residue that can be recycled.<br>• Collection: Conduct a detailed cost benefit analysis of the pneumatic solid waste system, taking into account investment and operating costs, compatibility with the recycling program, and the relative lack of flexibility of such systems.<br>• Treatment: Ensure that the incinerator has a sufficient air pollution control system to prevent the emission of pollutants that could negatively impact public health and the environment.<br>• Landfill: Ensure that the site receiving residue from SSTEC is an engineered facility operated in an environmentally sound manner. |
| Policy | • Waste Reduction: Apply waste reduction programs supported by regulations that ban specific materials or impose consumption-based charges.<br>• Recycling: Provide a comprehensive program of incentives, education, and prohibition of certain materials from the waste stream to encourage residents and businesses to recycle. As the proposed recycling program is highly ambitious and mainly based on source separation, consider tiered pricing of waste management services that charge a lower fee for waste that is source separated, which should encourage recycling. |

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| **GHG/ Carbon Finance** | |
| | • GHG-specific Indictors: Develop sets of cross-sector and intra-sector indicators that more comprehensively measure the potential for reducing specific GHG emissions. These indicators would apply to all sub-sectors: energy, transport, water and wastewater, and solid waste.<br>• Carbon Finance: Explore options for SSTEC to access carbon finance, either through the traditional sector based CDM approach or the emerging "city-wide" CDM methodology. |
| **Institution, Finance and Risk Management** | |
| Institutional Issues | • Integrated Management: Ensure that the integrated vision of the eco-city is sustained during project implementation by containing institutional fragmentation across the various stakeholders (e.g., JV Company, TECID and its subsidiary companies).<br>• Focus on Operational Issues: Develop sustainable operating arrangements for SSTEC assets early in project implementation to minimize possible tension and conflicts that can arise in complex projects, comprising public and private sector participants.<br>• Cross-Jurisdictional Coordination: Develop and fully address all infrastructure linkages with the Binhai New Area. Consider possible regional linkages and, whenever possible, support cross-jurisdictional coordination. |
| Investment and Finance | • Life Cycle Evaluation of Costs and Benefits: Evaluate investment projects on a full life cycle cost/benefit basis to avoid incorrect investment decisions and incentive mismatches.<br>• Pricing and Demand Management: Pay early attention to operational issues such as pricing and demand management activities that could directly impact project finances. Early assessment of demand management impacts is also important to avoid overdesigning infrastructure systems.<br>• Innovative, Long Term Financing: Ensure TECID finances its investments on a long term basis by pursuing innovative solutions such as carbon finance or issuance of environmental bonds. |
| Risk Management | • KPI Regulation and Enforcement: Evaluate progress towards meeting the KPIs on an ongoing basis through participatory approaches involving communities and residents.<br>• KPI as a Management Tool: Establish an explicit risk management framework with an appropriate monitoring and evaluation system linked to the phased development approach.<br>• Independent "Eco-Audits": Introduce an eco-audit that could independently measure and verify the project's compliance with the overall ecological vision and development. |

# Chapter I

# China's Ecological Urban Development: Progress and Challenge

## China's Unprecedented Urbanization and Growing Ecological Footprint

***Unprecedented Process of Urbanization.*** China is undergoing the largest scale of urbanization in history—and at an unprecedented pace. During the past three decades, the share of China's population living in cities more than doubled, reaching 44.9 percent in 2007. Based on current trends, urbanization in China will rise to about 64 percent by 2025, which translates to an increase in urban population of slightly over 350 million.[4] The annual population increase in Chinese cities over the next 20 years is forecasted to be about 17.7 million, the equivalent of one New York City (17.8 million) or Seoul (17.5 million) each year. By 2025, Chinese cities will house about 12 percent of the world's population, up from about 8 percent today.[5]

***Rapid Expansion of Urban Areas.*** China's strong growth of urban population in the past three decades was accompanied by the rapid expansion of urban areas. Developing countries are expected to triple their entire built-up urban area between 2000 and 2030 from 200,000 $km^2$ to 600,000 $km^2$.[6] China alone will generate over 65,000 $km^2$, or 16 percent of the new urban built-up area in the developing world.[7] This has resulted in significant conversion of agricultural land to urban use in rapidly growing cities. For instance, in the Beijing-Tianjing-Hebei region, urban land is estimated to have expanded 71 percent between 1990 and 2000. 74 percent of this urban land was converted from agricultural land.[8] China's government has grown concerned about the magnitude of agricultural land conversion and its future impact on self-sufficiency for food. China's arable land has rapidly decreased to a level close to the government-mandated national minimum ("red line") of 120 million hectares.[9] Another widespread public concern related to the loss of farmland is the social impact of displaced farmers.[10]

***Growing Resource and Environmental Pressures in Cities.*** As China's urbanization takes shape, China has contended with severe pressures on resource conservation and environmental protection, and environmental pollution has reached critical levels in many areas. In China's water sector, the per capita availability of freshwater was only 2,210 $m^3$ in 2004, about one-quarter of the world's average.[11] Specifically, about 400 of China's 660 cities are reportedly short of water; and 108 of these cities, mainly in Northern China, including mega-cities such as Beijing and Tianjin, are facing serious shortages.[12] Water scarcity is exacerbated by declining water quality in many cities: 90 percent of waterways flowing through urban areas are contaminated,[13] and around 23.1 percent of surface water rated higher than Category V (i.e., the most heavily polluted water bodies) in 2008.[14] With regard to air quality, China accounts for 13 of the world's 20 most polluted cities in terms of $SO_2$ pollution.[15] A recent study estimated that the cost of ambient air pollution in China's urban areas in air pollution-caused premature deaths and illnesses amounted to about US$63 billion in 2003, equivalent to 3.8 percent of China's 2003 GDP.[16] Many of these challenges will become more prominent under the simultaneous influences of urbanization, suburbanization, and mobilization.

***Increased Energy Consumption in Cities.*** In 2005, China accounted for 14.2 percent of global energy consumption, second only to the United States. Rising energy consumption is closely associated with increased urbanization. Urban residents consume 3.6 times more energy than their rural counterparts, with motorization and space heating and cooling being important contributors to the difference.[17] From 2000 to 2005, China's urban population increased by 103 million and total energy consumption rose 70 percent.[18] After industry, transport and buildings are the most energy consuming sectors, and represented respectively, 27.5 percent[19] and 20 percent[20] of total energy consumption in 2007. Rapid urbanization and economic growth in China have driven a dramatic construction boom. According to the Ministry of Housing and Urban-Rural Development, 1.8 to 2 billion $m^2$ of new floor space is being built each year. In 2007, 29 percent of the newly built structures failed to meet the national standard for energy-efficient buildings[21] As urbanization proceeds, energy demand in China will likely continue to increase substantially.

***Cities and Global Climate Concerns.*** Consumption of non-renewable energy is closely correlated with Greenhouse Gas (GHG) emissions. China continues to be the world's largest consumer and producer of coal, which accounted for 69.4 percent of China's primary energy supply in 2006,[22] China has become the world's largest global emitter of carbon dioxide, the principle greenhouse gas contributing to global warming.[23] Given that cities consume 75 percent of the world's energy and are responsible for 80 percent of GHG emissions,[24] cities are a central locus of climate change mitigation strategies. At the same time, climate change poses significant threats to cities in fragile and vulnerable regions, such as coasts, deltas, and low lying areas. Four out of the top twenty cities with the greatest percentage increases in populations exposed to present-day extreme sea levels are in China. In terms of increases in percentages of exposed assets, nine of the top twenty cities are Chinese, with Ningbo, Fuzhou, Tianjin, Xiamen, Guangzhou, and Hong Kong Special Administrative Region of the People's Republic of China (hereinafter to be referred as Hong Kong SAR, China) among the top ten.[25] The expansion of China's ecological footprint is therefore not just a concern for China, but the world.

## Ecological Urban Development in China

***Policies Guiding Ecologically Sustainable Development.*** Recognizing these resource and environmental challenges, China is at a critical stage in shifting its policy framework to guide economic growth towards greater sustainability. The Chinese government is paying increasing attention to the quality of growth, stressing the construction of a "resource-conserving and environmentally friendly society" [26] and "ecological civilization"[27] as key building blocks of the country's social and economic development.

Accordingly, China's 11th Five-Year (2006-2010) Plan for National Economic and Social Development sets ambitious targets, including a 20 percent reduction in energy use per unit GDP between 2005 to 2010, and doubling per capita GDP between 2000 and 2010.[28] For the first time, the Five-Year Plan incorporates quantitative indicators for energy efficiency, along with six other indicators on resource conservation and environmental protection.[29] In addition, the Renewable Energy Medium-Long Term Plan (2006-2020) envisages that the share of energy consumption from renewable sources will reach 10 percent by 2010, and 15 percent by 2020. In October 2008, China's State Council announced the National Land Use Master Plan (2006-2020), which sets more stringent 'red lines' for protection of arable land: a minimum of 121.2 million and 120.3 million hectares by 2010 and 2020, respectively.

To meet the national targets indicated above, China has set up an accountability system under which responsibilities for implementing and achieving key targets are assigned to provincial governments. The energy efficiency and pollution reduction targets and land conversion quota[30] were delegated to the provincial level and incorporated into the local government performance appraisal system.[31]

In 2007, national leaders announced a China National Climate Change Program (CNCCP)—the first ever comprehensive policy paper issued by the Chinese government in the context of increasing global climate concerns. In October 2008, the State Council released the White Paper: China's Policies and Actions for Addressing Climate Change, which further introduced China's goals, efforts, and upcoming actions on climate change mitigation and adaptation through 2010. A multi-ministry special institution to cope with climate change led by the Chinese Premier was established and seated in the National Development and Reform Committee (NDRC). The CNCCP program explicitly calls for provincial and local level strategies and actions to tackle climate change.

***Paradigm Shift in Urban Development.*** China's policy framework towards a more ecologically sustainable development pattern has profound implications on urban development. It has been increasingly recognized that "sound urbanization"[32] and the "new pattern of urban development" which is "resource-saving, environmentally friendly, economically efficient and socially harmonious"[33] should replace the traditional focus on "rapid urbanization" and the previous resource- and energy-intensive urbanization path. This requires a fundamental paradigm shift in urban planning and management practices to integrate ecological principles and resource management dimensions into the formulation, implementation, and evaluation of the urban development process.

***National Guidance on Ecological City Development.*** The concept of adopting sustainability as the driving objective and applying ecological principles to city planning has steadily gained momentum and attracted nationwide attention over the last 20 years.[34] Since 1992, national standards for an ecological urban development have been established and constantly updated by two national departments: the Ministry of Environmental Protection (MEP), which is in charge of environment protection, and the Ministry of Housing and Urban-Rural Development (MoHURD), which is in charge of urban development. Candidates for national pilot cities for ecological development were assessed each year and awarded through the two administrative systems, leading to an increasing number of cities adopting eco-city planning principles.

***National Standards by MoHURD.*** In 2004, based on the "National Standards for Garden City" initiated in 1992, MoHURD proposed more advanced "National Standards for Eco-Garden City."[38] Cities must be approved as garden-cities to qualify as eco-garden cities, which are recommended by the provincial Construction Bureaus, and are annually reviewed and selected by MoHURD. The Eco-Garden City Standard consists of 19 quantitative indicators, including seven natural environment indicators, five living environment indicators, and seven infrastructure indicators (Table 1.1). While the Garden City Standard focuses more heavily on landscape and green space coverage,[39] the Eco-Garden City Standard more strongly emphasizes and places more stringent requirements on the quality and coverage of cities' public infrastructure services and environmental treatment facilities, and levels of pollution control. In 2005, MoHURD's "National Standards for Garden City"[40] were updated to reflect requirements on green buildings and public transport, particularly in light of MoHURD's recognition of the importance of energy efficiency in cities. MoHURD's "National Standards for Eco-Garden City" are currently undergoing further revisions and updates.

In 2006, Shenzhen city became the first "National Eco-Garden" Model City. Among more than 139 cities that had qualified as Garden Cities since 1992, MoHURD proposed 11 cities in 2007 as "National Eco-Garden Pilot Cities," including Qingdao, Nanjing, Hangzhou, Weihai, Yangzhou, Suzhou, Shaoxing, Guilin, Changshu, Kunshan and Zhangjiagang. These pilot cities were required to formulate detailed plans to achieve the Eco-Garden City standards, which are subject to MoHURD's review and approval.

***National Standards by MEP.*** Since 1997, MEP named 63 cities and five districts as "National Environment Protection Model Cities/Districts"[41] based on 26 comprehensive indicators (quantitative and qualitative) covering socio-economic development, environmental quality, environmental

Table 1.1: Quantitative Indicators of "National Standards for Eco-Garden City" by MoHURD

| No. | Indicator Area | Indicative Value |
|---|---|---|
| Natural Environment | | |
| 1 | Species diversity index | ≥0.5 |
| 2 | Local plant index | ≥0.7 |
| 3 | Proportion of pervious surface in road and square in built-up area (%) | ≥50 |
| 4 | Urban heat island effect (Co) | ≤2.5 |
| 5 | Forestation coverage in built-up area (%) | ≥45[35] |
| 6 | Public green area per capita in built-up area | ≥12 |
| 7 | Green space coverage in built-up area (%) | ≥38 |
| Living Environment | | |
| 8 | No. of days per year in which ambient air quality meets or exceeds China's National Ambient Air Quality Grade II standard | ≥300 |
| 9 | Quality of water bodies meeting national surface water quality standard (%) | 100[36] |
| 10 | Quality of water from pipe network meeting national drinking water quality standard (%) | 100 |
| 11 | Noise pollution levels meeting national noise standard in built-up area (%) | ≥95 |
| 12 | Citizen satisfaction with environment quality (%) | ≥85 |
| Infrastructure | | |
| 13 | Infrastructure good condition index | ≥85 |
| 14 | Tap water coverage (%) | 100, 24-hour hot water supply |
| 15 | Sewage treatment rate (%) | ≥70 |
| 16 | Treated water utilization rate (%) | ≥30 |
| 17 | Domestic solid waste non-toxic treatment rate (%) | ≥90[37] |
| 18 | No. of hospital beds per 10,000 people | ≥90 |
| 19 | Average vehicle speed of major and secondary roads (km/h) | ≥40 |
| Updated Indicators from National Standard for Garden Cities (2005 revised) | | |
| | Proportion of energy-efficient buildings and green buildings | ≥50 |
| | Proportion of trips by public transport | ≥20% in big cities<br>≥15% in medium cities |

Source: 1) National Standard for Eco-Garden Cities, Ministry of Housing and Urban-Rural Development, 2004.
2) National Standard for Garden Cities, Ministry of Housing and Urban-Rural Development, 2005 revised.

infrastructure, and environmental management. These indicators are updated every few years, with the latest update in 2007, and all qualified cities are reviewed every three years to ensure their performance meets the updated standards. In December 2007, MEP announced revised "Indices for Eco-County, Eco-City and Eco-Province,"[42] which introduce stricter standards, particularly in energy consumption, water consumption, and pollutant emissions. For MEP to approve an eco-city, the central city within the city's jurisdiction must have qualified as an "Environment Protection Model City". MEP's Eco-City Standard has 19 qualitative indicators, including five economic indicators, 11 environmental indicators, and three social indicators (Table 1.2), among which 15 are obligatory and four are indicative.

Unlike MoHURD's Eco-Garden City Standard, which focuses mainly on urban built-up areas, MEP's Eco-City Standard targets the whole jurisdiction of a city, from the central city to surrounding suburban and rural areas. The Eco-City Standard also requires formulation of "Eco-County/City/Province Construction Planning," which reflects MEP's emphasis on urban-rural integration. In addition, compared to MoHURD's Eco-Garden City Standard, which focuses mainly on the physical environment, the Eco-City Standard introduces mandatory indicators to limit energy and resource consumption[43] and pollutant emissions.[44] The scope of the Eco-City Standard is also expanded to include indicators of economic and social development, although most of them are indicative in nature.

So far, MEP has identified 11 counties/districts and cities as national "Eco-counties/districts" or "Eco-cities," including Miyun county, Yanqing county in Beijing, Taicang city, Zhangjiagang city, Changshu city, Jiangyin city in Jiangsu province, Rongcheng city in Shandong province, Yantian district in Shenzhen, Minhang district in Shanghai, and Anji county in Zhejiang province.

***Challenges for National Eco-City Standards.*** By setting key ecological indicators at levels higher than current practices in many cities, the central government provides incentives for local governments

Table 1.2: "Indices for Eco-County, Eco-City and Eco-Province" by MEP

| No. | Indicator Area | Indicative Value | Type |
|---|---|---|---|
| Economic Development | | | |
| 1 | Rural net annual income per capita (RMB) | | Obligatory |
| | In developed areas | ≥8000 | |
| | In under-developed areas | ≥6000 | |
| 2 | Share of tertiary industry in GDP (%) | ≥40 | Indicative |
| 3 | Energy consumption (ton SCE per 10,000 RMB GDP) | ≤0.9 | Obligatory |
| 4 | Fresh water consumption ($m^3$ per 10,000 RMB industry VA) | ≤20 | Obligatory |
| | Efficiency coefficient of irrigation water | ≥0.55 | |
| 5 | Passing rate of enterprises that are required for clean production (%) | 100 | Obligatory |
| Environment Protection | | | |
| 6 | Forestation coverage (%) | | Obligatory |
| | In mountainous area | ≥70 | |
| | In hilly area | ≥40 | |
| | In plain area | ≥15 | |
| | Forest-grass coverage in cold area and meadow area (%) | ≥85 | |
| 7 | Proportion of protected area in total land area (%) | ≥17 | Obligatory |
| 8 | Ambient air quality | Meeting stipulated standard for different functional zones | Obligatory |
| 9 | Quality of water bodies | Meeting stipulated standard for different functional zones, no lower than Grade V | Obligatory |
| | Quality of water bodies in coastal area | | |
| 10 | Major pollutant emission (kg per 10,000 RMB GDP) | | Obligatory |
| | COD | <4.0 | |
| | $SO_2$ | <5.0 | |
| 11 | Quality of centralized drinking water sources meeting national surface/ground water Grade III standard (%) | 100 | Obligatory |
| 12 | Urban sewage centralized treatment rate (%) | ≥85[45] | Obligatory |
| | Industrial water reuse rate (%) | ≥80 | |
| 13 | Noise pollution levels | Meeting stipulated standard for different functional zones | Obligatory |
| 14 | Urban domestic solid waste non-toxic treatment rate (%) | ≥90 | Obligatory |
| | Industrial solid waste treatment rate (%) | ≥90,no hazardous waste[46] | |
| 15 | Urban public green space per capita | ≥11 $m^2$ | Obligatory |
| 16 | Environmental protection investment in GDP (%) | ≥3.5 | Obligatory |
| Social Development | | | |
| 17 | Urbanization rate (%) | ≥55 | Indicative |
| 18 | Central heating coverage in heated region (%) | ≥65 | Indicative |
| 19 | Citizen satisfaction with environment quality (%) | >90 | Indicative |

Source: Indices for Eco-County, Eco-City and Eco-Province. Ministry of Environmental Protection, 2007 to benchmark, monitor, and improve cities' urban development in more environmentally friendly and resource-saving ways. Aiming to achieve these standards, more and more cities are incorporating ecological dimensions into urban planning and management processes. However, the existing indicators are only a starting point, and there are challenges related to how these standards are set and implemented.

As mentioned above, the scope of existing standards is largely limited to the built environment and urban construction. For example, MoHURD's standard focuses heavily on green space development and expansion of infrastructure networks in built-up areas; this is construction-oriented and aligned to MoHURD's ministerial mandate. MEP's standard defines a somewhat broader set of indicators, including those related to energy and resource consumption and socio-economic development. However, some of MEP's indicators are indicative and others are hard to measure precisely. Furthermore, although it is common practice to regularly update these standards, most updates have been based on incremental improvements to existing indicators. As a result, more advanced indicators important to assessing ecological urban development, such as those measuring the use of renewable energy; recycling, reuse and management of resources; and GHG emission reductions have not yet been incorporated.

Another challenge is related to cross-department coordination. As indicated in the two tables above, there is some overlap in the indicators of the two National Eco-City Standards of MoHURD and MEP, yet the values of these indicators are set at different levels,[47] reflecting a lack of coordination between the two ministries. In addition, each standard, especially MEP's relatively broader one, includes various indicators whose administrative responsibilities fall under many different departments, which makes it difficult for MEP or MoHURD to directly administer the implementation of each indicator. Together, this reflects the limitation of eco-city standards being designed and governed separately by MEP and MoHURD, which likely constrains implementation of the respective departments' mandate, and makes coordination across sectors difficult.

More importantly, there is a need to define eco-city regulations, specific technical standards, norms, incentive schemes, and funding in more systematic ways, which would help to guide cities to achieve eco-city standards. A key at the national level is to develop integrated guidance, including regulations and incentive schemes, and corresponding institutional arrangements supporting supervision and coordination among different departments, which properly address limitations in how eco-city standards are defined and administered.

***Local Eco-City Initiatives.*** Under the guidance of the national 11$^{th}$ Five-Year Plan, many cities have for the first time included energy and resource efficiency and environment protection indicators in the quantitative indicators of their local Five-Year Plans. This reflects major progress in incorporating "green" elements into the long-standing "GDP-oriented" performance appraisal system of local governments. Driven by a desire to achieve these indicators, cities have surged ahead over recent years to pursue an eco-city agenda. Some cities have been recognized as national pilot eco-cities by MoHURD or MEP according to their respective national eco-city standards. However, as there are no agreed comprehensive definitions, integrated standard, or well-accepted methodology for "ecological city" development, cities are executing different approaches on different scales.

*Sectoral approach.* Based on local conditions, cities are actively experimenting in innovative technologies and improved management approaches in a variety of sectors, including renewable energy, water, energy-efficient buildings, and circular economies. Some cities have been recognized by the central government as national pilots for their achievements in particular areas (i.e., water resource conservation, circular economies). In some cases, authorities have established special institutions and developed and enforced local regulations and standards, representing a more institutionalized process for developing certain sectors (Box 1.1).

### Box 1.1: Examples of Local-Level Sector-Focused Initiatives

*Renewable energy.* Rongcheng city in Shandong province has relatively rich wind resources. The city has invested under stage one of an urban program in three wind power plants with total capacity of 200 million KWH per year. Cities such as Rizhao, Yantai in Shandong province, Nanjing in Jiangsu province, Wuhan in Hubei province, and Xingtai in Hebei province, have formulated regulations and provided fiscal incentives to enforce the integrated design, installation, and construction of solar energy facilities in new buildings, and in renovated public buildings.

*Water.* Cities with scarce water resources, such as Tianjin and Xiamen, have achieved significantly improved water efficiency by establishing special institutions responsible for promoting water saving in all sectors, and by applying various regulatory measures and advocacy activities. MoHURD and NDRC awarded these cities recognition as "Water Saving Cities" together with 38 other cities. Water from non-traditional sources is also being tested and promoted. The coastal city Qingdao in Shandong province is planning a sea water desalination treatment plant with a capacity of 100,000 tons/day to serve 0.5 million residents by 2011, the largest scale in China thus far.

*Energy-efficient buildings.* In cities like Beijing and Shenzhen, the share of newly constructed buildings achieving national standards of energy-efficient buildings has reached 100 percent, as opposed to a national average of 71 percent.

*Circular economy.* Shenzhen is the first among Chinese cities to issue a series of local regulations, technical standards, and fiscal incentives, led by the Shenzhen Economic Special Zone Circular Economy Promotion Code enacted in 2006, to promote cleaner production and usage of reclaimed water and solar energy. In 2007, Shenzhen Municipality was designated as one of the "National Pilot Cities for Circular Economy" by NDRC, MEP, and other line ministries.

Source: 1) www.mep.gov.cn; 2) www.chinajsb.cn; 3) www.people.com.cn

*Comprehensive planning approach.* As ecological urban development has increasingly attracted attention, Chinese cities have more commonly highlighted ecological sustainability as a driving objective in their city master plans. These plans serve as important tools in orchestrating different sectors to incorporate ecological principles in a coordinated manner. MoHURD also required Chinese cities and towns that were heavily hit by the Wenchuan Earthquake on May 12, 2008, to adopt eco-city development principles during their reconstruction process.[48]

Driven by national guidance and directives from MEP and MoHURD, cities have increasingly launched the development of explicit eco-city plans to more systematically guide them towards environmentally friendly and energy-efficient development. By 2008, 14 provinces and 150 counties and cities in China had commenced planning for "ecological settlement" at different scales.[49] For example, the Guiyang municipal government issued its "Code for Constructing a Circular Economy and Ecological City," which requires the formulation of a Circular Economy and Ecological City Master Plan. The principles and proposals of this plan will be incorporated into the city's five-year social and economic development plan, and reflected in the city's master plan and land use plan. A local eco-city plan usually puts forward indicators adapted from the various national eco-city standards. Most plans also include requirements to: set up institutions responsible for governance of eco-city development, establish special eco-city funds for eco-city construction, and develop detailed local regulations in specific areas, such as environmental protection, ecological compensation, circular economy, and clean production. Launching public campaigns to raise awareness of "green living" lifestyles are also sometimes mandated.

In some cities experiencing fast demographic and economic growth, increasing efforts are being made to develop new urban areas in sustainable and coordinated ways, often led by a comprehensive new city plan. Given the lack of experience in advanced eco-city development, and the high initial capital investment associated with large-scale new developments, these new eco-city initiatives often ask international partners for support, mainly on integrated approaches to eco-city planning and management, advanced environment-related technologies, and financial investment. New eco-city projects that have gained international attention include the Sino-United Kingdom Dongtan Eco-city in Shanghai, Caofeidian International Eco-City in Tangshan (Box 1.2), Sino-Finnish Mentougou Eco-City in Beijing, and the Sino-Singapore Tianjin Eco-City (SSTEC). In addition to these relatively high-profile developments, international cooperation has also supported small scale eco-community developments,

### Box 1.2: Caofeidian Eco-city, Tangshan

Caofeidian Eco-city represents one of the large-scale new developments that aim to direct fast urban growth in an ecological way. This eco-city is located 5 km northeast of the Caofeidian Industrial Area and Caofeidian port, 80 km from Tangshan city center, 120 km from Tianjin, and 220 km from Beijing. To attract high-end services and skilled employees essential to the rapid industrial development in the Caofeidian Industrial Area, planning of Caofeidian Eco-city was initiated in 2007. Stakeholders envisioned an "eco-friendly" city that is "resource and energy saving, economical livable and social harmonious".

Caofeidian Eco-city is projected to house 1 to 1.2 million residents in an area of 150 $km^2$ that is mainly wasteland. A start up area of 30 $km^2$ is planned as the central business center of the eco-city and is expected to house around 500,000 people by 2016. The master plan of 150 $km^2$ and a detailed plan of 30 $km^2$ were developed, and the master plan was approved by the Government of Hebei Province in 2008. An indicator system consisting of 57 indicators was also developed to guide the planning and instruction of Caofeidian Eco-city. Construction works for Caofeidian Eco-city started in September 2008.

Some notable features of Caofeidian Eco-city's plans include:

1. The share of public transport is expected to reach 70 percent by 2015 and the share of pedestrian and bicycles, 20 percent. A cost-effective Bus Rapid Transit (BRT) system will serve as the backbone of the transport network. By promoting green transport, the eco-city strives to limit the transport-related carbon dioxide emissions to lower than 20 kilogram/ person / kilometer.
2. Located in a region with a water shortage, Caofeidian Eco-city tries to promote the use of reclaimed water, desalinated water, and rain water. Water from these non traditional sources will account for 50 percent of the total water supply. 100 percent of domestic wastewater will be treated and reused.
3. Renewable energy sources such as solar, biogas, wind, and geothermal energy will account for more than 50 percent of the total energy supply. In addition, residual industrial heat from steelworks and electric power plants in industrial zones will also be important heating sources. Waste incineration and cool-heat-electricity cogeneration will be utilized as a subsidiary supply of heat. Seawater desalination facilities will be combined with thermal power plants during construction.

Source: Caofeidian Eco-city Master Plan; Caofeidian Eco-city Indicator System

such as the Huangbaiyu Eco-village project in Benxi, which was supported by partners from the United States.

***Challenge of Eco-City Development in China.*** It is clear that eco-city development has earned increasing attention from China's national government and local cities, and that attempts are being made to achieve sustainable urban development and better address climate change challenges. As discussed above, since comprehensive national standards for eco-city development still require development, cities are adopting various experimental approaches that require careful examination. As more cities announce their commitment to ecological development, it is important to closely monitor these cities' efforts to lead development towards an ecological future. Moreover, there is a risk that an eco-city might be perceived as only a "marketing brand" if no substantial results are achieved. This risk would manifest if cities continue to follow traditional planning approaches, such as focusing on physical construction targets, including green space provision and beautification projects, rather than application of effective resource management tools. It is also important that cities do not rely too heavily on administrative controls to reduce pollution, and adopt instead incentive schemes and technological innovation.

Another issue is how to ensure that eco-city plans are adapted to a city's local context. This is especially challenging for a new city development, as it requires careful considerations in urban planning and design to provide sufficient linkages (physical and social) to the central city, and to establish a sense of community for new residents. Many eco-city projects reveal mixed results given the complexities in green field development; some projects were difficult to implement and some were put on hold, as in Dongtan, Shanghai, and Huangbaiyu, Benxi (Box 1.3). A key lesson from these failed projects is that it is important for eco-city projects to earn strong support from local governments and local communities to ensure that plans are translated into real development.

It is in this overall context that the Sino-Singapore Tianjin Eco-City (SSTEC) project was initiated by China and Singapore.

### Box 1.3: Lessons from Eco-city Developments in China

**Dongtan Eco-City, Shanghai**
Dongtan is located on Chongming Island (Shanghai), the third largest island in China at the mouth of the Yangtze River. Dongtan Eco-City was planned to house 50,000 people by 2010 and 500,000 by 2040 in the 86 $km^2$ site. The urban area was planned to occupy one third of the site, with the remaining land retained for agriculture and a buffer zone of managed wetland between the city and the natural wetland. It was planned that Dongtan would produce its own energy from wind, solar, bio-fuel, and recycled city waste. Clean technologies such as hydrogen fuel cells were to power public transport. A network of cycle and footpaths was to help the city to achieve close to zero vehicle emissions. Farmland within the Dongtan site was expected to use organic farming methods to grow food. Buildings were to be energy efficient. However, although the plan was devised in 2005 and the first phase of the construction was expected to be completed by the Shanghai Expo in 2010, the project was put on hold and almost nothing has been built on the site to date. This illustrates that even high profile projects can face implementation challenges, particularly because of funding issues, changing local government priorities, and environmental concerns (i.e., there were concerns about the site's location, which endangers a wetland of global importance and extends commuting distances from Shanghai).

**"Ecologically Sustainable" Village in Huangbaiyu, Benxi, Liaoning Province**
Huangbaiyu is a poor village in northeast Liaoning province that was chosen in 2003 as a site of China's "ecologically sustainable" model village. The objective of this project was to cut energy costs by building new homes out of hay and pressed-earth bricks—a new technology developed in the United States. The designs were to incorporate full southern exposure, complete insulation, rooftop solar panels, radiant heat floors, and pipes to transport cooking gas produced by a nearby methane biomass plant. 370 scattered households in the village were planned to be centralized, and their farmlands were to be consolidated with additional land made available for farming and development. So far, only 42 houses have been constructed, and most in unplanned ways. This failure resulted mainly from a deficient understanding of local conditions. Farmers refused to live in the new houses as the new yards were not large enough to raise animals and sustain livelihoods; and some homes were built with garages, although no villagers can afford cars. Another problem is lack of oversight on costs and the construction process. Due to cost overruns and lack of government subsidies, house prices rose to $20,000, an amount villagers cannot afford.

Source:China's Grand Plans for Eco-Cities Now Lie Abandoned, Yale Environment, April 6 2009.

## Sino-Singapore Tianjin Eco-City Project Overview

***Tianjin's Ecological City Development and SSTEC.*** After being recognized as a national "Water Saving City" and "National Environment Protection Model City," Tianjin developed the "Tianjin Eco-City Planning Guideline" in September 2007 and the Tianjin Eco-City Construction Action Plan in January 2008, which aims to achieve MEP's national eco-city standards by 2015 (Box 1.4). As Tianjin is taking an incremental approach to renovating existing cities and towns, the SSTEC project was initiated in Tianjin's fast-growing new district, the Tianjin Binhai New Area (TBNA).

***Project Origin.*** After earlier cooperation initiated in 1994 between China and Singapore on China's Suzhou Industrial Park, the two countries signed a Framework Agreement in November 2007 to collaborate on SSTEC. The Agreement elevates the SSTEC project to the level of inter-government direct cooperation, and enables SSTEC to gain momentum from strong political commitment, while benefiting from Singapore's extensive knowledge and experience in integrated urban planning and water resource management. SSTEC completed its master plan in 2008, and is currently finalizing the control plan to guide overall implementation. Key milestones are listed in Box 1.5.

***Vision and Objectives.*** SSTEC is envisioned as an "economically sustainable, socially harmonious, environmentally friendly and resource-conserving" city which will become a "model eco and low carbon city replicable by other cities in China." It aims to achieve this vision by adopting an integrated approach to planning a new urban area in an environmentally sustainable manner. According to the draft master plan, SSTEC promotes quality of life by integrating land use and urban transport considerations and balancing employment and housing supply. SSTEC promotes the "use of clean/renewable energy and reuse/recycle of resources through innovative technologies and environmentally friendly policies and investments across various sectors," including in, inter alia, water, energy, land, and transport. SSTEC promotes an "efficient circular economy through the development of an ecological industrial system." Global climate change and social equity issues are also incorporated into the draft master plan by explicitly focusing on reducing GHG emissions and providing social housing.

### Box 1.4: Tianjin Municipality Ecological City Development

As a city facing water scarcity, Tianjin has adopted 21 local codes and regulations that promote water conservation, and is actively piloting water-saving technologies in sea water desalination, wastewater treatment, water reuse, and flood and storm management. Tianjin is leading many cities in industrial water efficiency. In 2005, Tianjin was recognized as a national "Water Saving City" by MoHURD and NDRC.

In view of Tianjin's efforts in environmental and pollution management that address the severe environmental problems of its manufacturing-based economy, MEP approved Tianjin city in 2006 as a "National Environment Protection Model City"—the only one among the four municipalities directly under the State Council that was awarded this title. Tianjin expects to meet the national standard for "Garden City" by 2009, with public green space per capita expected to reach 8 $m^2$ and coverage of green space in the built-up area to reach 38.5 percent.

In September 2007 Tianjin city developed the "Tianjin Eco-city Planning Guideline" (followed in January 2008 by the Tianjin Eco-City Construction Action Plan) which aims to achieve MEP's eco-city standard by 2015. In the guideline, Tianjin adapted national standards according to local conditions, and put forward a comprehensive indicator system, which consists of eight economic development indicators, 14 environmental indicators, and 11 social development indicators.

### Box 1.5: Key SSTEC Milestones to Date

*Framework Agreement.* On November 18 2007, a Framework Agreement to develop the SSTEC was signed by the Chinese Premier Wen Jiabao and the Singapore Prime Minister Lee Hsien Loong. A supplementary agreement was signed by the Ministry of Housing and Urban-Rural Development of China and Ministry of National Development of Singapore to guide the implementation of SSTEC.

*Key Performance Indicators.* Key performance indicators (KPIs) were developed in April 2008 based on the current Chinese national standards and best practices in Singapore, including 22 quantitative indicators and 4 qualitative indicators (Annex 1). The KPIs were formally approved by the Ministry of Housing and Urban-Rural Development on September 22, 2008. Any change to the KPIs will require review and approval via a formal process.

*Master Plan and Detailed Plan.* The draft Master Plan has been finalized and was reviewed and approved by the Tianjin Planning Committee and Joint Working Committee. It was released for public consultation in China and Singapore in mid-April 2008. The Master Plan was approved by the Tianjin Municipal Government in September 2008. The corresponding Control Plan for Phase I is currently being finalized, and is expected to be approved by the Government of the Binhai New District. Subsequently, detailed site plans will be developed for Phase I, which will be the responsibility of individual developers.

*Groundbreaking Ceremony.* The groundbreaking ceremony of SSTEC was officiated by China's Premier Wen Jiabao and Singapore's Senior Minister Goh Chok Tong, and was held on September 28, 2008. This marked the beginning of construction activities in the Eco-city in its 4 $km^2$ start-up area.

Source: World Bank SSTEC Mission Aide-Memoire, March 2009

***Scale and Timeline.*** By 2020, the SSTEC area is envisaged house 350,000 permanent and 60,000 temporary residents on 34.2 $km^2$. These characteristics reflect a medium size city according to Chinese standards. As articulated in the SSTEC master plan, SSTEC will be developed in three phases between 2008 and 2020. Phase I is being implemented over 2008-2010, and will cover a start-up area of 4 $km^2$ and involve a projected population of 85,000. Phase II (2011-2015) and Phase III (2016-2020) will each be implemented over 5 years. By 2020, SSTEC will be fully developed (Box 1.6).

***Key Performance Indicators.*** One notable feature of the SSTEC is that KPIs, including 22 quantitative indicators and four qualitative indicators, were developed during the planning process (see Table 1.3).

### Box 1.6: Three-Phase Development from South to North

Phase I (2008-2010) focuses on the South district, the sewage plant to the west of Qingjing lake, and the ecological exhibition and education base of the project. Phase II (2011-2015) focuses on the central district, international forum to the east of Qingjing lake, exhibition center, and an ecological recreation park. By end of Phase II, the basic spatial structure of the eco-city will be established, including its major infrastructure, public facilities, and the transport network linking it to the TBNA and the surrounding regions. Phase III (2016-2020) will focus on the mixed use district to the south of Qingjing lake, and the north and northeast districts.

Source: SSTEC Master Plan.

Table 1.3: SSTEC Key Performance Indicators

| No. | KPI Area and Details | Indicative Value | Timeframe |
|---|---|---|---|
| Natural Environment | | | |
| 1 | Ambient Air Quality | No of days per year in which ambient air quality meets or exceeds China's National Ambient Air Quality Grade II Standard ≥310 (85% of 365 days) | Immediate |
| | | No. of days per year in which $SO_2$ and NOx content in the ambient air should not exceed the limits stipulated for China National Ambient Air Quality Grade I Standard ≥155 (85% of 310 days) | Immediate |
| | | To meet the standard stated in the PRC's National Standard GB 3095-1996 | By 2013[50] |
| 2 | Quality of Water Bodies | To meet Grade IV surface water quality standard stated in the PRC's National Standard GB 3838-2002 | By 2020 |
| 3 | Water from taps attaining drinking water standards | 100 % | Immediate |
| 4 | Noise pollution levels should meet the stipulated standards for different functional zones | 100 % | Immediate |
| 5 | Carbon emission per unit GDP | 150 ton-C per one million US dollars | Immediate |
| 6 | Net loss of natural wetlands | 0 | Immediate |
| Man-Made Environment | | | |
| 7 | Proportion of green buildings[51] | 100 % | Immediate |
| 8 | Local plants index | ≥ 0.7 | Immediate |
| 9 | Public green space per capita | ≥ 12 $m^2$ per capita | By 2013 |
| 10 | Per capita domestic water consumption | ≤ 120 Liters per day per capita | By 2013 |
| Living Style | | | |
| 11 | Per capita domestic waste generation | ≤ 0.8 kg per day per capita | By 2013 |
| 12 | Proportion of green trips[52] | ≥ 30 % | By 2013 |
| | | ≥ 90 % | By 2020 |
| Infrastructure | | | |
| 13 | Overall Solid waste recycling rate | ≥ 60 % | By 2013 |
| 14 | Provision of free recreational and sport facilities within walking distance of 500 m | 100 % | By 2013 |
| 15 | Treatment to render hazardous and domestic solid wastes non-toxic | 100 % | Immediate |
| 16 | Barrier-free accessibility | 100 % | Immediate |
| 17 | Services network coverage | 100 % | By 2013 |
| Management | | | |
| 18 | Proportion of public housing | ≥ 20 % | By 2013 |
| Economic Sustainability | | | |
| 19 | Renewable energy usage | ≥ 20 % | By 2020 |
| 20 | Water supply from non-traditional sources | ≥ 50 % | By 2020 |
| Technological Innovation | | | |
| 21 | Number of R&D scientists and engineers per 10,000 labor force | ≥ 50 man-year | By 2020 |
| Employment | | | |
| 22 | Employment-housing equilibrium index[53] | ≥ 50 % | By 2013 |

Source: SSTEC KPIs.

Compared to MoHURD's eco-garden city standard and MEP's eco-city standard, the scope of these KPIs is broader and in some areas more advanced, especially for GHG emissions, renewable energy use, solid waste recycling, and water reclamation. Indicators that promote more energy efficient and resource-saving lifestyles are also included, such as those related to green transportation, green buildings, proximity of residential and work facilities, and limits on domestic water consumption and waste generation. Social equity issues are also incorporated in the KPIs by explicitly requiring provision of social housing. Qualitative indicators focus mainly on regional coordination and economic integration.

The KPIs are important to SSTEC not only because they provide clear guidance on planning and constructing the project, but because they help to ensure the expected outcomes are achieved through careful monitoring. By focusing on ecological dimensions, the KPIs constitute an inclusive "score card" for assessing the achievement of local officials in charge of city management, as opposed to simply assessing economic growth-related indicators, which is common practice in China.

***Most Ambitious KPIs.*** Some KPIs exceed current standards and practices in China and some are comparable to international best practices. If the KPIs are achieved, this will represent a substantial advance compared to "business as usual" development in Chinese cities. The most advanced and ambitious KPIs are in the following areas (to be met by 2020):

- KPI 5: Carbon emissions per unit GDP: ≤ 150 tons C per one million US$ GDP
- KPI 7: Proportion of green buildings: 100 percent
- KPI 11: Per capita domestic waste generation: ≤ 0.8 kg per day (by 2013)
- KPI12: Proportion of green trips: ≥ 90percent
- KPI 13: Overall solid waste recycling rate: ≥ 60 percent (by 2013)
- KPI 19: Renewable energy usage: ≥ 20 percent
- KPI 20: Water supply from non-traditional sources: ≥ 50 percent

Other KPIs are set at national standards (i.e., tap water quality), are comparable to national eco-city standards (i.e., public green area per capita, noise pollution levels), or have been met in Tianjin (i.e., 100 percent treatment to render domestic solid wastes non-toxic—already achieved in TBNA). Other KPIs are more likely to be indicative rather than obligatory, as they either require coordination with surrounding jurisdictions (i.e., ambient air quality, quality of water bodies), or are difficult to control through administrative measures (i.e., employment-housing equilibrium index). All principal KPIs are analyzed in the subsequent chapters, and a summary comparison of KPIs against domestic and international benchmarks is provided in Annex I.

In the subsequent chapters, this report reviews the SSTEC's plans and proposals, particularly how they, as currently articulated, can contribute towards achieving the objectives set by the KPIs. As such, the report aims to assist SSTEC policy makers in refining specific proposals and shedding light on how to approach the planning and development of eco-cities in China.

## Chapter II
# Urban Planning and Spatial Development

## Introduction

This chapter will review SSTEC's proposed development from an urban planning and spatial development point of view, and provide a sense of the extent to which the specific measures undertaken are contributing towards developing a more ecological urban development pattern. Recommendations are provided on how the specific plans or the overall development approach might be strengthened to ensure a higher likelihood of realizing SSTEC's vision. Specifically, the chapter looks into SSTEC's (i) location and site selection, (ii) spatial form and pattern, (iii) urban design, and (iv) overall urban planning approach. Urban planning and spatial development are fundamental aspects of ecological urban development, not least because they impact the economics and lay out the parameters of infrastructure system design and technology choices across all key urban sectors: transport, energy, water and wastewater, and solid waste.

## Location and Site Selection

***Responding to the Regional Economic Context.*** SSTEC is located to the north of the Tianjin Binhai New Area (TBNA) at the intersection of the Beijing-Tianjin urban development axis, and the Bohai rim coastal industrial zone. TBNA is 45 km from the Tianjin city center, 150 km from Beijing, and 50 km from Tangshan. With the new Beijing-Tianjin High Speed Rail extended to the TBNA, and other planned trunk transport connecting to Hangu and Tanggu, SSTEC will be able to join Beijing's one-hour economic radius, and will be better linked to the hinterland.

A key to understanding SSTEC's strategic location is the TBNA. The TBNA is a major economic development node in northern China. It encompasses one of the world's ten largest ports (Tianjin Port), and two major economic zones: the Tianjin Economic-Technological Development Area (TEDA) and the Tianjin Free Trade Zone (TFTZ). TBNA produces 44 percent of Tianjin's GDP with only 10 percent of its population.[54] It has experienced one of the fastest growth rates among cities in China, and attained an average annual GDP increase of 20.6 percent from 1994 to 2005. Regional arterial infrastructure has been expanded, and new infrastructure is expected in coming years. This includes expanding the airport and port, and investing in high speed rail from Beijing to Tianjin.[55]

Figure 2.1: SSTEC in the Regional Context

Source: Master Plan

TBNA was approved as China's National Pilot District of Comprehensive

Reforms and Innovation. It is envisioned to be the nation's new growth pole, following Shenzhen in the 1980s and Shanghai Pudong in the 1990s. Located in TBNA, SSTEC will enjoy a series of concessional policies applied in TBNA, and receive support from the central government.[56]

The economy of Tianjin relies heavily on manufacturing. Electronic information, chemical, metallurgy, automobile, and other manufacturing operations drive up to 60 percent of the economy. Most of the industrial structure is energy intensive. In China's11$^{th}$ Five-Year-Plan (2005-2010), Tianjin announced goals to achieve annual economic growth of 12 percent, and a 15 percent increase in energy efficiency by 2010. Tianjin's energy efficiency goal is lower than the national 20 percent target.[57] As energy demand is expected to increase in certain energy-intensive industries, such as heavy chemical industries and power plants,  SSTEC's proposed economic structure will likely contribute to Tianjin's goal of promoting energy-efficient industries and service sectors (Box 2.1).

### Box 2.1: Proposed Economic Structure in SSTEC

SSTEC has developed an initial plan for its socio-economic development through 2020. According to this plan, SSTEC aims to develop an economic structure that targets high value-added, environmentally friendly, and energy-efficient industries. SSTEC will provide 190,000 jobs comprising about 80 percent of the total working population. Most jobs will be in the service sector and some in light manufacturing. SSTEC's overall economic vision is to achieve high economic growth while maintaining low GHG emissions. By 2020, SSTEC's total GDP is expected to be 38.2 billion RMB (5.6 billion USD), and carbon emissions per unit of GDP are expected to be no more than 150 tons per one million USD. SSTEC's economic structure is based on real estate and green buildings, producer services, Research and Development (R&D), higher education in environmental sciences, culture and recreation, conference facilities, health care, and other service jobs. The focus on environment-related service industries aims to create synergy with TBNA and surrounding regions by upgrading manufacturing, logistics, and trade industries using green technologies cultivated and tested in SSTEC. Overall, SSTEC is positioned as a somewhat higher income development. The shares of people in SSTEC with incomes classified as high & medium-high, medium & low-medium, and low are projected to be, respectively, 60 percent, 20 percent, and 20 percent. For reference, Tianjin's central city has an income distribution of 42 percent, 39 percent, and 19 percent.

Source: SSTEC Master Plan.

The location of SSTEC makes good strategic sense in the context of its surrounding economic geography. However, appreciating SSTEC's strategic role requires that many of its plans be viewed not in isolation but as part of the larger regional network and economic context. If accomplishing some of SSTEC's KPIs simply entails relocating or displacing certain polluting industries or land uses outside its jurisdictional boundaries, then the net environmental impacts at the regional scale do not change. At the same time, regional economic and developmental dynamics, much of which is beyond SSTEC's control, can impact the viability of certain project proposals. For instance, the effects of the current economic downturn on trade and business at the regional level might impact land values and the financial underpinning some of SSTEC's development.

***Responding to an Overall Land Shortage.*** By selecting 34.2 $km^2$ of non-arable land and deserted salt pans, SSTEC will contribute substantially to the efficient use and revitalization of scarce land. Such site remediation has clear ecological benefits. Selecting such land will relieve development and urbanization pressures on an equivalent 34.2 $km^2$ of agriculturally productive land, thereby contributing economic, social, and ecological benefits, particularly in a context where agricultural land is increasingly lost to urbanization. As mentioned in Chapter 1, China has approached the government mandated 'red-line' (minimum) of 120 million hectares of arable land (In 2006, China had 121.7 million hectares of such land). Moreover, this site selection supports SSTEC's ecological vision, reinforces national priorities, and demonstrates an approach that can potentially be replicated elsewhere in China. In addition, the number of existing residents on this site is small relative to the size of the project (2157 people in three villages). Choosing this site minimizes relocation costs, and all original residents will be accommodated in the new eco-city.

***Responding to Tianjin's Demographic Context.*** TBNA has the fastest growing population in Tianjin, and contributes nearly half of Tianjin's population growth. The Tianjin metropolitan area (the entire Tianjin jurisdiction) can be categorized into four zones: the urban districts (essentially the city center), inner suburban clusters, coastal districts (Tanggu, Dagang, and Hangu, where most of TBNA is located), and suburban and rural areas. TBNA, which is about 40 km from the city center and is where SSTEC will be located, includes all three coastal districts and part of the inner suburban clusters. Though the projected average annual growth rate (compounded) among the urban districts (city center) is 0.2 percent over the next 10 years, it is 5.5 percent in the Binhai area where SSTEC is located. The city center will have to absorb 197,000 people between 2000 and 2020,[58] but the Binhai area will have to absorb 1.65 million people between 2005 to 2020.[59] In short, SSTEC is located in the region with the highest demand for new development. This location positions SSTEC to strategically absorb part of Binhai's 1.65 million population increase.

Table 2.1: Population Projections Up to 2020

| | 2000 Population | 2000 % of Tianjin Population | 2020 Population | 2020 % of Tianjin Population | 2000-2020 Population Change | 2000-2020 Average annual growth rate |
|---|---|---|---|---|---|---|
| Tianjin Metropolitan Area | 10,080,000 | 100% | 13,500,000 | 100% | 3,420,000 | 1.5% |
| Urban districts | 3,903,000 | - | 4,100,000 | - | 197,000 | 0.2% |
| Inner suburban area | 1,774,000 | - | 3,290,000 | - | 1,516,000 | 3.1% |
| Coastal districts | 1,139,000 | - | 2,410,000 | - | - | 3.3% |
| Suburban and rural area | 3,192,000 | - | 3,700,000 | - | 508,000 | 0.5% |
| TBNA | 1,350,000[61] | 13.4% | 3,000,000 | 22.2% | 1,650,000 | 5.5% |

Source: 1) Tianjin City Master Plan (2005-2020); 2) TBNA Master Plan (2006-2020)

***Responding to TBNA's Demand for Housing Stock.*** TBNA was initially planned as an economic development zone rather than a functional city, with a strong intention to attract foreign direct investment, export-oriented industries, and manufacturing that were moved from Tianjin's central city. The housing sector in TBNA is lagging behind. In light of TBNA's population projection and the goal of providing 40 $m^2$ of per capita floor area in residential buildings by 2010,[60] the gap in the housing sector is significant. Nearly16 million $m^2$ of residential buildings need to be built by 2010, and 64 million $m^2$ by 2020. As living standards rise and land for construction becomes scarce in Tianjin's central districts (within the outer ring), most of the increased housing stock is expected to be located in the TBNA and the suburban districts, where more land is available. From this perspective, the development of real estate in SSTEC responds to the housing demand in the region.

***Key Performance Indicators.*** There are two Key Performance Indicators (KPIs) related to urban planning. To reduce commuting-related economic losses and GHG emissions, SSTEC aims that at least 50 percent of employable residents in SSTEC will work within SSTEC. In setting this goal, SSTEC envisages providing adequate residential space for workers within its boundaries. However, it is unclear how this objective will be managed given the overall demand for housing in TBNA. In reality, it is difficult to plan or predict where people live and work, or whom employers recruit. The most a city can do is to enable a healthy mix and balance of economic activities and residential land uses based on demand projections. Attempts to influence employers to hire locally—or residents to work locally—are rarely successful. Moreover, while most non-work trips can be co-located close to residential uses within neighborhoods, work-related trips are relatively hard to control. In addition, SSTEC set a KPI that 20 percent of its total housing stock will be affordable housing (i.e., government-subsidized housing), aiming to accommodate low and medium income families (Box 2.2).

### Box 2.2: Affordable Housing Provision in SSTEC

The master plan has a specific provision for affordable housing. This provision stipulates that the proportion of affordable housing in SSTEC must be no less than 20 percent by 2013. This target corresponds broadly to the guidance provided by the national government. The 11th Five-Year Plan (2006-2010) indicates that the share of public housing should be 15-20 percent of all housing built between 2006 and 2010. Cities such as Shanghai, Xian, Dalian, Shenzhen, and Zhengzhou are in the 15-25 percent range. Tianjin currently has an affordable housing share of 30 percent. However, the affordable housing target does not convey much without establishing clear eligibility criteria and designated price points that correspond to incomes in the target demographic bracket. However, it is noteworthy that SSTEC's 20 percent target for affordable housing does correspond to its projected low-income population of 20 percent.

Source: SSTEC Master Plan and Socio-Economic Plan.

## Spatial Pattern

A city's spatial development process establishes the location, concentration, distribution, and nature of demand for key urban services, including transport, energy, water, and waste services. It determines the physical and economic constraints and parameters within which infrastructure investments and capacities will need to be designed, and associated costs recovered. Resource efficiency and GHG emissions are directly related to the choice and design of infrastructure systems and service delivery technologies. Good urban planning and spatial development can be thought of as proactive 'demand side' management for resource-efficient infrastructure systems. For instance, public transportation is financially viable only at certain threshold urban densities, and is optimized under certain spatial layouts and land use patterns. At the same time, urbanization downstream from a large water storage facility would likely reduce the need to pump water and construct distribution mains that would be required for more dispersed urbanization upstream from a water facility. In many municipalities, water and wastewater pumping can amount to greater than 30 percent of a city's energy bills.[62]

***Aggregate Density.*** The SSTEC Master Plan envisages a population of 350,000 on the 34 km$^2$ site. The resulting overall density will be 10,294 people/km$^2$. This is a little lower than the density of Tianjin's core city, which was 13,355 people/km$^2$ in 2000, and which is anticipated to drop to 12,668 people/km$^2$ by 2020.[63] SSTEC's density is planned to be almost twice the projected density in TBNA's core urban area, which is expected to have 6,684 people/km$^2$ by 2020. However, as 9 km$^2$ or 26 percent of SSTEC's land area will be open space, water, and greenbelt, a higher density of 14,000 people/km$^2$ is expected on the remaining 25 km$^2$ of land designated for construction. This proposed density places SSTEC among China's more densely populated cities. In 2005, for instance, Shanghai's population density was 13,761 people/km$^2$, while Beijing's was 7,237 persons/km$^2$.[64] China has some of the world's most densely populated cities, and while the typical trend is to disperse population, SSTEC plans to maintain high densities for good reason.

At an aggregate level, SSTEC's density is sufficient to justify and provide the economic demand base for infrastructure services that efficiently use resources, such as public transportation and district heating, which can contribute to ecological targets. For instance, these densities support options for surface mass transit, which requires a threshold of 5,000 - 10,000 people/km$^2$, such as 'bus rapid transit' and 'light rail transit,' and elevated or underground mass transit.

SSTEC's per capita urban construction land of 75 m$^2$ is less than the 106 m$^2$ in Tianjin and the national standard of 90-100 m$^2$. This allocation of per capita construction land will lead to more compact construction, efficient use of built space, and greater resource conservation and efficiency.

***Urban Form and Density Gradient.*** The planned area is essentially a linear corridor integrated through a spine (called an eco-valley) that links four districts. Along this spine are one city center, and two sub-centers. The centers and the spine are consciously integrated with transport considerations, as

Figure 2.2: Urban Form and Density Gradient


Source: Masterplan

demonstrated by the higher density gradient around the centers and along the spine (see Figure 2.2 below). By adopting densities that support transit and an appropriate urban structure, the intention was that 80 percent of the population will be within 800 m of a metro station. While these factors support transit-oriented development objectives, much of the success of public transport and non-motorized transport (walking and bicycling) will depend on micro-level urban design issues, which are discussed in the next section.

***Floor Area Ratio (FAR).*** An FAR indicates the maximum allowed ratio of a building's total constructed floor area to the total area of the building's plot of land. A higher FAR implies more intensive use of the same plot of land; i.e., more floor space on the same base area. FARs are powerful regulatory instruments that directly impact the consumption of urban land, and as a result, the efficiency of its use. In China, where the average FAR has risen in the past decade,[65] there is still a potential to allow a broader range of FARs in different locations by increasing land use intensity in designated nodes. This would help to reduce land consumption and infrastructure costs, lead to shorter walking distances, and facilitate public transport and economically feasible district heating systems. It would also offer potential to maximize the unique status of activity nodes, and to achieve a critical density to activate the city center in the new city. In SSTEC, the FAR is divided into six categories, moving from low intensities along the waterfront and ecological corridors, to higher intensities around the railway stations and in the city center.

- Highest intensity in dark red: city center, FAR>4.0;
- High intensity in red: sub-centers, 2.5<FAR<4.0;
- Medium-high intensity in orange-red: centers of residential communities, 1.6<FAR<2.5;
- Medium intensity in beige: other areas within 800 m. around railway stations, 1.2<FAR<1.6;
- Medium-low intensity in yellow: most areas more than 800 m from railway stations, 0.8<FAR<1.2;
- Low intensity in light manila: waterfront and along ecological corridors, FAR<0.8.

In most Chinese cities, FARs are not assigned in urban master plans. Instead, FARs are typically negotiated at project or planning levels at different times. SSTEC's decision to articulate FARs in its master plan is "good practice." Assigning FARs supports organized development, maximizes returns to the transport system, and facilitates the emergence of high-density nodes. In short, SSTEC's density gradient was carefully planned to match the city spine and the city nodes.

## Urban Design

Effective urban design can reinforce the public transport system and encourage pedestrian and bicycle use. It is advisable to maintain higher densities and spatial concentration along public transport corridors. At the same time, good urban design can complement high aggregate density with increased commercial street frontage that provides a continuous array of ground-level commerce in neighborhoods: restaurants, cleaners, grocery stores, hardware stores, cafes, and shops (etc.). Smaller block sizes linked to appropriate road networks can increase the exposed street frontage, reinforcing such commerce.

The aerial photograph in Figure 2.3 shows a commercial area in Hong Kong SAR, China that illustrates the successful application of urban design, consisting of smaller block sizes, mixed use zoning, and interlacing street networks, which are popular with pedestrians. Because the streets are lined with a range of daily commercial shops and facilities, most trips are made by walking or bicycling. Residents do not need to leave neighborhoods to fulfill basic needs, and enjoy walking in neighborhoods.

In addition to providing walk-able neighborhoods, good urban design should effectively integrate public transport services. For instance, residential locations should be designed to minimize travel distances, and, where travel is needed, ensure easy access to public transport. In Singapore, walkways from bus stops to most residential complexes are covered to protect against the rain. Complexes should be designed around bus stops to deliberately minimize walking distances and times to the bus stops. In addition, transit-oriented development must be encouraged, so that transport nodes become the locations for daily commercial transactions.

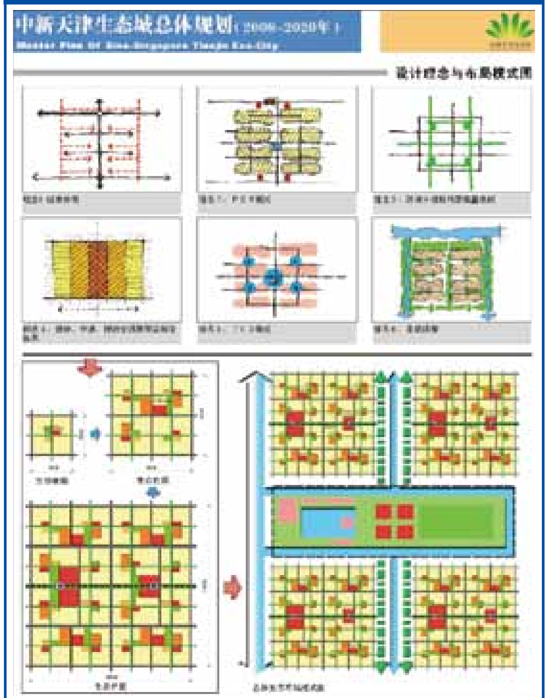
***What is SSTEC's Urban Design?*** Framed by a spatial structure of "one spine, three centers, four districts" and "one island, three waters and six corridors", SSTEC's basic urban design constitutes the following:

As is common in much new urban development in China, SSTEC supports a 400 by 400 m city block, called an eco-cell,which accommodates 8,000 residents. Roads will line the perimeter of these cells, though each cell will have four quadrants with pedestrian and bicycle only lanes. Each eco-cell will have a 'grassroots community center' with a service radius of 200-300 m. Four of these eco cells will aggregate to form an eco-community of about 30,000 residents. The eco-community will have a residential community center providing a higher level of activities. This residential community center will have a service radius of 400-500 m. Four to five of these eco-communities form an eco-district, and four of these eco-districts form

Figure 2.3: Mong Kok, Hong Kong SAR, China(Block size 40x100m)

Source: Google Earth

Figure 2.4: SSTEC Urban Design




Source: Masterplan

the eco-city. At the district level, the two sub-centers and the city center form the commercial core. As can be seen, a hierarchy of "live-work-play" spaces will be provided as follows: i) grassroots community centers; ii) residential community centers; iii) eco-city sub centers, and iv) the eco-city center—all within the nested design framework. The objective seems clear enough: to reduce the journeys to work and amenities via a four-grade public service system.

Control plans, including the architecture and urban design guidelines and height controls, are under preparation for the Phase I Start-up Area (4 $km^2$ with a population of 85,000). These plans address each of the four sub-levels: eco-district, eco-community, eco-cell, and individual lots within the eco-cell. The indication is that the eco-community and eco-district will have high control levels; targets set at these levels cannot be changed. Targets and parameters at the eco-cell level may be modified as long as the overall control for the eco-community and district is maintained. This offers some degree of flexibility to eco-cell development.

The proposed SSTEC urban design framework has several notable features. Rather than promoting ad-hoc urban sprawl, the SSTEC urban area more intentionally adapts the urban structure to the requirements of pedestrians, cyclists, and public transport. SSTEC's urban design also anticipates the need to satisfy many residents' daily needs and desires within a short distance from homes. Through the nested hierarchies of 'community centers,' SSTEC proposes to provide a community where citizens can walk 300-500 m to a wide variety of destinations: open spaces, businesses, leisure, recreational, entertainment, and cultural activities.

***Risks Posed by SSTEC's Urban Design.*** As is practiced in many new developments in China, SSTEC's road design is based on a minimum 400 by 400 m block. While these dimensions are not inherently challenging, and can be used to frame the urban design of a city, there are no roads or further subdivisions within the 400 by 400 m block in SSTEC, except for a green walkway and access roads. In cities like New York, Paris, and Stockholm, and in many older urban neighborhoods in China, more than 10 blocks could sometimes fit in a 400 by 400 m block. For instance, the minimum block sizes in Hong Kong SAR, China's Mong Kok neighborhood range from 100 m to 40 m. Without further subdivisions, this larger block size adds to the circulation within the larger city area. Moreover, larger roads then need to absorb more traffic as smaller road networks are not designed within blocks. This may contribute to a sense of physical disconnection between blocks.

If the 400 by 400 m blocks are not further subdivided (beyond access roads), SSTEC will have reduced street frontage in its block design. A 400 by 400 m block provides street frontage of 1,600 m. In New York City, street frontage includes another 10 lines of activity and reaches 3,600 m (see Figure 2.5). More street frontage enhances possibilities for differentiated street level activities, as it maximizes the 'catchment area' for commerce. It also facilitates greater penetration of service and emergency vehicles. SSTEC's relative loss of street frontage may detract from the vibrancy of its city streets. In addition, if the representation of an SSTEC block in Figure 2.5 holds true, then individual building lot designs will

Figure 2.5: Block Comparison: SSTEC and New York City

*Tianjin Block Structure compared to a New York City area of the same perimeter (1,600 meters). The difference in block size and street frontage can be seen.*

Source: Google Earth

include a green buffer between roads and commercial sites. Though designed to create the feeling of a green 'eco-cell', the large 400 by 400 m blocks may pose challenges if not subdivided.

## Planning Approach

***Integration:*** Building a city from scratch presents an opportunity to apply the best land use practices and spatial design principles, and to integrate and optimize land use planning with infrastructure system design. The process should begin prior to, and continue through, the development and implementation of the master plan. Service providers in critical infrastructure sectors (energy, water, transport, waste) need to work together with urban planners and designers to devise solutions that optimize the urban system. Opportunities for integration can be maximized through collaborative design and decision-making at the master-planning stage, and through collaborative implementation and management later on. This is a critical factor in ecological urban development, as many gains in resource efficiency and GHG emission reductions can be realized and locked-in at this stage.[66]

SSTEC has the potential to realize efficiency gains from integrated planning, particularly because it has an institutional structure that allows for cross-sector collaboration (see Chapter VII). However, achieving integrated planning in practice is difficult and only a few cities have managed to accomplish it. Stockholm's efforts in integrated planning, detailed below, offer a best practice example and lessons that can be incorporated into the phased development of SSTEC.

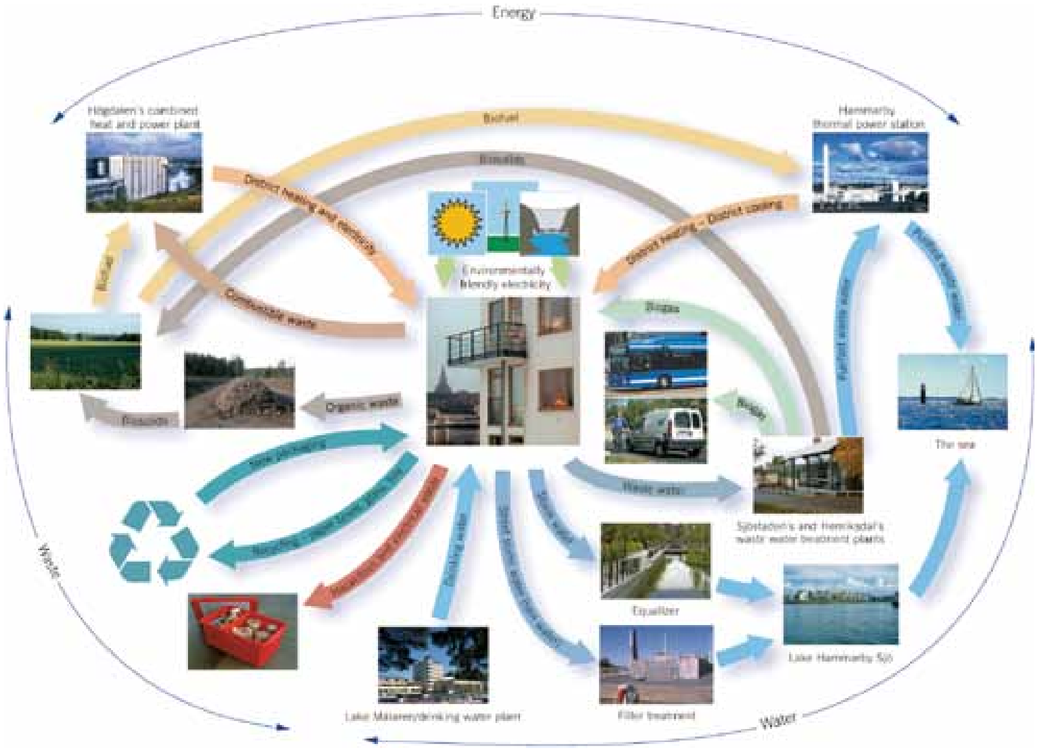
***Case Study 1: Stockholm: Integrated Planning and Management.***[67] Since 1995, Stockholm has been redeveloping a southern city district called Hammarby Sjostad. When planning this redevelopment, the city council aimed to be two times more sustainable than Swedish best practices (based on practices in 1995 when the redevelopment project began) on a range of indicators: most notably, energy efficiency per square meter. In Sweden, the average annual rate of energy use in regular new developments typically reaches 200kWh/m$^2$. Cutting edge practice produces average annual energy use of 120kWh/m$^2$,[68] while this project aimed to achieve 100kWh/m$^2$. Hammarby Sjostad also includes targets for, inter alia, water conservation, waste reduction and reuse, emissions reductions, reduced hazardous materials in construction, use of renewable energy sources, and integrated transportation solutions.

To integrate these efforts into a single direction, key representatives from different city departments were assembled into a project team led by a project manager and an environmental officer. These officials were charged with the responsibility to "guide and influence all stakeholders, public as well as private, to realize the environmental objectives of the project."[69] The team also had representatives from the city departments of planning, energy, waste, real estate, traffic, and water and sewage.[70]

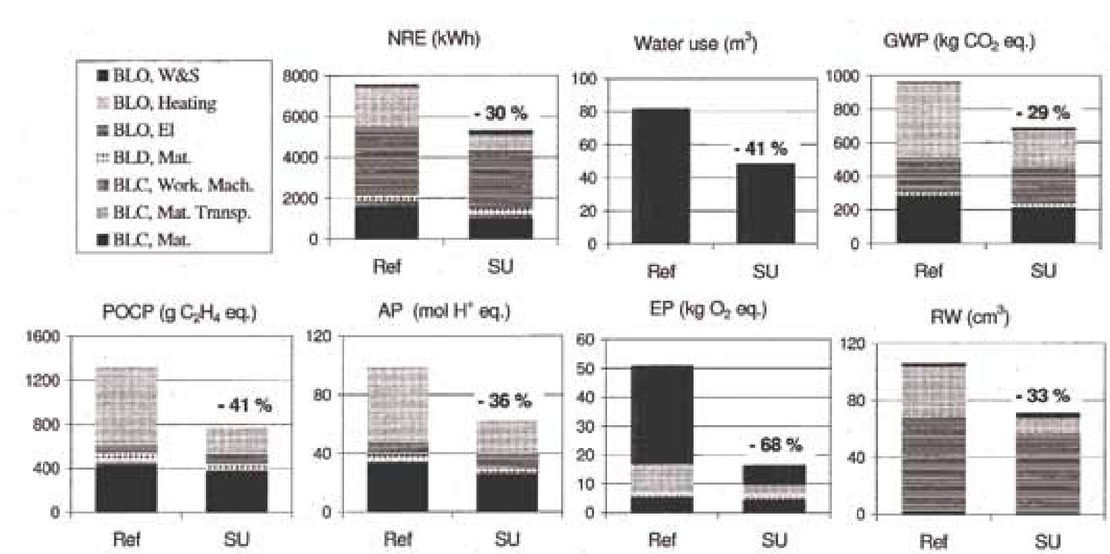
As a consequence, the city departments of waste, energy, and water & sewage collaboratively came up with the 'Hammarby Model.' This model streamlines various systems of infrastructure and urban service delivery, and provides the foundation and blueprint for achieving many of the sustainability targets outlined above.

Initial findings from the preliminary evaluations of the first phase of development ('Sikla Ude,' or SU) compared to a reference scenario (Ref) are tabulated on the following page. Outcomes include a 30 percent reduction in non-renewable energy use (NRE), a 41 percent reduction in water use, a 29 percent reduction in global warming potential (GWP), a 41 percent reduction in photochemical ozone creation production (POCP), a 36 percent reduction in acidification potential (AP), a 68 percent reduction in eutrophication potential (EP), and a 33 percent reduction in radioactive waste (RW).

## Figure 2.6: The Hammarby Model, Stockholm: An Example of Integrated Planning and Management [71]




## Figure 2.7: Initial First Phase Results of Hammarby Sjostad by the Environmental Load Profile Life Cycle Analysis Tool [72]

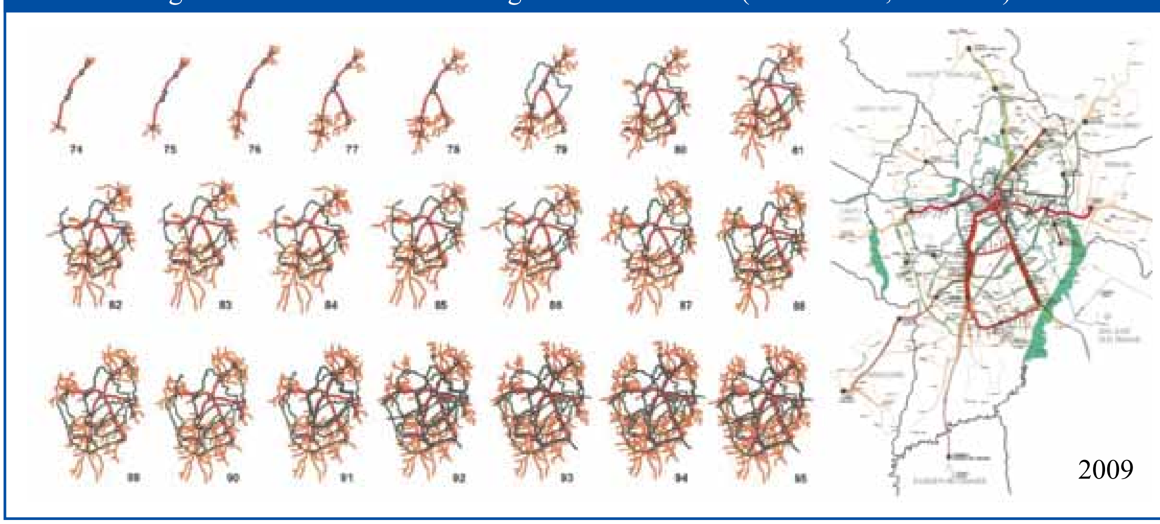


The key lesson of this case is that Stockholm's integrated approach to planning and management, which was adopted at project inception, was vital to realizing these ecological objectives.

Incremental Development. Strategic incremental development is another fundamental strategy supporting good urban planning. Incremental development entails the ability to sequence and plan development so that long term advantages are locked-in under the least risk, while maintaining a great degree of adaptability to changing situations. Planning new areas makes certain critical first steps easier for a city. This includes such activities as reserving the rights of way for roads and services, and allocating and designating land for open spaces and government and utility functions. These first steps can be incrementally scaled up as development progresses.

***Case Study 2: Curitiba: Strategic Incremental Development.*** In Brazil, the City of Curitiba adopted an incremental development strategy that has proved very successful since the 1970s. Anticipating demand, the city procured the basic rights of way for critical transport infrastructure, and developed infrastructure and service routes only when demand justified supply. By adopting this approach, the city absorbed demand in timely and organized ways, while allowing flexibility and responsiveness to market signals under minimal financial risk. Curitiba also enabled flexible planning by adopting transferable development rights. This flexibility enabled the city to maintain its aggregate density while allowing landholders to maintain their overall 'asset values'. It also helped to increase the preservation of green areas and cultural sites. By following an incremental approach, Curitiba produced a smaller ecological footprint and provided critical urban services over wider coverage than in many cities with greater fiscal resources. Curitiba has gained international recognition as one of the best examples of ecological and economic urban development.[73] Figure 2.8 illustrates the incremental development of the public transport system in Curitiba.

Figure 2.8: Evolution of the Integrated Bus Network (1974 - 1995, and 2009) [74]




***The Risks of 'New Town' Planning.*** 'New town' planning often presents a risk of building too much too fast based on demographic and economic projections and future real estate valuations. The laying of costly new infrastructure, the negotiation of large land transactions with powerful development interests, and the almost instantaneous construction of a city pose financial risks for all involved. The successes of such ventures are contingent on many uncontrollable variables that are hard to capture and 'model' in projections. In a competitive and globalized world with increasingly more mobile labor, fluid capital, and economic risks, an incremental approach provides a safer and more adaptable development path. Incremental moves made by a multitude of private actors and the government can reduce the socio-economic costs related to large scale land speculation and the potential over-sizing of infrastructure. Such moves often enable the market to function better within broader planning parameters, and to exercise self correction at a much smaller scale and in shorter time spans.

In addition to posing financial risks, new towns that are disconnected from an existing urban fabric and developed within a short time-span risk providing little authentic cultural and social context. Often, an existing social core is required to provide a sense of place, history, context, and belonging—all of which help cities grow and remain resilient in hard times.

***Case Study 3: Tama New Town on the Outskirts of Tokyo, Japan.***[75] Many new towns were developed in the suburbs of Tokyo during the 1960s to meet a huge demand for housing. Though some of these new towns initially helped people to access housing, many eventually proved unsustainable. For instance, the development of Tama New Town started in 1967 about 35 km southwest of Tokyo's city center. About 28.8 $km^2$ of land were developed for a planned population of 342,200. Initially, the town succeeded in attracting new residents, including families with children. However, in the 1990s, people moved closer to Tokyo to obtain better access to transportation, work, and cultural activities. In 2004, the population in the new town was 201,443—only about 60 percent of the original target. As a result, the vacancy rate of "first floor shops" was 30 percent. Residents in Tama reported a lack of social interaction and an absence of a sense of community. SSTEC should carefully examine the many lessons related to new town development in Japan and post-war Europe to avoid the mistakes associated with such development.

***Phased Development.*** SSTEC is expected to house 350,000 residents and provide jobs to 190,000 people within just 12 years. However, the development is planned in three phases moving from south to north. Phase I has already begun (2008-2013), and constitutes the development of the southern district, beginning with 85,000 people in a 4 $km^2$ Start-up Area. Phase II (2011-2015) will develop the central district. By the end of Phase II, the basic spatial structure of SSTEC will be established, including its major infrastructure, public facilities, and the transport network linking SSTEC with TBNA and surrounding regions. Phase III (2016-2020) will focus on the mixed-use district to the south of Qingjing lake, and the northern and northeastern districts.

As SSTEC evolves, the phases provide opportunities to make the most of incremental and integrated planning while reducing the risks of new town planning. The SSTEC project entails many unique processes. As the project moves through the phases, there will be needs and opportunities to revisit its weaknesses and enhance its strong points. It will also be important to maintain high flexibility and adaptability during the planning process. In other words, the master plan should not be a static blueprint. The second phase of development will be particularly important to solidifying the spatial form. For this reason, the first phase should be employed strategically to test and evaluate alternate propositions in, inter alia, urban design and private-sector engagement. The second phase should strongly reflect the evaluative lessons of the first phase.

***Implementation.*** A critical issue for large development projects based on long term visions is comparing the initial vision with accomplishments on the ground. Detailed implementation strategies and arrangements will need to be developed for SSTEC to translate its vision and urban development strategy into reality. Appropriate control and enforcement of development will ensure that the vision and intentions are not compromised during implementation. It will be helpful to have an overall management and enforcement strategy to ensure targets are reached. This is especially important when a large share of future investment is likely to be made by the private sector. At the same time, detailed assessments of the economic and financial risks associated with the project need to be carried out, and alternative or contingent plans and strategies need to be explored in the event that projections do not play out as modeled.

## Conclusion and Recommendations

Overall, SSTEC's urban and spatial development plan has elements that could contribute to a more ecological urban development pattern. The location of SSTEC not only makes strategic sense from an economic and demographic point of view, but the site selection itself strongly contributes to ecological objectives. The KPIs target reductions in travel-related emissions by supporting mixed use development and specific work-life ratios within SSTEC. At the same time, the KPI for affordable housing maintains a commitment to social inclusion. By supporting an aggregate density of 10,294 people/$km^2$, SSTEC exceeds the threshold of 5,000 - 10,000 people/$km^2$ generally required to render public transport viable. In addition, the distribution of densities and spatial forms in SSTEC aligns with and complements its trunk transport infrastructure. SSTEC's transit-oriented development encourages greater use of public transport. To reduce the need for motorized trips for everyday needs, the urban design provided nested hierarchies of 'community centers' at various scales (eco-cell, eco-community, and eco-district). By adopting this approach, SSTEC will provide a community where citizens can walk to a variety of destinations within 300 to 500 m. These destinations include open spaces, businesses, leisure and recreational facilities, and entertainment and cultural activities.

However, to further improve the project design from urban planning and spatial point of view, SSTEC decision-makers should consider these recommendations as the project moves forward:

- ***Spatial Structure and Urban Design.*** Though the spatial structure of SSTEC makes good sense from the point of view of transit-oriented development, the decision to follow the existing Chinese approach of adopting a 400 by 400 m minimum block size poses risks to realizing the vibrant and walk-able community envisioned by the project. It is recommended that some of the 400m blocks be divided into smaller units. On this point, traditional block sizes in the vibrant older neighborhoods of Chinese cities can offer good benchmarks for such urban design. In addition to adding variety to the existing scheme, experimenting with alternate block sizes during SSTEC's first phase would provide examples that could be evaluated and incorporated into designs considered for phase II and III.
- ***Integrated Urban Planning.*** As mentioned earlier in the chapter, integrating urban planning and management is challenging. Though the current plan has promoted integration in transport and land use, additional exploration of possibilities for integrating energy, water, and waste systems should be considered (see the Stockholm case). Typically, the optimization of water and energy systems can realize significant benefits, as is explored in more detail later in this report. Integrating land use planning and water system designs is also particularly important, as the efficiency of pumping water depends on where water treatment facilities are situated in relation to demand (a function of land use planning). The SSTEC project has a basic institutional structure in place that can form the basis for good integrated planning and potentially lead to efficiency gains across sectors. Given this setup, SSTEC should, as the master plan is implemented, look for opportunities for cross-sector collaboration to ensure that efficiency gains will actually manifest during implementation.

- ***Phased Development.*** Currently, SSTEC's phased development does not incorporate formal processes for evaluating the lessons of previous phases. It is broadly assumed that SSTEC's overall plan will remain unaltered through the project's development. At the same time, there is no built-in evaluation system or criteria to assess the effectiveness of the institutional and contractual processes related to land development and administration. SSTEC should consider developing a more detailed strategy that capitalizes on SSTEC's phased development schedule and supports integration of key lessons learned. By doing so, SSTEC can realize the benefits of incremental planning and mitigate the risks associated with new town development. This may entail revisiting the master plan at key intervals, and supporting more flexibility and adaptability in project development.

## Chapter III
# Energy Sector Overview

## Introduction

The energy sector is particularly important in urban planning because of its cross-cutting nature and multi-dimensional objectives. Without access to secure, reliable, and affordable energy, cities cannot prosper. Meanwhile, cities experience major environmental impacts, including, inter alia, air pollution and climate change, by consuming energy derived from fossil fuels. Cities such as the SSTEC, which aspire to socio-economic prosperity and environmental sustainability, must actively pursue energy efficiency across all urban sectors, optimize energy supply based on demand patterns and available energy sources, and engender conservation among citizens and institutions.

This chapter will review SSTEC's current plan for the energy sector against national and international practices, highlight issues that may require attention, and recommend actions that could strengthen the plan and its implementation. It is composed of five main sections: (1) overview of the current energy plan; (2) review of key performance indicators and sector specific objectives; (3) analysis of the energy plan from technical perspectives; (4) analysis of the energy plan from policy perspectives; and (5) summary and conclusions.

## Sector Overview

SSTEC has a two-pronged sustainable energy strategy that seeks to minimize energy demand and maximize the use of cleaner and renewable energy supplies. It prioritizes renewable energy as an important supplement to conventional energy sources, and plans to enhance energy efficiency by applying new energy, green building, and green transport technologies. It also strives to achieve a balance between district and distributed (decentralized) heating and cooling. To implement such a strategy, the first step is to understand the expected energy demand pattern in SSTEC, which depends on the setup of the city.

***Projected economic profile.*** As explained in Chapter II, SSTEC is expected to host a population of 350,000 permanent residents and 90,000 temporary residents in an area of 34 $km^2$ by 2020. It will attract high value-added, environmental friendly, and energy efficient industries. Most of SSTEC's economy by 2020 will be based on the service industry and light manufacturing, focusing on environment-related services and green technologies. With such an economic profile, SSTEC is expected to have considerably lower energy intensity[76] compared to Tianjin city, which has a significant share of energy-intensive heavy industries.

***Projected energy use patterns.*** Given SSTEC's projected land use, land area, and energy load, the annual energy demand in SSTEC is expected to reach 486,900 tons of Standard Coal Equivalent (SCE) by 2020. 80 percent of the demand will be attributable to buildings (46 percent from residential buildings, and 34 percent from commercial buildings[77]), and the remaining 20 percent to industries and transportation. Because of SSTECs economic structure, the share of energy consumed by buildings is much higher than the national average, which was over 25 percent in 2006 and is expected to increase to 40 percent by 2020.[78] The success of SSTEC's sustainable energy strategy will therefore largely depend on how well it is realized in buildings, especially with respect to the heating and cooling subsectors.

***Energy Supply.*** SSTEC plans to supply 80 percent of its total energy from conventional energy sources, and 20 percent from renewable energy sources. The main pillar of SSTEC's strategy is to rely on two Combined Heat and Power (CHP) plants: the Tianjin Beijiang CHP plant and Tianjin Beitang CHP plant. Both plants will supply electricity to the national grid and heat to SSTEC. The grid in turn will supply most of SSTEC's electricity. Heat will be supplied as hot water delivered in two transmission pipes into SSTEC. Natural gas will be supplied from Gansu and Shaanxi provinces, an, in the long term, from abroad. A gas distribution network will cover the whole city, and will be laid parallel to the district heating network. Most natural gas delivered to the non-industrial sectors will be used domestically for cooking and hot water.

About 16.32 million $m^2$ of the total building area in SSTEC will require space heating and cooling. Projections indicate that 12.32 million $m^2$ will be heated by the two CHP plants, representing a combined heating load of 509MW. The remaining 4 million $m^2$ are expected to be heated from local geothermal energy and heat pumps. Most of SSTEC's demand for cooling will be met by electric air conditioning, either through central HVAC (heating, ventilation, air conditioning) systems or room units. Plans call for a total of 2.58 million $m^2$ of floor area to receive district cooling using absorption chiller technology linked to the district heating network. Another 300,000 $m^2$ are expected to use natural gas-fired electricity, heating, and cooling tri-generation system.

Renewable energy will mainly be used for heating, cooling, domestic hot water, and street lighting. Located in the central and northern coastal geothermal field, SSTEC is relatively rich in geothermal heat. Geothermal energy and heat pumps will account for 69.1 percent of SSTEC's total renewable energy, and will be used for heating and cooling supply. Solar energy will account for 30.7 percent of total renewable energy, and will play a central role in domestic hot water preparation and street lighting. Wind resources in and near SSTEC are insufficient to justify large-scale application.

***Green buildings.*** All buildings in SSTEC are required to be "green buildings" based on the SSTEC Green Building Evaluation Standard (GBES), which was developed by the Tianjin Construction Commission with guidance from the Ministry of Housing, Urban, and Rural Construction. According to the GBES, nominal energy use for heating residential buildings is required to be at least 65 percent less (and at least 50 percent less for all public buildings) than those constructed in early 1980s.[79] In addition, the GBES specifies that heating/cooling systems and lighting and building appliances should use highly energy-efficient equipment and systems. The GBES requires that renewable energy should make up 10 percent of energy consumption in residential buildings, and 15 percent of energy consumption in public buildings.

## Key Performance Indicators

Key performance indicators (KPIs) have been developed to guide the planning and construction of SSTEC and to monitor and evaluate the progress of SSTEC's development. As shown in Table 3.1, the following KPIs are directly related to the energy sector:

- Carbon emissions per unit GDP: 150 tons per one million US$, compared to the United States' national target of 122 tons by 2012, and China's national average of 750 tons in 2004.
- Proportion of green buildings: 100 percent. The percent of green buildings in new construction was practically zero in Tianjin in 2008.
- Usage of renewable energy: share of renewable energy in energy supply shall be at least 20 percent, compared to the national target of 15 percent by 2020.
- Central heating coverage: 100 percent as compared to Tianjin's target of 90 percent by 2015.

Table 3.1: Energy Sector: Key Performance Indicators

| KPI Area and Details | Indicative Value | Timeframe | Domestic Standards | Domestic Benchmarks | International Benchmarks |
|---|---|---|---|---|---|
| Proportion of green buildings[80] | 100 % | Immediate | • National Standard for Green Building GB 50378-2006<br>• Technical Manual for Green Building Evaluation<br>• Garden City Standard: ≥50% energy-efficient buildings and green buildings | • China: less than 1% (current); 100% for Olympics buildings.<br>• Energy-efficient buildings: 16% of existing buildings in cities and towns (2008); 71% of newly built buildings (2007).<br>• BJ: energy efficient buildings: 49.93% of existing buildings | • Singapore: building area exceeding 2,000 $m^2$ should be 100% green building. |
| Carbon emission per unit GDP | 150 ton-C per one million US dollars | Immediate | • No national standard | • National Average: 750 (2004 | Country-wide targets by 2012:<br>• USA: 122<br>• Japan: 59<br>• EU: 103<br>Singapore in 2006: 350 |
| Services network coverage | 100 % | By 2013 | By 2013 Central Heating:<br>• Eco-City Standard: 65%Gas:<br>• Garden City Standard[81] 80% | Central Heating:<br>• TJ: 83.2% (2005); TJ Plan: ≥85% (by 2010); ≥90 (by 2015)<br>• BHNA: 75% (2005); ≥88% (by 2010) | - |
| Renewable energy usage | ≥ 20 % | By 2020 | • No national standard | • China: 7% (current): Plan: 10% (by 2010); 15% (by 2020);<br>• BJ Plan: 4% (by 2010); Olympics venue: 26.9% (2008)<br>• Caofeidian Eco-City Plan: 50% (by 2020) | • Finland: 25%;<br>• Sweden: 33.3%;<br>• Holland: 20% (by 2020);<br>• EU: 20% (by 2020). |

These broad energy-related KPIs are useful in providing general guidance for SSTEC's economic planning and particularly energy planning. It is indicative that SSTEC will pursue a service-oriented and knowledge-based growth strategy, strictly enforce green building standards, make extra effort to promote renewable energy, and rely on modern district heating systems. Generally speaking, these goals represent a more explicit focus on minimizing environmental impacts of urban development compared to prevailing practices in Tianjin and comparable cities.

However, the Carbon Emission per unit GDP indicator is less indicative when applied to a small city than to a region or nation because it embodies (or aggregates) many economic and energy characteristics that are better captured at a regional or national level. In particular, SSTEC will be dominated by high valued-added and energy-efficient industries, and is expected to have significantly lower carbon emissions per GDP compared to cities with high shares of heavy industries. Therefore, comparisons using this indicator should be carefully undertaken and may be more meaningful vis-à-vis cities and regions with similar economic structures and climate conditions. To give a more complete picture, an additional indicator such as carbon emissions per capita may be useful to capture population density effect.

The Central Heating Coverage indicator may also be misleading since it is traditionally used as an indicator measuring penetration of modern district heating systems in northern Chinese cities. However, in the case of Tianjin, and SSTEC in particular, there is significant potential to develop equally clean or cleaner distributed heating options, such as geothermal and gas-fired tri-generation. Thus SSTEC's target of attainting 100 percent coverage of central heating does not indicate an innovative part of the heat supply and masks the most interesting part of SSTEC's heating system. Since centralized heating already is a norm for new buildings in northern Chinese cities, an alternative indicator measuring the modernity and sustainability of space heating might be the percent of space heating provided by non-coal-fired technologies (although the electricity used by geothermal and heat pump systems may still be derived from coal-fired power plants).

SSTEC has developed other important quantitative sector targets in heating/cooling efficiency, renewable energy usage in heating/cooling systems, solar energy use, and natural gas usage (Table 3.2). The targets for renewable energy penetration in the relevant applications are ambitious compared to practices in Tianjin. It is important to keep in mind that such penetration targets should be pursued only if they make economic sense.

Table 3.2: Additional Quantitative Objectives of Energy Sector Plan of SSTEC

| Indicator | Indicative Value |
|---|---|
| Heating energy saving of residential buildings | ≥ 70%(compared the current Tianjin standard of 65%) |
| Heating/cooling energy saving of public buildings | ≥ 55%(compared with the current Tianjin standard of 50%) |
| Renewable energy usage in heating/cooling systems | ≥40% of building floor area |
| Solar energy usage in hot water system | ≥ 80% of building floor area |
| Solar energy usage in road/landscape lighting system | ≥ 90% |
| Natural gas usage in residential and public buildings | 100% of buildings |

## Analysis of the Energy Sector Plans -Technical Perspective

This section reviews the three key technical aspects of SSTEC's energy plan: (1) reducing energy demand through green buildings, (2) increasing cleaner energy supplies, especially for heating, cooling, and domestic hot water, and (3) achieving an overall 20 percent renewable energy share of total energy consumption by 2020.

### Green Buildings

A "green building" is a broad concept intended to consolidate key elements of sustainable practices in building design, construction, operation, and decommissioning to minimize a building's environmental impacts over its life cycle. The focus areas usually include energy efficiency, water conservation, indoor air quality, building materials, site management, and operations. This discussion focuses on the energy efficiency of green buildings, which is linked to all energy consuming activities of a building and factors affecting their efficiency.

***National Context.*** Buildings are major energy users in China. In 2006, buildings contributed more than 25 percent of China's total energy use. Nearly half the world's new buildings are built in China each year. Buildings are projected to account for 40 percent of the country's total energy consumption by 2020. The thermal integrity of a building—its ability to prevent heat loss in winter and heat gains in summer—has been a major focus of China's effort to improve energy efficiency. Much of the existing stock of residential buildings in northern Chinese cities could consume twice as much energy to achieve the same level of thermal comfort as similar residential buildings in developed countries under similar weather conditions. A number of national building codes, standards, and regulations have been issued to help improve the thermal integrity of buildings[82] In particular, to create a voluntary rating system that encourages green development, the Ministry of Housing and Urban Rural Development issued in 2006 the *Green Building Evaluation Standard (GB 50378-2006),* and detailed technical rules to establish an evaluation system for green buildings. China also has minimum energy efficiency performance standards for lighting devices, major appliances, office equipment, and other important energy-consuming equipment.

***Tianjin Context.*** In building-related energy efficiency, Tianjin is already a leader in China. The *Tianjin Energy Efficiency Design Standard for Residential Buildings,* issued in 2005 and revised in 2007, already exceeds the current national standard. For example, the Tianjin standard requires a 65 percent reduction in energy consumption for heating (compared to the national design standard of residential buildings in 1980-1981), while the current national standard requires a 50 percent reduction.

***SSTEC GBES.*** According to the KPIs, 100 percent of SSTEC's buildings will be green buildings in line with the SSTEC GBES, which is based on green building practices in both China and Singapore, and aims to be more systematic, advanced, practical, and instructional. *How does the SSTEC GBES compare to the National GBES, the current building standards, and the international building systems?*

## Comparison of SSTEC GBES with the National GBES

***Structure.*** The SSTEC GBES follows the same structure of the National GBES. Separate standards are developed for residential buildings and commercial buildings, and both include six categories that cover the life cycle of buildings: (1) Land conservation and outdoor environment, (2) Energy conservation and utilization of energy resources, (3) Water conservation and utilization of water resources, (4) Materials conservation and utilization of materials resources, (5) Indoor environment quality, and (6) Operation and management.

***Rating system.*** The rating system for the SSTEC GBES is slightly different than in the National GBES. In the National GBES, the performance standards under each category are classified into three parts: prerequisite, general elective, and preferred elective. All prerequisite items have to be met to qualify as a green building. Based on general elective and preferred elective items, a green building can be rated as one-star, two-star, or three-star. The rating system for SSTEC is similar to the United States' Leadership in Energy and Environmental Design (LEED) rating process. Under each category of LEED, the performance standards are classified into prerequisites and credits. Prerequisite items are required to qualify as a green building, and credit items are used to assign awards in three categories: silver, gold, and platinum. Instead of counting the credit items that are met, a continuous rating method is used. Each credit item is rated based on a formula specified in the rating guidelines. In addition, a set of weights are applied to each category to reflect their relative importance. For example, category two "energy conservation and utilization of energy resources" has the highest weight of 0.3. To encourage advanced technology, materials, and design concepts that are not specified in the evaluation guidelines, the rating system also includes an innovation bonus—a maximum of 10 extra innovation points that can be added to the total score.

***Advancement.*** SSTEC's GBES is intended to be more advanced than the National GBES. It includes some of the general elective or even preferred elective items in the National GBES in its prerequisite items. In particular, SSTEC GBES sets higher standards in plant coverage, renewable energy use, non-conventional water resource use, and wall material use. A more detailed comparison of the prerequisite items in both SSTEC GBES and National GBES for residential buildings is presented in Table 3.3.

## Comparison of SSTEC GBES with national and local building standards

A comparison of SSTEC GBES and the National GBES shows that SSTEC GBES is more stringent. However, as shown in Table 3.3, the prerequisite items in SSTEC GBES still largely refer to national and local building standards and regulations. In other words, all new buildings in Tianjin should meet those standards whether they are "green" or not. For example, the building energy efficiency requirement in SSTEC GBES uses the Tianjin Residential Building Energy Efficiency Design Standard, which applies to all new residential buildings in Tianjin. One would expect that a green building should attain a higher level of performance than the existing mandatory standards.

On the other hand, compliance with building codes is poor in China. The MoHURD discovered in recent nationwide inspections that 30 percent of projects under construction did not meet the national building energy efficiency standards.[83] Given that many Chinese buildings do not currently comply with mandatory building energy codes because of perceived higher costs, developers and owners may not respond well to stringent voluntary requirements for green buildings. In that sense, setting basic requirements in SSTEC GBES that are not far above the current building standards may be more realistic, since all buildings in SSTEC are required to be green buildings. After all, the green building program is not static, and should be adjusted to changes in national and local standards. Though all buildings in SSTEC are required to be basic green buildings, there are no clear targets above and beyond the basic requirement. The success of SSTEC's green building program will be measured by the quantity of silver, gold, and platinum buildings. It is important to ensure that all the basic requirements are met. But the real challenge to SSTEC is to incentivize building developers and owners to exceed the basic requirements, a topic which will be discussed later in this chapter.

### How does SSTEC GBES compare to international building rating systems?

Structurally, SSTEC GBES is similar to major international building rating systems, which are all credit-based systems. Given that LEED is well known, and has been used in China,[84] LEED is an example for more detailed comparison with SSTEC's GBES. Compared to LEED, SSTEC's GBES shares the same categories, except that SSTEC GBES has an additional category on operations and management that is actually a very important area for sustainable buildings in China. In terms of processes, the following two aspects are worthy of discussion.

***Time of rating.*** A rating can only be awarded after one year of property operation based on SSTEC's GBES, while the LEED Core and Shell system allows developers to submit their designs and achieve "pre-certification" before buildings are built. The post-facto certification system in SSTEC GBES is able to ensure that the predicted energy savings are actually achieved. This is especially important since compliance with building codes is poor in China, as discussed above. The "pre-certification" system, however, allows developers to capture some of the benefits of going green by getting higher rents and quicker leases, and ultimately drives more developers to build green. The two systems can work together and complement each other, so SSTEC's GBES may also consider adding a "pre-certification" system.

***Administration of the rating system.*** In the LEED system, LEED-accredited professionals help to administer the design and construction and an "unknown" third party evaluates the submitted LEED documentation. SSTEC's GBES notes that the quantitative items will be evaluated by the third party certified by SSTEC Green Building Evaluation Committee (GBEC) and the final award will be determined by GBEC. However, it is not clear who will be responsible for the evaluation of qualitative items, and how to ensure the quality of evaluation. Evaluating and certifying all the aspects of SSTES GBES for all buildings in SSTEC will require significant skilled manpower. One reason that China has poor building code compliance is that the local government does not have sufficient staff to oversee the compliance, especially for the energy efficiency component. It is suggested that SSTEC can adopt an accreditation program similar to the LEED Professional Accreditation program to train and accredit people to do the work.

In terms of content, while GBES covers key aspects of the life cycle of buildings, more detailed comparisons are conducted in the category of energy conservation. The following differences are worthy of discussions and are of particular interest to SSTEC.

***Energy commissioning.*** Energy commissioning is required in LEED, while no such requirement has been defined in SSTEC's GBES. Energy commissioning is used to verify that the project's energy-related systems are installed, and calibrated to perform according to the project requirements, basis of design, and construction documents. Energy commissioning has multiple benefits including reduced energy use, lower operating costs, fewer contractor callbacks, better building documentation, increased occupant productivity, and improved verification that the systems perform in accordance with project requirements. A recent study shows that projects with a comprehensive approach to commissioning

Table 3.3: Comparison of SSTEC GBES and National GBES for Residential Buildings

| Category | SSTEC GBES | National GBES | Current Tianjin Requirements** |
|---|---|---|---|
| Land conservation and outdoor environment | | | |
| Per capita land occupation | Low rise: <43m$^2$, mid to high rise: <24m$^2$, high rise: <15m$^2$ | NSR* | NSR |
| Green coverage | >=35%, >=2 m$^2$ per capita | >=30%, 1-2 m$^2$ per capita | NSR |
| Roof green coverage | >=10% | NSR | NSR |
| Public transportation | Less than 500 m walking distance | General elective item | NSR |
| Other items such as flood and radiation protection, day lighting and natural ventilation, and noise limit. | Refer to national standards | Refer to national standards. Standard on noise is a general elective item. | National standards |
| Energy conservation and utilization of energy resources | | | |
| Building energy efficiency | Refer to Tianjin standard | Refer to national standard and local standards. | Tianjin standard: 65% heating energy savings |
| Sunlight hours | Two hours during the "Severe Cold Day." | same | same |
| Renewable energy | 10% of the total building energy consumption | General elective item: 5% of the total building energy consumption; Preferred elective item: 10%. | NSR |
| Lighting | Refers to national standard | General elective item | National standard |
| Water conservation and utilization of water resources | | | |
| Utilization rate of non conventional water resources | No lower than 20% by 2012. | General elective item: no lower than 10%. | NSR |
| Other items such as water system design, water conservation equipment, use of non-conventional water. | Refer to national and Tianjin standards and regulations | Qualitative descriptions and many are general elective items | National and Tianjin standards and regulations |
| Materials conservation and utilization of materials resources | | | |
| Wall materials | Use of clay cannot exceed 20%. | NSR | NSR |
| Limitation on toxic contents in building materials | Refers to national standards | Refers to national standards | National standards |
| Indoor environment quality | | | |
| Heat engineering | Refers to national standards | General elective item | National standards |
| Temperature control | Indoor temperature can be controlled when heating or air conditioning is used. | General elective item | Same as in SSTEC GBES |
| Other items such as day lighting, indoor air quality, and building accessibility. | Refer to national standards | Refer to national standards | National standards |
| Operation and management | | | |
| Building intellectual system | Includes security, telephone, cable TV, internet, and operation and management system. Refer to national standards | General elective item | National standards |

*NSR: No specific requirement
**Current requirements in Tianjin need to be checked with Tianjin

attained nearly twice the overall median level of savings and five times the savings of the least thorough projects.[85] Adding this process to SSTEC's GBES is important because it not only helps to ensure that basic requirements for green buildings are met, but also is a risk-management strategy that detects and corrects problems that would eventually surface as far more costly maintenance or safety issues.

***Energy performance requirements for major energy end-uses.*** For energy efficiency, SSTEC GBES does not have clearly defined requirements for other energy systems besides building envelope and central heating. This is especially true for residential buildings. Criteria need to be developed for at least the following: (i) lighting; (ii) air conditioning; (iii) water heating; (iv) appliances; and (v) controls. The following are examples of the specific requirements used for LEED certification. The specific requirements for major energy end-uses suitable to SSTEC condition need to be developed.

- Lighting standard - 0.7 watt/sq. ft. to 1.0 watt/sq. ft.
- Air Conditioning - Seasonal Energy Efficiency Ratio[86] 12.0 to 15.0
- Water heating - Instantaneous gas - over 90 percent efficient.
- Tank heater - at least 80 percent efficient

Another area that the GBES has not mentioned is behavior-based energy efficiency. The American Council for an Energy Efficient Economy estimates that around 25 percent of total energy demand could be eliminated through behavior-based energy efficiency improvements.[87] After all, people demand energy services. How to incorporate behavior-based energy efficiency in green buildings in SSTEC and how to motivate developers to build green and residents to live green are issues that will be discussed in the next section.

## Energy Supply

***Overall structure.*** The energy supply strategy is based on a mix of fossil fuels and renewable energy and a mix of conventional but more energy-efficient technologies (e.g., CHP) and non- conventional technologies (e.g., heat pumps, solar water heaters, tri-generation). The overall structure of the SSTEC energy system is illustrated in Figure 3.1. As electricity comes from the national grid, and gas supply follows conventional design, the most important aspects of the energy supply system in SSTEC are how to optimize district heating/cooling systems and how to make economic use of renewable energy.

### Space Heating and Cooling

***Objectives.*** Space heating and cooling account for the largest parts of energy use in SSTEC's buildings. The strategy of the SSTEC heat plan is to utilize waste heat from the CHP plants, to prioritize renewable energy, and to improve system efficiency. The heat plan has set the following quantitative objectives that exceed current normal practices (Table 3.4).

***Heating/cooling supply.*** All buildings in SSTEC will be covered by central heating. The projected heat load of SSTEC in 2020 is about 800 MW, based on the residential building load of 38W/m$^2$ and the public/industrial building load of 50W/m$^2$. Of the total heat load, 75.49 percent will be covered through a district heating network supported by two external coal-fired CHP plants. The remaining 24.51 percent of the total heat load will be provided by distributed systems with internal sources in SSTEC, including renewable energy, such as geothermal and heat pumps, and tri-gen (electricity, heating, and cooling) systems. The heating area and proportions of various types of heat sources are shown in Table 3.5. Using the district heating network, a district cooling system is also planned to provide a cooling area of 2.58 million m$^2$. The rest of the cooling energy demand in SSTEC will be supplied by electricity.

***Analysis.*** Although the heat plan set an objective to exceed the current normal practice, the review finds that the district heating system in the current plan essentially follows conventional Chinese design standards. Instead of using the traditional DH scheme in China, SSTEC should consider learning from international best practice and piloting a DH scheme that could be more energy efficient. The following are options that are worth considering, and in some cases, a life-cycle cost analysis should be carried out to determine which option is better.

Figure 3.1: Simplified Scheme of the Energy System of SSTEC

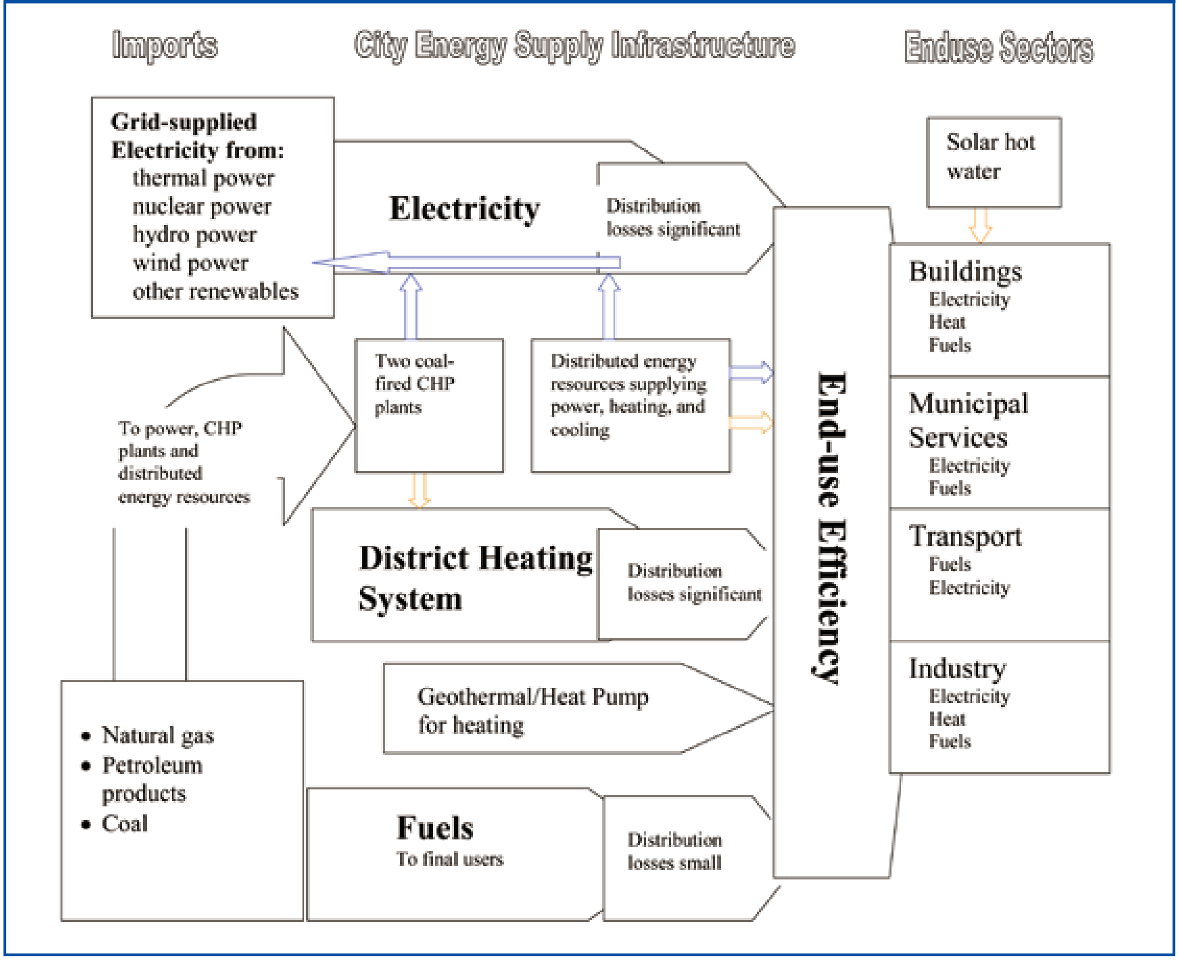



Table 3.4: Objectives of Heat Supply in SSTEC

| Contents | Normal Practice | SSTEC | Note |
|---|---|---|---|
| Coverage rate of heat supply (%) | / | 100 | All areas |
| Proportion of heat supply by renewable energy (%) | / | 15 | Geothermal energy, heat pump, solar energy, etc. |
| Building Design Heat Load (W/m$^2$) | | | All buildings should meet the energy-saving requirements. |
| Residential | 55 | 38 | |
| Public | 70 | 50 | |
| Industrial | 70 | 50 | |
| Network loss (%) | 5 | 2 | Hot water network |
| Utilization rate of condensed water (%) | / | 100 | - |

Source: SSTEC Heating Plan.

Table 3.5: Sources, Types and Capacity of Heating System of SSTEC

| Heat Source | | | Heating Area (1,000m²) | | | Proportion (%) | Energy saving |
|---|---|---|---|---|---|---|---|
| | | | 2010 | 2015 | 2020 | | |
| External | Steam of power plant | Beitang Heat-Power Plant [88] | 0 | 2190 | 7320 | 62.93 | equivalent to annual savings of 93,000 tons of standard coal through green building design and efficient distribution network |
| | | Beijiang Power Plant [89] | 2640 | 2950 | 2950 | | |
| | | Subtotal | 2640 | 5140 | 10270 | | |
| | Waste heat of power plants | Beitant Heat-Power Plant | 0 | 440 | 1460 | 12.56 | equivalent to annual savings of 35,000 tons of standard coal |
| | | Beijiang Power Plant | 530 | 590 | 590 | | |
| | | Subtotal | 530 | 1030 | 2050 | | |
| | Subtotal | | 3170 | 6170 | 12320 | 75.49 | |
| Internal | Renewable energy | Geothermal [90] | 220 | 220 | 600 | 22.67 | equivalent to annual savings of 119,000 tons of standard coal |
| | | Water-source heat pumps | 300 | 300 | 600 | | |
| | | Sewage-source heat pumps | 490 | 590 | 920 | | |
| | | Ground-source heat pumps | 800 | 1160 | 1500 | | |
| | | Road energy system [91] | 80 | 80 | 80 | | |
| | | Subtotal | 1890 | 2350 | 3700 | | |
| | Electricity, heating/cooling tri-generation system/gas | | 200 | 300 | 300 | 1.84 | equivalent to annual savings of 11,000 tons of standard coal |
| | Subtotal | | 2090 | 2650 | 4000 | 24.51 | |
| Total | | | 5260 | 8820 | 16320 | 100 | equivalent to annual savings of 258,000 tons of standard coal |

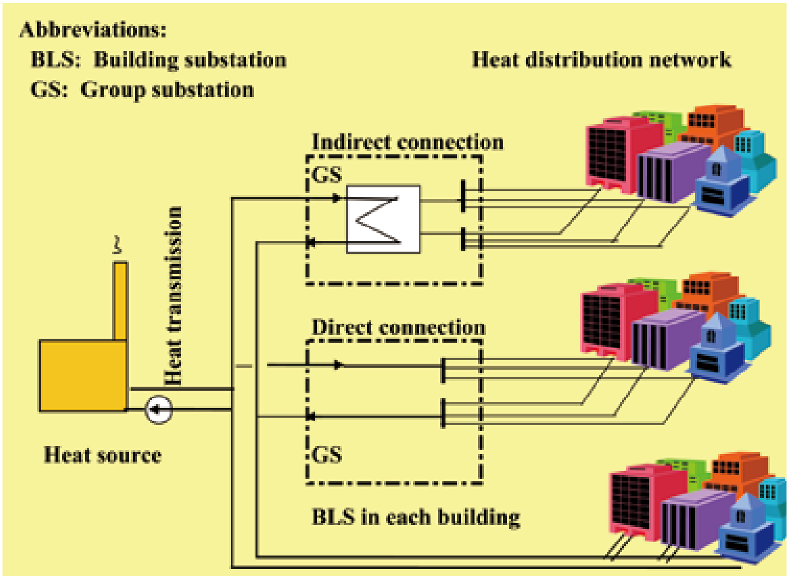
Source: SSTEC Heating Plan

***Low temperature system.*** Instead of using high temperature levels for heat supply, the option would be to use low water temperatures. For example, a low temperature system could use 65/xxoC as the water temperature to supply and return water to and from DH, instead of the planned 130/70oC. The “xx” temperature level depends on the size of radiators in rooms and the extent of floor heating in buildings. Low temperatures would reduce thermal network losses and eliminate some negative impacts on power generation associated with high temperatures. The pipelines of the network, however, would be larger (the diameter also depends on the “xx” temperature).

A low temperature system is a matured technology that is often used to utilize industrial waste heat (for instance, from a steel mill) to warm up buildings. Currently, there are plans in Shandong province (Weihai) to convert existing high temperature DH systems to low temperature ones.

***Group substation versus building-level substation.*** As is common elsewhere in China, SSTEC plans to have group substations serving a number of buildings. An alternative is to use a building substation installed in each single building or, in larger buildings, in each staircase. Figure 3.2 illustrates a simplified scheme of different substations. Building substations can improve energy efficiency by reducing electricity used for pumping and fuel used for heating. In addition, building substations permit better control of heat for respective buildings and consequently lower energy demand. An additional advantage is that return temperature can fall to 40-50 oC. As DH comes from the CHP plant, the return temperature has an important impact on efficiency, as lower return temperatures reduce the electricity losses in the turbine in the CHP plant (as discussed above in low-temperature system). To further reduce the return temperature, a cascade heating system could be considered. The cascade system would use the return water from one building as supply water for a next building that is equipped for a low-temperature heating system (e.g., floor heating). An illustrative example of life cycle cost-benefit analysis shows that

Figure 3.2: Scheme of District Heating Substations




although the initial investment cost is about 3 percent higher, using building substations can reduce life cycle cost by 25 percent compared to using group substations (detailed assumptions and calculations are shown in Boxes 8.4 and 8.5 in Chapter VIII).

The building-level substations represent common practice in Europe. Many European countries in transition are converting group substation dominated systems to building level substations. In Liaoning province, the World Bank-financed Liaoning Medium-size City Infrastructure Project III focuses on piloting building level substations in nine locations. The first substations will be installed in 2009.

***Optimal share of CHP and peak boilers.*** In the current heat plan, it is not clear whether all hot water delivered to the DH system will be produced in CHP mode, or whether a part will come from peak boilers. A cost-effective alternative option to supplying heat from co-generation in the CHP plants is to supply a base load from CHP, but meet peak load demand from heat-only boilers. Such a concept would allow the downsizing of the capacity of the CHP plant or production of more electricity, potentially yielding significant cost savings. It is understood that CHP plants are not part of SSTEC, and it may be institutionally challenging for SSTEC to decide the optimal share of CHP and peak boilers. However, integrated planning should be used as much as possible to achieve better system efficiency.

Use of DH system for cooling. An energy efficient and viable option for cooling is the utilization of hot water from the DH system as an energy source for absorption chillers. The current energy plan includes a district cooling system that would use the district heating network. The district cooling system is expected to provide a cooling area of 2.58 million $m^2$, about 20 percent of the total expected cooling area. However, the specific technologies and implementation plans are not clear. Such a system (i.e., the utilization of hot water from the DH system as an energy source for absorption chillers) could either be centralized or decentralized. A centralized system would produce cooling in the CHP plant (or at the city entry) and would require a separate network for distribution. The decentralized option would install chillers at end user facilities. Both options are highly efficient and use only a fraction of the electricity consumed by conventional cooling systems, but the decentralized option requires less investment costs. An additional benefit of such a cooling system would be reduced electricity peaks in summer time. Such a system would result in a substantial reduction of energy consumption. Separate generation of electricity, heating, and cooling would require about 50 percent more fuel energy. SSTEC may consider expanding this option if the operation works well in the Start-up Area.

## Renewable Energy

SSTEC has set an ambitious target that its total energy supply will comprise at least 20 percent of renewable energy. The strategy is to use geothermal sources and heat pumps for heating and cooling, and solar power for hot water and street lighting. Since SSTEC does not have abundant wind resources, wind power will be small scale and strictly demonstrational.

***Geothermal and heat pumps.*** Tianjin is relatively rich in geothermal heat. Geothermal and heat pumps are expected to provide space heating for 22.67 percent of the total heated floor areas in SSTEC. Although geothermal heat is considered renewable energy, electric power needed to pump such heat is neither renewable nor fully carbon free in China. The marginal power used for heat pumps is mostly generated by power plants fueled by coal. Therefore, heat supplied by geothermal and heat pumps cannot be fully treated as carbon-free renewable energy. For example, based on technical specifications in SSTEC heating plan, it is estimated that 38 percent of heat provided by the ground water heat pump system has carbon content.

Solar hot water system. Solar powered hot water will play a major role in achieving the renewable target. 60 percent of residential hot water supply will use solar water heaters, with a solar collector area of 320,000 $m^2$ providing about 1.85 million MJ of heat, equivalent to annual savings of 49,000 tons of standard coal. According to the sector plan, hotels, hospitals, and other public buildings in SSTEC should apply central hot water supply systems. Solar hot water is not only environmental friendly, but also cost effective. As shown in Table 3.6, compared to other options of using gas, electricity, or oil, solar hot water has the lowest cost in SSTEC. However, one concern is that the surface area of roofs may not be sufficient for solar panels.

Table 3.6: Comparison of Domestic Hot Water Sources

| DHW | | Solar | Gas | Electric | Oil |
|---|---|---|---|---|---|
| Consumption | $m^3/d$ | 4 | 4 | 4 | 4 |
| Temperature | oC | 45 | 45 | 45 | 45 |
| Duration | years | 15 | 10 | 10 | 5 |
| Investment | k RMB | 150 | 102 | 102 | 150 |
| Capital costs | RMB/d | 27 | 28 | 28 | 82 |
| Energy | kWh | 230 | 230 | 230 | 230 |
| Energy costs | RMB | 0 | 20 | 96 | 82 |
| Price of DHW | $RMB/m^3$ | 6.87 | 11.96 | 31.02 | 41.20 |

Source: Calculated based on the assumptions in the SSTEC's heating plan

Since sunshine is not always available, an alternative fuel such as gas or electricity can be used to complement solar hot water. If a solar hot water system is not used, another cost-effective option is to use the DH network to provide domestic hot water (DHW). If building level substations are installed, one or more heat exchangers can be added to substations. The incremental investment and fuel costs are low. In addition, this would allow year-round operation of the DH system, and provide maintenance benefits. Centralized DH and DHW systems supplied by CHP represent general practices in Europe, and have proven cost effective. SSTEC should consider this option.

***Solar Photovoltaic (PV) powered public lighting system.*** SSTEC plans to use a solar PV system to provide 90 percent of street and landscape lighting. The sector plan, however, does not indicate the cost of PV street lighting and how it compares to other alternatives. One alternative could be a Light Emitting Diode (LED) public lighting system, which is highly efficient and durable and could be more cost-effective on lifetime cost bases.

At this stage, a more detailed renewable energy plan is not yet available. Since SSTEC is not rich in renewable energy resources except for geothermal heat, meeting the 20 percent target for renewable target may be challenging. However, increasing energy efficiency and reducing overall energy consumption can also help to meet the target.

A low temperature system is a matured technology that is often used to utilize industrial waste heat (for instance, from a steel mill) to warm up buildings. Currently, there are plans in Shandong province (Weihai) to convert existing high temperature DH systems to low temperature ones.

## Analysis of the Energy Sector Plans - Policy Perspective

SSTEC has a good start in developing a strong energy plan from the technical perspective, but how to operationalize this plan and achieve the stated objectives depend on effective institutional and implementation arrangementd, and appropriate policies and regulations that ensure sector sustainability. This section focuses on analyzing the energy sector plan from a policy perspective.

### Institutions

The Tianjin Eco-City Energy & Investment Company (the Energy Company) and Tianjin Eco-City Construction & Investment Company owned by the main investors of SSTEC will be responsible for developing efficient and economic energy services. The Energy Company will be responsible for all investments in SSTEC's energy infrastructure, including power distribution, natural gas distribution, district heating, and distributed energy supply systems, such as gas-fired tri-gen (electricity, heating, and cooling) systems and ground-source heat pump systems. Upon construction, these facilities will be leased to and operated by utility companies or independent operators. A major undertaking of the Energy Company will be investments in the heat supply systems in SSTEC, which will include a large district heating network (supported by two coal-fired CHP plants) and many distributed heating systems. The Energy Company is also responsible for a planned district cooling system that utilizes the district heating network. Building level energy connections will be the responsibility of construction companies. Tianjin Eco-City Construction Investment Company will be responsible for construction of all public buildings. Both the Energy Company and the Construction Company are subsidiary companies of the Tianjin Eco-City Investment and Development Company (TECID).

In short, TECID will be a multi-service provider for heat and gas, and the owner of district heating networks and renewable energy facilities. Operation and maintenance will be outsourced to subcontractors, who will receive a fixed fee for their services. Billing and collecting will remain the responsibility of TECID. Having a single multi-service utility gives SSTEC a unique opportunity to apply integrated planning and operation. For example, networks for water, district heating, natural gas, internet, and cable can be constructed together, and utility services for electricity, heating, and water can be metered and billed together. One disadvantage of this setup is that the company may abuse its monopolistic power. To prevent that, a service contract between the municipal government and the company should be carefully prepared, including clearly defined responsibilities and verifiable performance indicators.

### Policy and Regulatory Measures

Policy and regulatory measures seem to focus on the thermal efficiency of buildings, district heating system, and renewable energy use. Experiences from Europe and North America have demonstrated that active policies and regulations supporting energy efficiency on both the demand and supply sides can achieve substantial energy efficiency improvements. Planners should be aware of such measures and try to integrate them into plans.

Minimum energy performance requirements for major energy end-uses. Many countries now have regulations and standards requiring minimum energy efficiency levels for energy-consuming equipment, appliances, and building components. Although SSTEC GBES includes some of those requirements, more requirements need to be developed for other energy systems, in addition to those for building envelope and central heating. In addition, special programs can be initiated to disseminate energy efficiency information, and to incentivize adoption of more energy efficient equipment.

***Mandating solar hot water system.*** SSTEC aims to supply 20 percent of its energy using renewable sources, and 60 percent of residential hot water supply will use solar water heaters. However, it is not clear how these targets will be achieved. Will solar absorbers become mandatory for domestic warm water preparation? As demonstrated by the City of Rizhao in Shandong Province, mandatory installation of solar panels can work, but other policies and measures such as financial incentives, technical assistance, and awareness campaigns should be used to make programs successful (Box 3.1).

### Box 3.1: An Extensive Solar Water Heating Program in Rizhao, China

Rizhao, an urban area with about 350,000 people in northern China, is using solar energy to provide water, heating and lighting. Under a municipal government retrofit program starting in the early 1990s, the city made it mandatory for all buildings to install solar water heaters. After fifteen years of efforts, 99 percent of households in the central district obtained solar water heaters. Solar water heating is now considered common sense. In total, the city has over a half-million $m^2$ of solar water heating panels, the equivalent of about 0.5 megawatts of electric water heaters. Most traffic signals and street and park lights are powered by solar cells, reducing the city's carbon emissions and local pollution. Using a solar water heater for 15 years costs about 1,934 USD (15,000 Yuan) less than running a conventional electric heater, which equates to saving 120 USD per year per household in an area where per capita incomes are lower than the national average.

This achievement is the result of a convergence of three key factors: a regional government policy that promotes and financially supports the research, development, and deployment of solar water heating technologies; a new industry that takes the opportunity in strides; and city leadership that not only has a vision, but also leads in action and brings along other stakeholders.

How does it work?

- Municipal government, the community, and local solar panel industries had a strong political will to adopt this practice.
- Shandong provincial government provided subsidies and funded the research and development of the solar water heater industry.
- The cost of a solar water heater was reduced to the same level as an electric one, about $190, which is 4-5 percent of the annual income of an average household in Rizhao city, and about 8-10 percent of a rural household’s income.
- Panels are simply attached to the exterior of a building. The city assists in the installation of such panels on houses.
- The city raises awareness through community campaigns and education: Rizhao held open seminars and ran public advertising on television.
- The city mandated that all new buildings incorporate solar panels, and oversaw the construction process to ensure proper installations.

Source: State of the World 2007: Our Urban Future, World Watch Institute

***Pricing.*** Using price signals is an effective way to lead energy users toward more energy efficient behaviors. Tianjin is already a leader in reforming heat pricing, from a square-meter based tariff to a two-part consumption-based tariff. SSTEC will adopt consumption-based billing for heating. But it is not clear if this will also apply to cooling if a central cooling system is used. SSTEC currently does not have pricing authority on energy and water. However, due to its unique city profile, SSTEC may want to propose that the Tianjin Pricing Bureau pilot alternative electricity pricing, such as time-of-use electricity pricing.

***Incentive programs.*** People may not like mandates, but they do respond to incentives. Experiences from developed countries have shown that green building incentive programs, such as providing grants, low-interest loans, tax credits, lines of credit, rebates, density bonuses, and technical assistance can motivate people to go green. Table 3.7 depicts a few of the incentive programs for energy efficiency and renewable energy available in the Unites States. One concern about using financial incentives, such as tax credits and grants, is that they may negatively impact a city’s general fund resources. A recent report analyzing economic impacts of the Oregon Energy Tax Credit Program shows that the net benefits

Table 3.7: Example of Incentive Programs for Energy Efficiency/Renewable Energy in the US

| Source | Description, Intended Audience |
|---|---|
| **The Local Government Commission**<br>Financing and Project Assistance for Energy Efficiency in Buildings | The Local Government Commission (LGC) is a nonprofit, nonpartisan, membership organization that provides inspiration, technical assistance, and networking to community leaders who are working to create healthy, walk-able, and resource-efficient communities.<br>For: Government, Consumers, Industry, Nonprofits |
| **California Energy Commission**<br>California's Emerging Renewables Rebate Program | The Emerging Renewables Program provides rebates to consumers who install qualifying renewable energy systems. Through this program, the Energy Commission provides funding to offset the costs of purchasing and installing new renewable energy systems using emerging renewable technologies.<br>For: Consumers, Industry, Nonprofits |
| **Maryland Energy Administration**<br>Green Building Tax Credit | Maryland provides a tax credit for the construction of green building. The credit is worth up to 8 percent of the total cost of the building. Buildings must be located in a priority funding area and be at least 20,000 square feet.<br>For: Industry, Nonprofits |
| **New Jersey Department of Community Affairs' Office of Smart Growth**<br>Smart Future Planning Grant Program | The Smart Future Planning Grant program provides grants to municipalities, counties and non-profit agencies to help plan for the future. The program focuses on seven key categories, including green building.<br>For: Government, Nonprofits |
| **New Resource Bank**<br>Solar Home Equity Financing (California only) | New Resource Bank offers California homeowners Solar Home Equity Loans or Lines of Credit to finance solar power projects.<br>For: Consumers |
| **Arlington , VA : Department of Environmental Services**<br>Green Building Incentive Program | The Green Building Incentive program allows developers to request a slightly larger building than would normally be allowed by County Code if the project receives official LEED certification from the USGBC at one of the four LEED award levels.<br>For: Industry |

Source: Nesmith, W. (2008) An Analysis of Green Building Tax Incentives.

include not only increased tax revenues for state and local government, but also increased output, new jobs, increased wages, and saved energy (Box 3.2). It is understood that tax policy, such as using tax credits, is currently beyond SSTEC's authority, but similar benefits can also be achieved through other incentive programs. Indeed, incentive programs can have very high rates of return.

***Cost of green.*** All buildings in SSTEC are required to be green buildings. This can be challenging if developers are reluctant to implement green building standards because of perceived higher costs. Is building green really more expensive than building non-green? According to the China Real Estate Association, the implementation of energy-saving standards increases property costs by 5-10 percent, and not the average of 17 percent widely quoted by developers.[92] A recent study that compares construction costs of LEED buildings and non-LEED buildings finds that "there is no significant difference in average cost for green buildings as compared to non-green buildings."[93] Therefore, it is important to let developers know that building green does not necessarily cost more, and incorporating sustainable design features into construction can attract more customers and be profitable. The proposed green building demonstration component from the GEF SSTEC project will be particularly useful for this purpose. In addition, providing information and technical assistance, supporting research and development of green industries, and using economies of scale can also reduce the costs of going green.

***Energy performance contracting.*** To achieve the sector objectives of higher energy efficiency and greater shares of renewable energy, the requirements for energy management capacity and incremental initial financing will be high. One option is to promote the use of energy performance contracting. Energy performance contracting is an innovative financing technique that uses cost savings from reduced energy consumption to repay the cost of installing energy conservation measures. Normally offered by Energy Service Companies (ESCOs), this innovative financing technique allows the capture of benefits from energy savings without upfront capital expenses for building owners, since the costs of the energy improvements are borne by the performance contractor and reimbursed by energy savings. Other advantages include the ability to use a single contractor for management and energy audits, and to guarantee energy savings from a selected series of conservation measures. One application of using ESCO and the concept of energy performance contracting in solar energy is called the solar service model. As shown in Box 3.3, under this model, the customer hosts an onsite generation system and buys power but does not own the PV equipment. In addition, this model can be structured to minimize and transfer risk to those entities that can best manage such risks. By eliminating upfront capital expenses and risks to the host customer, this innovative business model can significantly increase the use of PV technologies. Such a model can be applied to public buildings' solar hot water systems in SSTEC. Energy performance contracting is a relatively new concept in Tianjin. Energy planners in SSTEC should help developers to familiarize themselves with the concept and relevant contracting procedures.

***Behavior-based energy efficiency.*** Traditionally, most energy efficiency programs have aimed to accelerate the uptake of technology by providing information and incentives. However, one critical element of energy use is people's behavior, including operating behavior (e.g., turning off lights) and purchasing behavior (e.g., purchasing CFLs). Many experts estimate that at least half of energy use is dependent on operating behavior, rather than specific technologies employed in a home. In fact, researchers have found energy use varies by up to three times in identical houses and four times in apartments across cultures. Therefore, behavior-based energy efficiency programs inform consumers about their current energy uses, request commitments to specific reduction targets, provide tools to meet these targets, and issue regular feedback on progress. Box 3.4 offers more information on approaches that can be used to motivate behavior- based energy efficiency. When properly managed, these programs can dramatically reduce residential energy demand with minimal costs to ratepayers.

### Box 3.2: Economic Impact of Using Energy Tax Credit in Oregon

***What is an energy tax credit?***
Oregon has energy tax credit programs for both business and residents. For the Residential Energy Tax Credit (RETC) program, residents can obtain a maximum credit of US$1,000 (per year) for efficient appliance purchases, a maximum credit of US$1,500 (per year) for installation of renewable energy equipment, and US$1,500 (per year) for the purchase of an alternative fuel or hybrid vehicle. For the Business Energy Tax Credit (BETC) program, the tax credit amount is 35 percent of eligible energy project costs deducted from Oregon income tax liability, and is available to all business, trade, or rental property owners within Oregon.

***How is the net economic impact of the tax credit programs defined?***
The net economic impact is defined as the difference in economic impacts between the tax credit program spending and the Base Case scenario in which the BETC and RETC programs do not exist, and the tax credit funds are assumed to be spent on other Oregon government programs following historical spending patterns.

***What is the net economic impact?***
The combined spending on the BETC and RETC programs for 2006 totaled US$73.8 million for tax credits and program administration. The effect of these tax credits combined with spending by businesses and residences taking advantage of these tax credits had the following net impacts on the Oregon economy in 2006:

- Output in Oregon's economy increased by US$142.7 million
- 1,240 new jobs were created in Oregon
- Oregon wages increased by US$18.6 million
- Tax revenues for state and local government increased by US$10 million
- Oregon commercial and residential energy costs decreased by US$48 million

In addition to the first year spending impacts, the energy savings achieved by the measures covered by these tax credits will continue in subsequent years after the tax credit is paid out. This substantially increases the lifetime benefits of these purchases as most measures covered by these programs have an expected useful equipment life of 15 years or more.

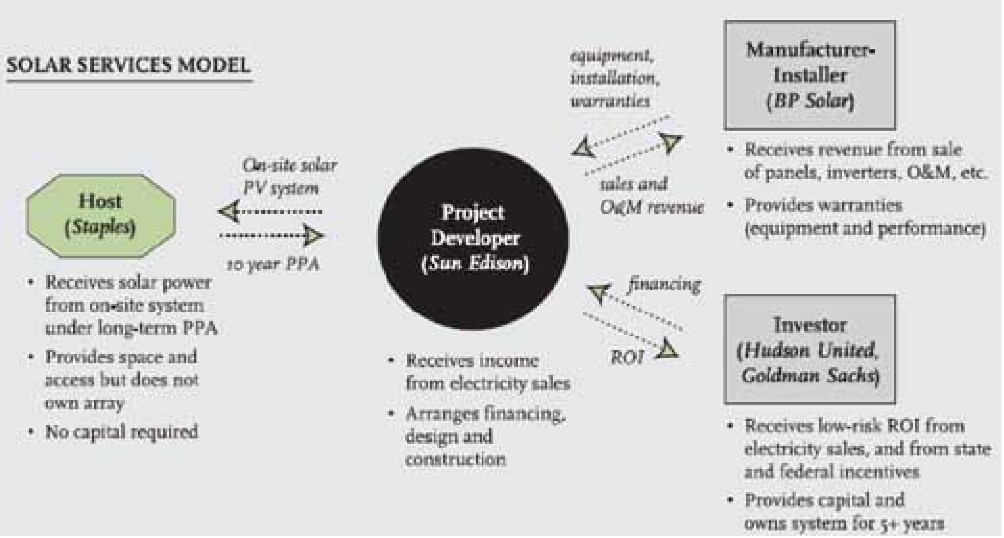
Source: ECONorthwest (2007), Economic Impacts of Oregon Energy Tax Credit Programs in 2006. Report prepared for the Oregon Department of Energy

## Box 3.3: ESCO and Solar Service Model

High capital cost of solar PV is the major barrier to its wide adoption. One way to overcome this is through energy service companies using energy performance contracting, which is known as the solar service model. Under this arrangement, the customer hosts an onsite generation system and buys its power but does not own the PV equipment. By eliminating up-front capital expenses to the host customer, this innovative business model could significantly increase the use of PV technology.

Staples is one of the first major corporations to use such a model for solar power. In 2004, Staples signed contracts with SunEdison, LLC to purchase 10 years worth of solar electricity from two 280-kW on-site solar PV projects at two of its distribution centers in California, which serve about 10 percent of each facility's load. The figure shows how the model worked for Staples. The project developer, SunEdison, arranged the financing, design, equipment supply, and construction of both sites. In return, Staples signed a ten-year, fixed-price power purchase agreement (PPA) with SunEdison, with the option of renewing it in five-year intervals. Hudson United Capital (now TD Banknorth), a financial lender specializing in renewable energy projects, provided construction and senior-term loans, and a Goldman Sachs affiliate supplied the equity. The PV units were manufactured and installed by BP Solar.

This type of model can be structured to minimize risk and transfer risk to those entities that can best manage it. For example, Staples can assign the rights to the PPA to a future tenant or landlord, which allows Staples to transfer its obligations if it vacates the property. In addition, BP Solar offers a performance guarantee that its array will generate a certain number of kilowatt-hours of electricity per year as it is confident of the performance of its equipment. Hudson United and Goldman Sachs receive a low-risk return on their investment through the sale of fixed-price electricity to a financially stable firm and the monetization of renewable energy incentives including depreciation benefits and a federal tax credit.




Source: World Resource Insttitue (2006). Switching to Green: A Renewable Energy Guide for Office and Retail Companies

***Program approach.*** To achieve the best results, a program approach should be used to connect key stakeholders and to combine incentives with regulatory standards, measures, and other policies. As Box 3.5 shows, Seattle's green building program includes an action plan that identifies key strategies: a mandate that new municipal buildings over 5,000 square feet meet at a minimum the LEED silver standard, and an incentive program that provides financial assistance and bonuses for density. Harnessing strong relationships to the city's water and energy utilities, and their incentive programs, this program connects developers, design teams, and building permit applicants to green building resources, and helps to eliminate code-barriers to building green. As a result, Seattle has one of the highest concentrations of sustainable buildings in the United States, and a powerful sustainable building industry.

### Box 3.4: How to Motivate Behavior-Based Energy Efficiency

There are a variety of approaches that leverage behavior, but best practice combines the following elements, all of which focus on what motivates real people:

- Personalized Information. People don't want generic tips, they want information that's customized to their own situation, both in terms of costs and benefits. Hardware, software and in-home energy audits can all play a part in communicating actionable information to consumers.
- General and Specific Commitments. People must make both general commitments (e.g., I will reduce my energy use by 20 percent) and commitments to specific actions (e.g., I will unplug my appliances). Psychological studies across a variety of subjects have demonstrated the importance of commitment, and energy efficiency is no different. If these personal goals are linked to a broader community, city, province or national goal, all the better.
- Social Pressure. People tend to do what their friends, peers, and neighbors are doing. So when it comes to managing home energy use, it's no surprise that keeping up with someone is a powerful motivator. That compact fluorescent bulb may not seem so bad once all of your neighbors have installed them. And if you know that all of your friends are actively reducing their energy use, you're much more likely to do so yourself.
- Constant and Contextual Feedback. People love to know how they're doing. But with only monthly energy bills, it can be difficult for the average consumer to feel the feedback between their actions and any resulting benefits. Bill analysis, real-time monitoring and other forms of feedback communication go a long way towards influencing household energy behavior, both in terms of peak demand and total energy use.

Source: Frank, A. (2009). Residential Energy Efficiency: It's the Behavior, Stupid . Efficiency 2.0.

### Box 3.5: Green Building Program in Seattle

Through a collection of successful regulatory standards, measures and in¬centives for the building industry, Seattle now has one of the highest concentrations of sustainable buildings in the United States and a powerful sustainable building industry worth US$671 million.

***How does it work?***
Having initially established a Green Building Team in 1999, Seattle regrouped its green building experts to form a single business unit called City Green Building in 2005. Its main program is funded through interdepartmental resources and staffed by green building experts in residential, commercial, institutional and city capital projects. Using its strong relationships with the City's water and energy utilities and their incentive programs, it connects developers, design teams and building permit applicants with green building resources and helps eliminate code-barriers to building green.

A fundamental element of the City's green building program is the promotion and measurement of the environmental impact of buildings and third party verification. Seattle's successful programs include:

- Sustainable Building Action Plan – This identified key strategies for promoting green buildings in the marketplace. The two most important strategies identified were to lead by example and to develop a standard for green building.
- The Sustainable Building Policy – This requires new municipal buildings over 5000 square feet to meet a minimum of LEED Silver standard. To date, over US$500 million investment in state-of the art sustainable buildings has resulted in 10 LEED Certified projects owned by the City (5 Gold, 3 Silver, 2 Certified), with a further 28 projects planned or in development.
- City LEED Incentive Program 2001- 2005 – The City of Seattle provided support to green buildings through its City LEED Incentive Program, with incentives of over US$2 million for energy conservation, over US$2 million for natural drainage/water conservation, and over US$300,000 for design and consulting fees for LEED™ projects. This was launched in 2001 as a joint program of Seattle City Light and Seattle Public Utilities – it provided upfront soft-cost assistance to projects committing to LEED. Funds can be used for additional design and consulting fees and for participation in the LEED program. Funding levels were: US$15,000 for LEED Certified, and US$20,000 for LEED Silver or above.
- Density Bonus – offers downtown commercial, residential and mixed-use developments greater height and/or floor area if a green building standard of LEED Silver or higher is met. Projects must achieve LEED Silver rating and contribute to affordable housing and other public amenities. Three projects have so far registered, and five projects are currently considering registration.

Source: Frank, A. (2009). Residential Energy Efficiency: It's the Behavior, Stupid . Efficiency 2.0.

## Conclusions: Summary Recommendations

SSTEC aims to be an economically sustainable, socially harmonious, environmentally friendly, and resource-conserving city that can be replicated elsewhere. From the energy planning and management perspectives, attaining this objective will require SSTEC to actively pursue end-use energy efficiency across urban sectors, optimize energy supply based on demand patterns and available energy sources, and engender conservation among citizens and institutions. These actionable elements are reflected in available energy sector plans, some stronger than others. Overall, the existing energy plans—noticeably the green building plan (and related standards, guidelines, and implementation procedures), the heating/cooling plan, and renewable energy utilization plan—focus on technical solutions to achieve SSTEC's green targets. This is a good and necessary first step towards delivering on SSTEC's green promises. But equally important is setting up effective institutional arrangements and the devising proper policy and regulatory instruments to make the technical solutions achieve their intended results. Thinking through the key institutional, policy, and regulatory issues and additional analyses of alternative technical solutions, especially in terms of their life-cycle costs and implications for operational management, will enhance the cost-effectiveness and the efficiency of operationalizing the major energy plans of SSTEC. The following are the main findings of this energy sector review and suggestions and recommendations for strengthening SSTEC's overall energy planning and management.

### Green Buildings

As buildings will comprise an 80 percent of SSTEC's energy consumption—mainly for space heating, cooling, and powering appliances and equipment—SSTEC rightly attaches great importance to green buildings. SSTEC has developed its own green building evaluation standard and a series of detailed implementation guidelines. The GBES will be applied to all buildings in SSTEC, representing an unprecedented effort in China. Overall, SSTEC's GBES is more stringent than the national GBES, and compares favorably to LEED, one of the most recognized green building rating systems internationally. The review finds that the following aspects of SSTEC's green building plan may be enhanced:

- The prerequisite items in SSTEC's GBES still largely refer to existing national and local building standards and regulations, especially in energy efficiency. In other words, the basic green buildings are not necessarily breaking any new grounds in some of the main evaluation areas.
- SSTEC's GBES does not have specific energy performance requirements for key energy end-uses in buildings, such as lighting, major appliances, air conditioning, and water heating.
- SSTEC's GBES does not have requirements for energy commissioning, a critical element for ensuring that energy systems are installed properly and perform as designed.
- Finally, SSTEC may also consider an accreditation program similar to the LEED Professional Accreditation program to train and accredit people to help administer the design and construction of green buildings.

### Choice of Space Heating/Cooling Technologies and System Optimization

SSTEC's heating/cooling plan highlights modern district heating technologies and efforts to utilize low-carbon heating and cooling options. The review finds that the current district heating system essentially adheres to conventional Chinese design concepts for large district heating systems, and could be improved by considering techniques to enhance its cost-effectiveness and energy-efficiency that are widely adopted in modern district heating systems in northern Europe:

- Using a low temperature regime for supply/return water of district heating, which reduces network thermal losses as well as negative impacts on power generation linked to the current high temperature regime; and
- Using building level substations instead of group substations, which reduces electricity used for pumping and fuel used for heating; and
- Using the district heating system to supply domestic hot water, which enhances the energy efficiency of the CHP plant (in non-winter periods), and facilitates maintenance of the district heating system;
- When considering the above alternatives, a life cycle cost analysis should be employed to help determine which option is better.

### Application of Renewable Energy Technologies

The main pillars of SSTEC's renewable energy plan are to: 1) directly use geothermal energy and ground-source heat pumps for heating and cooling; 2) employ solar power to meet 60 percent of domestic hot water needs; and 3) provide 90 percent of public lighting from solar PV systems. It is worth noting that heat supplied by geothermal systems and heat pumps cannot be considered a carbon-free, renewable energy source as the electricity to operate pumps is generally derived from non-renewable sources. This review also cautions against the costs of installing solar PV-powered public lighting systems. A possible alternative might be an LED public lighting system, which is highly efficient and durable, and may be more cost-effective on a lifetime cost basis. Large-scale solar water heating in a densely populated city like SSTEC is not only environmentally friendly, but also cost effective. SSTEC can certainly learn from Rizhao City's experience. In general, centralized solar hot water systems will be a good choice for public buildings. Further investigation will be needed to determine the extent and design configuration of solar water heating systems that best serve residential users in apartment buildings. Providing domestic hot water supply through the district heating system may be a close competitor to the large-scale, solar water heating planned for SSTEC in terms of life-cycle costs. There may be merits to further identifying which building types (for example, high rises) may be better served by domestic hot water from the district heating system owing to the capacity constraints of solar hot water systems.

### Institutions, Policies and Regulations

Translating plans into actions and results requires capable institutions and enabling policies and regulations. To-date, SSTEC has responded well. SSTEC's establishment of a super municipal infrastructure investment company promotes an integrated perspective on the construction of municipal service facilities. The Energy Company, which will build and own all energy supply systems, will help to ensure that energy demand is satisfied through efficient and cost-effective supply options, in ways that maximize low-carbon and renewable energy resources. The Energy Company should consider contracting schemes to incentivize efficient operations. Capacity to implement SSTEC's GBES should be strengthened given ambitious goals in this area. This will include staffing SSTEC's administration offices to enhance technical expertise, acquiring support from agencies of the Tianjin Municipal Government, and delivering training and education to key stakeholders of the green building supply chain. In the longer term, SSTEC will need to explore an institutional setup that enables effective and continuous responses to evolving needs related to sustainable urban energy planning and management.

SSTEC's GBES is state-of-the-art in China, and is expected to be strengthened to align with international best practice. In addition to supporting technical standards, SSTEC should consider adopting broader policies to incentivize sustainable energy activities among its citizens, businesses, and organizations. This might include introducing smart pricing and billing systems for electricity, as well as grants, low-interest loans, lines of credit, rebates, bonuses for density, and technical assistance. SSTEC should also develop and implement behavior-based energy efficiency programs. Key components of such programs might include informing consumers about energy use, requesting commitments to energy reduction targets, providing tools to meet these targets, and sending regular feedback on progress.

As a new city, SSTEC provides rare opportunities to demonstrate how different pieces of urban development can be put together to promote urban economic growth, reduce environmental impacts, and enhance social stability. Although SSTEC's proposed energy plans are a good beginning, they are not without flaws. This review is one step in a continuous process to adapt SSTEC's energy planning and management to the challenges and changing needs as the SSTEC project develops further.

# Chapter IV
# Transport Sector Overview

## Introduction

This Chapter reviews SSTEC's transport planning. It assesses the proposed technical solutions and policy objectives in terms of their contributions towards a more sustainable, ecological urban development pattern, including their potential to reduce greenhouse gas (GHG) emissions. Although the transportation sector plan is still under development, the chapter reviews operational level planning contained in the master plan. Based on this initial analysis, the chapter recommends areas for potential improvement, which SSTECAC may consider as it develops its transportation strategy and detailed sector plans. A particular emphasis was placed on assessing the integration of urban and transport planning given that, as explained in Chapter II, the overall spatial and urban design will have significant impacts on SSTEC's ability to realize its sustainable transport plan objectives.

The chapter is structured as follows: (i) introduction, sector overview, and KPIs relevant to the sector; (ii) analysis of the transportation plan from a technical perspective; (iii) analysis of the transportation plan from a policy perspective; and (iv) summary and conclusions.

## Sector Overview

The overall transport strategy aims to achieve "green transportation". This strategy is based on the following main pillars: (i) develop SSTEC as a relatively high-density city that will enable transit oriented development (TOD); (ii) effectively integrate land use and urban transit planning thereby reducing demand for personal motorized transportation; (iii) provide a comprehensive, fully-integrated public transit system with a high level of community accessibility; (iv) deliver a regional transport strategy designed to provide efficient connectivity to key centers while minimizing unnecessary travel though the eco-city; (v) introduce 'leading-edge' green technology to public transit; and (vi) deliver a range of policies and strategies designed to discourage private motorized travel, including, inter alia, parking strategies and 'intelligent' transport management systems.

***Regional Transport Network.*** Planning of the regional transport network is the responsibility of the Tianjin Urban Planning Institute, which has been working closely with SSTEC to ensure that the transport planning is supporting the overarching needs of the eco-city. The two key objectives are to: (i) ensure that all the necessary regional transport corridors are provided; and (ii) that as a regional design principle unnecessary traffic is diverted away from the SSTEC precinct.

***Integration of Urban Plan and Transport.*** The mass transit master plan intends to ensure that it: (i) fully reflects the planned urban form; (ii) links with the city's planned land use; (ii) details an agreed and functional mass transit plan that best fits land use requirements; (iii) encourages the development of transit oriented development, particularly in and around key nodal points; and (v) promotes and maintain community desires to use green transport solutions.

***Road Network.*** A hierarchy of roads is provided comprising six-lane arterial roads (including Bus Rapid Transit (BRT) or bus priority lanes), four-lane major roads connecting communities, and minor 'green' roads for uses other than personal motorized transport. Arterial and major roads are designed on a grid system. This road grid effectively creates urban blocks of 400m by 400m within which mixed-use development occurs.

***Public Transport.*** A three-tier, multi-modal integrated public transport system is planned for SSTEC. The first tier is a mass transit rail corridor transiting north to south through the entire eco-city. This rail line is an extension of the Tianjin-Binhai metro and will continue north to Hangu (when completed). The second tier is a network of light rail connecting residential areas and other patronage generators to the metro corridor. The third transit tier is a bus network connecting to both the metro line and the LRT routes. This network, to be operated by 'state of the art' low-emission vehicles, will penetrate residential suburbs and provide connections to lower demand destinations.

***Green pedestrian/cycle network.*** Routes for walking and cycling are provided in the grassroots community,[94] and these routes link the community with public facilities that people visit on a daily basis. Other walking and cycle paths run contiguous to the grid road system. Green routes also lead to the public transport (tram/bus) stops on the road network. Above the metro corridor is a 'green valley' providing recreational facilities and walking and cycling connections to commercial centers and metro stations.

## Key Performance Indicators

To guide the implementation of the transport strategy, the transport KPI postulates that 90 percent of all trips shall be undertaken by "green" transport by 2020, and 30 percent by 2013.[95] "Green transport" is defined as walking, cycling, and riding public transport. This is the sole KPI identified for the transport sector. Table 4.1 compares this KPI to domestic and international benchmarks.

Given China's comparatively low level of motorization, the 90 percent target constitutes only a small increment, if any, over existing "green transport" benchmarks. For example, in 2000, Tianjin's green transport level was 91.5 percent.[96] In other cities in China, the green transport rates often range from 80 to 90 percent. Though this target may represent a negligible or small increment over existing green transport practices, it may constitute a significant increment over prevailing practices in 2020 given anticipated increases in motorization.[97] In this context, the KPI targeting 90 percent green transport by 2020 is likely to be an ambitious target.

However, the short term target of achieving a "green transport" share of 30 percent by 2013 is a significant under-achievement of what is possible in a purposely designed eco-community—particularly in the Chinese context where significant walking and cycling occurs. This target implies that for the initial phase of the eco-city development, SSTEC would be significantly less "green" from a transport sector perspective than comparable developments in Tianjin and elsewhere in China. This is a cause for concern because of path dependency in the transport sector: once residents are used to motorized transportation, it is more difficult to ensure a shift towards public transport once available.

The 90 percent mode share of green transport is forecast to comprise 60 percent public transport and 30 percent walking and cycling trips. This modal split should be reflected as a secondary indicator. The constituent parts of green transport can thus be more closely monitored and managed. This is important, as there is a significant difference between travel patterns in environments with high public transport usage and low walking and cycling trips and those with a low public transport and high walking/ cycling share. Moreover, these factors affect the provision of public transport resources, service designs, and network planning. Both models may reflect a KPI aiming for a 90 percent share of green trips, but they are substantially different in resource requirements, infrastructure demands, and operation costs.

Furthermore, to allow for precise KPI measurement, it is important to clarify how the mode shares of trips are apportioned, particularly because planning has not considered mixed-mode journeys. For example, good urban design for green transport provides for walking to metro stations or other transit nodes, and then completing journeys by public transport. In measuring KPI performance, will such journeys be identified as non-motorized trips, public transport trips, or both?

Given the importance of transport services to GHG emissions, SSTEC should establish targets for reduced GHG emissions linked to specific "green transport" initiatives. Consistent to introducing leading-edge, low-emission technologies in the bus fleet, robust emission standards should be set for private motor cars and commercial vehicles. Such standards would promote clean 'green' vehicles throughout the SSTEC community—which could be captured in additional, secondary KPIs. Given the extensive and costly infrastructure investments, secondary indicators on social and financial affordability might also be useful. Indicators like journey cost or transport expenditure as a percent of personal income or GDP/capita would be appropriate to help measure affordability. To measure financial sustainability, an indicator such as the operating ratio (recurrent costs divided by operating revenues) of the public transport system is often used.

Table 4.1: Transport Sector: Key Performance Indicators

| KPI Area and Details | Indicative Value | Timeframe | Domestic Standards | Domestic Benchmarks | International Benchmarks |
|---|---|---|---|---|---|
| Proportion of green trips [98] | ≥ 30 % | By 2013 | • Garden City Standard: Proportion of public transportation ≥20% for big cities; ≥15% for medium cities | • Tianjin (2000): 91.5%<br>• Tianjin Plan: 75-80% (by 2020);<br>• BHNA Plan: 65-75% (by 2020)<br>• TEDA: 47.8% [99]<br>• Shanghai (2006): 56%<br>• Beijing (2006): 64%<br>Chongqing (2006): 88%<br>• Hong Kong SAR (2001) 83.8% | • Rio de Janeiro 85%<br>• Bogota 85%<br>• Lima 84%<br>• Moscow 73.7%<br>• Curitiba 71%<br>• Warsaw 71.4%<br>• Budapest 66.9%<br>• Sao Paulo 66.4%<br>• Amsterdam 66.1%<br>• Prague 64.4%<br>• Vienna 64.0%<br>• Berlin 60.8%<br>• New York ≥ 60%<br>• Tokyo ≥60% |
| | ≥ 90 % | By 2020 | | | |

## Analysis of Transport Sector Plans—Technical Perspective

This section reviews the technical aspects of the transport sector master plan, covering: (i) transport planning in the regional context; (ii) travel demand methodology and results; (iii) integration of urban and transport planning; (iv) design of the internal road network; (v) design of the public transport network; and (vi) walking and cycling strategies.

***Analysis of the Regional Perspective.*** As mentioned in Chapter II, SSTEC is located 40 km from the Tianjin city center and 150 km from Beijing. The site is 10 km from the core district of the Tianjin Binhai New Area (TBNA), with the southern tip only a 5 to 10 minute drive from the TEDA. Figure 4.1 shows the locations of Tianjin Municipality and the SSTEC. The main regional transportation corridors are shown along with details that highlight the eco-city's location from a local area perspective. The localities of Tianjin City, Hangu, TEDA, Binhai, and Dagang are important for regional passenger transit and commercial trips. Connectivity with these local centers must be viewed as part of the overall transport strategy for SSTEC.

Regional transportation connections are not the responsibility of SSTEC. Such connections have been planned and coordinated by the Tianjin Urban Transport Planning Institute, and will be implemented by the Binhai Metropolitan Transport Authority. As such, the extension of the metro line from Binhai into SSTEC, and other regional road and rail connections, are planned to connect not only to the sub-regional

Figure 4.1: Regional Transportation


Source: Masterplan

Figure 4.2: Regional Transport Corridors


Source: Masterplan

centers of Tianjin, but also the provincial centers of the greater northeast region. In particular, east-west connectors to the south, and north-south connectors to the west of SSTEC will provide direct commuter connections to other centers. SSTEC sits strategically across a number of commercial and public transportation corridors. As the eco-city develops, it will be important that the strategic and regional linkages be maintained. The regional transport corridors are shown in Figure 4.2.

The transport sector plan reflects these regional linkages and the need for regional connectivity. Appropriate connections between sub-regional centers are provided, and a good plan has been developed allowing inter-regional traffic, both passenger and freight, to bypass SSTEC. The concept of a "metro spine" linking other regional centers, particularly Binhai and Tianjin city, is also sound. The intention is that this line extends not only into SSTEC, but also to the northwest to the Tianjin Railway Station, and through SSTEC and beyond to connect Hangu to Tianjin (when completed). Moreover, this metro should be viewed as a regional passenger transport connection, and not just part of the SSTEC transport plan.[100]

***Analysis of Travel Demand.*** As the viability of the transport plan depends on the accuracy of the planning data, the methodology that the planners used to develop the transport model and predict travel demand must withstand close scrutiny. Because SSTEC is a greenfield site, no origin destination (OD) or travel demand surveys were conducted. Instead, planners relied on base-case comparative analysis and predicted travel demand based on modeling and examples from other cities.

The SSTEC transport planners used the following methodology: (i) base-case data was selected from actual 2006 data from Shanghai, forecasted travel data for TEDA in 2008; and 2020 projections for the Binhai New Area; (ii) travel demands for three OD categories were predicted: travel to work, travel to education, and travel for daily life; (iii) travel demands were generated from the urban master plan, taking into account the location of key community facilities, residential areas, and other travel demand generators; (iv) 112 OD areas were identified and VISSUM software used for modeling; and (v) based on modeled OD demand, planners calculated estimated traffic flow per hour, passenger demand flows per hour along transit corridors, public transport demand, route selection, and public transport mode choice.

The travel data for the three base-case areas (Shanghai, Binhai, and TEDA) upon which SSTEC planning is based is shown in Table 4.2 along with the planned mode share for SSTEC.

As can be seen in Table 4.2, the green transport target of 90 percent can be separated into 10-15 percent personal motorized transport, including taxis; 55-60 percent public transport; and 30 percent walking and cycling.[102] The SSTEC's expectation to limit private motor vehicle trips to 10-15 percent of all journeys represents an ambitious target. However, the 30 percent target for walking and cycling trips appears low,[103] not only against the selected base cases, but also compared to shares in other Chinese cities. The comparisons suggest that SSTEC's planned share of walking and cycling trips represents only half to two-thirds of the shares in other Chinese cities. Such a low share may partially reflect the urban design features discussed in Chapter II and further explained below.

Table 4.2: Base Case Mode Share

| Locality | Car | Public transport | Walking & cycling |
|---|---|---|---|
| Shanghai 2006 | 18.4% | 23.5% (incl. taxi) | 58.1% [101] |
| Binhai 2020 | 20-25% | 55-60% (incl. taxi) | 15-20% |
| TEDA 2008 | 36.8% (incl. taxi) | 15.4% (bus, metro) | 47.8% |
| SSTEC | 10-15% (incl. taxi) | 55-60% | 30% |

Source: SSTEC November 2008

Given low projected shares of car travel and walking and cycling trips, achieving the green transport KPI of 90 percent will depend, above all, on realizing a high public transport share of 55-60 percent. This is very ambitious, and has been achieved in few cities, such as the Tokyo/Yokohama region of Japan. In addition, few cities have achieved a 90 percent share of green transport trips, underlying the significance of SSTEC's target. Table 4.3 presents international benchmarks of the percentile of green trips achieved in multiple global cities.

Table 4.4 provides a comparison of mode shares in a number of Chinese cities that clearly demonstrates the disparity between the public transport and walking/cycling KPI of SSTEC and those prevailing in other Chinese cities.

SSTEC's KPI for green transport exceeds that being achieved presently in other cities. However, although the target for public transport in SSTEC is three times the average being achieved elsewhere, the walking and cycling target is only 55 percent of the share in other Chinese cities. Unless the share of walking and cycling can be elevated, or the forecasted 60/30 percent mode split between public transport and walking and cycling be clearly justified, SSTEC may have difficulties achieving the green transport KPI of 90 percent.

Table 4.3: International Benchmarking of Green Trips 2001

| City | Percentage of Daily Trips by Green Transport (%) | City | Percentage of Daily Trips by Green Transport (%) |
|---|---|---|---|
| Amsterdam | 66.1 | Madrid | 48.5 |
| Athens | 36.05 | Manchester | 31.95 |
| Barcelona | 53.1 | Marseilles | 45.9 |
| Berlin | 60.8 | Medellin, CO | 95 |
| Bern | 59.7 | Moscow | 73.7 |
| Bogota | 85 | Munich | 59.4 |
| Bologna | 43.5 | Nantes | 36.1 |
| Brussels | 41.1 | Newcastle | 42.9 |
| Budapest | 66.9 | Oslo | 40.9 |
| Caracas | 82 | Paris | 53.6 |
| Curitiba | 71 | Rio de Janeiro | 85 |
| Copenhagen | 51.1 | Rome | 43.8 |
| Dubai | 22.7 | Rotterdam | 51.6 |
| Geneva | 48.8 | Salvador | 86 |
| Ghent | 34.6 | Sao Paulo | 66.4 |
| Glasgow | 34.1 | Singapore | 54.9 |
| Graz | 53.6 | Stockholm | 53 |
| Helsinki | 56 | Stuttgart | 41.1 |
| Hong Kong SAR, China | 83.8 | Turin | 45.9 |
| Lima | 84 | Valencia | 58.6 |
| Lisbon | 52 | Vienna | 64 |
| London | 49.9 | Warsaw | 71.4 |
| Lyons | 45.7 | Zurich | 53.5 |

Source: UITP "Mobility in Cities Database (2001) published 2005"

Table 4.5 presents international benchmarks on the shares of daily trips undertaken on public transport. The highest achieved share of public transport is in Tokyo/Yokohama (62.5 percent). Some cities achieved their public transport shares by adopting a single public transport mode. For example, Bogotá, Curitiba, and Lima employ only buses. However, in Tokyo/Yokohama, the aggregate share of public transport includes about 47 percent rail trips, as well as metro trips and bus trips.[105]

***Analysis of Trip data presented by SSTEC.*** Substantial reviews were undertaken to analyze the forecasted trips generated by different travel modes and travel purposes. The objective was to assess road capacity, public transport services, parking strategies (etc.) against forecasted demand. The tables below analyze planned populations, job data, trip purposes, and trips generated by travel mode.

Table 4.6 summarizes the total number of trips by activity. Table 4.7 identifies the total number of daily trips by transport mode for journeys within, into, or out of SSTEC. However, SSTEC's analysis has not yet considered mixed trips: for example, a combination of walking and public transport. If the high number of predicted mixed trips is analyzed, the mode shares may vary considerably.

Travel forecasting has been based on base-case comparative data and trip generation models linked to land use planning. It is critical that this analysis, which underpins sector planning, be independently and comprehensively validated. If flawed, the models will lead to either inadequate transport solutions or unnecessary over-investment in roads and public transport infrastructure. The quality of such analysis is therefore paramount. Further detailed study is required prior to SSTEC's detailed design phase to confirm the preliminary assessments.

***Analysis of Urban and Transport Plans.*** Detailed aspects of urban planning are considered in Chapter II. This review analyzes the integration of planned land use with that of urban transport, and comments on specific issues related to the transport sector KPIs. For SSTEC to achieve its strategic environmental goals, it is essential that: (i) the urban form includes transit-oriented developments (TOD) collocated with public transport hubs servicing residents and businesses; (ii) the urban density is sufficient to stimulate non-motorized and public transport; (iii) the urban form is micro-designed to promote walking

Table 4.4: Green Transport in Chinese Cities 2006

| City (2006) | PT (%) | NMT (%) | Total Green (%) |
|---|---|---|---|
| Beijing | 22 | 42 | 64 |
| Changzhi | 13 | 59 | 72 |
| Chongqing | 25 | 63 | 88 |
| Dongguan | 14 | 59 | 73 |
| Guangzhou | 28 | 40 | 68 |
| Jiaozuo | 9 | 80 | 89 |
| Jinan | 17 | 69 | 86 |
| Linfen | 23 | 26 | 49 |
| Luoyang | 7 | 76 | 83 |
| Nanchang | 16 | 70 | 86 |
| Shanghai [104] | 38 | 18 | 56 |
| Urumqi | 39 | 44 | 83 |
| Weihai | 16 | 53 | 69 |
| Wuhan | 24 | 54 | 78 |
| Xi'an | 32 | 39 | 71 |
| Xianyang | 10 | 77 | 87 |
| Zhengzhou | 12 | 71 | 83 |
| Average | 20.3 | 55.3 | 75.6 |
| SSTEC KPI | 60 | 30 | 90 |

Source: WB/GEF/China Urban Transport Partnership Program

and cycling within residential precincts; (iv) a fully integrated public transport system forms part of the social fabric of the community; and (v) the transport infrastructure contributes to and does not detract from the integration of grassroots communities and wider connectivity across the city.

The master plan for SSTEC includes TOD at key transport hubs. This will stimulate the use of green transport as people will be able to live, work, and undertake recreation around community centers accessible to mass transit. This, in turn, encourages walking and cycling.

The planned hierarchy of communities, including escalating levels of community services and facilities, forms the core of the urban plan.[106] The review confirms a commitment to the principle of integrated urban and transport planning that supports the development, along with other strategies, of a land form and spatial design that facilitates and complements the use of "green transport".

A major concern, however, is whether or not the urban plan facilitates non-motorized connectivity between communities. The 400 by 400 m urban block creates mixed use communities, which is beneficial. Importantly, multiple activities are emphasized within these cellular communities. This minimizes the need for long-distance travel, as people can work and engage in recreation close to their dwellings. Although non-motorized mobility is provided within these communities, walk-abilty is fractured by the major road network that criss-crosses the city, thereby creating significant barriers between the 400 by 400 m community blocks.

***Analysis of SSTEC's Internal Road Design.*** A hierarchy of roadways is planned comprising six-lane arterial roads, four-lane secondary roads, and minor roads for non-motorized traffic. Dedicated bus lanes and bus priority measures will be provided on roads used by buses. Overall, the road network (and other infrastructure) will occupy 20 percent of SSTEC's total land area. The design of these roads and the allocation of road widths for the road easements are consistent with design guidelines for major roads in China and national road building codes. These design guidelines focus, however, on providing capacity amid rapidly increasing motorization. This car-centric philosophy is not necessarily consistent with road designs more suitable to green transportation and the harmonious eco-city environment. Such an environment would benefit from smaller, more roads that do not present barriers to neighborhood walk-ability, and are less inclined to promote car use. Moreover, the size of the 400m by 400m urban blocks and the road widths risk detracting from non-motorized mobility.

The major roads are six lane arterials with an overall road easement of 67 m, as shown in Figure 4.3. These include provisions for LRT and pedestrian and cycle ways. SSTEC's main road grid seems excessive in terms of likely traffic demand, and does not favor a compact urban form, despite the fact that the six-lane roads include bus-only or BRT lanes. During the planning process, an alternative road design was proposed that would have limited road widths to four and two lanes. However, this

### Table 4.5: International Benchmarking of Public Transport Mode Share 2001

| City | Percentage of Daily Trips by PT (%) | City | Percentage of Daily Trips by PT (%) |
|---|---|---|---|
| Amsterdam | 14.7 | Manchester | 9.35 |
| Athens | 27.9 | Marseilles | 11.4 |
| Barcelona | 18.8 | Medellin | 43 |
| Berlin | 24.6 | Moscow | 49.3 |
| Bern | 21.2 | Munich | 21.9 |
| Bogota | 57 | Nantes | 12.8 |
| Bologna | 14.4 | Newcastle | 16.1 |
| Brussels | 13.6 | Oslo | 15.4 |
| Budapest | 43.5 | Paris | 18 |
| Caracas | 60 | Rio de Janeiro | 45 |
| Curitiba | 45 | Rome | 20.2 |
| Copenhagen | 12.1 | Rotterdam | 9.71 |
| Dubai | 6.7 | Salvador | 53 |
| Geneva | 15.3 | Sao Paulo | 29 |
| Ghent | 4.78 | Singapore | 40.9 |
| Glasgow | 10.6 | Stockholm | 21.6 |
| Graz | 18.4 | Stuttgart | 11 |
| Helsinki | 27 | Turin | 21.1 |
| Hong Kong SAR, China | 46 | Valencia | 12.4 |
| Lima | 69 | Vienna | 34 |
| Lisbon | 27.5 | Warsaw | 51.6 |
| London | 18.8 | Zurich | 23 |
| Madrid | 22.4 | Tokyo/Yokohama | 62.5 |

Source: UITP "Mobility in Cities Database (2001) published 2005"

### Table 4.6: SSTEC Daily Trips by Purpose

| SSTEC Daily Trips by Purpose | | |
|---|---|---|
| Purpose | Percentage | Number |
| Work | 50% | 530,000 |
| Education | 14% | 148,400 |
| Shopping/social | 36% | 381,600 |

Source: SSTEC Nov. 2008

### Table 4.7: SSTEC Trip Data by Mode Share

| SSTEC Trips by Mode | | | | | |
|---|---|---|---|---|---|
| Mode | Intra SSTEC | | Inter SSTEC | | Total Trips |
| | % of trips | Total trips | % of trips | Total Trips | 1,060,000 |
| Car | 10% | 66,780 | 22.5% | 88,245 | 155,025 |
| Public Transport | 60% | 400,680 | 57.5% | 225,515 | 626,195 |
| Walking/cycling | 30% | 200,340 | 20% | 78,440 | 278,780 |

Source: SSTEC Nov. 2008

alternative was bypassed in favor of wider roads, even though narrower roads align more closely to the eco-city design and the concept of interwoven 'urban villages'. If road capacity is excessive and the design of the road network fails to minimize car use, SSTEC may find it difficult to achieve its 90 percent green transport KPI, as residents maximize the advantages created by a car-centric road layout.[107]

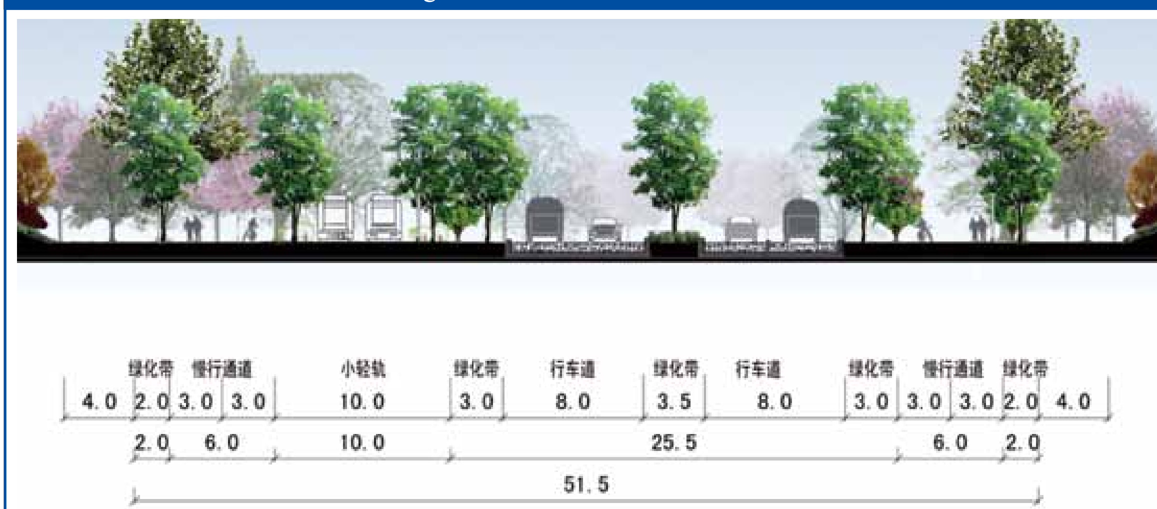
Under current road design plans, underpasses and overpasses would be desirable midway between blocks, and pedestrian controlled traffic signals will be needed at intersections. Finally, it is important to note that the cross-sectional designs of major roads provide lanes for LRT, walking, and cycling. There is no reason why LRT and non-motorized modes must follow roadways. It is aesthetically pleasing for foot and bicycle paths, and even LRT corridors, to pass through green areas. Bypassing roads and crossing green areas may also permit direct and sometimes shorter connections to community facilities. An added benefit is that the cross-section of major road easements would be reduced accordingly.

SSTEC's other main roads include four-lane roads with overall road easements of 51.5 m, as shown in Figure 4.4. These roads also include provisions for LRT, pedestrians, and cyclists.

Figure 4.3: Six-Lane Arterial Road


Source: Masterplan

Figure 4.4: Four-Lane Main Road




Source: Masterplan

***Analysis of the Public Transport Network.*** A three-tier, multi-modal integrated public transport system is proposed for SSTEC. The first tier is a mass transit rail corridor transiting north to south through the eco-city. The second tier is a network of light rail, which provides arterial connections to the metro spine. Light rail brings people from outer areas to metro stations, and provides services to major trip generators that cannot reach the metro on foot. The third tier is a network of eco-friendly buses connected to the metro line and the LRT routes. These buses serve destinations and cross-city routes with less demand. The elements of the transit system are analyzed below. The overall design is good, albeit expensive in terms of proposed technology.

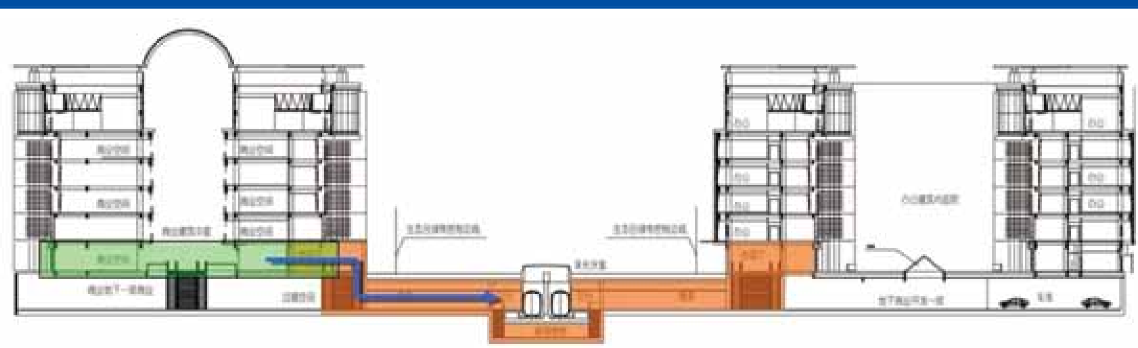
***Analysis of Metro.*** When completed, the metro line will be an extension of the present metro line connecting Tianjin city to Binhai (though implementation of the metro is not immediate). It will be a north to south mass transit spine through the eco-city. The length of the metro within SSTEC is 12 km.[108] The broader regional plan provides for three developments along this line. These are: (i) the continuation of this line into SSTEC; (ii) the continuation of this line within Tianjin city to the Tianjin Railway station; and, in due course, (iii) the extension of the metro line northward from SSTEC to Hangu. Of the eco-city's planned population of 350,000, some 280,000 people (80 percent) will live within 800 m of the metro corridor. This may account for the predicted low percentile of walking and bicycle trips. If all or most journeys within this walking and bicycling radius use public transport, the high target for public transport usage is logical and justifiable. All predictions will nonetheless require validation.

The metro extensions are an important element of the overall public transport plan. The metro will provide a mass transit corridor for journeys within the eco-city, and facilitate essential intra and inter-regional connections. If the metro did not provide regional transport connections, SSTEC's limited population of 350,000 would likely be inadequate to sustain the system's development. The master plan initially provided two design options for the metro: a subway system and an elevated system. A subway system is now the preferred design in the master plan. From an aesthetic perspective, a subway design would be more appealing than an elevated structure. The option to lay the metro 'at grade' on the surface was not considered. This would be far cheaper than digging a subway or constructing an elevated rail system, and certainly more visually appealing than an elevated rail. An 'at grade' system could also be protected by an environmentally sympathetic barrier and an arboreal screen.

The design of the metro provides internal access from adjacent buildings to main stations, as shown in Figure 4.5. This represents good design assuming effective signage and easy access to entrances, and designs that are aesthetically pleasing. Access should also be designed to ensure safety and security.

***Analysis of Light Rail.*** The metro corridor is supported by a network of four light rail (LRT) or 'tram'

Figure 4.5: Direct Below Ground Access to Metro Stations



Source: Masterplan

Figure 4.6: Aesthetics of LRT and BRT
Unattractive LRT in Portland, Oregon, and attractive bus transit in Eugene, Texas

Figure 4.7: LRT Routes

Source: Masterplan

lines. The proposed LRT technological solution is a non pantograph, third rail system. However, this concept would work equally well with less capital intensive technology: with trams/LRT or BRT as the main transit mode, and buses as the feeder mode.[109] LRT was selected over BRT because it was assessed to be more 'attractive' and more likely to stimulate public transport ridership. In addition, it has greater capacity than BRT. LRT was also considered more environmentally beneficial than BRT, and aesthetically 'greener' at points of use. This latter point is something of a fallacy, as depicted in Figure 4.6. The environment of any mass transit system can be sympathetically designed regardless of mode.

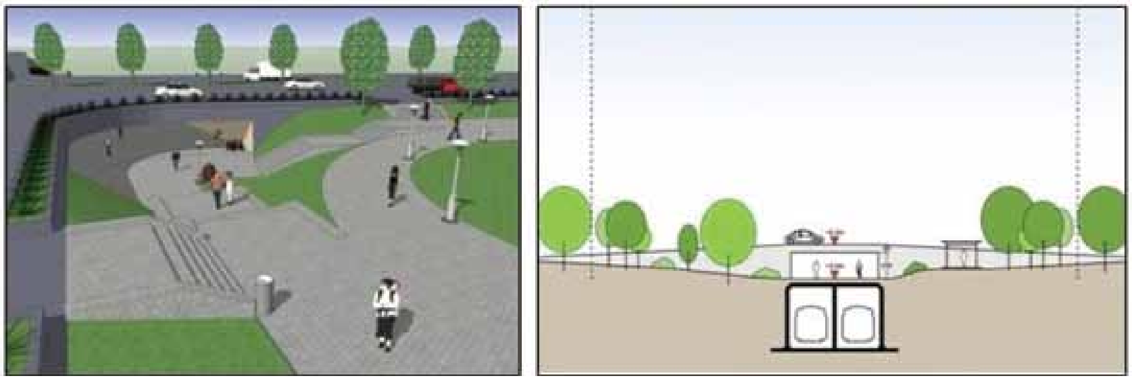
LRT is substantially more expensive to construct and operate compared to BRT. Though the specific differential between LRT and BRT can fluctuate significantly based on design, site, and construction parameters, international experience suggests a capital cost differential between LRT and BRT of about 50 percent.[110] Operating and recurrent costs of BRT are similarly estimated at about 60 percent of those of LRT.

SSTEC's four LRT routes and LRT stations are shown in Figure 4.7. The LRT network will provide two-way routes located on one side of general traffic roadways. The transport master plan also delineates future LRT lines that will extend outside the SSTEC, with a view to strengthening regional public transport connections. Forecasts of passenger demand for each route have been undertaken which shows that either a LRT or BRT network can meet forecasted demand.[111]

***Analysis of Bus Services.*** The metro and LRT mass transit systems are supported by a bus network operated by 'clean' vehicles. Several inter-regional bus routes already pass through SSTEC. These routes service the Tianjin-Hangu and Tangu-Hangu corridors. Coordination will be required with operating agencies on ongoing needs for intra-regional bus services and routes in relation to SSTEC.

To date, there has been no detailed analysis of the bus network, service designs, or operational plans. The bus service network will need to be designed strategically and implemented progressively as the eco-city community develops. The principle aim is that all residents should live within 400 m of a

Figure 4.8: Green Valley above Metro



Source: Masterplan

public transport mode. The importance of the bus network design should not be underestimated. The bus system will provide connectivity between homes, destinations, and the mass transit systems. As a greenfield site, SSTEC offers a great opportunity to develop a bus system that reflects international best practice in services and network design.

***Analysis of Transit Integration.*** The full benefits of integrated public transit will be revealed not only through integrated infrastructure, but also integrated planning at the highest possible level, integrated ticketing to promote seamless cross-modal journeys, and integrated branding and marketing. Early transport planning has emphasized connectivity between the metro and LRT networks. For example, five metro/LRT interchanges have been proposed. Of these, two will connect to three LRT lines, and the other three will connect to two LRT lines. This provides a good level of network connectivity. Within the LRT network, 16 stops are proposed as interchanges between LRT lines.

***Analysis of Travel by Non-motorized Means.*** The transport sector plan emphasizes non-motorized travel solutions. Three components of non-motorized transport have been incorporated into the urban form and transport plan. First, the plan supports the establishment of a ‘green valley’ above the underground metro corridor conforming to the ‘cut and cover’ subway design. This green valley will provide a recreational, walking, and bicycling precinct 50-100 m wide over the 12 km metro line through the eco-city.[112] Second, a network of non-motorized transport roadways dedicated to cycling and walking will be established. Five non-motorized roads, each 16 m wide, will connect the main commercial centers to the arterial green valley. Third, non-motorized, five meter-wide roadways will be provided on each side of motorized roads to provide equal thoroughfares for those not using motor vehicles. Walking trails will also be provided along waterway beautification areas.

Figure 4.9: Green Valley above Metro

Source: Masterplan

Though the planned road corridors

present significant barriers to non-motorized travel on the periphery of residential blocks, urban designs that connect the blocks to areas of the green valley will promote the objective of green transport.

The impacts of the proposed urban and transportation designs on the KPIs' low target for walking and cycling are quite incongruous. On the one hand, a quality urban form focused on the green valley and green corridors will stimulate walking and cycling within and across the communities. This suggests that the 30 percent walking and cycling mode share is potentially understated. On the other hand, the road network and the 400 by 400 m community blocks present disincentives to travel by non-motorized means. It is clearly a central issue whether SSTEC's road network will follow traditional engineering guidance, or whether the road grid will be designed to reflect the specific travel demands of the eco-city.

## Analysis of Transport Sector Plans : Policy Perspective

The above section showed that SSTEC has put in place planning parameters and infrastructure plans that could, in principle, support its green transportation strategy. However, infrastructure proposals need to be supported by and complemented with policy measures. Such policies should support the SSTEC's objective of maximizing the use of public transport and encouraging walking and cycling, while minimizing private motor vehicle use.

Overall, a number of 'push' and 'pull' policies are necessary to encourage walking and cycling and public transport ridership, while dissuading motorized transport. The 'pull' components include providing a quality public transport system and supporting quality infrastructure services, including integrated ticketing, good branding, and effective customer service, some of which have been discussed above. The 'push' component reflects strategies to discourage the use of private motor vehicles and 'push' owners toward public transport. Such strategies include parking restrictions, limits on parking availability, and congestion taxing.

***Infrastructure Investment Phasing Policy.*** A major overarching issue is how to phase SSTEC's implementation, especially in public transport. Progressive implementation of a quality public transport system concurrent with the development of the community is essential. The key objectives are to initially promote and then maintain public inclinations to use transit rather than personal motorized transport.[113] If lower standards are introduced initially, SSTEC may not be able to migrate to a better system in later years, or achieve the transport-related KPI. A high level of public transport service must be delivered at the outset to prompt a voluntarily shift from personal motorized transport.

However, the question is how to progressively stage public transport investments. Though the metro is considered a regional transportation system and would be developed without the SSTEC project, investments between the planned LRT and bus network could be incremental. Although data are not yet available, the Tianjin metro line to Binhai is apparently underutilized. This appears to be attributable to the absence of strong 'anchors' at either end of the line, and under-population along the corridor between Tianjin and Binhai. The plans to extend the metro line to the Tianjin Railway Station and to Hanggu will provide such anchors and thus possibly strengthen the viability of this line.

Another key question is how to provide significant public transport investments that ensure sufficient patronage to generate reasonable returns on investment. The tension between the need for early and comprehensive provision of public transport, and the risk of low public transport ridership, must be carefully analyzed and managed. However, on balance, in eco-cities, policy initiatives should err on the side of supporting a comprehensive public transport system.[114]

***Travel Demand and Infrastructure Design.*** The section reviewing the technical aspects of the transport plan addressed travel demand and infrastructure design, particularly the road network. National and municipal guidelines for road design clearly form the basis of the road network in SSTEC. What is not so clear is the degree to which these designs have been influenced by the eco-city ethos, which discourages motorization and promotes 'livability' through good environmental design. Literature and case studies from other eco-cities[115] suggest that roads should be narrower; the usual, long, wide boulevards should be avoided; and frequent cross-streets should be provided to shorten block sizes. These approaches promote the feeling that the city is a collection of 'urban villages' across which non-motorized travel has priority.

Travel analysis has determined the peak volume of motorized traffic within and passing into and out of SSTEC. Ensuring that the supply of road space does not exceed demand will facilitate the slow growth of motorization in SSTEC. This is a threshold policy issue for decision makers: will the road network conform to traditional standards, or will unique solutions be harnessed that meet the reasonable expectations of motorists, but still harmonize with non-motorized travelers?

***Travel Demand Management (TDM).*** TDM is the application of a wide range of policies, programs, services, and products to influence how, why, when, and where people travel, with a view to making travel behaviors more sustainable. Important elements in TDM include: (i) building parking fees charged at stations in underground commercial and multilevel parking garages; (ii) reduced cost 'park and ride' facilities at public transport interchanges to promote green transport, particularly in outlying areas; (iii) congestion taxes (if needed); and (iv) restricted areas that require car motorists to pay fees to enter regardless of congestion. These are all sound economic control policies that contribute to managing demand for personal motorized transport.

Policies impacting parking availability and costs will significantly impact car owners' desires to use their motor vehicles, and therefore represent a strategic issue in SSTEC. The intended parking strategy for SSTEC foresees: (i) different strategies for different areas (e.g., commercial centers will offer less parking at higher prices); (ii) long term parking outside commercial areas to encourage the use of public transport for work trips and thus reduce traffic congestion; (iii) minimal parking on public streets; and (iv) enhanced regulation and enforcement of parking infringement.[116] In addition, SSTEC will introduce a parking strategy and car park code that initially adopts only 70 percent of the national standards—a level which may be reduced over time.

An important issue discussed in Chapter II is the potential for SSTEC to have more upper income residents than is typical in Chinese cities. This may lead to a higher motor vehicle density. Travel demand policies thus are particularly important. In addition, specific social research should be undertaken to assess the potential impact of the project's socio-economic structure on car ownership and usage.

***Transit Integration.*** Transit integration is also an important element in the design of the public transportation system. Integrated ticketing is proposed for the metro and LRT, but not the bus system. Additional studies should be undertaken with a view to integrating all public transport modes into a single ticketing system to ensure passenger transfers across the public transport network are as seamless as possible. Significant evidence suggests that full integration of ticketing boosts public transport ridership. Numerous ticketing solutions can facilitate the inclusion of the bus network into a holistic integrated ticketing system.

***'Green' Vehicle Technology.*** Both the metro and LRT will be electrically powered. Electrically-powered transport provides environmental benefits, though the power must be generated somehow. Certain electric-powered vehicles contribute to GHG emissions at points of use, but still provide environmental benefits over carbon-based vehicle fuels.

The third element of the planned public transport system is a network of ‘clean buses.’ Clean fuel technology has produced derivatives, principally ‘clean’ diesel, CNG/LNG, hybrid diesel-electric buses, and super capacitor-powered buses. The newer and more sophisticated the technology, the more expensive the bus and, in some cases, the infrastructure that supports operations. Hybrid buses are evolving as a viable alternative. However, super-capacitor buses, although in limited operation in Europe, are still in R&D stages, and several years may be needed before they are proven economically and operationally viable (although trials are being undertaken around the world, including in Shanghai and Guangzhou).

Determining the final choice of ‘green’ technology for public transport infrastructure adopted in SSTEC is a policy issue. But noting the significant cost escalations for high-tech solutions, preferred technologies may not be viable among service operators unless significant operational subsidies are provided. The extent of any such subsidies and adopted technologies is a matter of policy.

***Environmental Policies.*** A number of countries are now seeking to define appropriate quantitative values and targets for “low” emissions. For example, the European Union adopted a target of 180 grams of $CO_2$/km for cars by 2012. In Australia, for every liter of petrol combusted in a motor vehicle, 2.3 kilograms of $CO_2$ are released. The Australian transport sector accounts for about 13.5 percent or 76 million tons of Australia's total GHG emissions.[117] Environmental polices support low-emission public transport vehicles; establish vehicle emission standards; enhance auditing, regulation and enforcement; and provide incentives (reduced charges) for energy-efficient vehicles. SSTEC would benefit from clear, succinct policies on: (i) precise GHG emission reduction targets; (ii) vehicle emission controls (penalties and incentives); and (iii) auditing regimes for vehicle compliance that exceed those in other Chinese cities.

Specific vehicle emission policies in SSTEC include: (i) mandating Euro 4 emission standards for all vehicles; and (ii) providing incentives for vehicles that limit emissions to Euro 5 or better (this includes measures to limit energy use, such as incentives for hybrid clean cars, and parking controls, such as cheaper parking for green cars). Specific regulations will be required to mandate emission standards for private motor vehicles. Yet, these regulations can be applied only on vehicles registered in the eco-city. It is not clear how emission standards for other vehicles visiting SSTEC can be mandated.

***Intelligent Transport Systems (ITS).*** SSTEC is designed as a ‘digital city’. ITS forms a part of the integrated digital city platform strategy, and includes traffic management systems, real-time passenger information, intelligent transit services, and advisory services. ITS will improve traffic flow from a ‘do nothing’ scenario and thereby reduce GHG emissions. ITS represents a major investment strategy and enhances knowledge. Setting targets for emissions is essential. Executing a cost-benefit analysis of each ITS proposal to assess environmental and other performance would help the SSTEC to prioritize each initiative. SSTEC would benefit from technical assistance to formulate ITS strategies and technical solutions.

SSTEC plans to introduce Enhanced Smart Card technology. Integrated “smart cards” will provide electronic ticketing and travel data, and serve as digital platforms to collect data on other passenger activities. Additional personal data may be stored if desired. Integrated ticketing and seamless passenger transfers are also enhanced by smart-card technology.

***Commercial Vehicles.*** SSTEC policy restricts the use of heavy vehicles. Land use planning provides that: (i) no heavy industrial sites will be developed, as such sites often require higher use of heavy vehicles; and (ii) industrial parks will be located at the edge of the eco-city adjacent to planned heavy vehicle routes. SSTEC’s planned commercial vehicle policies, which are good practice, will: (i) restrict heavy vehicles to predetermined routes; and (ii) deny heavy vehicles access to commercial centers during peak periods.

***Institutional Policies.*** SSTEC has not agreed on institutional arrangements in the transport sector, other than recognizing that an organization will be needed to oversee delivery of public transport services. Departmental accountability for policy development and regulatory oversight,[118] and operational management of transit services, will be needed to coordinate the planning and delivery of the transport sector plan. Institutional oversight will be needed for detailed service designs, network planning, all aspects of LRT start-up and bus services, and coordination with the metro operator. Early intervention is required to ensure a smooth rollout. Lengthy lead times are needed to plan and establish transit services in a greenfield environment, and early intervention is required if services are to be delivered effectively. SSTEC is being advised by local bus companies in TEDA to determine requirements for bus services. Reviewing best practices in transit planning will help SSTEC to deliver services in a timely manner.

## Conclusions: Summary Recommendations

The overall assessment is that SSTEC's transport strategy effectively underpins the transport-related KPI that 90 percent of all trips should be undertaken by green transport, though fully realizing this target by 2020 is ambitious. If SSTEC achieves this target, this clearly will contribute to making SSTEC a model for ecological urban development. There are however, some key issues which have the potential to adversely impact the achievement of this KPI:

- The 90 percent mode share of green transport is forecast to comprise 60 percent public transport and 30 percent walking and cycling trips. These shares contrast with many relevant benchmarks. The 60 percent public transport rate is particularly high by all standards, and the walking/cycling target of 30 percent is low by Chinese standards.
- Though the KPI target currently represents a small increment over the existing share of green transport, achieving the KPI by 2020 may constitute a significant increment over the likely prevailing practices. However, the interim KPI that targets 30 percent green transport trips by 2013 reflects a significant under-achievement of what is possible in a purposely designed eco-community, particularly in the Chinese context where significant walking and cycling occurs.
- The currently proposed road dimensions and block size risk limiting non-motorized mobility, creating significant barriers between communities, and reducing community cohesiveness. The proposed road design may support car-centric communities, and could undermine achieving the green transport KPI.
- It is unclear how the low target of 10-15 percent personal motorization will be achieved, particularly if enabling TDM strategies are progressively introduced. The intention to phase-in the level of compliance with TDM strategies, particularly parking, and emission control standards for public transport vehicles, pose some risk to achieving the green transport KPI in later years.

In this context, the following key recommendations are made:

From a technical perspective, it is recommended:

- The veracity of the travel demand model be reviewed and outputs updated. In particular, care should be taken to verify the base data from as many diverse sources as possible. Other potential base-case options should also be considered, particularly from new development areas with similar demographics as SSTEC. This is critically important as all infrastructure investments are heavily dependent on the viability of the transport model.

- Livability and mobility in the eco-city be enhanced by developing more, but narrower roads, thereby reducing the 400 by 400 m blocks, and supporting non-motorized travel. It is appreciated that any significant change now will have a major impact on the whole design of the city. However, it is considered critical to the whole urban form of SSTEC that it be purpose-designed with the strategic objectives of the city in mind.
- Evidence be developed as to how specific infrastructure commitments (e.g., road design, public transport investment) relate to the KPI and the travel demand model. This will require a detailed review of road and other infrastructure capacities, the proposed public transport capacity, and city parking spaces (etc.) against the forecasted modal splits, and related KPI mode shares.
- A detailed business case be developed for the LRT versus the BRT option. This should review, in parallel, the designs, capital costs, recurrent costs, capacities and operational impacts of both technologies to determine the optimum technical and cost effective solution.

From a policy perspective, it is recommended:

- A policy for phasing in 'green' public transport infrastructure concurrent with the program to develop the city through 2020 be developed, paying particular attention to relevant investment costs and projected cost recovery needs during development stages.
- A policy for the phasing of TDM strategies across all dimensions (i.e., parking fees, low cost 'park n' ride' facilities at public transport interchanges; congestion taxes; and restricted areas for car use) be developed to ensure high-level coordination of the competing imperatives of eco-city targets and commercial and residential property sales strategies.
- Institutional arrangements be introduced for the development of transport policies, together with the regulation and enforcement of public transport initiatives and TDM strategies. This may involve the establishment of a new agency, operating businesses, and regulatory strategies superior to those generally evident in Chinese urban areas.
- GHG emission reduction targets for the transport sector be developed. This will require further application of the transport model to identify indicative trip distances. By combining these distances with the forecasted mode split and travel volumes, emissions can be calculated and compared against a base case along various indicators, such as passenger/km. Once projected reductions are identified, these might form an additional, secondary KPI.
- Secondary indicators be developed. The 90 percent mode share of green transport is forecast to comprise 60 percent public transport and 30 percent walking and cycling trips. This modal split should be reflected as a secondary KPI. Furthermore, to allow for precise measurement of the KPI, it is important to clarify how the mode shares are apportioned, particularly because planning has made no reference to mixed-mode journeys. Operationally focused indicators, including those measuring cost recovery and affordability, should be considered.

# Chapter V
# Water Sector Overview

## Introduction

This chapter reviews SSTEC's plans for the water sector. As in other sectors, the master plan has been developed, but detailed sector plans and feasibility studies are under preparation. The chapter aims to: (i) analyze the specific sector and sub-sector proposals under development; and (ii) recommend options for improvement. The analysis will focus on the two ends that frame water sector performance in SSTEC: (i) achieving efficient service delivery by effectively managing supply and demand and optimizing the use of water resources; and (ii) preserving the environment by ensuring proper wastewater and storm water management and high rates of water reclamation and reuse.

## Sector Overview

SSTEC is located in Tianjin which, like much of northern China, faces extreme water shortages. Average per capita water resources available in Tianjin reach only 160m$^3$/year, compared to China's much higher national average of 2,200m$^3$/year, and a global average of 7,340m$^3$/year. To meet its needs, Tianjin relies heavily on water transferred from rivers and groundwater from other regions.[119]

***Water Supply.*** The eco-city will be supplied by two water treatment plants to its north (Hangu) and south (TEDA). These plants are surface water treatment plants that employ conventional treatment processes, including coagulation and sedimentation followed by filtration and chlorine disinfection. The two plants will be able to satisfy the water demand in the eco-city, which is estimated to reach 72,400 m$^3$/day by 2020. In addition, the city will receive about 86,000 m$^3$/day from reclaimed water sources, and 7,900 m$^3$/day of desalinated water from the Beijang CHP power plant. Table 5.1 illustrates the projected balance of water supply and demand in SSTEC in 2020.[120]

***Wastewater Management.*** SSTEC is expected to produce 76,000 m$^3$/day of sewage. The sewage will be collected and pumped through five pumping stations to the Hangu Yingcheng wastewater treatment plant (WWTP) which is under construction (Phase I) and financed by the World Bank. Phase I will

Table 5.1: Forecasted Balance of Water Demand and Supply for SSTEC in 2020

| Category by use of water | Water Demand (m$^3$/day) | Conventional water demand (m$^3$/day) | Reclaimed water demand (m$^3$/day) | Desalinized water demand (m$^3$/day) |
|---|---|---|---|---|
| Domestic | 42,000 | 32,100 | 6,300 | 3,600 |
| Institutional | 35,700 | 27,300 | 5,400 | 3,000 |
| Industry | 9,100 | 5,000 | 3,600 | 500 |
| Landscaping | 13,700 | - | 13,700 | - |
| Street cleaning | 2,500 | | 2,500 | - |
| Warehouse & other land use | 3,100 | 1,400 | 1,550 | 150 |
| Replenishment for water body | 50,000 | - | 50,000 | - |
| Others | 10,600 | 6,600 | 3,300 | 700 |
| Total | 166,700 | 72,400 | 86,400 | 7,900 |

Source: SSTEC Water Sector Plan

provide 100,000 $m^3$/day of treatment capacity and Phase II 50,000 $m^3$/day. The WWTP will treat sewage from the Hangu urban area, TEDA Modern Industrial Park, and SSTEC. Table 5.2 provides information on the quality of the projected effluent, which corresponds to Class 1 A standard. The detailed design and configuration of the collection system has not yet been developed, except for the collection system outside SSTEC in the Hangu built up area (implemented under the Bank project). The sludge produced from the wastewater treatment plant is expected to be sent to a nearby landfill.

***Storm Water.*** Storm water is collected in a separate dedicated system. The city is divided into five catchment areas from which storm water will be collected and pumped for direct reuse and/or discharge into the Ji Canal and water bodies. Storm water will be disposed into the Ji Canal before potentially being reused, though some will be treated beforehand to remove possible contaminants.

***Water Reclamation and Reuse.*** Reclaimed water from the treated wastewater effluent and storm water will play a significant role in SSTEC's water supply. Reclaimed water will account for 52 percent of total water demand. As shown in Table 5.1, the three biggest uses for reclaimed water will be to replenish water bodies, landscape, and fulfill domestic needs (e.g., toilet flushing). Replenishment of water bodies will account for 58 percent of this total.[121] Importantly, all wastewater will be treated and reused, except storm water.

***Water Bodies.*** An "Ecological Protection and Rehabilitation Master Plan" is being prepared whose aim is to improve the water quality in existing water bodies. Besides offering environmental and recreational value, these water bodies will be used as reservoirs that store reclaimed water for periods of high demand. This system includes canal bypasses, and foresees the rehabilitation of wetlands that have been accumulating sewage.

Table 5.2: Quality of Treated Wastewater Effluent from Hangu WWTP

| COD mg/l | BOD mg/l | SS mg/l | TN mg/l | NH3-N mg/l | TP mg/l |
|---|---|---|---|---|---|
| 50 | 10 | 10 | 15 | 5 | 0.5 |

## Key Performance Indicators

The water strategy was formulated in conjunction with a set of Key Performance Indicators (KPIs).[122] The KPIs related to the water sector are summarized in Table 5.3, and include the following:

- ***Water supply from non-conventional sources.*** The KPI that aims for at least a 50 percent share of water from non-conventional sources in SSTEC sets this project apart from other water sector developments in China. It is an ambitious target that exceeds common practices in China. It also aligns with international best practices, such as in Singapore. This KPI is a strong point of the project, though the design of the water reclamation system will have to be evaluated based on strict cost benefit and cost effectiveness analyses.
- ***Per capita domestic water consumption.*** The KPI that aims for per capita water consumption of 120 liters per day (lcpd) reflects current consumption trends in Tianjin and Beijing which is low by international standards. To ensure this target is achieved over the medium term, efficient supply and demand management practices need to be implemented to counter increases in water demand as incomes rise.
- ***Quality of water bodies.*** This KPI calls for improving the quality of water in natural bodies, such as wetlands, canals, and lakes, to meet Class IV surface water standards. This is an ambitious target, as only 22 percent of water bodies in BHNA met the national standard in 2006. Tremendous efforts must be made to protect and regulate water disposed into the river

upstream of SSTEC, and activities related to this KPI need to be coordinated at a regional level.

- ***Tap Water attaining drinking water standards.*** This KPI is relatively straightforward as it

Table 5.3: Water Sector: Key Performance Indicators

| KPI Area and Details | Indicative Value | Timeframe | Domestic Standards | Domestic Benchmarks | International Benchmarks |
|---|---|---|---|---|---|
| Quality of Water Bodies | To meet Grade IV surface water quality standard stated in the PRC's National Standard GB 3838-2002 | By 2020 | • National Standard for Surface Water Quality GB 3838-2002<br>• Eco-City Standard: to meet national standard GB 3838-2002 and no lower than Grade V | • TJ Plan: surface water quality in the built-up areas should meet Grade V and above by 2010<br>• BJ Plan: water quality of the central city and new developing area should meet the National Standard by 2010.<br>• Average meeting GB 3838-2002 rate of Chinese cities: 86.50% (2007) | - |
| Water from taps attaining drinking water standards | 100 % | Immediate | • National Standard for Drinking Water Quality GB 5749-2006<br>• Eco-Garden City Standard: 100% meeting GB 5749-2006 | • SH: 99.95% (2005);<br>• Shenzhen: 99.56% (2008);<br>• Guiyang: 100% (2009) | - |
| Net loss of natural wetlands | 0 | Immediate | • No national standard | National 11th Five Year Plan for Forestry states: 50% of natural wetlands and 70% of important wetlands should be protected | - |
| Per capita domestic water consumption | ≤ 120 Liters per day per capita | By 2013 | • National standard if water quality for water quantity for city residential use GB/T503312002 : 85-140 lcpd<br>• Tianjin quota for water quantity for city's residential use DB12/T158-2003: 70-120 lcpd | • TJ: 130.4 (2006)<br>• BJ: 110~130 (2007)<br>• Wuhan Plan: 170 (by 2010)<br>• SH: 160 (2003); Plan: 180 (by 2020)<br>• Hunan province quota: 160<br>• Ningxia province quota: 90-130<br>• Xiamen city quota: 150-180<br>• HK: 203 | • Singapore: 154<br>• Cologne: 137<br>• Amsterdam: 154<br>• HK: 203<br>• Sydney: 254<br>• Tokyo: 268<br>• Los Angeles: 440 |
| Water supply from non-conventional sources | ≥ 50 % | By 2020 | • No national standard | • BHNA: Reclaimed Water: 9% (2008); Plan: 40% (by 2010). Desalinated seawater: 14% (2008); Plan: 25% (by 2010).<br>• BJ: Water recycling rate ≥ 50% for central city and new towns by 2010;<br>• Caofeidian Eco-City Plan: 40% (by 2020) | • Singapore: ≥50% (current) |
| Services network coverage | 100 % | By 2013 | Central Sewage Treatment:<br>• Eco-City Standard: ≥85%<br>• Eco-Garden City Standard: ≥70%<br>Tap water:<br>• Eco-Garden City Standard: ≥100%<br>• Garden City Standard: 90% | Central Sewage Treatment:<br>• TJ: 75% (2005); TJ Plan: ≥85% (by 2010); ≥90% (by 2015)<br>• BHNA: 59% (2005) | Sewer Coverage:<br>• Singapore: 100% (current)<br>• Tokyo center area: 100% (2006)<br>Tap Water:<br>• Tokyo center area: 100% (2006) |

corresponds to existing national standards, and water is received from the two existing water treatment plants in Hangu and TEDA.[123]

- ***Net loss of natural wetlands.*** This KPI refers to the preservation of natural wetlands. Though no related national standard exists, this target is higher than related targets in the 11th Five Year Plan. Given that the master plan fully incorporates the protection of wetlands, and that SSTEC is developed as a green field site, this KPI can be assumed met from the outset.

SSTEC has also developed other sector targets, including: (i) a daily per capita limit of 220 lcpd and corresponding limit of 102 liters of water for other public institutions; (ii) total maximum water utilization of 320 lcpd (including industries); (iii) non-revenue water of less than 10 percent; and (iv)100 percent coverage of wastewater treatment and effluent compliant with the Class 1 A standard.

SSTEC's KPIs and sector indictors cover important areas, particularly in water reclamation and per capita consumption. However, additional secondary indicators should be considered to guide the achievement of the primary KPIs, especially those related to efficient demand and supply management, and the sustainability of water services and the water sector. These could include indicators on: (i) specific energy consumption: these would help to assess the energy efficiency of water sector activities, such as water supply and wastewater collection and treatment; (ii) fixed and operational costs: these would help to gauge the value of various system designs and construction, and the efficiency of service companies; (iv) cost recovery: these would help to measure the extent of recovered costs via various revenue mechanisms, as well as assess sector sustainability; and (v) customer management: these could include indicators that assess  response to customer complaints and inquiries.

## Analysis of the Water Sector Plans—Technical Perspective

The proposals in the water sector are technically sound overall. Certain areas might need to be improved in the design phase: for example, the systems' spatial layouts and configurations, and the selection of appropriate pumps and pressure control devices. Improvements would help to optimize the systems' capital and operational costs, while ensuring that energy consumption is kept to a minimum, which is important from financial and GHG emission perspectives. The current proposal to dispose sludge in a nearby landfill may be the cheapest option, but does not reflect best practices for an eco-city. SSTEC's main innovation is in water reclamation where the project set an ambitious target.

***Water Supply.*** SSTEC's water supply will be secure and reliable as water will be supplied by multiple sources. Water will be provided by the Hangu water treatment plant in the north, the TEDA water treatment plant in the south, and the desalination plant at the Beijiang CHP plant. Moreover, supplying water through a ring main will increase the reliability of the distribution system and help to ensure energy efficiency. Capitalizing on a good basic design, additional recommendations include the following.

***Review the need for water desalination.*** The utilization of excess heat from the Beijang CHP plant to run the desalination plant is a viable arrangement. However, the desalinated water comprises only a small share of the total supply. Unless it is critical, the primary objective should be to maximize electricity production in the CHP plant.[124]

***Optimize the distribution system.*** As the distribution system is still being designed, it is recommended to consider the following issues.

(i) *Optimization of the distribution system design.* This could lead to minimizing water distribution costs. The distribution system within the city needs to utilize a looping system rather than a branch configuration. Adopting a looping system will improve connectivity between the demand nodes, and create more branches to feed any specific zone. As the total costs of distribution are optimized, energy savings need to be given distinctive weight over capital costs. Box 5.1 illustrates the advantages of a loop system configuration. The analysis reviews energy savings and system resizes that allow extra investment in more links to be paid back over the short-term. A complete optimization analysis should lead to greater savings, as it will affect the sizing of pipes, pumps, and the operation of storage tanks. The pressure that is needed in the system is also a factor in determining pipe diameter. The pressure requirements are determined by law and the nature of the terrain. These concepts should be introduced. The possibility of using variable flow pumps should also be explored.

(ii) *Proper operation of the system at an adequate pressure.* As demand varies during the day, the pressure in the distribution system will vary. Unnecessarily high pressure will increase leakage and lead to higher energy consumption. Proper demand management, utilization of storage reservoirs, variable speed pumps, and pressure control valves are tools to better regulate the pressure in the distribution

### Box 5.1: Effect of Distribution System Configuration on Energy Consumption

The schematic below represents a small town that has an hourly water demand of 450 $m^3$. The demand is split between nodes 2, 3, 4 and 5. The town is served via a fixed speed pump linked to a reservoir at an elevation of 10 m. For illustrative purposes, two scenarios were considered.
Scenario 1: Link 1-5 does not exist
Scenario 2: Link 1-5 was constructed

*Distribution System Data*

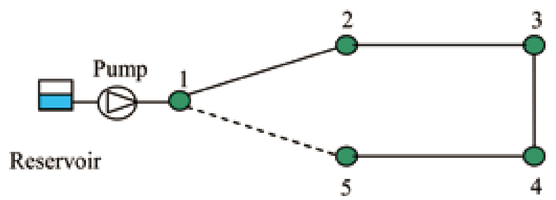
| Node | Demand ($m^3$/hr) | Elevation (m) |
|---|---|---|
| 1 | 0 | 10 |
| 2 | 100 | 30 |
| 3 | 50 | 30 |
| 4 | 100 | 30 |
| 5 | 200 | 25 |

| Pipe | Diameter (mm) | Length (m) |
|---|---|---|
| 1-2 | 500 | 1000 |
| 2-3 | 400 | 1000 |
| 3-4 | 400 | 1000 |
| 4-5 | 300 | 1000 |
| 5-1 | 400 | 1000 |

*Analysis Results*

| Node | Pressure[1] (m) | Pressure[2] (m) |
|---|---|---|
| 1 | 58.33 | 43.75 |
| 2 | 37.02 | 23.39 |
| 3 | 34.58 | 23.03 |
| 4 | 27.13 | 22.47 |
| 5 | 23.58 | 27.66 |

(1) node pressure for Scenario 1
(2) node pressure for Scenario 2




Results:

1. In Scenario 2, the pump was replaced by a smaller one and power demand dropped to 71.5 kW from 95.3 kW (25%).
2. Annual energy saving is 209 MW/hr, which can cost US$20,000 per year.
3. The capital investment to complete the loop and construct pipes 1-5 is less than US$100,000, and can be reimbursed in about 5 years from energy savings.
4. Further improvements can be achieved if a full optimization analysis is conducted that targets the sizes of the pipes (diameters), while maintaining other hydraulic parameters, like flow velocities and node pressures within the recommended hydraulic design limits.

The spatial distribution of demand centers may be seen as inputs governed by land use plans. However, the distribution system components (networking, pipes sizes, etc.) and active and passive elements (pumps, valves, and storage tanks) can still be optimized. Energy consumption is linearly proportional to the length of a pipe. It is even more sensitive to the pipe diameter (D) and the proportionality is a function of D to the power 1/5th. An under designed 2 inch diameter pipe will consume as much as 32 times the energy as a 4 inch diameter pipe at the same flow rate.

Source: Frank, A. (2009). Residential Energy Efficiency: It's the Behavior, Stupid . Efficiency 2.0.

system. Box 5.2 illustrates energy savings of 20 percent realized in some Brazilian cities that adopted proper operation modes.

***Wastewater Management.*** SSTEC will have complete sewage coverage. All sewage will be treated in the new Hangu Yingcheng WWTP that is under construction. The plant is expected to receive sewage of various qualities. It is advisable to introduce measures to pre-treat some sewage streams to guarantee optimal operation and minimize the total costs of reuse. The cost of pretreatment will depend on the quality of the targeted sewage, and the nature of its contaminants. The sewerage network needs to be hermetically tight to prevent intrusion of salty water (originated from the salty soil in SSTEC). Appropriate pipe material and fittings need to be selected.[125]

## Box 5.2: Watergy Case Study: Fortaleza, Brazil

**Challenges**

The importance of this project was highlighted by the Brazilian energy crisis in 2000 and 2001. Because over 70 percent of the energy generated in Brazil comes from hydropower, droughts and energy shortages have been inextricably linked. During the energy crisis and drought in 2000 and 2001, all consumers were required to reduce their energy consumption by 20 percent. The Alliance to Save Energy has worked with the Companhia de Água e Esgoto do Ceara (CAGECE) in northeast Brazil since 2001 to develop and implement measures supporting more efficient use of water and energy. This partnership has aimed to improve the distribution of water and access to sanitation services, while reducing operational costs and environmental impacts. The partnership was important not only to reducing energy use at CAGECE, but also to establishing an example for similar projects nationwide, as the water and sanitation sector accounts for 2.3 percent of Brazil's energy consumption.

**Background**

The designs of water distribution systems are based on population projections from statistical and historical data over a 20 to 30 year planning horizon. Because of this, many designs oversize storage, treatment, and distribution infrastructure. This over-design entails energy consumption levels much greater than required to satisfy demand, especially from booster stations. Design criteria affect not only pumping stations, but also pipe sizes, reservoir capacities, and the construction of treatment facilities and booster stations. Water systems must be able to expand to satisfy increasing demand, but not while sacrificing efficient energy use.

**Objectives**

The partnership between the Alliance and CAGECE strove to develop a methodology providing CAGECE with the tools and the knowledge to produce initiatives that result in savings and rational uses of energy and distributed water. As the work progressed, it became clear that the developed model would be useful to other water and sanitation companies in Brazil looking for ways to increase efficiency.

**Approach**

An automation system in water distribution systems is allowing operators to obtain strategic data to control equipment in real time. The automation of the water supply system in the Fortaleza Metropolitan Region allows for correction of deficiencies in the system, particularly those that are caused by over-design. Complementing continuous efforts by CAGECE, Alliance actions in 2002 included:

- Establishing baselines for energy consumed and water distributed for CAGECE
- Implementing efficiency measures that led to a reduction in operational energy consumption
- Developing a financing proposal with the Government of Brazil's Fight Against Electricity Waste Program (PROCEL) to implement energy efficiency projects with CAGECE's operations staff. The technical support provided by the Alliance resulted in the development of energy efficiency projects, cost/benefit analysis, and specifications of equipment that could be financed.
- Arranging for $5 million in financing for energy efficiency projects by CAGECE. These projects included automated operations, rewinding and replacement of motors, maximizing the efficiency of existing pump system , and increasing storage capacity to allow the shutdown of pumps during peak hours.
- Creating an operations procedures manual that serves as a reference for daily performance for operations crews and CAGECE management.

**Key Results**

- Energy saved: 88 GWh over 4 years
- Households newly connected to water while water consumption remained constant: 88,000
- $2.5 million saved per year with an investment of $1.1 million.
- Standardization of operational procedures and reliability of operational data
- Ability to act in real time with the system control devices.
- $CO_2$ Emissions Avoided: 220,000 tons/year

Source: Alliance Save Energy and Watergy, Energy Efficiency

***Sludge Management.*** In addition to the treated effluent, the wastewater treatment plants produce significant amounts of sludge composed of settled biological material and biomass. The proposed plant is based on an activated sludge process, which will produce significant quantities of sludge that have potential for digestion and energy generation. This is a well known practice not only in developed countries, but also developing ones. The generated methane from the digesters is captured and used as an energy resource. Commonly, treatment plants are equipped with gas turbines and generators that use methane as a primary source of energy to produce electricity. The generated electricity can be sufficient to cover most electricity demand for treatment and/or sold to the distribution grid. As will be explained in Chapter VII, this approach also provides options to access Carbon Finance through the Clean Development Mechanisms (CDM).

In light of this discussion, the current proposal to dispose sludge in a landfill needs to be reconsidered. The proposed approach will negatively impact the environment, and can be a significant source of groundwater pollution. Such practices do not reflect the right image and expectations of an eco-city. Though landfills tend to be the cheapest solutions, their use runs counter to practices in an eco-city.

***Storm Water.*** The storm water collection system should be separate from the sewage collection system. This minimizes the overall cost of treatment. The provisions to treat storm water from the first weather events at the wastewater treatment plant also help to protect storm water quantities from heavy contamination. Most storm water can then be used to directly replenish water bodies. The master plan should allow for minimal energy consumption to pump storm water to its final uses.

***Water Reclamation and Reuse.*** The sector plans call for maximizing the use of reclaimed water from treated wastewater and storm water. The reclaimed water supply will thus form 52 percent of SSTEC's total water supply. This is a very ambitious target and corresponds to best international practices in countries such as Singapore. The proposed plans call for constructing a separate storm water and wastewater collection system, and a parallel reclaimed water distribution system.

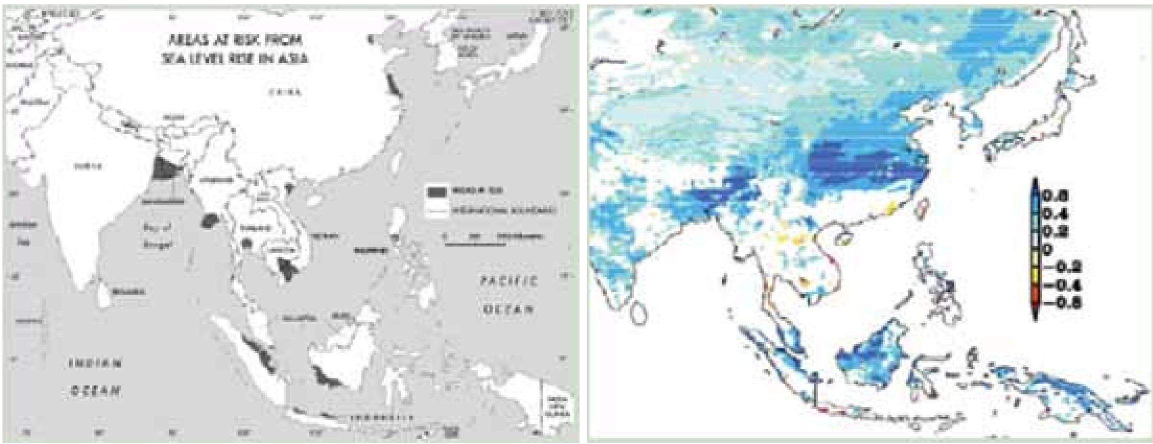
Overall, the high level of water reuse is justified in Tianjin, which is experiencing extreme water shortages. However, SSTEC should consider analyzing the need to reuse reclaimed water to minimize energy consumption, which would in turn lower capital investment needs. Moreover, the construction of a dual system (distribution, metering, and management) to supply reclaimed water for residential purposes is complex and costly which would need to be examined further given that domestic water uses represent only 15 percent of total domestic demand. Examining the feasibility of this proposal is recommended, including through a detailed cost benefit analysis.

It is also important to properly allocate the costs of wastewater treatment among users. Most costs are borne by domestic and industrial water users, as their generated sewage needs to be treated to environmentally accepted disposal standards. This normally entails secondary treatment through activated sludge processes. The additional treatment (tertiary) costs associated with water reuse can be as low as US$ 0.10 per $m^3$. Compared to the costs of treating the next available nonconventional water resources, such as desalinated seawater (US$ 0.60/$m^3$), reusing treated wastewater is competitive.

***Water Bodies.*** The master plan will support rehabilitation of the existing canals, wetlands, and lagoons. The plan will also support the development of waterfront at the mouth of the river. The specific plans have not been fully developed, and it is not yet clear how rehabilitation will be implemented. The KPI related to wetlands calls for surface water to comply with Class IV standards. This is ambitious, and will entail controlling disposals upstream and a joint regional effort. As mentioned earlier, the effluent from the wastewater treatment plant does not satisfy Class IV standards. The effluent will need polishing before being discharged into water bodies.

***Water and Climate Change.*** Climate change will result in a rise in sea level (Figure 5.1a), and more drought along the coast and in the middle of China (Figure 5.1b). This could exacerbate water scarcity. Given a projected rise in sea level as high as 0.5m along the Chinese coast near SSTEC, water infrastructure must be located at safe altitudes, and flood protection measures need to be undertaken. Moreover, the sea front needs to be managed to protect water bodies from contamination by intruding saline seawater. Climate change may also bring more flooding, which has implications on the designs of drainage systems in coastal areas.

Figure 5.1a: Area at Risk from 0.5 m Sea-level Rise in Asia (left)
Figure 5.1b: Annual Mean Daily Precipitation Changes Expected by 2100 (mm) (right)




## Analysis of Sector Water Plans—Policy Perspective

SSTEC is currently focused on construction issues in the eco-city. However, operational issues are equally important and need to be considered early in the process. Important operational issues include: demand management and pricing; water conservation strategies and activities; regulatory and enforcement issues; and implementation arrangements. This section highlights the major policy, regulatory, and institutional issues that need to be considered to ensure sector sustainability.

***Demand Management and Pricing.*** Water pricing is an important demand management tool that can strongly improve sector efficiency. However, the current flat tariff structure in Tianjin and Hangu does not provide the right incentives for demand management and water conservation. Following

### Box 5.3: Energy Use in the Water Sector

The operation of water and wastewater systems is often the largest outlay of municipal energy budget. For example, Californian cities on average spend over 50 percent of their energy budget on water and wastewater pumping (Lantsberg, 2005). It is estimated that 2-3 percent of the world's energy consumption is devoted to pumping and treating water, and that there is a potential for energy savings of more than 25 percent. In many cities, both energy and water are scarce resources. Thus, there is a natural synergy in attempts to save energy and water and address related efficiency issues. Many systems in developing countries often have outdated equipment, poor system designs, leaks, and other non-metered water losses stemming from inadequate investment capital and know-how to undertake improvements. Many also operate under limited commercial incentives to be efficient. This situation spawned a program by the Alliance to Save Energy called "Watergy", which demonstrated significant benefits for developing-country cities in increasing clean water access by reducing energy costs and water losses.[126] In Fortaleza (northeast Brazil), Box 5.2, the Alliance worked with the local utility, the Companhia de Água e Esgoto do Ceara, or CAGECE, to develop and implement measures to improve the distribution of water and the access to sanitation services, while reducing operational costs and environmental impacts. CAGECE invested about R$3 million (about US$1.1 million), including in the installation of an automatic control system, and saved US$2.5 million and 88 GWh over four years. More importantly, the utility was able to install an additional 88,000 new connections while still decreasing its overall energy costs.

Source: Eco2: Ecological Cities and Economic Cities international best practice, this project should consider adopting increasing block tariffs, which charge a higher unit price for higher levels of water consumption. This promotes water conservation, and will help to maintain the low per capita consumption envisaged for SSTEC.

A progressive tariff structure and the application of a conservation tax contributed significantly to the success of Singapore's water conservation program (Box 5.4). The Public Utility Board of Singapore planned to cut water use by 10 lpcd and, among small to medium enterprises, achieve a 10 percent reduction. These targets are being realized by applying comprehensive demand and supply management. Singapore is installing water saving devices including: (i) low flow showerheads, (ii) constant flow regulators, and (iii) aerators. These are being installed free of charge to households with above average water consumption. Singapore is co-financing products and projects to help small and medium enterprises cut their monthly water bills by 10 percent. Moreover, Singapore has achieved 'good practice' recognition by reusing 100 percent of treated wastewater under its NEWater program. Other cities, such as San José in California, have set similar targets.

Higher water prices do not need to conflict with equity and affordability concerns. Low-income households need to be protected, which can be achieved in different ways. For example, tariffs for the lowest income households can be set below cost-recovery levels, while higher income earners subsidize the gap through tariff surcharges. Some countries, such as Chile, provide targeted subsidies to households.

To ensure equity and transparency, water prices should generally align to real costs and target direct beneficiaries. For instance, domestic water tariffs should reflect the costs associated with water production, distribution, and wastewater collection and treatment at environmentally acceptable levels (i.e., the secondary wastewater treatment level). Additional costs of treatment (tertiary) and of distribution of reclaimed water should be borne by users of reclaimed water.

***Water Conservation.*** The SSTECAC and the water service utility/company need to consider a strong conservation program to complement infrastructure investments and water demand management. Water conservation leads to both water and energy savings and a greener and more sustainable environment. Singapore is a good case study for introducing water conservation policies. Box 5.5 illustrates an example from Canada. Under the pilot program described in this box, domestic water use dropped by 50 percent by applying efficient devices and fixtures. Although Canada is a water rich country and the pilot was in a locality where per capita consumption was originally 400 lpcd, the same measures, interventions, and lessons can be applied elsewhere, even in water stressed regions like the SSTEC. Toilets, kitchens, and showers are the biggest sources of consumption. This consumption can be reduced by heightening public awareness and investing in incremental devices like water fixtures.

***Regulation.*** Even without a more formal independent regulator, SSTECAC will need to establish a regulatory unit to ensure compliance with service standards. Some regulatory functions can be contracted to SSTEC's service providers, such as requiring that they track performance indicators. In general, a regulator's responsibilities include ensuring compliance with service standards and sector policies to ensure sustainability along three dimensions: (i) the environmental regulation subsystem (licensing for abstraction and disposal); (ii) quality regulation subsystem (ensuring drinking water, treated wastewater, and works comply with quality standards); and (iii) economic regulation subsystem (reviewing prices to ensure that imposed tariffs are proportionate to real costs; promoting efficiency and conservation; and enabling sustainable services that are affordable by the poor).

***Institutional Issues.*** The water sector poses a relatively high risk of institutional fragmentation. As shown in Chapter VIII, the TEC Energy Investment Company is responsible for constructing SSTEC's water distribution system. The JV Company is responsible for constructing the storm water, wastewater, and water reuse distribution system. The construction of the wastewater treatment and water reclamation plants is the responsibility of the TEC Environmental Protection Company. This is clearly a highly fragmented setup, notwithstanding that all but the JV Company are subsidiaries of the Tianjin Eco-City Investment and Development Company (TECID). The risk of institutional fragmentation is higher if one considers operational dimensions. As was explained above, water will be supplied by water treatment plants in Hangu and TEDA. Therefore, key questions related to this institutional structure need to be resolved early in the project. Will it be possible to apply different standards in the service areas of Hanghu and TEDA, especially in water demand management? Will standards applied in SSTEC be different than those applied in TEDA and Hangu? If not, will this make it more difficult to introduce increasing block tariffs to effectively manage water demand?[127]

Synchronizing implementation activities during SSTEC's construction phase is also important. The master plans identify common routes for water, reclaimed water, and wastewater networks. In principle,

### Box 5.4: Singapore Incentive and Demand Management to Support the Water Conservation

**A. Water Efficiency Fund**

To balance the ever-increasing needs of industry, individuals, and the environment, PUB set up the Water Efficiency Fund (WEF) to encourage companies to consider efficient ways to manage their water demand or promote water conservation.

Projects Eligible for Funding and Funding Framework: Feasibility Study; Water Audit; Recycling Efforts /Use of Alternative Source of Water; and Community-wide Water Conservation Campaigns and Programs

**B. Water Tariff Structure**

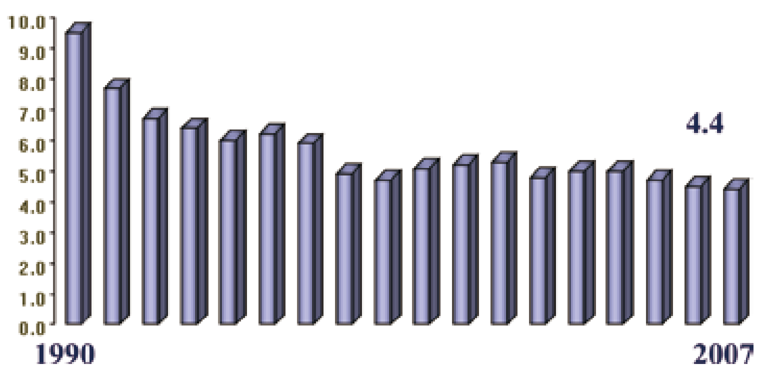
| Potable Water Tariff Category | Consumption Block ($m^3$ per month) | Tariff($/$m^3$) [before GST] | Water Conservation Tax (% of tariff) [before GST] |
|---|---|---|---|
| Domestic | 0 to 40 | 1.17 | 30 |
| | Above 40 | 1.40 | 45 |
| Non-Domestic | All units | 1.17 | 30 |
| Shipping | All units | 1.92 | 30 |

Industrial Water Tariffs (inclusive of GST)

| Tariff Category | Consumption Block ($m^3$ per month) | Tariff (cents/$m^3$) | WCT (% of tariff) | WBF (cents/$m^3$) |
|---|---|---|---|---|
| Industrial Water | All units | 43 | - | - |

**C. Outcomes**

Besides pricing to manage water consumption, PUB embarked on community-driven public education programs, such as the Water Efficient Homes program and the 10L Challenge, to encourage home and building owners to adopt good water saving habits and measures. Singapore managed to reduce per capita domestic water consumption from 165 liters/day in 2003 to 157 liters/day in 2007. The target is to achieve per capita daily consumption of 155 liters/day by 2012.



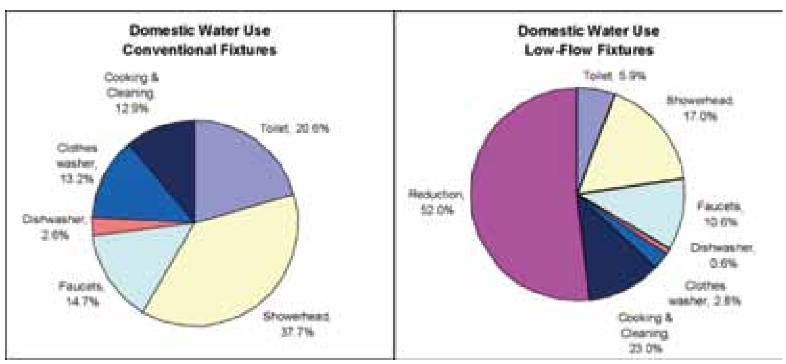
these common routes will help to reduce construction costs, as different service pipes can be installed simultaneously.

Under international practice, a single service provider often provides all water services in a city, including water treatment, distribution, and customer management. Water sources are sometimes within city limits under the jurisdiction of a service provider. At other times, sources are outside city boundaries and managed by a different provider. Regardless, it is preferred that the same service provider assume the responsibilities for storm water collection, flood management, and wastewater collection and treatment. This combination helps to ensure better management of services, clear lines of accountability, and efficient operations. For instance, water providers that are also wastewater utilities are well

### Box 5.5: Domestic Water Consumption in Canada and Conservation

The average domestic consumption for a home in Canada is approximately 350 to 400 liters per person per day (300 l/d for indoor use, and 100 l/d for outdoor use). Canadians use considerably more water than most nations. Water flows during the summer from mountain glaciers, but the snowpack is diminishing. To sustain access to water, Canada will need to conserve water—both now and in the future.

Discussion:
Domestic water is used in bathrooms (by toilets, showers, and faucets), kitchens (for dishwashing and food preparation), and for washing laundry. The following charts illustrate the percentage of water used for each activity using conventional and low-flow fixtures (based on a typical use pattern).




These values are based on a family of four people, as follows:

| Fixture | Family Use | Fixture Water Consumption | Fixture Water Consumption |
|---|---|---|---|
| Showerhead | 8 minutes / person / day | 15 liters / minute | 7 liters / minute |
| Toilets | 5 flushes / person / day | 13 liters / flush | 6 liters / flush solids |
| 3 liters / flush urine | - | - | - |
| Faucets | 5 minutes / person / day | 10 liters / minute | 7 liters / minute |
| Kitchen (cooking & cleaning) | 15 minutes / day | 10 liters / minute | 7 liters / minute |
| Conventional Dishwasher | 1 use / day | 33 liters / use | 8 liters / use |
| Top-load Clothes Washer | 7 uses / week | 170 liters / use | 36 liters / use |

The toilet is the single highest source of water consumption in the home, and 70 percent of household water is used in the bathroom. Logically, toilets and showerheads represent the greatest opportunities for water reduction in homes.

Low-flow fixtures include dual flush toilets, in which one button provides a 3 liter flush for urine, and a second button a 6 liter flush for solids. Showerheads and faucets can be designed to reduce flows without noticeable performance reductions. New appliances like dishwashers and front-loading clothes washers use significantly less water. Using low-flow fixtures can reduce water consumption in homes by over 50 percent, from approximately 1200 l/d (interior use) to 600 l/d. This does not include outdoor water use, such as for landscaping.

Reference: http://www.thelivinghome.ca/index.php?option=com_content&task=view&id=98&Itemid=132

positioned to encourage customers to apply local treatment to reduce their sewage discharge. They also have incentives to protect water resources because they bear the costs of treatment.[128]

## Conclusion: Summary Recommendations

SSTEC's proposed water system is well conceived, though some aspects of the proposals will need to be revisited during the detailed planning phase when feasibility studies are developed. SSTEC's partnership with Singapore offers an excellent opportunity to learn from the latter's successful experiences. The most notable feature of SSTEC's proposals is that they support maximizing the use of reclaimed water from treated wastewater and storm water, and target that 50 percent of SSTEC's total water supply will come from non-conventional water sources. This target is very ambitious, but can be rationalized given the prevailing water scarcity in Northern China, including Tianjin.

The following recommendations may be useful to further develop SSTEC's water sector in optimal and sustainable manner:

From a technical perspective, it is recommended to:

- Optimize the designs of distribution systems (water and reclaimed water) to minimize total costs and energy consumption. This may require advice from distribution system optimization specialists.
- Conduct a feasibility study on the dual water supply system using reclaimed water for domestic uses. The daily supply of reclaimed water targeted for domestic use is 6,300 $m^3$. This represents 15 percent of the total domestic supply, and will be used for toilet flushing. This will require a dual supply system, which may not be cost effective. Moreover, it might be more feasible to treat the water tp a higher standard and use one water distribution system only.
- Re-examine the need for desalinated water, and assess the optimal operation of the Beijang power plant as a cogeneration plant.
- Reassess the UAFW target. The 10 percent target for UAFW is relatively high, especially in a new city. Countries like Singapore manage to achieve 4.4 percent.
- Consider pre-treatment of industrial wastewater. This will result in lower wastewater treatment costs.
- Revisit sludge disposal plans. An eco-city should be expected to adopt more environmental friendly approaches like digestion and composting. These processes are widely applied in developed and developing countries, and the technologies are well proven.
- Improve energy efficiency in the operation of the various systems. This can be achieved by implementing leak control programs, and equipping networks with telemetry systems for pump scheduling, pressure control, and bursts control.
- Design the wastewater and storm water system to anticipate the likely impacts of climate change and rising sea levels.

From a policy perspective it is recommended to:

- Apply water conservation practices and programs. These should address both water supply and demand. Appropriate tariff structures to promote water demand management are important while ensuring cost recovery, conservation, and equity.
- Strengthen public awareness and participation, as public involvement is crucial to the success of the demand management and conservation programs.
- Establish appropriate regulatory oversight. Absent an independent regulator, the SSTECAC will need to establish a regulatory unit to monitor regulations to ensure the realization of the KPIs and other emerging service standards.
- Consider using one operating company for all water sector services, including enforcement of onsite treatment and recycling. The operating company should also be involved in the design and construction phases.
- Closely coordinate the construction of different systems undertaken by contractors. SSTEC needs to capitalize on the synergies of system installation. For instance, the pipe system, telemetry system, and other electromechanical equipment share many similarities between them.
- Establish secondary indicators to complement the KPIs, including those measuring or assessing energy consumption, cost recovery, and customer management.

# Chapter VI
# Solid Waste Sector Overview

## Introduction

A well functioning waste management sector is critical to successfully implementing a new urban development project, such as the one planned for Tianjin Eco-City. A properly designed and operated waste management system is important to protect not only the environment, but also public health, aesthetics, and city finances.[129]

This chapter reviews the characteristics of municipal (residential and commercial) solid waste in the eco-city, while referencing current practices of solid waste management in Tianjin municipality. Waste management practices in Tianjin and potential options for the eco-city are defined and compared. The chapter also addresses the treatment and disposal of hazardous waste.

## Sector Overview

SSTEC is considering several initiatives to strengthen the environmental orientation of the waste management sector. These initiatives, which represent advances in China's solid waste management practices, include the following:

- Waste Reduction. Waste reduction initiatives seek to reduce the quantity and/or toxicity of waste at generation points by redesigning products or changing patterns of production and consumption. Two measures to reduce the quantity of solid waste generated in the eco-city are proposed: one related to packaging, and the other to the control of food sales.
- Waste Collection. Trucks typically collect and transport municipal waste and recyclables to a treatment or disposal facility. As an alternative to conventional truck-based collection, the eco-city is considering a pneumatic solid waste collection system. The pneumatic collection system will be initially implemented on a pilot basis in the start up area.
- Recycling/Materials Recovery. The key advantages of recycling and recovery are reduced quantities of disposed waste and the return of materials to the economy. The eco-city targets a recovery rate of 60 percent, while China's average actual recovery rate is about 20 percent, largely attributable to informal waste picking.
- Incineration/Waste-to-Energy. Incineration of waste with or without energy recovery measures can reduce the volume of disposed waste by 90 percent. Volume is a more important measure than weight in assessing the demand on landfills. A part of the waste from the eco-city may be sent to an existing incinerator in Tianjin.
- Landfill. The waste and/or residue from other processes in the eco-city will be transported to the Hangu landfill, an existing disposal facility. Landfills, a common last disposal site for waste, should be engineered and operated to protect the environmental and public health.

This chapter reviews these initiatives in the context of the overall waste generation, collection, transport and disposal plans for solid waste in SSTEC. The chapter compares these activities with select international experiences, and offers suggestions for consideration by SSTEC's decision makers.

## Key Performance Indicators (KPIs)

Three waste management KPIs are proposed for the eco-city. One KPI entails a lifestyle change that affects per capita domestic waste generation rates (see Table 6.1). The other two KPIs relate to infrastructure: the overall recycling rate and the treatment of hazardous waste to render it non-hazardous. An additional sector indicator that is being considered aims to achieve source separation of 80 percent.

Some of the performance indicators are ambitious, such as the target to limit daily per capita domestic waste generation to 0.8 kg which is 27 percent lower than the existing rate in Tianjin (1.10 kg per capita).[131] In addition, the targeted recycling rate is high, especially when considering that informal solid waste pickers may be banned in the eco-city. In China, informal waste pickers contribute significantly to reducing the quantity of disposed waste. The hazardous waste indicator is de facto already achieved, as all hazardous waste in the Binhai New Area is now being rendered non-hazardous. Though the KPIs in Table 6.1 are ambitious from an environmental perspective, they provide the eco-city with worthwhile objectives that could justify an eco-city title in the waste management field.

To meet the objectives measured by the KPIs, the eco-city must complement infrastructure investments with strong policy measures. For example, strong financial and other incentives need to be implemented to encourage recycling. The eco-city may need to consider explicitly banning the disposal of certain materials for recycling and/or treatment, such as toxic waste. These issues are addressed in the following sections.

Table 6.1: Solid Waste Sector: Key Performance Indicators

| KPI Area and Details | Indicative Value | Timeframe | Domestic Standards | Domestic Benchmarks | International Benchmarks |
|---|---|---|---|---|---|
| Per capita domestic waste generation | Net generation rate: ≤ 0.8 kg per capita per day | By 2013 | Code for Planning of Urban Environmental Sanitation Facilities GB 50337-2003: 0.8-1.2 | Tianjin: 1.10 (2007)<br>Beijing: 1.18 (2007)<br>Ningbo: 1.2 (2007)<br>Wuhan central district: 1.21 (2008) | South-East Asia: 0.74 (2000)<br>Singapore: 0.89 (2007);<br>East Asia: 1.01 (2000)<br>Japan: 1.1;<br>South-Central Asia: 0.57 (2000) |
| Overall solid waste recycling rate | ≥ 60 % | By 2013 | No national standard | Beijing Plan: separation & collection rate 60%; comprehensive use rate of industrial solid waste 80% by 2010.<br>Beijing 2008 Olympics venue: 50%.<br>Shenzhen: 45% (by 2010) | Singapore :<br>51% (2006);<br>Plan: 60% (by 2012)<br>Seattle, Wash. (USA) 48% (2007)<br>Plan: 60% (by 2012) |
| Treatment to render hazardous and domestic solid wastes non-toxic | 100 % | Immediate | Eco-City Standard: 90%<br>Eco-Garden City Standard: 90%<br>Garden City Standard: 60%<br>Environment Protection Model City Standard[130]: treatment of domestic solid wastes≥ 85%; treatment of hazardous solid wastes: 100%. | Tianjin: 81% (2005); TJ Plan: ≥90% by 2010; 100% by 2015<br>BHNA: 100% (2005)<br>Beijing: current: 93%;<br>BJ Plan: 99% for central districts, 80% for suburb districts by 2010<br>Average of Chinese cities: 67.58% (2007) | - |

## Waste Generation, Reduction, and Composition

The options for managing solid waste in SSTEC or existing city areas will partly depend on the quantity and composition of discarded waste, which are described below.

***Net Generation.*** The quantity of waste discarded in a city depends on the per capita generation rate, which is directly correlated to income and population. Cities with higher incomes tend to generate more waste than similarly sized cities with lower incomes. People with higher incomes spend more money on goods and services, which creates waste. As shown in Table 6.2, the waste generation rate increases with income. In comparable size cities (e.g., those with populations of one million), the waste produced ranges from 500 to 1,600 tons[132] per day (tpd) according to average income levels.

Table 6.2: Net Waste Generation Rates

| Income Level | Net Generation Rate (kg / capita / day)[1] | Waste Quantity (tons / day) [2] |
|---|---|---|
| Low | 0.5 | 500 |
| Middle | 0.7 | 700 |
| High | 1.6 | 1,600 |

1. kg = kilogram.
2. Assumed population of 1.0 million.

***Net Waste Generation.*** Waste generation is generally measured by the quantity of disposed waste (i.e., net generation rate). Waste generation measurements normally exclude waste sorted by residents or commercial establishments for recycling, and recyclables recovered by the informal sector (i.e., the recovered recyclables generation rate). Recyclables should be added to disposed waste to obtain a total estimate of the quantity of waste discards (gross waste generation). Uncollected waste should also be included, though it is assumed that there will be little to no uncollected waste in the eco-city. The formula below demonstrates these relationships.

*Gross Generation Rate = Net Generation Rate + Recovered Recyclables Generation Rate*

In China, recyclables recovered by the informal sector have been estimated to comprise up to 25 percent of gross waste generation.[133] The reported net generation rates in Tianjin range from 1.10 kg per capita[134] for the permanent and temporary populations to 0.55 kg per capita for the floating population. Tianjin reportedly collects 5,800 tpd for treatment and/or disposal.

In the eco-city, the baseline net generation rate, assuming no waste reduction measures are implemented, was forecasted to be 1.26 kg per capita per day in 2010 (based on permanent population only; if floating population would be included, per capita rate would be lower). This rate is projected to drop to 0.81 kg per capita per day by 2020[135] (see Table 6.3), likely attributable to the proposed 60 percent recycling rate. Though the per capita net generation rate is expected to fall, growth in SSTEC's permanent population will result in an increase in disposed waste from 64 tpd in 2010 to 431 tons by 2015.

Assuming the waste reduction measures are implemented, the forecasted daily per capita net generation rate should fall by about 25 percent in 2010, 2015, and 2020, relative to a scenario without such measures. Given the scope of the waste reduction activities outlined below, the targeted decrease in net

Table 6.3: Forecast Net Generation Rates in SSTEC 2010-2020

| Year | Permanent Population | Forecast Net Generation Rate Without Waste Reduction Measures (kg / capita / day) | Forecast Net Waste Quantities Without Waste Reduction Measures (tons / day) | Forecast Net Generation Rate With Waste Reduction Measures (kg/ capita / day) | Forecast Net Waste Quantities With Waste Reduction Measures (tons / day) |
|---|---|---|---|---|---|
| 2010 | 50,000 | 1.26 | 63 | 0.94 | 47 |
| 2015 | 200,000 | 1.17 | 234 | 0.88 | 176 |
| 2020 | 350,000 | 0.81 | 431 | 0.62 | 330 |

generation rates will be challenging to achieve.

***Waste Reduction Measures in the Eco-City.*** SSTEC plans to reduce waste discarded in the eco-city through two measures:

- Clean vegetables. Vegetables available for sale are typically sold raw and fresh. Peels and other organic waste are generated when raw vegetables are prepared. To reduce waste, vegetables sold in the eco-city will be processed into prepared foods and available in supermarkets only. The residue from processed vegetables may be composted or recovered as animal feed. Vendors will be prohibited from selling fresh, unprocessed vegetables. This approach may reduce residential food discards, but other factors should be considered. Processed vegetables must be sold in packages to minimize spoilage, and they are also less fresh.
- Green packaging. A shift towards reusable, recyclable, and/or biodegradable packaging materials is part of the waste reduction plan. Additionally, merchants will no longer be permitted to offer a 'free' plastic bag for client purchases. The idea is to encourage consumers to switch to reusable shopping bags. Beijing is implementing a similar shopping bag program.

The emphasis of the waste reduction plan is to encourage consumers to shift from high-consumption lifestyles to alternatives that generate less waste. Though the proposed waste reduction measures are positive, it is uncertain whether the measures will achieve the desired outcomes. Therefore, the system must have sufficient capacity to handle additional waste in the event that waste reduction initiatives take longer to achieve their objectives or fall short of their aims. More importantly, food processing is more appropriately considered a recycling measure, as vegetable residue can be recycled into compost or used as animal feed. The processing does not eliminate waste, but addresses waste earlier in the food distribution chain. This is a beneficial move, but is not truly a waste reduction measure.

The waste reduction measures could be implemented either through regulations or financial incentives, such as taxes. The latter might include supplementary charges on fresh produce to cover the cost of managing solid waste. A financial incentive option might allow consumers who desire fresh vegetables to purchase them if they pay a premium. In addition, markets might be required to collect source-separated food waste from consumers. Requiring markets to consolidate such residue might be a more efficient and ecological means of recycling organic discards than converting fresh vegetables into processed food. The rate of spoilage associated with fresh versus processed vegetables also needs to be considered.

It is difficult to implement waste reduction measures in the residential waste stream. However, commercial operations pay for waste management services based on the quantity of discarded waste, which provides a financial incentive to reduce and/or recycle waste. One internationally renowned residential waste management program is Germany's packaging regulations developed under the 1994 European Union Directive on Packaging Waste. Under these regulations, suppliers are encouraged to shift to waste reduction measures, such as reusable packages, and to reduce toxicity (heavy metals). Suppliers are made responsible for managing used packages, including recycling of returned packaging material. Many companies participate in the 'Green Dot' scheme, through which returned packaging is recycled. Though such a program may be effective at a national level, its effectiveness in a city is uncertain as consumers can easily shift their purchases to outside markets. The city of Yokohama pursued another innovative and effective program for waste management that emphasizes public awareness and stakeholder engagement, as illustrated in Box 6.1 on the next page.

***Gross Waste Generation.*** The estimated gross generation rate, which includes the 25 percent of discards recycled prior to disposal, is projected to increase in the eco-city as waste pickers may be prohibited in the area.[136] Under this scenario, the quantity of waste to be managed either with or without waste reduction measures increases (see Table 6.4).[137]

Waste reduction is a desirable objective, but reductions are difficult to achieve at the residential level as residents do not have the same financial incentives as commercial entities. Most waste reduction occurs as consumers shift their purchasing habits; manufacturers sell more durable goods and lighter products; and/or buyers forego purchases. Pricing mechanisms that cause shifts in consumer buying patterns, and bans of certain types of products, such toxic goods, may be the most direct means of achieving waste reduction objectives.

***Composition.*** The composition of waste also varies by income level. The percent of food waste tends to be highest among lower income households. However, as income increases this share generally decreases as consumers purchase more prepared foods. Preparing fresh food tends to result in more food waste from peels, pits, and other residue.

The composition of waste is important to consider in selecting approaches to managing the waste stream. For example, a city with a high level of food discards should provide more frequent collection to minimize the potential to attract vermin, which may carry diseases. Refuse with a high food waste

Table 6.4: Estimated Gross Waste Discards in SSTEC, 2010-2020

| Year | Net Waste Quantity Generated Without Waste Reduction Measures (tons / day) | Forecast Recyclables Recovered by Informal Sector (tons / day) | Gross Waste Quantity Generated Without Waste Reduction Measures (tons / day) | Net Waste Quantity Generated With Waste Reduction Measures (tons / day) | Forecast Recyclables Recovered by Informal Sector (tons / day) | Gross Waste Quantity Generated With Waste Reduction Measures (tons / day) |
|---|---|---|---|---|---|---|
| 2010 | 63 | 16 | 79 | 47 | 16 | 63 |
| 2015 | 234 | 58 | 292 | 176 | 58 | 234 |
| 2020 | 431 | 108 | 539 | 330 | 108 | 431 |

Box 6.1: Waste Reduction through Stakeholder Engagement

Yokohama's G30 Plan identifies the responsibilities of stakeholders, including households, businesses, and the city government, to achieve waste reduction through the "3Rs" (reduce, reuse, and recycle), a polluter-pays-principle, and extended-producer-responsibility. The plan provides a mechanism for an integrated approach to reduce waste ,and detailed action programs. For example, citizens must separate their waste into 15 categories and dispose of it at designated places and times based on the waste category. Businesses are requested to provide products and services that create less waste, and to implement the 3Rs. The city, as one of the largest generators of waste, is committed to reducing waste and working with citizens and business.

To raise awareness of the G30 approach, the city conducted environmental education and promotional activities and requested public action to achieve the G30 goal. To promote waste separation, the city conducted more than 11,000 seminars for the public and neighborhood community associations to explain waste reduction methods,[138] including how to separate waste. The city also sponsored 470 campaigns at all railway stations, and about 2,200 awareness campaigns at local waste disposal points (among other places).[139] Campaign activities were also held at supermarkets, local shopping streets, and at various events. The logo for G30 has been printed on city publications and vehicles, and displayed at city events.

As a result of these efforts, Yokohama achieved its 30 percent waste reduction target for the FY2001-FY2010 period in FY2005. In FY2007, the city had reduced waste by 38.7 percent, despite an increase in population of 165,875 since 2001.

| | |
|---|---|
| Reduction of total amount of waste (FY2001-FY2007) | 623,000 tons ( -38.7%) |
| Economic Benefit | US$1.1 billion in capital costs saved by incinerator closure<br>US$6 million in operational costs saved by incinerator closure<br>Lives of landfill sites extended |
| $CO_2$ reduction (FY2001-FY2007) | 840,000 tons |

Source: Eco2 Cities: Ecological Cities as Economic Cities content lends itself to aerobic composting. Food waste will decay rapidly in compost operations. Its high moisture content benefits the composting process. Conversely, waste streams with high food waste and moisture content are not good for incineration systems. Waste will only auto-combust if the moisture content is less than 50 percent. Supplemental fuel is often needed to burn waste with a high moisture content.

***Tianjin and Eco-City.*** China's waste composition profile has traditionally varied among areas using coal for cooking and home heating, and areas using gas (see Table 6.5). This variation is exacerbated seasonally among northern cities that produce a high percentage of coal ash waste during winter months. Overall, the average level of coal ash in China's discards is forecasted to fall by 2030.

Table 6.5: Waste Composition, China and Tianjin

| Material | Urban MSW China Using Coal, 20001 | Urban MSW China Using Gas, 20001 | Urban MSW China, 20301 | Tianjin, 20032 | Eco-City With Implementation of Waste Reduction Measures, 2010 | Eco-City With Implementation of Waste Reduction Measures, 2015 |
|---|---|---|---|---|---|---|
| Food/Organics | 41% | 65% | 51% | 56.9% | 54.8% | 51.8% |
| Paper | 5% | 9% | 15% | 8.7% | 11.8% | 14.4% |
| Wood | - | - | - | 1.9% | 2.5% | 2.8%3 |
| Metals | 1% | 1% | 2% | 0.4% | 1.0% | 0.9% |
| Glass | 2% | 2% | 3% | 1.3% | 4.6% | 4.4% |
| Plastics | 4% | 13% | 14% | 12.1% | 12.0% | 11.2% |
| Textiles | - | - | - | 2.5% | 3.4% | 4.3% |
| Miscellaneou, ash and other | 47% | 10% | 15% | 16.2% | 9.9% | 10.2% |

NA – Not available.
1. Hoornweg, Dan; Lam, Philip; Chaudhry, Manisha. Waste management in China: Issues and recommendations. Urban Development Working Paper No. 9; World Bank. Washington, DC. December 2005.
2. Wei Zhoa; vander Voet, Ester; Yufeng Zhang; Huppes, Gjalt. Life cycle assessment of municipal solid waste management with regard to greenhouse gas emissions: Case study of Tianjin, China. Science of the Total Environment (2009).

In 2003, food and organic waste represented about 57 percent of Tianjin's municipal solid waste. In comparison, the eco-city expects that the share of food and organic waste will be 55 percent in 2010, and then decline to 52 percent in 2015 after implementing the proposed waste reduction measures. The moisture content of the waste stream is uncertain, but is expected to be in the upper 50 percent range.[140] As noted, moisture content can affect the viability of incineration systems regardless of energy recovery modalities, unless a supplemental fuel is employed.

Waste composition percentages should be viewed in broad terms as the data, even when based on field sampling, have limited reliability. However, the data can depict trends and be used to assess progress on desired objectives. Data on waste composition can form indicators on the use of materials, the potential for recovering recyclables, and the suitability of the waste stream for combustion and related processes.

## Waste Collection and Transfer

Waste is collected in Tianjin daily. Community committees hire workers to collect waste door-to-door and transport it to drop off points, where it is amassed in collection trucks. Solid waste will also be collected and disposed of daily in the eco-city. Daily collection means only limited space will be needed for waste storage in residences and commercial operations.

***Truck Based Collection.*** Table 6.6 lists the estimated number of trucks that will collect municipal refuse

Table 6.6: Forecast Truck Fleet for SSTEC Based on Gross Waste Generation, 2010-2020

| Year | Forecast Truck Fleet Without Waste Reduction Measures | Forecast Truck Fleet With Waste Reduction Measures |
|---|---|---|
| 2010 | 13 | 10 |
| 2015 | 47 | 38 |
| 2020 | 86 | 70 |

Source for gross waste generation quantities: Table 6.3.

1. Truck fleet assumption: average truck net payload - 3.5 tons; Route trips per day - 2; Contingency / out-of-service trucks - 10 percent of the fleet. Preceding assumptions based on waste collection in the exiting areas of Tianjin that rely upon trucks for pickup and transport to a transfer station, treatment plants, or landfill. The trucks in Tianjin are 5-ton, diesel-fueled vehicles. Their load factor is estimated to be 0.7, which provides a net payload of 3.5 tons. In 2003, Tianjin had a fleet of 993 trucks. This truck fleet could collect the estimated 5,800 tpd of waste discarded in Tianjin, under the following (reasonable) conditions.
   - 834 trucks, or 84 percent, of the fleet of 993 trucks are active in waste collection; the balance of the fleet includes contingency vehicles, trucks out of service for maintenance, or trucks serving other uses. A typical share of contingent or out of service trucks is 10 percent.
   - A reasonable assumption that each operational waste collection truck completes two routes per day.

in the eco-city between 2010 and 2020. The estimates, which are based on the existing truck fleet in Tianjin, may be overstated, as the eco-city is a single development that considers the layout and density of residential, commercial, and other properties. Moreover, the efficiency of truck waste collection improves as population density increases. Offsetting factors, such as traffic congestion or narrow streets, diminish gains from higher population density. Waste collection operations can address traffic congestion by conducting services at night when fewer vehicles are on the road.

As all waste in the eco-city is expected to be managed by the formal sector, the waste that would have been removed by the informal sector (waste pickers) was incorporated to estimate the size of the truck fleet. Though the fleet was calculated based on expected waste tonnage, the trucks could be allocated for other services, such as transporting recyclables or organics for composting. The number of trucks may vary depending on round trip travel distances and, more importantly, times to destinations (transfer stations, treatment facilities, or landfills).

***Pneumatic Collection System.*** An alternative to truck collection being considered is an underground piping network harnessing pneumatic pressure to transport waste and recyclables from residential and commercial facilities to consolidation point. The collected materials are then deposited in containers and trucked to a treatment facility, landfill, or processing facility for recyclables. A sample schematic of a pneumatic collection system is provided in Figure 6.1.

### Box 6.2: Pneumatic Solid Waste System—Barcelona

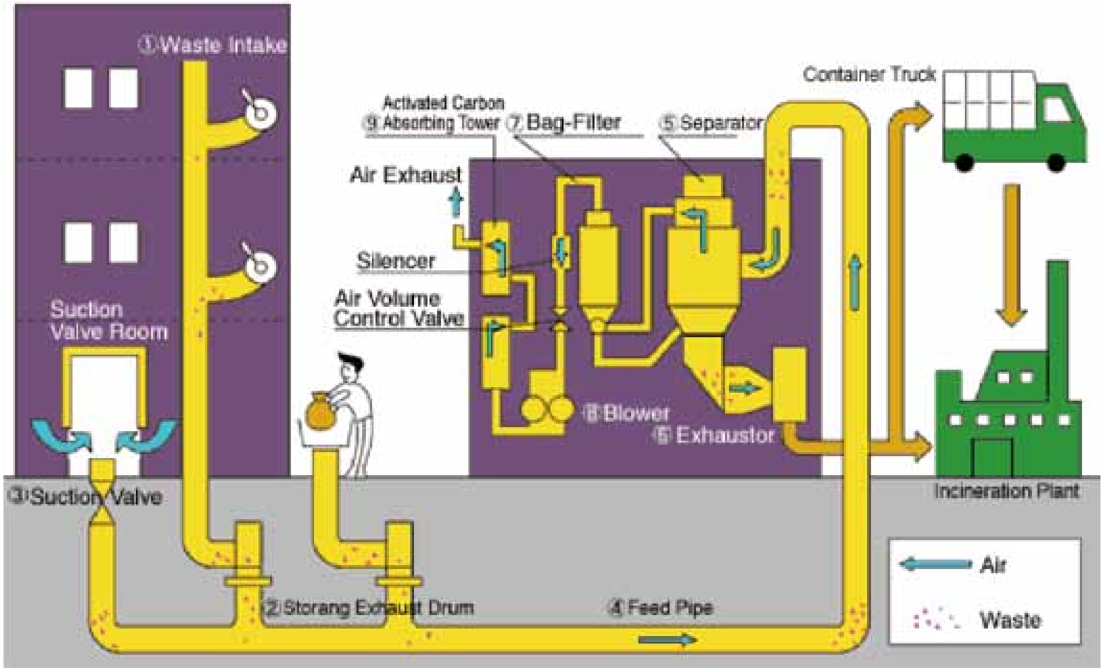
Barcelona introduced a pneumatic solid waste system in 1992—at the time of the Barcelona Olympic Games. Barcelona's master plan envisages that by 2025, 500,000 inhabitants, about 30 percent of the population, would be served by pneumatic solid waste systems. Today, the city has 8 pneumatic service districts for solid waste serving 100,000 households.

A typical pneumatic solid waste system in Barcelona consists of a service area comprising 8,000 households within a 2 km radius containing 400-500 disposal points (inlets) connected to 6-8 km of pipe network and a transfer station, where waste is transported in 16 ton-trucks for disposal. The waste stream is separated into two tracks: (i) organic, which is sent to a biogas plant; and (ii) residual, which is land filled. Recyclables are handled separately, although they could, in principle, be integrated into the pneumatic solid waste system.

A key question relates to the cost effectiveness of the pneumatic solid waste system relative to a more conventional system. Pneumatic solid waste systems are generally more cost effective in new urban areas compared to retrofits in existing urban areas. This is mainly due to the pneumatic system's lower costs for civil works, as its infrastructure can be installed with other urban infrastructure (water, electricity, etc.). In Barcelona, incremental upfront capital expenditures for installing a pneumatic solid waste system in a new urban area are estimated at Euro 700 - 1600 (up to building entrances). Operating costs are about Euro 50 per ton (including capital depreciation and replacement), which are estimated to be 20-30 percent lower than conventional disposal systems. However, comparing costs across countries is difficult as labor costs vary but are a critical determinant of operating costs.

Source: Site Visits and EnVec Company Interviews.

Figure 6.1: Pneumatic Waste Collection System Schematic [145]




In Leon, Spain, the advantages of a pneumatic system include less visual impact from containers and waste in public places, less environmental impacts from trucks, lower operational costs, and improved sorting of waste at collection points, where waste and recyclables are put into the pneumatic network.[141] The main disadvantages relative are high capital investment costs, inconveniences during construction, and possible blockages in the piping network and at collection points.

In pneumatic systems, trucks transport waste and recyclables collected at collection points to transfer stations, treatment facilities, or landfills. The truck payloads, the distances traveled, and, more importantly, the haul times, determine the number of trucks needed, their trip frequencies, and associated emissions.

There is conflicting information in the current literature on the carbon emission variations between pneumatic and truck-based systems.[142] [143] Other environmental considerations linked to both truck and pneumatic systems include noise, aesthetics, and non-carbon emissions. In general, pneumatic systems appear best suited for areas with narrow streets that render truck collection difficult, such as central parts of older cities, or crowded neighborhoods.[144]

In sum, an independent adviser should undertake a thorough investigation of pneumatic and truck collection systems in the eco-city. This assessment should analyze technical, operational, and cost factors of these collection systems and should be done before making significant capital expenditures. At this time, there are plans to implement a pneumatic system on a pilot basis. Caution is justified before committing to a pneumatic system without properly considering operational expenditures.

***Transfer Stations.*** Transfer stations are used to consolidate waste from collection vehicles for long distance transport to treatment or disposal facilities (typically more than 25 km, or 30 minutes, one way, depending on local conditions). The master plan for the eco-city indicates that eight transfer stations will be built, but there are no specific plans for these stations at this development stage.[146] Detailed plans will be devised after a pilot test of a pneumatic waste collection system is completed. Transfer stations linked to either truck or pneumatic systems may be needed to consolidate loads prior to transport to a treatment or disposal facility.

## Recycling and Composting

Recycling, especially by waste pickers in the informal sector, is important to waste management in China. An estimated 2.5 million Chinese work as waste pickers and recover up to 20 percent of the waste stream.[147]

***Recycling Waste Quantity.*** In the eco-city, the recycling and source segregation rates are expected to be 60 percent and 80 percent, respectively. Source segregation is the preferred means of recycling traditional materials, such as metals and paper, and organics (food related discards). Moreover, materials that could contaminate recyclables are kept separate from other waste.

The planned recycling rate of 60 percent is optimistic given that the countrywide average is only 20 percent. China's existing recycling rate was achieved with the help of informal waste pickers, who may be excluded from operating in the eco-city. Achieving a 60 percent recycling rate in the eco-city would be a significant achievement. Moreover, national recycling rates among the five countries with the highest recycling levels are all less than 60 percent (see Table 6.7). Furthermore, a source separation rate of 80 percent, or 48 percent of the materials to be recycled, assumes a high level of residential and business cooperation.

Table 6.7: Recycling: Five Countries with Highest Rates

| Country | Recycling Rate |
|---|---|
| Switzerland | 52% |
| Austria | 50% |
| Germany | 48% |
| Netherlands | 46% |
| Norway | 40% |

Note: the data may understate the recycling rate in urban areas, which would be expected to be higher than the national average.

The high share of organics in a recovery program that aims to attain a recycling rate of 60 percent means that residents will need to be encouraged to separate food waste. This will require frequent (probably daily) collection to prevent odors, especially during warmer weather, and to avoid attracting vermin. Based on the eco-city's estimated gross waste, 47 tpd of sorted recyclables are forecasted in 2010, assuming no implementation of the proposed waste reduction measures (see Table 6.8). An estimated 38 tpd of this quantity will be source-segregated recyclables.

Table 6.8: Gross Waste Quantity Forecasted to be Recycled and Source Segregated and Waste Without the Proposed Waste Reduction Measures, 2010-2020

| Year | Gross Waste Quantity (tons / day) | Recycled Quantity, 60% Rate[1] (tons / day) | Source Segregation Quantity, 80% Rate[2] (tons / day) | Non-Source Segregated Waste for Collection (tons / day) | Waste (tons / day) |
|---|---|---|---|---|---|
| 2010 | 79 | 47 | 38 | 41 | 32 |
| 2015 | 292 | 175 | 140 | 152 | 117 |
| 2020 | 539 | 323 | 259 | 280 | 216 |

1. Recycle quantity = Gross waste Quantity * Recycle rate (60 percent).
2. Source segregation quantity = Recycling quantity * Segregation rate (80 percent).
3. Non-source segregated waste for collection includes recyclables to be recovered at a treatment facility.
4. Waste is gross waste less the recycle quantity.

Municipal officials and non-government organizations (NGOs) that may be involved in waste management could help to educate residents and business on the value of separating waste for recycling. In addition, it may be possible to price collection services to encourage recycling. For example, under a pneumatic system, those who generate waste might be required to take their waste to a staffed collection point and pay for it based on weight. Recyclables could be accepted at a lower fee or at no charge. Recyclables could be placed in plastic bags that permit staff to see the contents to reduce the potential to improperly categorize waste.

In 2010, an estimated 41 tpd of waste will need to be collected. Of this quantity, 9 tpd will be recovered in a recycling facility; leaving 32 tpd of waste for treatment and/or disposal. These amounts will increase as the population of the eco-city grows.

If the proposed waste reduction measures are successfully implemented, the eco-city's gross waste will be less than the forecasted amount without the waste reduction measures. This corresponds to fewer recyclables sorted from the waste stream, source segregated discards, and waste that will eventually be taken to a treatment facility and/or landfill (see Table 6.9).

Table 6.9: Gross Waste Quantity Forecast to be Recycled and Source Segregate and Waste With the Proposed Waste Reduction Measures, 2010-2020

| Year | Gross Waste Quantity (tons / day) | Recycled Quantity, 60% Rate[1] (tons / day) | Source Segregation Quantity, 80% Rate[2] (tons / day) | Non-Source Segregated Waste for Collection (tons / day) | Waste (tons / day) |
|---|---|---|---|---|---|
| 2010 | 63 | 38 | 30 | 33 | 25 |
| 2015 | 234 | 140 | 112 | 122 | 94 |
| 2020 | 438 | 263 | 210 | 228 | 175 |

1. Recycle quantity = Gross waste Quantity * Recycle rate (60%).
2. Source segregation quantity = Recycling quantity * Segregation rate (80%).
3. Non-source segregated waste for collection includes recyclables to be recovered at a treatment facility.
4. Waste is gross waste less the recycle quantity.

As stated above, the eco-city's worthwhile objectives of recycling 60 percent of municipal waste and attaining 80 percent source separation are highly ambitious, especially in a new community with no history of recycling.

Seattle, Washington has actively pursued recycling for at least the past two decades. In 2007, the city recycled more than 48 percent of its waste. Looking forward, the city aims to recycle 60 percent of its municipal waste by 2012. To achieve this objective, Seattle instituted a variable pricing scheme based on the number of containers to be collected for disposal, with no charge for recyclables. Additionally, certain materials, such as old corrugated containers, have been banned from disposed waste and must be recycled.

***Recyclables Sorting Plant.*** Source segregated recyclables may require intermediate processing at a materials recovery facility to further separate recyclables prior to being sold as commodities. The amount of manual and mechanical processing depends on the level of contamination, and whether materials are collected separately or as a mixed group of recyclables. An advantage of source segregation is avoiding contamination inherent in mixed municipal waste. A sorting facility will reportedly be built near the digestion plant at the Hangu wastewater treatment plant.

***Mixed Waste Sorting Facility.*** A range of mechanical and manual options exist to recover materials from mixed waste. These options can be pursued at stand alone facilities, or in combination with other waste management activities, such as sorting at transfer stations. The materials recovered from mixed waste will have a lower value than source separated recyclables. Nonetheless, recovery of materials reduces the waste needing further treatment and/or disposal.

***Aerobic Composting /Anaerobic Digestion.*** Food waste primarily obtained from source segregated waste could be used as feedstock for an aerobic composting facility. The end product of composting is a soil conditioner that provides benefits to agricultural and horticultural soils.[148] However, compost is not a fertilizer. There are existing composting operations in Tianjin that might be able to accommodate additional organics from the eco-city.

The organic waste recovered from the eco-city will reportedly be sent to an anaerobic digestor that will accommodate sewage sludge and a fraction of organic municipal waste. The digestor will be built at the site of the Hangu wastewater treatment plant. The methane generated will be used to produce electricity (digestor gas is typically 60 percent methane). Organic waste beyond the capacity of the anerobic digestor could be sent to the existing aerobic composting facility in the Tianjin area, or to a new facility for the eco-city.

Effectively processing separated, recyclable material and recovering additional material from mixed waste are important to achieving the objectives of the eco-city. Suitably managing food waste will also be important. Without due care, the quality of recyclables will decline and derive less revenue, thereby reducing the sustainability of waste management efforts. In addition, poorly managed facilities can become undesirable neighbors by generating nuisances such as odors and vermin.

## Treatment and Disposal

***Incineration/Waste To Energy and Related Thermal Processes.*** One incineration facility (combined with a power plant) is operating in Tianjin. Additionally, it is reported that this and other incinerators in China require supplemental fuel (coal) to provide sufficient heat to evaporate moisture in the waste stream attributable to high food (organic) content.

***Landfill with or without Landfill Gas Capture and Use.*** Hangu landfill, which is outside of the eco-city, will be the disposal site for the eco-city's waste. In addition to the Hangu landfill, three other landfills receive waste from Tianjin, including the Shuangkou landfill, financed by a World Bank loan. In addition, the Shuangkou landfill is a registered Clean Development Mechanism (CDM) project that captures methane[149] gas generated from waste decomposition and uses it to generate electricity, which is sold to the power grid. The World Bank is a Trustee for the "carbon" buyer—the Spanish Carbon Fund. The type of disposal operation and the degree of landfill gas capture and treatment, if any, will affect the environmental and carbon footprint of the Hangu landfill. If the waste from the eco-city is sent to any landfill in Tianjin, except the Shuangkou site, upgrading the site to modern standards, including construction of gas recovery facilities, would strengthen the eco-city's waste management program. Regardless of which site is selected, the eco-city should enter into a well-defined agreement delineating the landfill's disposal capacity.

## Hazardous Waste Treatment

Hazardous waste will also have to be addressed in the eco-city. The KPI addresses the need to manage thorough treatment of hazardous wastes generated in the eco-city. Treatment will vary depending on the type of hazards associated with the waste. Some hazardous waste may be suitable for recycling for other uses. For example, flammable liquids might be employed as fuel in industrial applications. Infectious wastes can be rendered non-infectious through incineration, autoclave treatment, and other processes. Once sterilized, such wastes can be sent to a standard municipal waste landfill.

## Waste Management Education

The proposed waste management program for the eco-city provides a unique laboratory for learning that could be tapped by an environmental engineering program or other technical or academic program. It also provides opportunities to gain valuable insights into operational practices, including financial aspects of operating a solid waste program. The proximity to Tianjin also offers opportunities to study existing and new approaches to waste management. Moreover, the options for academic and valuable "real world" studies of urban services are extensive in all areas of solid waste management, from waste reduction strategies to disposal options. A university program might be initiated at a new school, such as one proposed for the eco-city, or with an existing university such as Tianjin University.

## Conclusion: Summary Recommendations

Overall, the proposed integrated waste management plan, which is based on an agreed hierarchy of waste management components and associated KPIs, represents a worthwhile and challenging program for the eco-city. However, the program may be overly ambitious, unless the current infrastructure focus investment plans are complemented with strong policy measures. In summary, the key components of the waste management program include:

- Waste reduction.
- Collection.
- Recycling.
- Treatment of solid and hazardous waste with residue disposal.

***Waste Reduction.*** The waste reduction component seeks to reduce the share of food-related discards in the waste stream by processing vegetables to remove parts that could enter the residential waste stream. In addition, the waste reduction plan aims to shift packaging materials to 'green' materials, which can be reused or recycled, and/or are biodegradable. Though desirable, waste reduction measures are difficult to implement successfully. The proposed waste reduction measures represent an excellent start towards reducing the eco-city's waste stream. Processing vegetables is a means to recycle food discards farther up the food chain before they reach consumers. Aside from addressing issues concerning consumer preferences on the freshness of their food supply, the eco-city should consider setting up collection points to gather food residue, which can then be recycled into compost or animal feed.

***Collection.*** Instead of truck collection, the eco-city is considering employing a pneumatic system on a pilot basis (in the start up area) to collect waste and recyclables. There are limited examples of pneumatic systems being used on the scale envisioned by the eco-city. Proceeding with a pneumatic system should be done with care, taking into account both capital and operating costs, compatibility of the system with the eco-city's recycling program, and the lack of flexibility of such systems.

***Recycling.*** The proposed recycling program, which is geared primarily towards source separation, is highly ambitious. A comprehensive program of incentives, education, and prohibition of certain waste materials may be needed to encourage residents and businesses to recycle adequately. A longer phase-in period might also be valuable to prevent discouragement if aggressive targets are not met.

***Treatment.*** The municipal waste that remains after recycling may be sent to an incineration facility outside the eco-city prior to disposal. The quantity of waste after reduction and recycling will be small relative to the throughput capacity of a cost efficient incinerator, thus such a facility might receive waste from outside the eco-city. Nonetheless, the incinerator should have an adequate pollution control system that prevents the emissions that could negatively affect public health and the environment.

***Landfill.*** Regardless of the landfill selected, the eco-city's landfill site should be an engineered facility that is operated in an environmentally sound manner. In addition, the opportunity to develop a CDM-eligible landfill gas capture project should be explored. The CDM also supports activities that reduce methane emissions, such as aerobic composting, anaerobic composting, and incineration. Aspects of such projects should be fully explored if they are under serious consideration.

***Hazardous Waste.*** The treatment of hazardous and infectious waste is important to render such wastes non-hazardous and non-infectious prior to disposal. Given that all hazardous waste in the Binhai New Area is arealy being rendered non-hazardous, this objective should be easy to fulfill for Tianjin Eco-City.

# Chapter VII
# GHG Emission Reduction Potential

## Introduction

SSTEC's sector plans were reviewed in the previous chapters. This chapter takes a cross-sectoral approach to reviewing SSTEC's envisaged urban development pattern as it relates to Greenhouse Gas (GHG) emission reductions and climate change mitigation. Given that SSTEC aims to become a "model low carbon city", this presents a good opportunity to review SSTEC's plans in terms of their potential to lower GHG emissions. It is important to note that the technological interventions covered in this chapter go beyond the draft SSTEC master plan to enable envisioning a city-wide low carbon development program. The emission reduction potential is also larger than those investigagaed in the GEF project.[150]

Urban areas are the fastest growing source of global GHG emissions, and an estimated 80 percent of GHG emissions derive from cities.[151] At the same time, cities present the greatest potential for reducing GHG emissions. As such, SSTEC's attempt to develop along a low carbon urban development trajectory will be instructive and, if successful, could be replicated elsewhere in China and beyond.

Reducing GHG emissions is an important environmental goal in itself. However, it can also bring financial benefits—through accessing carbon finance under the Clean Development Mechanism (CDM) or other carbon markets. To access carbon finance markets, detailed, bottom-up methodological approaches are needed to assess GHG emission reductions. Methodologies developed under the CDM of the Kyoto Protocol of the United Nations Framework Convention on Climate Change (UNFCCC) are examples of such approaches. Tianjin's Shuangkou landfill gas project is a registered CDM project, and the city is familiar with the CDM process.

However, CDM and other carbon methodologies essentially focus on single sector interventions, such as activities in the waste sector, and do not address a range of opportunities to reduce GHG emissions in a city, especially in buildings and non-motorized transport. Moreover, current methodologies generally do not address policy and management interventions. As such, cities find it difficult to access carbon finance commensurate with their real potential to reduce GHG emissions.

As a result, the Bank's Carbon Finance Unit is exploring options for developing a new "city-wide" carbon finance methodology. This chapter uses this new methodology, which is in the early stages of development, on a pilot basis to estimate emission reductions for the whole SSTEC project. As the methodology is under development, the results of applying this approach to Tianjin should be considered a work in progress. Nevertheless, the approach is useful to assess SSTEC's potential GHG emissions and the associated financial benefits of carbon finance.

This chapter is structured as follows: (i) overview of the potential for GHG mitigation in key sectors in a city; (ii) description of the emerging "city-wide" carbon finance methodology; (iii) application of the methodology on a pilot basis to SSTEC; (iv) estimation of the financial benefits of accessing carbon finance; and (v) conclusion.

## GHG Mitigation Potential in Cities

As mentioned in earlier chapters, cities offer many options for GHG emission reductions, particularly in three key sectors: waste management, energy, and transportation. Of these three sectors, energy and transportation are the biggest potential sources of emissions—and offer the greatest potential for reductions.

- *Energy:* Energy is mainly required for heating, cooling, and lighting in residential, commercial, industrial, and public spaces in a city. Interventions to reduce GHG emissions can be classified as demand- or supply-side efficiency improvements, or use of renewable energy sources. Most emission reduction opportunities relate to improving the energy efficiency in buildings.
- *Transport:* GHG emissions in the transport sector depend on the amounts, types, and carbon content of fuel combusted in vehicles. GHG mitigation interventions primarily focus on switching fuel, enhancing fuel efficiency, and changing transport modes. The biggest potential for reducing emissions involves switching fuels and promoting non-motorized transport.
- *Waste:* Efforts to reduce emissions in the municipal solid waste and wastewater subsectors include generating less waste, improving the efficiency of waste collection, methane avoidance, and upgrading treatment technologies. Energy generated from combusting methane could displace fossil-fuel based electricity.

The range of interventions for reducing GHG emissions includes policy measures, such as implementation of building codes or recycling requirements; technologies, such as public transportation systems or solar street-lights; and other interventions, such as awareness campaigns. A list of commonly used approaches is shown in Table 7.1. This list is not exhaustive, but illustrates some GHG emission reduction possibilities in a city.

## Emerging "City-wide" Carbon Finance Methodology

As discussed in the preceding paragraphs, opportunities to reduce GHG emissions exist in all sectors in a city. The challenge is to quantify the precise amount of emissions reduced through specific interventions. Methodologies for quantifying many types of GHG emission reductions are available under the CDM.

However, as the GHG reduction potential of many smaller sources of emissions, such as a single waste site, a small water supply system, or street-lighting, is modest, but the cost of measurement high, many urban activities are unable to access financial benefits in the carbon market. The objective of the proposed "city-wide" carbon finance methodology is to aggregate the GHG impact across various sources in a city to simplify and streamline quantification and monitoring approaches. One of the key objectives of this methodology is to facilitate development of a city-wide GHG mitigation and carbon finance program.

A methodology to quantify GHG emission reductions involves the following key components:

- identification of applicability conditions;
- defining the boundary of the intervention;
- establishing a 'business-as-usual' or baseline scenario;
- assessing the additionality of the intervention and emission reductions;
- quantification of the emission reductions; and
- monitoring the intervention and emission reductions.

## Table 7.1: Illustrative List of Interventions

| Sector | Example of Intervention | Measurement Approach | Estimation Approach |
|---|---|---|---|
| Energy Sector | | | |
| Energy Efficiency (demand-side) | Street-lighting | AMS II.C | kWh/km |
| | Water pumping | AM0020 | kWh/$m^3$ |
| | Buildings envelope, heating and cooling | - | W/$m^2$ |
| | Electrical equipment (lighting, refrigeration, etc) | AMS II.C<br>AM0048 | kW/TR<br>kW/lm |
| Energy Efficiency (supply-side) | New District heating networks | AM0044 | kJ/km |
| | Efficiency improvement in district heating | AM0058 | kJ/unit of fuel |
| Energy Efficiency (supply-side) | Solar water heating | AMS I.C | kWh/$m^3$ |
| | Solar lighting (streets or households) | AMS I.A | kWh/km |
| | Heat pumps for heating and cooling | AM0072<br>AMS I.C | kWh/$m^2$ |
| Transport Sector | | | |
| Carbon Content of Fuel and fuel switch | Reducing carbon content of fuel by blending sustainable biofuel with fossil fuel | AMS T | $gCO_2$/litre |
| | Conversion of a public bus from diesel to diesel hybrid, e.g., electricity or CNG | AMS C, S | |
| Fuel economy and Energy Efficiency | Enforcement of higher fuel economy standard for different type of vehicles that reduce the fuel consumption per distance travelled | - | $gCO_2$/unit wt |
| | Standardized vehicle maintenance; engine retrofit | AMS III.AA | |
| | Installation of a regenerative breaking system in an electric train system | AMS III | |
| | Neighborhood logistics for daily provisions and goods transport; scheduled waste collection; | - | $gCO_2$/unit wt |
| Modal Shift: shifting number of trips and distance travelled from motorized private vehicles to public transport and NMT | Promoting transit oriented development, including non-motorized transport | - | VKT and $gCO_2$/km |
| | Implementation of public transport, e.g., Bus Rapid Transit (BRT), Light Rail Transit (LRT), and Mass Rapid Transit (MRT) corridors and feeder systems | AM0031 | |
| | Travel Demand Policies, including parking cost, reduced parking availability; congestion pricing ; car-free areas; etc. | - | |
| Waste Sector | | | |
| Solid waste disposal | Reduce waste generation (waste reduction) | - | Composition data, Kg/person and $CH_4$/kg |
| | Improve waste collection rate | CDM Tool | IPCC 2006 |
| | Recycling | - | kWh/kg |
| | Methane avoidance<br>Anerobic digestion<br>Aerobic composting | AMS III.F<br>AM0025 | $CH_4$/kg (IPCC 2006) |
| | Incineration, Refuse Derived Fuel, other thermal processes (pyrolysis) | AMS-III.E<br>AMS-III.F;<br>(pyrolysis)<br>AM0025 | IPCC 2006 |
| | Landfill gas (methane) capture and flaring/energy production | AMS-III.G<br>ACM0001 | IPCC 2006 |
| Waste water | Sludge treatment system – anaerobic digestion (methane capture and flaring/energy production) or aerobic management (land application) | ACM0014 | IPCC 2006 |
| | Anaerobic treatment of organics in wastewater and methane capture and flaring/energy production) | AMS-III.H | |
| | Aerobic treatment of organics in wastewater displaces anaerobic treatment | AMS III.I | |
| | Improve collection/treatment | - | |

The "city-wide" methodology is limited to programs or activities undertaken by a city authority, and its implementing agencies and contractors. A city is a multi-layered, complex governance system. However, to establish a clear boundary for emissions that can be attributed to a city, the city is considered as a single administrative unit. Emissions from sources that the city can control are categorized as direct, while sources that a city can influence are categorized as indirect. For example, direct sources include public buildings and public services, indirect sources include commercial buildings and private vehicles.[152]

A critical element is to establish a "business as usual" scenario or "baseline" that can be used to assess whether any proposed intervention is additional. For a typical existing city, the baseline is based on current and projected city services. For a new city, common practices in the region, country, or neighboring city can serve as a proxy. In both cases, the baseline is assessed for individual interventions and can directly refer to government standards or policies. Depending on the choice of the baseline scenario, the emission reduction estimates will also vary. Assessing additionality is a key requirement for ensuring the environmental integrity of the intervention. Monitoring is also important to verify quantification and the appropriate trading of emission reduction benefits linked to a project.

The "city-wide" methodology has two approaches to quantify GHG emission reductions in a city: (i) a "measurement" approach—which is based on the approved CDM methodologies; and (ii) an "estimation" approach, which is based on the Intergovernmental Panel on Climate Change (IPCC) and other approaches. The city-wide program would have the flexibility to choose the most suitable approach, depending on local circumstances and capacities.

The "measurement" approach involves the use of 13 CDM methodologies covering more than 20 technological options in the transport, waste, and energy sectors, which can be extended as new CDM methodologies become available. CDM methodologies enable projects to measure and monitor reduced GHGs compared to 'business-as-usual' trends and "baselines" for specific sources of emissions. They impose strict monitoring requirements.

The "estimation" approach estimates improvements in the efficiency of service delivery. This track allows the use of IPCC default values, proposed CDM methodologies, and simplified macro-parameters to measure emission reductions as well as monitor project activities based on energy intensity and specific energy consumption parameters. This could be a useful alternative for cities that provide basic public services more efficiently, but whose service impacts are not easy to measure and monitor. Such macro-approaches are perceived to have greater uncertainty than calculated GHG emission reductions directly attributable to project interventions. As a result, conservative default factors are used, and discounted, i.e., by 20%, to account for uncertainties.

The "city-wide" carbon finance methodology is work in progress. More work is needed to establish appropriate administrative limits of city authorities, incorporate the full range of direct and indirect sources of urban GHG emissions, identify effective interventions to address or influence GHG sources, and finally calculate GHG emission reduction benefits. The calculations should also take account of the risks of double-counting benefits, interactive effects between sectors, technologies and policies, and limitations on resources for monitoring. The current methodology also leaves out important issues, such as the impact of urban spatial form on GHG emissions.[153]

## SSTEC and GHG Emission Reduction Estimation

This section provides GHG emission reduction estimates for SSTEC based on the preliminary application of the city-wide methodology. Earlier chapters discussed SSTEC's sector plans and emission sources, which can be broadly categorized into waste, transport, energy, and water sectors. This section describes the planned, proposed, and other possible policy and technology interventions for SSTEC, and their GHG emission reduction potential. Assumptions are derived from the current sector plans as discussed in earlier chapters.

SSTEC has set specific GHG emission target of 150 ton-C/1 million US$GDP, as part of its KPIs. Featuring a GHG related KPI is a good idea as it incorporates concerns on GHG and climate change mitigation into the city's management process. However, SSTEC's target is ambitious considering that in 2006 Hong Kong SAR, China reported emissions of 190 ton-C and Shanghai 429 ton-C per 1 million US$GDP. China's national average in is also a much higher 750 ton-C per 1 milion US$GDP. However, as discussed in Chapter III, the KPI will be less useful when applied to a relatively small city such as SSTEC, as it aggregates many economic and energy characteristics that are more easily captured at a regional or national level. Comparisons using this indicator should be applied carefully and may be more meaningful to cities and regions with similar economic structures and climate conditions. To give a more complete picture, an additional indicator such as carbon emissions per capita can be useful to a capture the effects of population density.

From the review of the sector plans, as described in Chapters III-VI, it is evident that emissions can be reduced through a range of activities. A key challenge is to ensure that these activities are above-and-beyond the "business-as-usual" or "baseline" scenario. In the following analysis, baselines are derived on a project-by-project basis. As this is a new city, it does not have any existing baseline. Furthermore, as the city is expected to be fully constructed and inhabited by 2020, a comparable baseline would have to be realistic for 2020 as well. Due to the inherent uncertainties in projecting emissions linked with consumer choices in the future, multiple emission reduction scenarios are possible. The baseline scenarios considered include: (i) common technological practices in China in transport, energy efficiency, the building sector, and waste management; and (ii) the use of electricity from the eastern China grid to support renewable energy sources.

The following paragraphs include brief descriptions of SSTEC's plans, including potentials for GHG mitigation in each sector. GHG emission reduction estimates address planned and proposed interventions and use a combination of approaches (see Table 7.1). For each project activity, a baseline is determined, and the GHG impact of the proposed intervention compared with the baseline scenario, to quantify GHG emission reductions.

## Waste Sector

As described in Chapter V and VI of this report, the waste sector plans are still evolving, especially on sludge management and waste disposal. However, the estimation of emission reductions assumes that good practices in waste management are being pursued. The specific areas evaluated for GHG emission reductions include (for assumptions, see the footnotes of Table 7.2):

- *Waste Reduction:* Estimates reflect SSTEC's program to reduce the quantity of waste discarded in the eco-city, and to promote 'green' packaging.
- *Methane Avoidance:* Aerobic composting, anaerobic digestion with gas capture, and incineration with or without energy recovery (including refuse-derived fuel) are waste treatment options that avoid generating methane. SSTEC is considering the following:

- *Sludge.* SSTEC is planning an anaerobic digestor system to treat sludge (solid residual) from wastewater treatment. In a digestor, the volatile (organic) solids are reduced by 50 to 60 percent producing methane. The proposed plan involves the addition of up to 200 tons per day of organic waste (food residue) to the digester. The methane produced could be used to produce electricity for on-site use, and/or sold to the power grid.
- *Incineration.* An existing incinerator in Tianjin requires supplemental fossil fuel (coal) to remove the moisture from food waste so that it can burn. Food waste will exceed 50 percent of the waste to be discarded in the eco-city, and was reported to have a moisture content of 58 percent in 2003 (Table 6.5, Chapter VI). This moisture content is much higher than desirable for combustion.

- *Solid Waste Disposal:* SSTEC's residue from waste treatment is expected to be sent to the Hangu landfill. Reflecting experiences at the existing Shuangkou CDM project, it is assumed that SSTEC's land-filled waste will recover landfill gas (LFG) and use the captured LFG (about 50 percent methane) for power generation.

As shown in Table 7.2, GHG emission reductions can be achieved through waste reduction, landfill gas recovery, anaerobic digestion, and incineration. Among these techniques, incineration and anaerobic digestion offer the largest estimated GHG emissions reduction potential.

Table 7.2: Waste Management Opportunities for SSTEC

| Waste | Intervention (A) | Possible baseline option (B) | Difference (B)-(A) | GHG Emission Reductions ($tCO_{2e}$/avg.yr) |
|---|---|---|---|---|
| Municipal Solid Waste | Waste Reduction 1 | Forecast Waste Composition and Quantity | Reduction in $CH_4$ | 4,100 |
| Municipal Solid Waste (Organics) / Wastewater Sludge | Anaerobic Digestion 4 | Landfill without Gas Capture, based on 408 tpd of municipal waste and sludge | Reduction in $CH_4$ | 61,200 |
| Municipal Solid Waste | Incineration 5 | Landfill without Gas Capture, based 500 tpd of municipal waste | Reduction in Reduction in $CH_4$ | 75,000 |
| Municipal Solid Waste | Landfill Gas Capture 2,3 | Landfill without Gas Capture, based on 234 tpd of municipal waste | Reduction in $CH_4$ | 18,000 |

Assumptions
1. Based on reduction of vegetative waste only:
   - 9 percent reduction in vegetative waste.
   - Forecast baseline generation rate 234 tpd (Table 6.3).
   - Forecast composition for food/organics (Table 6.5).
   - Reduction in total waste quantity (12 tpd or 5.1 percent).
   - Landfill gas capture assumes the gas will be captured at a rate of 50 percent and used (95 percent) for power generation with some excess gas (5 percent) flared. Emissions reductions based on a waste loading at the landfill of 234 tpd.
2. The landfill suggested as a depository for waste from the Eco-City is reportedly in need of various upgrades to qualify as an engineered landfill, although this is uncertain at present. An upgraded site would benefit the Eco-City through reduction in the quantity of greenhouse gas emitted to the atmosphere as well as to other parts of Tianjin that also send waste to this disposal site.
3. Wastewater treatment plant sludge estimated based on the assumption outlined below. The organic solid waste was proposed at 200 tons per day. The sludge quantity was estimated as:
   - An equivalent dwelling unit (EDU) population = 2.5 persons.
   - Wastewater flow per EDU = 0.66 $m^3$ per day.
   - Total suspended solids = 500 mg per liter.
   - Sludge generation (dry weight basis) = 41.7 tons per day.

   Sludge generation (wet weight basis) = 208 tons per day (dewatered using a belt filter press).
4. Waste quantity assumed to be 500 tons per day, which is a about the minimum size for a field erected incineration facility. Potential incinerator size under consideration is unknown. Other assumptions include facility will recover the combustion heat in the form of steam to generate electricity, based on an on-line availability of 95 percent. The carbon released from the combustion of supplemental fuel to dry the waste sufficiently for combustion was not accounted for.

## Transport Sector

As explained in Chapter IV, SSTEC's relatively high target population density supports a transit-oriented development model. This model, coupled with explicit provisions for "clean vehicle" technologies, provides an excellent opportunity for SSTEC to implement low carbon transport policies that reduce GHG emissions in the transport sector. The estimated GHG reductions fall into the following two areas (for assumptions, see the footnotes of Table 7.3):

- *Modal Split:* SSTEC's KPI aims for a 90 percent share of "green" transport (i.e., walking, cycling, and use of public transport). Though China's cities have historically had high shares of green transport between 80 percent and 90 percent, rising incomes have promoted greater use of private vehicles. SSTEC's following strategies target reduced GHG emissions:
  - integrated transportation and land use planning to promote increased use of public and non-motorized transportation;
  - implementation of green public transportation technologies to improve the fuel efficiency and operational efficiency of public transit;
  - travel demand management policies to discourage the use of private automobiles and improve traffic flow.
- *Switching fuels:* If SSTEC were to provide alternative fuels to public and private vehicles in the eco-city, this could result in significant GHG emission reductions.

As seen in Table 7.3, the modal split, which includes a large number of policy and management measures, could result in significant emission reductions. However, enforcing fuel standards that limit the carbon content of fuels and vehicles registered in the eco-city area would have an even greater impact. It is important to note that this calculation is based on a resident population of 350,000, and captures only the transport of people within the eco-city.

Table 7.3: Transport Sector Opportunities for SSTEC

| Transport | Intervention (A) | Possible baseline option (B) | Difference (B)-(A) | GHG Emission Reductions ($tCO_{2e}$/avg.yr) |
|---|---|---|---|---|
| Modal split (Share of green transport within eco-city area) | 90% (planned) | 80% (declining to 35% by 2020) | 55% | 210,474 |
| Fuel Switch (Indicative) | 10% blend of zero emission fuel | No use of alternate fuels | 10% | ~400,000 |

Assumptions:

1. Days per year: 360
2. Total Passenger Trips per Day: 1,060,000 (Table 4.7)
3. Baseline Fuel Efficiency: 15 percent less efficient than with project (EU Std)
4. Electricity Emissions Factor: 0.79kg.kWh (IEA 2008)
5. Carbon Content of Fuel: IPCC 2006
6. Fuel Volume: US EPA 2001
7. Fuel switch: 25 percent of all vehicles in SSTEC convert to CNG
8. Baseline option: 35% [This is derived from 2 data sources, (a) share of green transport in SSTEC in 2013, which will be increased to 90% by 2020 and, (b) the rapid growth of private transport in China, which is expected to decrease the share of public transport from 80% in 2008 to around 35% in 2020] There could be several other options, which would provide other estimates of GHG emission reductions.

## Energy Sector

As explained in Chapter III, SSTEC has decided to adopt a strong sustainable energy strategy supporting the use of a cleaner and renewable energy supply. SSTEC plans to encourage green buildings, energy efficient technologies, a 20 percent share of renewable energy sources, and complete coverage by central heating systems. These initiatives would cover most public services. The specific estimated GHG emission reductions fall into three areas (assumptions are in the footnotes of Table 7.4):

- *Energy demand-side:* SSTEC plans to ensure 100 percent compliance with the green building code (15 million $m^2$ of green buildings); installation of high-efficiency pumping systems for rainwater, sewage, water supply, and recycled water; and deployment of energy efficient, solar street lights. Emission reductions are determined by comparing the energy consumed by the old and inefficient equipment to the reduced energy consumed by the new, more energy efficient equipment.
- *Energy supply-side:* SSTEC plans to establish a new district heating and central air-conditioning systems. Current plans will establish group level sub-stations to supply heat. The city will source a part of its electricity and heat requirements from two CHP plants. Any technological improvements in the power plants influenced by SSTEC could result in an apportioned share of emissions reductions for the eco-city. These reductions are not, however, included in the current estimations.
- *Renewable energy:* SSTEC has an ambitious plan to source 20 percent of its electricity needs from renewable energy sources, including solar, geothermal, and biogas. The biogas-based electricity could fulfill auxiliary power requirements of SSTEC's waste treatment plant. Solar power will be used for street-lighting and heat pumps for heating and cooling services. Emission reductions from installing renewable energy based technology are calculated based on the amount of obviated electricity generated from a fossil-fuel based power plant.

As shown in Table 7.4, within the energy sector, the building sub-sector is the one with the single largest potential for GHG emission reductions.

Table 7.4: Energy Sector Opportunities for SSTEC

| Waste | Intervention (A) | Possible baseline option (B) | Difference (B)-(A) | GHG Emission Reductions ($tCO_{2e}$/avg.yr) |
|---|---|---|---|---|
| Residential, public, commercial, industrial | Green building standard | Current building code | | 261,111 |
| Street-lighting I | Efficient lamps | Conventional lamps | 30% | 210 |
| Water pumping | Efficient pumping systems | Conventional pumping system | 20% | 5,390 |
| Street-lighting II | Solar PV | Conventional lamps | 100% | 698 |

Assumptions: The main assumption is the installation of 100% of the following tasks:

1. Construction of entire 15 million $m^2$ of building stock in complete compliance with the proposed green building standard. This emission reduction estimation is based on difference between the building standards ($kWh/m^2$). These numbers are based on a whole-building simulation model, which includes building envelope, electricity and space heating and domestic hot water systems.
2. Installation of 14,000 solar street-lights, energy efficient 3,000 streetlights: operating for 2,920 hours every year and displace, 100 percent electricity and improve efficiency by 30 percent respectively
3. Installation of 7 high efficiency pumping systems, which are 25 percent more efficient than conventional systems
4. Installation of solar water heaters in 100,000 households with 1,200 hours of annual usage.
5. Grid emission factor of 0.87 tons$CO_2$/MWh.

## Emission Reduction Estimates and Carbon Markets

It is important to reemphasize that the "city-wide" methodological approach continues to be developed, and that these results represent preliminary efforts to apply this approach to SSTEC's evolving plans. Based on calculations, and assuming implementation of all considered technologies and policies, SSTEC's emission reductions could reach up to one million tons $CO_2$/year by 2020, with the transport and energy sectors clearly contributing most of the reductions.[154]

Emission reductions certified under the CDM or verified through the voluntary mechanisms allow projects to earn credits, each equivalent to one ton of $CO_2$. These credits can be traded and sold on the carbon market. The carbon market is broadly divided into voluntary and compliance markets. The existing project-based compliance markets are dominated by CDM projects, though the number of Joint Implementation projects is rising. Voluntary markets support activities to reduce emissions not mandated by policymakers, including certifications to support carbon neutrality. Different markets have varying requirements for methodological rigor, regulatory requirements for baselines, additionality, and so forth. They also have different methods for setting the prices of credits.[155]

As SSTEC is developing concrete city management policies and preparing detailed infrastructure designs, it should consider incorporating measures that help to improve efficiency while reducing GHG emissions, thereby possibly leading to revenues from carbon finance.

In Table 7.5, indicative calculations of the potential financial benefits of accessing the carbon market are provided. The Base Case was calculated using the GHG emissions above assuming that carbon credits provide US$10 per ton of $CO_{2e}$. The Low Case assumes a 20 percent lower GHG reduction at a price of US$5 per ton of $CO_{2e}$. The High Case assumes a scenario where SSTEC invests aggressively in measures and policies that lead to significant reductions in GHG emissions. The High case assumes GHG emissions drop a further 20 percent from the base case, and that credits are priced at US$15 per ton of $CO_{2e}$.

Under the Base Case, the Carbon Finance potential is up to US$10 million per year. This doubles to US$18 million per year under the High Case, but falls to US$4 million per year under the Low Case.

Table 7.5: Preliminary Estimates of Quantity and Value of GHG Emission Reductions

| Sector | Low case | | Base Case | | High case | |
|---|---|---|---|---|---|---|
| | ERs ($tCO_{2e}/y$) | Value (USD mil/y) | ERs ($tCO_{2e}/y$) | Value (USD mil/y) | ERs ($tCO_{2e}/y$) | Value (USD mil/y) |
| Waste | 126,640 | 0.63 | 158,300 | 1.58 | 189,960 | 2.84 |
| Transport | 488,380 | 2.4 | 610,474 | 6.10 | 732,569 | 10.98 |
| Energy | 213,927 | 1.06 | 267,409 | 2.67 | 320,890 | 4.81 |
| Total | 828,946 | 4.14 | 1,036,183 | 10.36 | 1,243,419 | 18.65 |

## Conclusions

As discussed in this chapter, the potential for GHG emission reductions exists in various policy and technology interventions undertaken by city authorities. Cities can identify and implement interventions in their own service operations, such as water pumping, street-lighting, heat supply networks, etc. More importantly, cities can implement administrative and policy interventions to influence the behavior of residents and commercial organizations, such as traffic management, building code enforcement, recycling laws, etc. Due to the integrated nature of urban life, city authorities can undertake strategic approaches to urban planning and low carbon lifestyles.

This chapter indicates significant scope for SSTEC to plan and incorporate GHG reduction policies and technologies in its evolving sector plans. SSTEC is pioneering some approaches in the detailed plans being prepared for Phase I's start-up area, which will allow SSTEC to scale-up interventions city-wide at a later stage.

To maximize the benefits linked to GHG emission reductions and to be eligible for carbon finance, SSTEC should strive to exceed "business-as-usual" standards at the regional and national levels. SSTEC also needs to be able to measure its performance and quantify its success. Without these elements, SSTEC will not be able to become a "model low carbon city" and generate financial benefits from carbon finance. In this context, SSTECAC should consider the following recommendations:

- Develop additional GHG emission reduction indicators, both intra and cross-sector ones, to more comprehensively measure GHG emission reductions of the project; and
- Continue to explore and identify the best options for accessing carbon finance, either through a traditional CDM project or through the emerging "city-wide" carbon finance methodology (the World Bank's GEF project can help in this respect).

## Chapter VIII

# Institutional, Financial, and Risk Management Challenges

The implementation of SSTEC builds on strong foundations. The project is guided by a clear vision and supported by strong leadership at the local and national levels. It has established dedicated administrative capacity and project implementation is underway. However, to ensure that implementation proceeds effectively, some challenges must be overcome. SSTEC is a large project with an untested, innovative vision. It aims to build a new, more ecologically sustainable city on a tight implementation schedule. Such a project presents significant risks that need to be actively managed to ensure that the original project vision can be implemented effectively. The example of Dongtan, mentioned in Chapter I, is the most recent example of many projects that have encountered significant implementation problems.

This chapter provides a consolidated overview of SSTEC's institutional structure and challenges, its investment and financial plans, and outlines specific risks during project implementation. As such, it addresses and pulls together many of the key cross-cutting themes of the project. Overall, the SSTEC project presents a distinct opportunity to implement many of the recommendations in the previous chapters, especially when compared to the counterfactual of Chinese urbanization which is, in part, characterized by a less planned, less integrated and more ad hoc urban development. This is especially the case because SSTEC has established integrated administrative capacity: the Sino-Singapore Tianjin Eco-City Administrative Committee (SSTECAC) in charge of directing overall project development, and the Tianjin Eco-City Investment and Development Co. Ltd. (TECID), an integrated multi-sector infrastructure development corporation. In principle, this organizational setup will enable the project to realize the important benefits of a more integrated approach to urban development.

## Institutional Structure and Challenges

***Overview.*** The institutional and organizational structure of SSTEC reflects its nature as a bilateral project between the Chinese and Singaporean Governments. The implementation arrangements are divided into areas where the Chinese side takes responsibility and where Singapore is involved, mainly through a Joint Venture (JV) Company (Co.) formed between Singaporean and Chinese counterparts. The Chinese side will take the lead responsibility in acquiring land and constructing basic infrastructure, such as the transport network and key public buildings (schools, hospitals, etc.). The JV Company will be responsible for developing a part of residential and commercial real estate, and will be engaged in some infrastructure development. SSTEC's organizational structure is complex, as it involves multiple participants from the public and private sector across the two countries. It is principally governed by the SSTEC Framework Agreement, the SSTECAC Regulation, and a "Commercial Agreement" between all parties concerned.[156]

***Administrative Agencies.*** SSTECAC is the Chinese local authority responsible for the overall implementation and coordination of the project. SSTECAC was set up specifically for the project and is responsible for all government administrative functions. SSTECAC is governed by the "Regulations for the Administration of the Sino-Singapore Tianjin Eco-City", which gives SSTECAC an integrated mandate to oversee the eco-city planning and implementation processes. The Chairmen of SSTECAC reports to the Chairman of the Administrative Committee of the Binhai New Area and the Mayor of

Tianjin Municipality. However, because SSTECAC does not correspond to a government district, implementation of the project must be coordinated with the two existing district governments in which SSTEC is located, namely the Hanghu and Tangu districts, and, more broadly, with the Binhai New Area and Tianjin Municipality.[157]

### Box 8.1: SSTEC Project National-level Coordination.

The Governments of the People's Republic of China and the Republic of Singapore signed a Framework Agreement that governs the overall implementation of the SSTEC project. Coordination of the SSTEC project at the national level is ensured by a Joint Steering Committee, co-chaired by the Deputy Premiers of China and Singapore. The lead Ministry on the Chinese side is the Ministry of Housing, Rural and Urban Construction; and eight additional Ministries and offices are involved, including NDRC, the Ministry of Finance, and the Ministry of Environment, and the Mayor of Tianjin. Below the Steering Committee, a Joint Working Committee was established that is co-chaired by the Ministers of the Ministry of Housing, Rural and Urban Construction of China, and the Ministry of National Development of Singapore. The Joint Working Committee comprises the same Ministries as the Joint Steering Committee, with the representative from Tianjin being the Chairman of the New Binhai Area. The lead Ministry on the Singapore side is the Ministry of National Development of Singapore, with an additional four Ministries represented in the Steering and Working Committees.

Source: SSTEC Press Releases

### Box 8.2: SSTEC in the Binhai New Area

The Tianjin Binhai New Area is a major development area—established with the intention of replicating the success in development of Shenzhen and Pudong, Shanghai. However, unlike Pudong, the TBNA is not in the official administrative strata of the government system in the People's Republic of China. It consists of several districts in Tianjin Municipality, namely Tangu District, Hangu District, and Dagang district. SSTEC is geographically located in two of the districts of Binhai New Area: Tangu and Hanghu. The SSTEC project is therefore administratively connected to Tangu and Hanghu districts governments, the Administrative Committee of Binhai New Area, and Tianjin Municipality.

Source: SSTEC Interviews

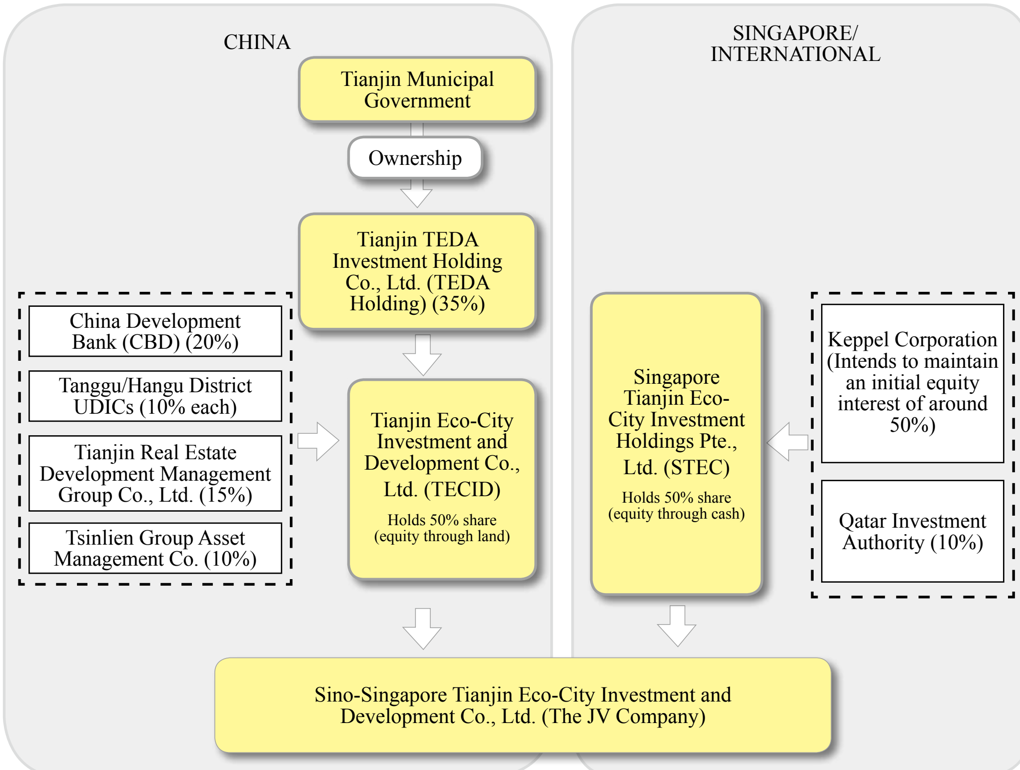
***Implementing Companies.*** As shown in Figure 8.1 below, there are two principal implementing companies.

*Tianjin Eco-City Investment and Development Co. Ltd. (TECID)*—the Chinese Consortium. TECID has an initial registered capital of RMB 3 billion and is owned by Tianjin TEDA Investment Holding Co. Ltd. (TEDA Holding) (35 percent), China's State Development Bank (20 percent), Tianjin Real Estate Development Management Group Co. Ltd. (15 percent), Tianjin Tangu Urban Construction Investment Corporation (10 percent), Tianjin Hanbin Investment Co. Ltd. (Hangu District) (10 percent), and Tsinlien Group (Tianjin) Asset Management Co. Ltd..

*Sino-Singapore Tianjin Eco-City Investment and Development Co. Ltd.*—the JV Company between TECID and Singapore Tianjin Eco-City Investment Holdings Pte., Ltd. (STEC). STEC, in turn, is the Singapore Consortium, owned by Keppel, which intends to maintain a 50 percent stake over the medium term.[158] The JV Company has an initial registered capital of RMB 4 billion contributed in equal shares by TECID and STEC.[159] The JV Company will be managed by TECID and STEC, each of which will be entitled to nominate an equal number of Directors to the Board. TECID will appoint the Chairman of the Board, who will act as the legal representative of the JV Company, and STEC will appoint the Chief Executive Officer.

***Respective Responsibilities.*** The respective responsibilities of TECID and the JV Company are defined in the Commercial Agreement between both parties. TECID's responsibilities include: (i) purchasing land and site formation; (ii) construction of basic infrastructure, including for water, electricity, heating, natural gas distribution, renewable energy, landscaping and solid waste collection, and waste treatment; and (iii) provision of public facilities, such as schools, universities, and hospitals (etc.). To manage the construction and implementation processes, TECID established four subsidiary companies. TECID is

Figure 8.1: Project Implementation Overview



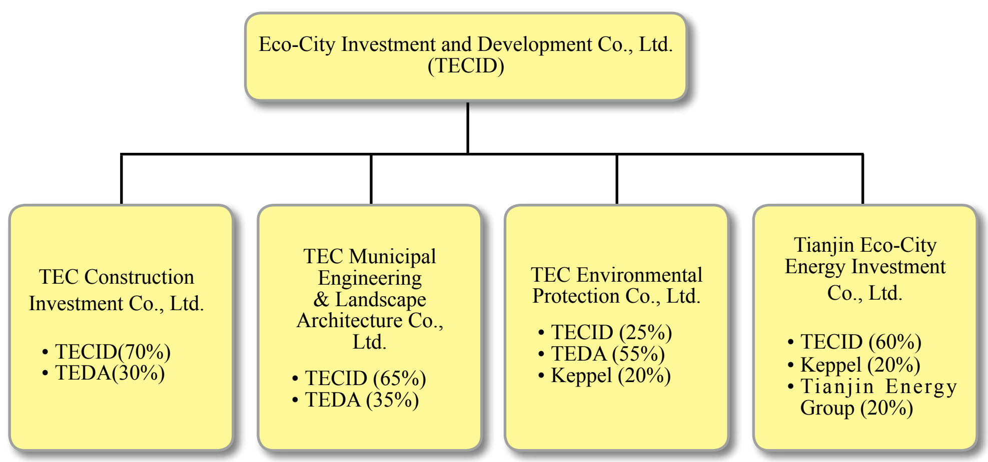

the holding company responsible for overall management and for raising financing required for these four subsidiaries.[160]

- TEC Energy Investment Company: responsible for renewable energy and the supply and distribution of water, gas, power, heat, and telecommunications. 60 percent of TEC Energy Investment Co. is owned by TECID; 20 percent by Keppel; and 20 percent by Tianjin Energy Group.
- TEC Environmental Protection Company: responsible for wastewater treatment and reclamation, water body rehabilitation, and the collection, transfer, and transport of solid waste, including through the proposed pneumatic collection system. 25 percent of TEC Environmental Protection Company is owned by TECID, 55 percent by TEDA Group, and 20 percent by Keppel.
- TEC Construction Investment Company: responsible for public facilities, including schools, hospitals, and universities, etc.. 70 percent of TEC Construction Investment Co. is owned by TECID, and 30 percent by TEDA Group.
- TEC Municipal Engineering and Landscape Architecture Company: responsible for landscaping. 65 percent of TEC Municipal Engineering and Landscape Architecture Co. is owned by TECID, and 35 percent by TEDA Group.

The above arrangements refer only to SSTEC's construction phase. Only limited decisions have been taken on how to operate the assets created under TECID. Though this is not atypical in China's urban infrastructure construction process, such a setup may create difficulties at later stages of project implementation. Overall, it is recommended that operation and maintenance of the key utilities services be outsourced to sub-contractors, who will receive a fixed fee for services, while TECID will retain responsibility for billing and collection. Furthermore, the initial review of sector plans and feasibility studies suggest that insufficient attention has been directed towards cross-sectoral efficiency gains. This is somewhat disappointing as, in principle, the institutional setup should support cross-sectoral collaboration.

The JV Company is essentially the master-developer of SSTEC. Specifically, the JV Company will be responsible for: (i) residential and commercial real estate development; and (ii) construction of some infrastructure, specifically the road network (including traffic lights and road signs), the wastewater collection system, the storm water collection system, and the reclaimed water distribution system.[161] After the construction phase, the responsibilities for operating the assets created under the JV Company will be transferred to TECID. However, TECID is only in the early stages of developing a comprehensive operational management strategy.

Figure 8.2: TECID Subsidiary Companies




***Tianjin Eco-City and Binhai New Area.*** There are significant institutional inter-linkages between the Tianjin Eco-City and the Binhai New Area. For some regional infrastructure, such as the metro system, the inter-linkages are clearly articulated and are fully defined, with the Binhai Mass Transit Development Co. Ltd. in charge. In other cases, the inter-linkages are not clearly spelled out, and there is a relatively strong risk of institutional fragmentation. For example, while the water supply pipelines within SSTEC are provided by TEC Energy, the water supply system and water treatment outside the eco-city are managed by TEDA Water Company, Jinbin Water Company, and Hangu Water Company. Important challenges include coordinating and managing infrastructure services across institutional boundaries in Binhai New Area. Questions such as whether Tianjin Eco-City will be fully integrated into the regional service delivery system must be addressed.

***Recommendations.*** Reflecting its nature as a bilateral project, SSTEC has a complex institutional structure. The SSTEC Framework Agreement, SSTECAC Regulations, and the Commercial Agreement provide an initial foundation for successfully commencing project implementation. However, continued attention will be needed to address key institutional and management challenges to ensure the successful implementation of SSTEC, particularly given the project's complexity and multiple public and private sector participants.

### Box 8.3: Land Acquisition

TECID has pledged 53 percent of available land[162] in SSTEC to the JV Company, which corresponds to all land that can be commercially developed. The land price was agreed (as defined in the commercial agreement with the JV company) at RMB 12 billion (which corresponds to RMB 635,000 per mu).[163] The JV Company will pay TECID RMB 10 billion (cash) to acquire the land. The remaining RMB 2 billion represent the equity investment by TECID in the JV Company, corresponding to 50 percent of its registered capital. STEC will contribute to capital in cash.

To date, TECID owns only part of the land[164] in the SSTEC project area. 16 $km^2$ were actually acquired, for which TECID paid a total of about RMB 4 billion. The remaining land needs to be acquired. TECID estimates that currently-owned land is sufficient for the initial development of SSTEC as, according to the commercial agreement with JV, only half of the project's land will need to be provided to the JV Company in the project's first five years. The remaining land will be transferred in phases over the course of project implementation.

Source: SSTEC Interviews

- *Integrated Management Approach.* The establishment of integrated administrative capacity embodied in SSTECAC and a multi-sector infrastructure corporation, i.e. TECID, provides a solid foundation for implementing integrated urban planning and development. As mentioned in Chapter II, many efficiency gains can be realized through an integrated urban planning and development approach. Yet, in practice, few cities manage to decisively implement such an approach. SSTEC's challenge is to ensure that the "integrated vision" of the eco-city does not get lost during implementation. The key will be to contain institutional fragmentation across the various participants, especially between TECID and the JV Company, and within TECID and across its subsidiaries. An initial review of the sector and feasibility studies suggests that insufficient attention has been paid to enabling cross-sector efficiency gains.
- *Focus on Operational Issues.* To date, SSTEC's project management has focused on the project's initial construction phase, in which TECID and its subsidiary companies function essentially as construction companies. Though this corresponds to general practices in China, it is important to begin developing sustainable operating arrangements for the assets created in SSTEC early during project implementation. This will ensure a more strategic and long term project management approach. Early attention on the operational dimensions of the project is important to minimize tensions and conflicts that often arise in complex projects involving multiple public and private sector participants. It is also important from financial and economic points of view, as detailed in the next section.
- *Cross-Jurisdictional Coordination.* Given that much of SSTEC's infrastructure connects closely to that of the Binhai New Area, possible regional linkages must be addressed. As above, important questions need to be answered. How will the water supply inside SSTEC be managed in relationship to the water sector in Hanghu district? Will there be room for differential pricing of customers in and outside of SSTEC to strengthen water demand management and ensure water conservation, which is an important goal of the eco-city? If the water sector is managed in an integrated manner, how can differential standards be achieved between the eco-city and the rest of the service area? These regional integration and cross-jurisdictional coordination challenges need to be developed and fully addressed.

## Investment Planning and Financing

Estimates of SSTEC's total project costs are not available, though is it is clear that significant investments will be required to achieve the project's objectives. Between 2009 and early 2010, SSTEC has announced (to-date) investment projects amounting to RMB 10 billion, which include various basic infrastructure investments and some residential and commercial real estate development. SSTEC's investments fall into three broad categories:

- *TECID and TECID Subsidiary Company Investments.* These investments pertain to basic public infrastructure investments, including public buildings such as schools and hospitals. Initial investment estimates are available, but these are only indicative. TECID's current investment plan indicates RMB 14.6 billion, which includes investments in all three phases of development. However, these budget figures will undergo substantial revisions during SSTEC's detailed planning and costing phase.[165]
- *Binhai New Area Public Utility Investments.* Existing Utility Companies/ SOEs in the Binhai New Area will undertake certain investments in areas outside of SSTEC that nonetheless connect in critical ways to the SSTEC project. For example, the Tianjin Binhai Mass Transit Development Co. Ltd. will invest in the metro system. Some cost estimates are available, such as for the metro system, which is expected to cost RMB 3 billion for its 12 km line, or for the CHP plants, which are forecast at RMB 1.1 billion.
- *JV Company Investments.* These are essentially private sector investments in residential and commercial real estate development, except JV Company's investments in basic infrastructure. No estimates of the JV Company's investment costs currently exist.

Table 8.1: TECID Investment Overview

| | Sector Coverage | Investment Cost (RMB) | Timeframe | Comments |
|---|---|---|---|---|
| (1) TECID Total | All basic infrastructure and public facilities | 14.6 billion | 2008-2020 | Note that public transport investments are not included |
| TEC Construction Investment Co. | Public facilities, incl. schools, hospitals, university | 6.3 billion | - | - |
| TEC Energy Investment Co. | Supply and distribution of water, gas, power, heat, telecommunications, and renewable energy | 2.9 billion | - | - |
| TEC Environmental Protection Co. | Wastewater treatment and reclamation, water body rehabilitation, collection/transfer of solid waste | 2.2 billion | - | Including pneumatic solid waste system (RMB190m); Including Hangu WWTP (RMB420m) |
| TEC Municipal Engineering and Landscape Co. | Landscaping | 3.2 billion | - | - |

***Comprehensive Investments Evaluation.*** Given the significant size of the investments, good investment planning and analysis is required. A review of the draft sector plans and initial feasibility studies suggests that, to-date, limited efforts have been made to rigorously and comprehensively evaluate investment alternatives. As investments are evaluated, both upfront capital investments expenditures and operational and maintenance costs should be fully taken into account. Otherwise, correct investment decisions may not be taken. Operation and maintenance costs for long-life infrastructure and buildings typically represent about 90 percent of total lifecycle costs. In the City of Hamilton, Canada, for example, initial construction expenditures for a civic building accounted for merely 8 percent of total expenditures over its 30-40 year life, while operation and maintenance costs accounted for 92 percent.[166]

***Importance of "Life Cycle Cost/Cost Benefit Analysis".*** During the planning and investment decision phase, it is critical to systematically review investment alternatives to identify the most cost effective solution for a specific sector objective. A well established methodology exists to achieve this goal: life cycle and cost benefit analysis of alternative investments options. Life cycle analysis considers not only investment costs, but also long term operation and maintenance costs of created assets, appropriately discounted. In China, however, and in the SSTEC project, a life cycle approach is not being consistently applied. Operational costs often fail to be fully estimated and/or to be appropriately discounted and included in a comprehensive financial and economic analysis. Life cycle analysis is especially important for environmental investments, as higher upfront investments often associated with higher ecological standards may be, fully or in part, offset by lower operating and maintenance costs.

Given that SSTEC's detailed cost estimates are not yet available, no evaluation and life cycle cost comparison of proposed investments could be undertaken. The initial review of some of SSTEC's draft feasibility studies suggests that investment decisions are following the traditional approach: assessing investment alternatives based on relative rankings of investment costs with incomplete attention to operating costs. To illustrate that this approach does not always lead to optimal investment decisions, an example in the energy sector was analyzed and is presented below.

### Box 8.4: Life Cycle Cost/Cost Benefit Analysis

Life cycle costing (LCC) can help to improve estimates of the financial and economic costs associated with any development project. As the term implies, life cycle costs include all the costs incurred by a project throughout its life cycle, including construction, operation, maintenance, rehabilitation, and replacement costs. Part of the challenge is integrating cash flows over time. This includes optimizing the capital and operating costs, ensuring adequate cash flows over the longer term, and recapitalizing investments so that funds are available for replacement at the end of the life cycle. LCC is especially important for the long-lived investments typical in city infrastructure and land use development.

LCC requires that a life expectancy and rate of depreciation be estimated for each type of asset. It is then possible to quantify maintenance and rehabilitation requirements. The maintenance of city infrastructure systems—pipes, facilities, pumps, and roads—can be extremely costly and significantly impact the cash flow and financial sustainability of any project. Operation and maintenance also have fiscal impacts as costs are often financed by general budget revenues.

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Source: Based on Eco2 Cities: Ecological Cities as Economic Cities

***Energy Sector Example—District Heating.*** As described in Chapter III, the proposed district heating system represents common practice in China: primary networks under high temperature and pressure link combined heat and power (CHP) plants to group substations, which connect to buildings via secondary networks under lower temperature and pressure. One group substation typically serves 10-30 buildings. However, this approach is not the least cost solution according to a full life cycle costs analysis.

Instead of constructing 111 group substations across SSTEC that each supply10-30 buildings via secondary networks, a small substation could be installed in each building's basement. This would significantly improve energy efficiency by reducing electricity for pumps and fuel for heat. Specifically, heat consumption would likely fall by 10 percent and electricity consumption by 75 percent compared to the traditional district heating design. It would initially cost more to construct a higher number of small substations, but the costs of pipes to extend the primary network to building basements would be lower. Overall, the investment costs of installing building substations would be 10 to 20 percent higher. However, lower heat and electricity consumption would result in lower life-cycle costs. Other significant economic and environmental benefits would result from reduced heat and electricity consumption, such as a possible 10 percent reduction in GHG emissions.

The district heating case is only one example that illustrates the importance of life cycle cost analysis. Internationally, there are many other examples. As explained in Chapter III, many sustainable energy actions, especially energy efficiency measures, despite having higher initial costs, have lower lifecycle costs than business-as-usual alternatives. In the building sector, Melbourne's Council House 2 (Australia) reduced use of electricity by 82 percent, gas by 87 percent, and water by 72 percent, and corresponding $CO_2$ emissions by 87 percent over a financial payback period of about 10 years.[167] In the United States,

### Box 8.5: Life Cycle Cost Analysis for District Heating

During preparation of a World Bank project in Liaoning Province, local Design Institutes compared group substations (GS) with building level substations (BLS) across nine cities, including Yinkou, Benxi, Haicheng, Gongchangling, Fushun, Huludao, and Dalian. The results for Dalian are presented in Box 8.6.

Key assumptions include the following. 2007 prices were used for electricity (RMB850/MWh) and coal (RMB75/MWh). The price of heat was estimated as the coal price divided by the efficiency of the boilers (83 percent) and the transmission network (95 percent). In both cases (GS and BS), annual maintenance costs were estimated at 1.2 percent of investment costs. The layout of the networks in both cases was also optimally designed, which resulted in a shorter overall network in the BLS case. The network was shorter because some parallel pipes in the GS case (i.e., the parallel primary and secondary pipelines connecting the GS to both networks) were replaced by one primary pipeline.

n both cases, network pipes were sized according to nominal water temperatures (primary 135/70oC and 80/60oC supply / return) and respective water flows. In Dalian, which may reflect practices in the Tianjin Eco City, the buildings were higher than 12 floors. Moreover, floors above 12 must have a different static pressure. In the GS case, four pipes had to be used to separately connect the high and low floors, and these pipes were under different pressure levels. In the BLS case, different pressure levels were taken into account by using two heat exchangers in the substation: one for higher and one for lower floors. Only two primary pipes were needed to connect the substations to the primary network.

The investment costs of pipes were adopted from the local Design Institute. The substation prices were adopted from three different sources: two European manufacturers active in China and the ADB financed district heatin project completed in Ulaan Baatar, Mongolia. The average of these prices was used in the analysis.

In both cases, life cycle analysis was undertaken to calculate first year investment costs, and operational costs (water, electricity, heat) over 25 consecutive years. The calculations are shown as the cost of heating per square meter of heated area.

Box 8.6 presents relevant results in Dalian. Life cycle cost analysis shows that in Dalian, the GS is 25 percent more costly than the BS. In eight of the nine cases analyzed, the BLS was superior to the GS. Though the costs may be different in SSSTEC, the general conclusions are likely to hold.

Source: World Bank Project Information

an analysis of the financial costs and benefits of LEED certified office and school buildings found that a minimal upfront investment of about 2 percent of construction costs typically yields (20-year) life cycle savings of over ten times the initial investment.[168]

***Distribution of Costs and Benefits.*** However, what these examples have in common is that the costs and benefits of investments do not necessarily accrue to the same entities. For example, while higher investment costs associated with a Green Building are initially assumed by the building developer, the lower energy, water, and gas costs accrue to the building owner and/or tenants. Developers should be able to recoup higher investment costs through higher property prices. In this context, the Green Building Standards (including the proposed silver, gold, and platinum standards) could serve as useful signals to help achieve differential pricing according to environmental benefits. Other options include introducing Energy Service Companies (ESCOs) as explained in Chapter III.

Resolving this potential conflict is less obvious in other cases, as illustrated by an example in SSTEC's wastewater sector. The JV Company is assuming the investment costs of wastewater and sewerage at fixed and agreed prices, but the operational and maintenance savings attributable to the optimized but more costly designs will benefit the operator. Does the JV Company have the appropriate incentives to invest in more energy efficient pumping stations, although the benefits will not accrue to the company? These interrelationships between financial and institutional issues will need to be fully developed and addressed.

Table 8.2 provides indicative potential payback periods for various urban investments that favor sustainable energy and ecologies. In all cases, it is important to identify who benefits from lower operating costs. This facilitates the realization of these and other ecological innovations, while minimizing operational difficulties attributable to institutional and financial mismatches.

***Pricing and Demand Management.*** Multiple opportunities exist beyond the project's investment phase

## Box 8.6: Results of Life Cycle Cost Comparison—District Heating

| Item | Unit | 1<br>2009 | 2<br>2010 | 3<br>2011 | 25<br>2033 |
|---|---|---|---|---|---|
| ***GS - Group substations*** | | | | | |
| **Total costs** | RMB/Yr | 918 717 | 798 203 | 798 203 | 798 203 |
| Fuel costs | RMB/yr | - | 700 387 | 700 387 | 700 387 |
| Heat unit costs | RMB/MWh | | 95 | 95 | 95 |
| Heat demand | MWh/yr | | 6 300 | 6 300 | 6 300 |
| Thermal network losses | MWh/yr | | 409 | 409 | 409 |
| Losses due to insufficient control | MWh/yr | | 631 | 631 | 631 |
| as pecentage | % | | 12 % | 12 % | 12 % |
| Fuel price | RMB/MWh | | 75 | 75 | 75 |
| Electricity | RMB/yr | - | 42 392 | 42 392 | 42 392 |
| Electricity consumption with project | MWh/yr | - | 50 | 50 | 50 |
| Electricity price | Rmb/kWh | | 850 | 850 | 850 |
| Maintenance (only material) | RMB/yr | - | 11 024,6 | 11 024,6 | 11 024,6 |
| Personnel | RMB/yr | - | 15 000 | 15 000 | 15 000 |
| Staff number with project | man-months | - | 1 | 1 | 1 |
| Unit personnel costs | RMB/m, person | - | 15 000 | 15 000 | 15 000 |
| Investment | RMB | 918 717 | | | |
| Floor area | m2 | 55 233 | 55 233 | 55 233 | 55 233 |
| **NPV (costs)** | RMB | 6 368 022 | - | | |
| **NPV (floor area)** | m2 | 433 200 | - | | |
| **Heating costs/floor area** | **Yuan/m2** | **14,70** | 25 % more costly | | |
| ***BLS - Building substations*** | | | | | |
| **Total costs** | RMB/Yr | 1 055 100 | 597 787 | 597 787 | 568 462 |
| Fuel costs | RMB/yr | - | 534 321 | 534 321 | 534 321 |
| Heat unit costs | RMB/MWh | | 95 | 95 | 95 |
| Heat demand | MWh/yr | | 5 260 | 5 260 | 5 260 |
| Thermal network losses | MWh/yr | | 235 | 235 | 235 |
| Losses due to insufficient control | MWh/yr | | 105 | 105 | 105 |
| as pecentage | % | | 2 % | 2 % | 2 % |
| Fuel price | RMB/MWh | | 75 | 75 | 75 |
| Electricity | RMB/yr | - | 6 405 | 6 405 | 6 405 |
| Electricity consumption with project | MWh/yr | - | 8 | 8 | 8 |
| Electricity price | Rmb/kWh | | 850 | 850 | 850 |
| Maintenance (only material) | RMB/yr | | 12 661 | 12 661 | 12 661 |
| Personnel | man-months | | 15 000 | 15 000 | 15 000 |
| Staff number with project | RMB/m, person | - | 1 | 1 | 1 |
| Unit personnel costs | | - | 15 000 | 15 000 | 15 000 |
| Investment | RMB | 1 055 100 | | | |
| Floor area | m2 | 55 233 | 55 233 | 55 233 | 55 233 |
| **NPV (costs)** | RMB | 5 082 844 | - | | |
| **NPV (floor area)** | m2 | 433 200 | | | |
| **Heating costs/floor area** | **Yuan/m2** | **11,73** | | | |

Source: World Bank Project Information

to optimize planning and management to impact total project costs and environmental sustainability. Pricing and demand management are good examples. As shown in Chapter III and V, demand management and pricing of energy and water are proven ways to reduce consumption, which reduces operating costs and environmental footprints. In the transport sector, congestion pricing is a demand management tool. Addressing pricing and demand management early during project design allows a project to capitalize on important feedback loops in investment decisions.

***Project Financing.*** As mentioned above, SSTEC's total investment costs are not yet available and, consequently, its financing strategy is only emerging. To date, TECID has mobilized total financing of RMB 2.45 billion, though this financing is short-term, and maturities of one to three years. TECID is investigating options to finance its investment requirements, including additional commercial loans, insurance loans, and corporate bonds. Developing a sound, long term financing strategy is critical to ensuring the sustainable implementation of SSTEC. Based on indicative cost estimates, TECID is estimated to require total financing of up to RMB 13 billion.

***Carbon and Other Innovative Financing.*** As mentioned in Chapter VIII, carbon finance (with which Tianjin Municipality is well familiar) can potentially contribute to meeting SSTEC's investment needs. SSTEC might support a stand-alone CDM project, or, if further developed and officially approved, a "city-wide" CDM methodology. Other innovative financing solutions could also be introduced. Though China's current corporate and municipal bond market remains highly restrictive, SSTEC could, as the market matures, link its municipal or corporate bond strategies to its environmental agenda. Though not completely applicable to China's circumstances, a bond issuance in Bulgaria illustrates the potential for linking a financing agenda to broader environmental objectives.

Table 8.2: Indicative Economics of Sustainable Energy Options

| Sector | Short-Term Payback (under 5 years) | Medium Term Payback (5-10 years) | Long Term Payback (10+ years) |
|---|---|---|---|
| Public Buildings | Equipment retrofits<br>Labeling building performance<br>ESCO contracting<br>Solar water heating | Building envelope measures<br>Green roofs<br>Training in good practices in building O&M | Building codes<br>Certification of building materials<br>Building integrated PV<br>Equipment standards |
| Public Lighting | Lighting retrofits using high pressure sodium vapor and/or metal halide<br>Redesign of lighting systems<br>Control systems and sensors | Retrofits using LEDs | Street and traffic lighting standards |
| Transport | Optimization of traffic signals<br>Fuel efficiency vehicle standards<br>Congestion taxes/tolls | Alternative fuels for public buses, taxis<br>Bus rapid transit systems | Modal shifts<br>Vehicle inspection and maintenance programs<br>Changes in land use patterns to promote densification |
| Water/ Wastewater | Pumping retrofits<br>Right-sizing of pumps<br>Leak reduction<br>Load management<br>ESCO contracting | System redesign and optimization<br>Methane recovery for power generation from wastewater<br>Water DSM (low-flow outlets, drip irrigation) | - |
| Solid Waste | | Methane recovery for power generation from landfills<br>Recycling programs | - |
| Electricity/ Heating | Supply-side loss reduction<br>Power factor correction measures<br>Improved metering and pricing<br>Renewable energy portfolio standards<br>Retrofits of boiler and piping systems | Combined heat and power<br>Load management<br>Energy storage systems<br>Promotion of distributed generation with feed-in tariffs | - |
| Cross-Cutting | Bulk purchase of efficient products<br>Awareness raising on energy issues to public sector staff<br>Agency awards and contests for energy efficiency | Procurement standards for product procurement | Improved city design and planning systems |

Source: Eco2 Cities: Ecological Cities as Economic Cities

***Recommendations.*** Given significant investments and financing needs, SSTECAC and related project implementing companies, including those under TECID, need to develop a convincing investment and financing strategies. Doing so is important for a number of reasons, not least of which is to ensure that the project stays within a defined budget and remains affordable to a socially diverse community.

- *Life Cycle Evaluation of Costs and Benefits.* On the investment side, it is critical that SSTEC's investment projects are appropriately evaluated on a full life cycle cost/cost benefit basis. Otherwise, there is a significant risk that incorrect investment decisions will be taken, which could endanger the viability of the project from financial, economic, and ecological points of view. As explained, many ecological solutions can pay for themselves if long term operating costs are duly considered. However, it is important to be mindful that in some cases the benefits of lower operating costs may accrue to a different entity than the one responsible for investments. This can create incentive mismatches that prevent correct investments.

- *Pricing and Demand Management.* Beyond the investment phase, there are multiple options to realize cost savings through optimized planning and management decisions. A good example relates to pricing and demand management. These activities have direct financial and environmental impacts, and influence upfront investment decisions by potentially lowering initial investment costs. Paying attention to operational issues, such as demand management, early in the project cycle is critical to ensuring that the right investment decisions are taken.
- *Innovative, Long Term Financing.* Given that constructed assets are expected to have long lives, it is essential that TECID finances its investments on a long term basis. Currently, only short term financing has been raised. In addition, SSTEC has the potential to harness innovative financing solutions besides matching long term assets to long term liabilities. For example, environmental bonds could be issued to support development of the SSTEC. Carbon finance is another potential avenue either through traditional "stand-alone" carbon finance projects or the "city-wide" carbon finance methodology, as explained in chapter VII. The financing dimensions of SSTEC should not be limited to TECID, but should include schemes that incentivize residents to install environmentally friendly appliances.

Box 8.7: Environmental Bond Issue

The municipality of Varna, Bulgaria decided to modernize its street lighting system by replacing conventional street lighting with more energy efficient lights. This modernization was financed by issuing bonds. The bonds were put in private placement and were sold in one day. The annual savings of electricity amounted up to 10,035 MWh, or Euro 512,000. Due to the innovative financing approach, the payback period was less than three years.

Source: Eco2 Cities: Ecological Cities as Economic Cities

## Risk Management Challenges

Institutional, investment, and financing challenges often represent roadblocks to the successful implementation of projects of the scale of SSTEC. A proactive risk management system can help to detect possible risks to project implementation early in the project cycle. The risks that eco-cities will not achieve their objectives are real: the case of Dongtan provides a recent and real example here. This section highlights four key risks.m.

***Project Cost and Financial Risk.*** One of the biggest risks relates to the financial aspects of implementing the project. Many strategic decisions need to be made based on assumptions and uncontrollable variables, which are difficult to precisely capture in models. The review of initial feasibility studies suggests that the principle of cost containment is not being fully incorporated into the investment decision process, as illustrated in the District Heating example (Box 8.5). High potential costs associated with the pneumatic solid waste collection system or the proposed LRT (as opposed to the BRT network) are other examples. Collectively, the danger of implementing financially unconstrained investment plans, especially for infrastructure, could significantly impact the total cost of the project—and substantially increase financial risks. A good cost containment and financial risk management strategy is therefore required.

***Commercial versus Public Interests.*** Commercial pressures relating to economic and real estate development will be principal drivers of the SSTEC project. Balancing important commercial and public interests to ensure that SSTEC's overarching ecological objectives are maintained constitutes an ongoing challenge that requires careful trade-offs and decisions. At the outset, commercial and public objectives may be mutually reinforcing. However, once implementation obstacles arise, trade-offs may become more difficult. For example, if SSTEC does not generate sufficient local employment, how will this impact the "green transportation" KPI, particularly if more commuting trips need to be made out of the eco-city? Commercial and real estate development pressures will undoubtedly be strong. How to balance these pressures with public sector interests to ensure sustainable ecological urban development is likely to be a principal challenge of the SSTEC.

***Affordability and Social Inclusion.*** Overall investment costs and commercial interests will, in turn, influence the social profile of SSTEC. As mentioned in Chapter II, it is unlikely that SSTEC will become a vibrant urban community unless it is socially diverse and developed in an inclusive manner. Without social inclusion, SSTEC's overall project objective of "building a harmonious city" may be compromised. The KPI on affordable housing is a step in the right direction to ensure balanced social development. However, the extent to which measures will be effective depends, inter alia, on the specific thresholds sales and rental prices adopted. Overall, it is important to ensure that the project remains affordable to a wide spectrum of residents and promotes social diversity and social inclusion—instead of becoming an "eco-enclave".

***Reputational Risk.*** There are risks that SSTEC could be perceived as engaging in "eco-branding" and "eco-labeling" if the project does not achieve its ecological goals and surpass practices and performance elsewhere in China. The KPIs are excellent first steps in managing "eco-branding" risks. As was shown in the preceding chapters, some KPIs clearly indicate incremental ecological improvements over prevailing urban development practices, especially in Green Transportation, Green Buildings, water reclamation, and solid waste management. Other KPIs correspond to existing national standards. Articulating clearly where the project aims to advance the urban environmental agenda is therefore important.

***Recommendations.*** Developing visions and urban development strategies are only the first steps in developing an eco-city. To be effective, plans must be translated into development on the ground. Appropriate development controls and enforcement are required to ensure that visions are not compromised during project implementation. This is especially important in SSTEC's case as a large share of investment is expected from the private sector. The KPIs will help to ensure that SSTEC's vision and strategy are safeguarded during implementation. Specific recommendations to strengthen the use of the KPIs to control risks include the following:

- KPI Regulation and Enforcement. Article 16 in the Framework Agreement calls for an explicit KPI monitoring system and the public disclosure of KPI performance. The KPIs are key drivers of SSTEC, and continually evaluating progress on these indicators is critical. Ideally, KPI assessments undertaken by SSTECAC should involve residents and the community, which would support SSTEC's goal of building a socially harmonious community. In addition, international practices commonly involve residents in city performance assessments. For example, residents in New Zealand's Waitakere eco-city, which is expected to have a population of 200,000 by 2010, are invited to assess their eco-city in a "State of the City" report that covers its social, natural, and economic environments. A similar participatory approach could be used in SSTEC.
- KPI as a Management Tool. The utility of the KPIs could be strengthened by linking them to an established and explicit risk management framework. Such a risk management framework could help to identify roadblocks and challenges related to project implementation early in the project cycle. This would be useful, as SSTEC's phased development permits continuous learning and improvement based on appropriate monitoring and evaluation. Under an enhanced KPI risk management framework, the lessons learned during implementation could be captured early, and systematically fed into subsequent development phases.
- Independent "Eco-Audits". Another option is to introduce the concept of "eco-audits." An eco-audit would start by monitoring the KPIs, and gradually adopt independent auditing and

verification of performance. The latter activities would strengthen measurement, credibility, and compliance with the overall ecological vision and development of SSTEC. Eco-audits exist in a variety of forms, and are increasingly applied at the urban level. The European Eco-Management and Audit Scheme (EMAS) is one example (see Box 8.8). Moreover, SSTEC could be the first city in China to introduce an independently verified ecological urban development model.

### Box 8.8: The European Eco-Management and Audit Scheme (EMAS)

EMAS is an initiative established by European Regulation 1836/93 (later replaced by Council Regulation 761/01) to help public and private organizations (including cities) to evaluate, report, and improve their environmental performance. To register for EMAS, an organization must: i) develop an environmental policy; ii) establish an environmental management system; iii) carry out an internal environmental audit; iv) develop an environmental statement; and v) obtain validation by an EMAS Verifier and become registered. Each EU country has a national Competent Body that is responsible for the registration of EMAS organizations; an Accreditation Body that is responsible for EMAS Verifiers; and EMAS Verifiers that are independent of the organization being verified. The Verifiers certify that the organization's environmental policy, environmental management system, internal audit, and environmental statement comply with EMAS Regulation. Participation in EMAS is voluntary. However, with growing concern and demand for environmentally friendly services and products, demonstration of environmental performance and sustainability is becoming important for organizations. As of April 2009, 4,319 organizations, including public entities or local/district councils in 28 European countries, are registered in EMAS.

The Leicester City Council in the United Kingdom (population 280,000) has applied EMAS. The City Council uses EMAS to manage and improve its environmental performance to achieve its sustainable development goals. The City Council focused on improving performance of its public works, with a view to ensuring waste minimization and prudent use of energy, water, and natural resources. The Council also focused on environmental training for City Council employees and councilors, contractors and suppliers, and local students and teachers, which was accomplished by extending the EMAS scheme to local schools and education programs. As a result, the City Council achieved improved environmental outcomes: increased share of electricity from renewable sources; decreased water consumption at the City Council; increased use of bicycles; reduced $SO_2$ emissions from Council vehicles; reduced paper consumption, and so on. Every year, the City Council produces an Environmental Statement with an assessment of its performance towards environmental targets, which is checked by an independent UK verifier to ensure that the Environmental Statement complies with the EMAS standard. Annual independent EMAS verification of the Environmental Statement ensures that the City Council's environmental performance is transparent and credible.

Source: EMAS Website <http://ec.europa.eu/environment/emas/index_en.htm>

## Chapter IX

# Conclusion, GEF Project and Summary Recommendations

Overall, the SSTEC project presents an interesting example of a new urban development pattern—one that aims to develop on a more ecological trajectory compared to prevailing standards. Analyzing the project enabled a better understanding of the practical challenges of undertaking such new development. The project has many strong points. Above all, it clearly articulates a vision for developing city in a more sustainable ecological manner from the outset. In some areas, SSTEC's targets are ambitious, and, if achieved, would improve urban environmental sustainability. In others, the targets are somewhat less ambitious and follow prevailing practices in China. In both cases, achieving the targets requires that many issues, including those identified in this report, are successfully addressed during the ongoing project implementation process.

The report developed a 'snapshot' picture of the SSTEC project at mid-year 2009, after the master plan had been developed but before many of the specific details were analyzed through the feasibility study and detailed design processes. Achieving appropriate solutions will require detailed analysis and will need to be based on relevant "good practices" in China and elsewhere, as well as lessons learned during the early stages of project implementation. The report is only one step in a continuous process to adapt SSTEC's plans to the challenges and changing needs of the project as it evolves.

***Next Steps.*** For the World Bank, the next stage of assistance is to continue to support the through preparing a Global Environment Facility (GEF) project. The findings of this report, as summarized in Table 9.1 below, provide one input for the preparation of the GEF project. The main components of the GEF project are as follows:

- Component (1): TA, Software and Equipment for Implementation of SSTEC's Master Plan and Dissemination Activities. There will be two main activities. First, the provision of an Eco-City Advisory Panel which will provide guidance for the implementation of the SSTEC Master Plan, based on international best practices. The Eco-City Advisory Panel will assist SSTECAC in the following areas: (i) overall implementation of the SSTEC Master Plan; (ii) project management and coordination for the GEF project; (iii) monitoring and evaluation of the implementation of the SSTEC Master Plan; and (iv) replication and dissemination of the experiences of the SSTEC project. Second, the provision of TA, capacity building and associated software and equipment for the establishment of enabling policy, regulatory, incentive, institutional and financing mechanisms to help SSTECAC implement SSTEC Master Plan.

- Component (2): TA for Public Transport System. This component will help SSTECAC develop an integrated public transport system, focusing on the mass transport system, including possible Bus Rapid Transit (BRT) which will be introduced as the first step of the SSTEC public transport system. This component will also include activities to strengthen institutions to support the planning, development, and regulation of public transport.
- Component (3): Green Building Pilot Investment and TA. The component will take an integrated approach to supporting both pilot investments and TA to help SSTECAC implement its green building program. The pilot investments are intended to demonstrate Green Building Evaluation Standard (GBES) implementation procedures and replicable energy/water efficiency technologies and practices. The TA will be provided to make the GBES as complete and effective as possible in promoting energy conservation in the building sector across SSTEC.

Table 9.1: Summary Recommendations

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| **Urban Planning and Spatial Development** | |
| | • Spatial Structure and Urban Design: Consider dividing some of SSTEC's 400m by 400m blocks into smaller units to create vibrant neighborhoods and add spatial variety through good urban design.<br>• Integrated Urban Planning: Ensure integrated planning across all infrastructure sectors; optimize and synchronize land use planning with infrastructure system design to realize cross-sectoral synergies and enhance resource use efficiency.<br>• Phased Development: Develop a detailed strategy on how to capitalize on SSTEC's phased development schedule; this strategy should capture the benefits of incremental planning, introduce a "learning" approach to developing the project, and reduce risks. |
| **Energy Sector** | |
| Technical | • Green Buildings: (i) As the Green Building Evaluation Standard (GBES) largely incorporates existing national and local building standards and regulations, especially in energy efficiency, provide appropriate incentives for buildings to be built at a higher (silver, gold, platinum) standard, rather than just the pre-requisite level. (ii) Introduce specific energy performance requirements for key end-users in buildings; such requirements could cover, inter alia, lighting, major appliances, air-conditioning, and water heating. (iii) Introduce commissioning of energy systems in buildings; and (iv) Consider introducing a GBES accreditation program similar to the Leadership in Energy and Environmental Design (LEED) program in the United States.<br>• Heating/Cooling System: As the current proposed district heating system essentially reflects conventional Chinese design concepts, improve the district heating system by considering: (i) Using a low temperature regime for supply/return water in district heating; (ii) Using building-level sub-stations instead of group sub-stations; (iii) Using the district heating system for domestic hot water; and (vi) Using CHP plants for base loads and meet peak load demand by heat only boilers.<br>• Renewable Energy: Examine renewable energy options to choose more cost-effective options based on lifetime costs, particularly for photovoltaic powered public lighting systems. Also, consider installing centralized solar systems in public buildings, and determine the optimal share of district heating-supplied hot water relative to solar hot water. |
| Policy | • Institutions, Policies, and Regulations: Explore an institutional setup that will effectively and continuously address the evolving needs and issues of sustainable urban energy planning and management—in terms of both operating and regulating the energy system (particular with respect to the GBES).<br>• Enhance and Incentivize Sustainable Energy Actions: Adopt a broader set of policies to further incentivize sustainable energy actions among citizens, businesses, and organizations. This might include a smart pricing and billing system for electricity use, and grants, low-interest loans, line of credits, rebates, bonuses for density, and technical assistance to motivate people to go green. Behavior-based energy efficiency programs should be developed and implemented. |
| **Transport Sector** | |
| Technical | • Further Data Analysis: Given its importance to the overall transportation plan, review the veracity of the travel demand model. In particular, verify the base data from as many diverse sources as possible. Appropriately consider other relevant comparators, particularly new development areas with similar demographics as those planned for SSTEC.<br>• Road Design and Urban Form: Enhance the livability and mobility in the eco-city by considering developing more but narrower roads, thereby subdividing the planned 400m by 400m blocks and better promoting non-motorized travel.<br>• Detailed Review of Capacities in Transport Infrastructure: Analyze how specific infrastructure commitments (e.g., road design and public transport investments) relate to the travel demand model. Undertake a detailed review of capacities in roads, infrastructure, public transport, city parking, and other relevant areas against the modeled modal split forecasts.<br>• Review LRT and BRT Options: Develop a detailed business case for the LRT over the BRT option. This should review, in parallel, both technologies' designs, capital costs, recurrent costs, capacities, and operational impacts to determine the optimal technical and most cost effective solution. |

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| Policy | • Develop 'Phasing-In' Policy: Develop a policy for phasing in 'green' public transport concurrent to SSTEC's development through 2020, focusing particularly on investment costs and projected cost recovery needs during the development stages.<br>• Travel Demand Management (TDM): Develop a policy for phasing in TDM strategies across all its dimensions to ensure high-level coordination of the competing imperatives of fulfilling SSTEC's targets while ensuring commercial and residential property sales.<br>• Institutional Arrangements: Introduce institutional arrangements that support adequate transport policy as well as regulation and enforcement of TDM strategies and public transport initiatives. This might involve establishing a new agency, operating businesses, and regulatory strategies.<br>• Develop Secondary Indicators: Develop indicators that better capture the constituent parts of the green transport KPI, including measurements of the share of public transport and walking/cycling. To allow for precise KPI measurement, clarify how mode shares of trips are apportioned. Consider additional indicators for operational issues, such as cost recovery and affordability. |
| Water Sector | |
| Technical | • Design of Water Distribution System: Optimize the designs of distribution systems (water and reclaimed water) to minimize total costs and energy consumption.<br>• Dual Water Supply System: Conduct a costs benefit analysis on the proposed dual water supply system using reclaimed water for domestic uses, as it may not be cost effective.<br>• Desalinated Water: Reexamine the need for desalinated water and assess the optimal operation of the Bejiang power plant as a cogeneration plant.<br>• Unaccounted-for Water: Reassess the UFW target of 10 percent as it is relatively high, especially for a new city.<br>• Industrial Wastewater: Consider pre-treatment of industrial wastewater, which will result in lower treatment costs.<br>• Sludge Disposal: Revisit sludge disposal plans as an eco-city's approach should more closely align to current good practices like digestion and composting; such processes are widely applied in developed and developing countries, and the technologies are well proven.<br>• Energy Efficiency: Improve energy efficiency in various system operations. Consider implementing leak control programs, and equipping networks with telemetry systems to facilitate pump scheduling, pressure control, and burst control.<br>• Wastewater and Strom Water System: Design the wastewater and storm water system to anticipate the likely impacts of climate change and rising sea levels. |
| Policy | • Water Conservation: Apply water conservation practices and programs that address both the supply and demand for water. Consider appropriate tariff structures that promote water demand management while ensuring cost recovery, conservation, and equity.<br>• Public Involvement: Strengthen public awareness and participation; public involvement is crucial to the success of demand management and conservation programs.<br>• Regulatory Oversight: Establish appropriate regulatory oversight. Absent an independent regulator, SSTECAC will need to establish a regulatory unit to monitor regulatory compliance to ensure the realization of the KPIs and other emerging service standards.<br>• Operating Company for Water Sector Services: Consider using one operating company for all water sector services, including enforcement of onsite water treatment and reuse.<br>• Coordinated Construction: Closely coordinate contractors' construction of different systems to ensure synergistic and, when possible, simultaneous system installation.<br>• Develop Secondary Indicators: To complement the water sector KPIs, consider other indicators focused on operational issues, including energy consumption and cost recovery. |
| Solid Waste Sector | |
| Technical | • Waste Reduction: Consider comprehensive waste reduction strategies, including establishing collection points to gather food residue that can be recycled.<br>• Collection: Conduct a detailed cost benefit analysis of the pneumatic solid waste system, taking into account investment and operating costs, compatibility with the recycling program, and the relative lack of flexibility of such systems.<br>• Treatment: Ensure that the incinerator has a sufficient air pollution control system to prevent the emission of pollutants that could negatively impact public health and the environment.<br>• Landfill: Ensure that the site receiving residue from SSTEC is an engineered facility operated in an environmentally sound manner. |
| Policy | • Waste Reduction: Apply waste reduction programs supported by regulations that ban specific materials or impose consumption-based charges.<br>• Recycling: Provide a comprehensive program of incentives, education, and prohibition of certain materials from the waste stream to encourage residents and businesses to recycle. As the proposed recycling program is highly ambitious and mainly based on source separation, consider tiered pricing of waste management services that charge a lower fee for waste that is source separated, which should encourage recycling. |

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| **GHG/ Carbon Finance** | |
| | • GHG-specific Indictors: Develop sets of cross-sector and intra-sector indicators that more comprehensively measure the potential for reducing specific GHG emissions. These indicators would apply to all sub-sectors: energy, transport, water and wastewater, and solid waste.<br>• Carbon Finance: Explore options for SSTEC to access carbon finance, either through the traditional sector based CDM approach or the emerging “city-wide” CDM methodology. |
| **Institution, Finance and Risk Management** | |
| Institutional Issues | • Integrated Management: Ensure that the integrated vision of the eco-city is sustained during project implementation by containing institutional fragmentation across the various stakeholders (e.g., JV Company, TECID and its subsidiary companies).<br>• Focus on Operational Issues: Develop sustainable operating arrangements for SSTEC assets early in project implementation to minimize possible tension and conflicts that can arise in complex projects, comprising public and private sector participants.<br>• Cross-Jurisdictional Coordination: Develop and fully address all infrastructure linkages with the Binhai New Area. Consider possible regional linkages and, whenever possible, support cross-jurisdictional coordination. |
| Investment and Finance | • Life Cycle Evaluation of Costs and Benefits: Evaluate investment projects on a full life cycle cost/benefit basis to avoid incorrect investment decisions and incentive mismatches.<br>• Pricing and Demand Management: Pay early attention to operational issues such as pricing and demand management activities that could directly impact project finances. Early assessment of demand management impacts is also important to avoid overdesigning infrastructure systems.<br>• Innovative, Long Term Financing: Ensure TECID finances its investments on a long term basis by pursuing innovative solutions such as carbon finance or issuance of environmental bonds. |
| Risk Management | • KPI Regulation and Enforcement: Evaluate progress towards meeting the KPIs on an ongoing basis through participatory approaches involving communities and residents.<br>• KPI as a Management Tool: Establish an explicit risk management framework with an appropriate monitoring and evaluation system linked to the phased development approach.<br>• Independent “Eco-Audits”: Introduce an eco-audit that could independently measure and verify the project’s compliance with the overall ecological vision and development. |

## Annex 1

# Key Performance Indicators (KPI) for SSTEC

Table A1.1: Quantiative Key Performance Indicators

| KPI Area and Details | | Indicative Value | Timeframe | Domestic Standards | Domestic Benchmarks | International Benchmarks | Comments |
|---|---|---|---|---|---|---|---|
| Natural Environment | Ambient Air Quality | No of days per year in which ambient air quality meets or exceeds China's National Ambient Air Quality Grade II Standard ≥310 | Immediate | • National Standard for Ambient Air Quality GB3095-1996[169]<br>• Eco-Garden City Standard[170]: ≥300<br>• Eco-City Standard (for North China)[171] ≥ 280<br>• Environment Protection Model City Standard[172]: ≥ 310 | • China Plan: 75% of major cities in China meeting National Grade II Standard: ≥292 (by 2010)[173]<br>• TJ: 298 (2005); 320 (2007); Plan ≥310 (by 2010)[174]<br>• BHNA: 314 (2007); Plan ≥310 (by 2010)[175]<br>• BJ: 246 (2007); Everyday during 2008 Olympics (total of 17 days); Plan: to meet GB 3095-1996 by2010[176] | - | • Same as Environment Protection Model City Standard, higher than eco-city and eco-Garden city standard<br>• Same as the target of Tianjin and BHNA for 2010;<br>• Lower than actual Tianjin (320 days) and BHNA (314 days) in 2007;<br>• Note that this is a target that cannot be fully controlled by actions taken in SSTEC alone; |
| | | No. of days per year in which $SO_2$ and NOx content in the ambient air should not exceed the limits stipulated for China National Ambient Air Quality Grade I Standard ≥155 | Immediate | • National Standard for Ambient Air Quality GB3095-1996 | - | - | |
| | | To meet the standard stated in the PRC's National Standard GB 3095-1996 | By 2013[177] | • National Standard for Ambient Air Quality GB3095-1996 | - | - | |

| KPI Area and Details | | Indicative Value | Timeframe | Domestic Standards | Domestic Benchmarks | International Benchmarks | Comments |
|---|---|---|---|---|---|---|---|
| Natural Environment | Quality of Water Bodies | To meet Grade IV surface water quality standard stated in the PRC's National Standard GB 3838-2002 | By 2020 | • National Standard for Surface Water Quality GB 3838-2002[178]<br>• Eco-City Standard[179]: to meet GB 3838-2002 and no lower than Grade V | • TJ Plan: surface water quality in the built-up areas should meet Grade V and above by 2010 [180],[181]<br>• BJ Plan: water quality of the central city and new developing area should meet the National Standard by 2010[182].<br>• Average meeting GB 3838-2002 rate of Chinese cities: 86.50% (2007)[183] | - | • Given that only 22.2 percent of water bodies in BHNA meet the national standard in 2006[184], relatively ambitious target;<br>• Comparable to National Standard GB 3838-2002<br>• Note that this is a target that cannot be fully controlled by actions taken in SSTEC alone; |
| | Water from taps attaining drinking water standards | 100 % | Immediate | • National Standard for Drinking Water Quality GB 5749-2006;<br>• Eco-Garden City Standard[185]: 100% meeting GB 5749-2006; | • SH: 99.95% (2005);<br>• Shenzhen: 99.56% (2008);<br>• Guiyang: 100% (2009) | - | • Same as Eco-Garden City Standard<br>• Same level has been achieved by other cities in China, i.e. Guiyang |
| | Noise pollution levels should meet the stipulated standards for different functional zones | 100 % | Immediate | • National Standard for Noise GB 3096-2008;<br>• Eco-City Standard[186]: 100% meeting GB 3096-2008;<br>• Eco-Garden City Standard[187]: 95% meeting GB 3096-2008; | • TJ: 82.4% (2005); Plan: 90% (by 2010); 95% (by 2015)[188]<br>• BHNA: 80% (2005); Plan: 90% (by 2010); 95% (by 2015)<br>• BJ: All areas meet GB 3096-2008 except for Class 4 area which is below the standard by exceeding 8.2dB during the night in 2007 | - | • Same as Eco-City Standard; Higher than Eco-Garden City Standard<br>• Higher than target of Tianjin and BHNA for 2015. |
| | Carbon emission per unit GDP | 150 ton-C per one million US dollars | Immediate | • No national standard | • No national standard | Country-wide targets by 2012:<br>• USA: 122<br>• Japan: 59<br>• EU: 103<br>• Singapore: 350 (2006) | • SSTEC KPI aims to improve significantly on current national carbon emission per unit GDP average;<br>• This indicator however is normally only applied at the country level due to measurement problems at the city level; |

| | KPI Area and Details | Indicative Value | Timeframe | Domestic Standards | Domestic Benchmarks | International Benchmarks | Comments |
|---|---|---|---|---|---|---|---|
| Natural Environment | Net loss of natural wetlands | 0 | Immediate | • No national standard | • National 11th Five Year Plan for Forestry states: 50% of natural wetlands and 70% of important wetlands should be protected[189] | - | • Higher than the targets put forward in National 11th Five Year Plan; |
| Man-made Environment | Proportion of green buildings [190] | 100 % | Immediate | • National Standard for Green Building GB 50378-2006<br>• Technical Manual for Green Building Evaluation[191]<br>• Garden City Standard[192]: ≥50% energy-efficient buildings and green buildings | • China: Green building: less than 1% of existing buildings (current); 100% for Olympics buildings. Energy-efficient buildings: 16% of existing buildings in cities and towns (2008); 71% of newly built buildings (2007).<br>• BJ: energy efficient buildings: 49.93% of existing buildings | • Singapore: building area exceeding 2,000 $m^2$ should be 100% green building. | • Compare to current China's situation, SSTEC target of 100% is high;<br>• Higher than Garden City Standard;<br>• Same level (100%) was achieved by Beijing Olympics buildings. |
| | Local plants index | ≥ 0.7 | Immediate | • Eco-Garden City Standard[193]: ≥0.7 | - | - | • Same as Eco-Garden City Standard |
| | Public green space per capita | ≥ 12 $m^2$ per capita | By 2013 | • Eco-City Standard[194]: ≥11<br>• Eco-Garden City Standard[195]: ≥12 for built-up area;<br>• Garden City Standard[196]: ≥7.5 for big cities (more than 500,000 p); ≥8.5 for small and medium cities | • TJ: 8.4 (2005); Plan: ≥10 (by 2010); ≥ 11 (by 2015)[197]<br>• BJ Plan: 12.6 (2007); ≥15 (by 2010); meets 16-18 (by 2020) [197] | • Singapore: 8<br>• Curitiba, Brazil: 51 (2005)[199] | • Same as Eco-Garden City Standard; Higher than Eco-City Standard and Garden City Standards;<br>• Higher than Tianjin's target by 2015;<br>• Lower than Beijing's target (15) by 2010; |
| Living Style | Per capita domestic water consumption | ≤ 120 Liters per day per capita | By 2013 | • National standard of water quantity for city residential use GB/T503312002 : 85-140 l/pd for Tianjin municipality[200]<br>• Tianjin quota of water quantity for city's residential use DB12/T158-2003: 70—120 l/pd | • TJ: 130.4 (2006)<br>• BJ: 110~130 (2007)<br>• Wuhan Plan[201]: 170 (by 2010)<br>• SH: 160 (2003); Plan: 180 (by 2020)<br>• Hunan province quota: 160<br>• Ningxia province quota: 90-130<br>• Xiamen city quota: 150-180<br>• HK: 203 | • Singapore: 154<br>• Cologne: 137<br>• Amsterdam: 154<br>• Sydney: 254<br>• Tokyo: 268<br>• Los Angeles: 440[202] | • Indicator sets lower target than current Tianjin and Beijing's level;<br>• Lower compared to other provinces and cities' quota, but at upper end of Tianjin quota;<br>• Target is advanced compared with international practices |

| KPI Area and Details | | Indicative Value | Timeframe | Domestic Standards | Domestic Benchmarks | International Benchmarks | Comments |
|---|---|---|---|---|---|---|---|
| Living Style | Per capita domestic waste generation | ≤ 0.8 kg per day per capita | By 2013 | • Code for Planning of Urban Environmental Sanitation Facilities GB 50337-2003: 0.8-1.2 | • TJ: 1.10 (2007)<br>• BJ: 1.18 (2007);<br>• Ningbo: 1.2 (2007);<br>• Wuhan central district: 1.21 (2008) | South-East Asia: 0.74 (2000)[203 204]<br>Singapore: 0.89 (2007)<br>East Asia: 1.01 (2000)[205]<br>Japan: 1.1<br>South-Central Asia: 0.57 (2000)[206]<br>• USA: 2.18 | • Indicator sets lower waste generation target relative to practices in other major Chinese and international cities. |
| | Proportion of green trips[207] | ≥ 30 % | By 2013 | • Garden City Standard[208]: Proportion of public transportation (bus, tram and urban rail) ≥20% for big cities; ≥15% for medium cities | • Tianjin (2000): 91.5%<br>• Tianjin Plan: 75-80% (by 2020);<br>• BHNA Plan: 65-75% (by 2020)<br>• TEDA: 47.8%[209] (projected in 2008)<br>• Shanghai (2006): 56%<br>• Beijing (2006): 64%<br>• Chongqing (2006): 88%<br>• Hong Kong SAR (2001) 83.8% | • Rio de Janeiro 85%<br>• Bogota 85%<br>• Lima 84%<br>• Moscow 73.7%<br>• Curitiba 71%<br>• Warsaw 71.4%<br>• Budapest 66.9%<br>• Sao Paulo 66.4%<br>• Amsterdam 66.1%<br>• Prague 64.4%<br>• Vienna 64.0%<br>• Berlin 60.8%<br>• New York ≥ 60%<br>• Tokyo ≥60% | • Target for 2013 is too low considering current Chinese context where trip mode of walking and cycling is significant.<br>• Target for 2020 is higher than Tianjin plan and same as current HK. |
| | | ≥ 90 % | By 2020 | | | | |
| Infrastructure | Overall solid waste recycling rate | ≥ 60 % | By 2013 | • No national standard | • BJ Plan: separation & collection rate 60%; comprehensive utilization rate of industrial solid waste 80% by 2010.<br>• BJ 2008 Olympics venue: 50%<br>• Shenzhen: 45% (by 2010)[210] | • Singapore: 51% (2006); Plan: 60% (by 2012)<br>• Seattle, Wash. (USA): 48% (2007); Plan: 60% (by 2012) | • Higher than current practices in China;<br>• Same as Singapore's target by 2012 |
| | Provision of free recreational and sport facilities within walking distance of 500m | 100 % | By 2013 | • National Livable City Guideline[211] promotes provision of free sports facilities within walking distance of 1,000m and free open parks within 500m | - | - | • Higher than National Guideline |

| KPI Area and Details | | Indicative Value | Timeframe | Domestic Standards | Domestic Benchmarks | International Benchmarks | Comments |
|---|---|---|---|---|---|---|---|
| Infrastructure | Treatment to render hazardous and domestic solid wastes non-toxic | 100 % | Immediate | • Eco-City Standard[212]: 90%<br>• Eco-Garden City Standard[213]: 90%<br>• Garden City Standard[214]: 60%<br>• Environment Protection Model City Standard[215]: treatment of domestic solid wastes≥ 85%; treatment of hazardous solid wastes: 100% | • TJ: 81% (2005); *TJ Plan: ≥90% by 2010; 100% by 2015* [216]<br>• BHNA: 100% (2005)<br>• BJ current: 93%; BJ Plan: 99% for central districts, 80% for *suburb districts by 2010*[217]<br>• Average of Chinese cities: 67.58% (2007)[218] | - | • Higher than Eco-City Standard; Eco-Garden City Standard, and Garden City Standard;<br>• Higher than Beijing's target for 2010;<br>• However, same level as already achieved in BHNA; |
| | Barrier-free accessibility | 100 % | Immediate | • National Barrier-free City Standard[219]: 100% for newly built public buildings and residential buildings | • Beijing Olympics Facilities: 90% | • Developed countries: almost 100% | • Same as National Barrier-free City Standard;<br>• Higher than level achieved at Beijing Olympics facilities.<br>• Same as current developed countries' level |
| | Services network coverage | 100 % | By 2013 | Central Sewage Treatment:<br>• Eco-City Standard[220]: ≥85%<br>• Eco-Garden City Standard[221]: ≥70%<br>Tap water:<br>• Eco-Garden City Standard[222]: ≥100%<br>• Garden City Standard[223]: 90%<br>Central Heating:<br>• Eco-City Standard[224]: ≥65%<br>Gas:<br>• Garden City Standard[225]: 80% | Central Sewage Treatment:<br>• TJ: 75% (2005); TJ Plan: ≥85% (by 2010); ≥90% (by 2015)<br>• BHNA: 59% (2005)<br>Central Heating:<br>• TJ: 83.2% (2005); *TJ Plan: ≥85% (by 2010); ≥90 (by 2015)*<br>• BHNA: 75% (2005); *≥88% (by 2010)* | Sewer Coverage<br>• Singapore: 100% (current)[226]<br>• Tokyo center area: 100% (2006)<br>Tap Water<br>• Tokyo center area: 100% (2006) | • Higher than Eco-City Standard; Eco-Garden City Standard, and Garden City Standard,<br>• Higher than plans for Tianjin and BHNA<br>• Same as targets in developed cities overseas; |
| Management | Proportion of public housing | ≥ 20 % | By 2013 | • No national standard | • China Nationwide overall goal: 15-20% by 2010[227] | International comparison difficult as public housing definitions vary across countries (Hong Kong SAR: 50%; Singapore: 80%) | • Comparable to national target |

| KPI Area and Details | | Indicative Value | Timeframe | Domestic Standards | Domestic Benchmarks | International Benchmarks | Comments |
|---|---|---|---|---|---|---|---|
| Economic Sustainability | Renewable energy usage | ≥ 20 % | By 2020 | • No national standard | • China: 7% (current): *Plan: 10% (by 2010); 15% (by 2020)*[228];<br>• *BJ Plan: 4% (by 2010)*[229]; Olympics venue: 26.9% (2008)<br>• *Caofeidian Eco*-City Plan: 50% (by 2020) | • Finland: 25%;<br>• Sweden: 33.3%;<br>• Holland: 20% (by 2020);<br>• EU: 20% (by 2020). | • Higher than current national level and plan for 2020;<br>• Same as targets by EU and Holland for 2020.<br>• Lower than the level achieved by Beijing Olympics venue and Caofeidian target by 2020 |
| | Water supply from non-traditional sources | ≥ 50 % | By 2020 | • No national standard | • BHNA: Reclaimed Water: 9% (2008); Plan: 40% (by 2010). Desalinated seawater: 14% (2008); *Plan: 25% (by 2010).*<br>• *BJ: Water recycling rate ≥ 50% for central city and new towns by 2010*[230]*;*<br>• *Caofeidian Eco-City Plan: 40% (by 2020)* | • Singapore: ≥50% (current) | • Higher than current practices in China<br>• Higher than Caofeidian target in 2020<br>• Same as current Singapore level |
| Technological Innovation & Employment | Number of R&D scientists and engineers per 10,000 labor force | ≥ 50 man-year | By 2020 | • No national standard | • *China Plan: 14 (by 2010)*[231]<br>• BJ plan: 220 (by 2020)[232];<br>• *SH plan: 45 by 2010, 60 by 2020*[233] *(note: this is Number of R&D employees per 10,000 persons)* | • USA: 92 (2002);<br>• Japan: 101;<br>• Germany: 68;<br>• France: 71 (2003) | • Higher than national target by 2010.<br>• Lower than Beijing and Shanghai target for 2020<br>• Still much lower than overseas countries |
| | Employment-housing equilibrium index[234] | ≥ 50 % | By 2013 | • No national standard | - | - | • SSTEC distinctive indicator |

Note: TJ (Tianjin); BHNA (Binhai New Area); TEDA (Tianjin Economic and Development Area); BJ (Beijing); SH (Shanghai); HK (Hong Kong SAR).

## Table A1.2: Qualitative Key Performance Indicators

| KPI Area | KPI Details |
|---|---|
| Coordinated Natural Ecology | Maintain a safe and healthy ecology through green consumption and low-carbon operations |
| Coordinated Regional Policies | Adopt innovative policies that will promote regional collaboration and improve the environment of the surrounding regions |
| Social and Cultural Coordination | Preserve historic and cultural heritage and protect scenic resources |
| Coordinated Regional Economy | Promote the reasonable division of functions at the regional level |

## Annex 2

# Summary Profiles of Eco-City Initiatives in China

Annex 2 summarizes of findings from a stocktaking study, undertaken by the Chinese Academy of Urban Planning and Design, which identifies and analyzes other major eco-city initiatives in China.[235]

Part I summarizes eco-city development in four cities, namely Caofeidian Eco-City in Tangshan, Shenzhen in Guangdong province, Yangzhou in Jiangsu province, and Huaibei in Anhui province. Part II lists an additional 18 cities undergoing ecological urban development, which include cities of various scales from China's eastern to western regions. Together, these 22 cities represent most of the national pilot eco-cities thus far recognized by the Ministry of Environmental Protection and Ministry of Housing and Urban-Rural Development (Figure A2.1 and Figure A2.2).

Figure A2.1: National Eco-Cities and Eco-Counties approved by MEP (left)
Figure A2.2: National Eco-Garden Cities approved by MoHURD (right)

Miyun county, Yanqing county, Taicang city, Zhangjiagang city, Changshu city, Jiangyin city, Rongcheng city, Yantian district, Minhang district, and Anji county

Shenzhen, Qingdao, Nanjing, Hangzhou, Weihai, Yangzhou, Suzhou, Shaoxing, Guilin, Changshu, Kunshan and Zhangjiagang

## Part I: Summary Profiles of Four Cases

### A.Case 1: Caofeidian Eco-City, Tangshan

### Introduction

Caofeidian Eco-City represents another large-scale new development that aims to direct fast urban growth in an ecological way. Caofeidian Eco-City is located 5 km to the northeast of Caofeidian Industrial Area and Caofeidian port. It is 80 km from Tangshan city center, 120 km from Tianjin, and 220 km from Beijing. As a major economic growth center in Tangshan and Heibei province, Caofeidian Industrial Area was one of the national demonstration projects for a circular economy approved by the NDRC in 2005, and aims to promote recycling of resources and zero-release of pollutants in its four leading industries, including refined steel, equipment manufacturing, chemical industry, and modern logistics. The industrial development in Caofeidian has gained steady momentum and support from the national government, especially after a new one billion ton oilfield was found in this region in 2007. To attract high-end services and skilled employees that are essential for industrial development, the planning for Caofeidian Eco-City was initiated in early 2007. The Eco-City is envisaged to be an "eco-friendly" city that is "resource and energy saving, economically livable and socially harmonious".

## Scale and Timeline

Caofeidian Eco-City is envisaged to house 1 to 1.2 million residents on an area of 150 $km^2$. A start up area of 30 $km^2$ was planned as the central business center of the eco-city, and is expected to house around 500,000 people by 2016. The master plan of 150 $km^2$ was developed jointly by SWECO Company of Sweden and the Beijing Tsinghua Urban Planning and Design Institute, and was approved by the Government of Hebei Province in 2008. The detailed plan for the 30 $km^2$ area was developed by the Beijing Tsinghua Urban Planning and Design Institute. An indicator system consisting of 57 indicators was developed to guide the planning and implementation of Caofeidian Eco-City. Construction works in Caofeidian Eco-City started in September 2008, and an estimated investment of RMB 97.7 billion is expected in 2009.

## Key Features

Some notable features of Caofeidian Eco-City's plans include:

1) *Choice of wasteland.* Caofeidian Eco-City is being built above wasteland and tidal land and does not occupy farm land. The cost of land reclamation is around RMB 117 per $m^2$, which is relatively low as no land expropriation and resident relocation is required during construction. Soil conditions are being improved by building a freshwater environment by setting double sea dikes, constructing a green space system integrated into coastal flood prevention engineering, and supporting oilfield green land and estuary wetlands. The coverage of green land will reach more than 30 percent by 2015.

2) *90 percent green transport.* Caofeidian Eco-City proposes to prioritize walking and public transportation, and to adopt a Transit Oriented Development (TOD) approach. By doing so, the city strives to limit transport-related carbon dioxide emissions to less than 20 kilograms per person per km. By 2015, the share of public transport is expected to reach 70 percent, and the share of pedestrian and bicycle use 20 percent. A cost-effective Bus Rapid Transit (BRT) system will serve as the backbone of the transport network, with light rail as a supplement in some areas and local buses as feeders to the BRT system. Measures to reduce the demand for private cars and to maximize the use of public transport are also considered, such as, for example, limiting the provision of parking lots, reducing fares for public transportation, levying taxes on people owning multiple private cars, etc. However, no specific regulations have been developed during the planning phase.

3) *Water from non traditional sources at or above 50 percent.* Located in a region with water shortages, Caofeidian Eco-City aims to promote the use of reclaimed water, desalinated water, and rain water. 100 percent of domestic wastewater will be treated and reused, which is advanced compared to the 85 percent sewage treatment rate and 30 percent treated water reuse rate required by the National Eco-City Standards. Caofeidian Eco-City also strives to improve water efficiency by limiting water consumption per unit of GDP to less than 150 $m^3$ per 10,000 Yuan. However, per capita domestic water consumption is projected to be 180 liters per person per day by 2015, which is not necessarily advanced compared to Chinese cities in regions with scarce water resources.

4) *Over a 70 percent share of renewable energy and waste heat supply.* Renewable energy sources, such as solar, biogas, wind, and geothermal sources, will account for more than 50 percent of the Eco-City's total energy supply. In addition, industrial waste heat from steelworks and electric power plants in industrial zones will also be important heating sources. Waste incineration and cool-heat-electricity cogeneration will be utilized as subsidiary heating supplies. Seawater desalination facilities will be combined with thermal power plants during their construction.

5) *Social aspects are also considered in the  Caofeidian Eco-City plan.* For example, the share of affordable housing was proposed to be more than 20 percent of the total housing stock. All residents will be able access bus stations within 300 m, and public service facilities within 500 m.

### Challenges

Though Caofeidian Eco-City benefits from a comprehensive indicator system setting clear targets for planning and constructing the new city, some key indicators have the same levels as national eco-city standards, such as the COD Emission Intensity and Energy Consumption per unit GDP. These indicators are likely to be comparable to those in other cities in China pursuing an eco-city agenda, but do not necessarily represent advanced targets. Moreover, to achieve the targets for environmental quality and waste heat supply, Caofeidian Eco-City needs to closely coordinate with the Caofeidian Industrial Zone. In this respect, cross-jurisdiction coordination was strengthened in March 2009 after Caofeidian Eco-City was officially incorporated along with the Caofeidian Industrial Zone and two other jurisdictions into the Caofeidian New District, a vice city level government approved by Hebei Province.

## B.Case 2: Eco-City Development in Shenzhen, Guangdong Province

### Introduction

Shenzhen has experienced the fastest growth among Chinese cities over the past twenty years. Its population reached more than 8 million and its economy grew to the largest in Guangdong Province and the fourth largest in China. Shenzhen's high speed economic development also brought significant environmental and social problems. A large number of migrant workers has generated pressure on urban infrastructure. In 2007, for example, only two-thirds of surface water in Shenzhen complied with national quality standards. In 2005, the centralized treatment rate of urban sewage was only 38 percent, lower than the average in Chinese cities. To shift the city's economic-centered development towards sustainability, the Shenzhen municipal government declared in 2005 that it aimed to change its image from "rapid Shenzhen" to "efficient Shenzhen" and "harmonious Shenzhen". Efforts are underway to create an urban green space system, improve air and water quality, implement clean production, and support green transport and green buildings. In 2006, Shenzhen developed its Eco-City Construction Plan for 2006 to 2020, and proposed an eco-city indicator system based on Ministry of Environment Protection's national Eco-City Standard. This system has 23 indicators covering socio-economic development, resource utilization, and the ecological environment. The goal is to be recognized as an MEP national eco-city by 2010. In addition to being recognized as a "National Model City for Environment Protection" in 1997, Shenzhen City was designated in 2007 as the first national pilot of an eco-garden city by the Ministry of Housing and Urban-Rural Development.

### Key Features

1) *Regional ecological system.* Though available land is limited, nearly half of Shenzhen's land area was strictly protected from construction. Shenzhen also benefits from its multi-center spatial structure, which helps to prevent urban sprawl. In addition to the Shenzhen Eco-

City Construction Plan, Shenzhen has developed the Shenzhen Green Space System Plan, Shenzhen Biological Diversity Conservation Plan, Shenzhen Ecological Forest Construction Plan, and Shenzhen Wetland Plan to guide the protection and construction of a regional ecological system that includes green space, wildlife habitats, coastal areas, wetlands, etc. In 2005, Shenzhen's public green area per capita reached over 16 $m^2$, much higher than the 12 $m^2$ defined by national eco-city standards. Shenzhen also has good air quality. In 2005, ambient air quality met or exceeded Grade II of China's National Ambient Air Quality Standard for 360 days, much higher than the 300 day national eco-city standard.

2) *Energy and resource efficiency.* Shenzhen is more advanced in energy and resource efficiency in terms of resource consumption per unit GDP compared to other cities in China. For example, energy consumption per unit of GDP was 0.63 tons of standard coal per ten thousand yuan in 2005, and this is expected to decrease to 0.5 by 2010 and 0.35 by 2020. These rates are much lower than the national eco-city standard of 0.9. Water consumption per unit GDP was 33.8 $m^3$ per ten thousand yuan in 2005, which was much less than the national eco-city standard of 150 $m^3$ . Shenzhen has also put forward an indicator to monitor land use intensity, measured by construction land per unit of GDP. In 2005, land use intensity was 14.47 $m^2$ per ten thousand yuan, and this is expected to decrease 40 percent to 8.42 $m^2$ by 2010. This is an advanced target compared to other cities.

3) *Energy efficient buildings.* In 2006, Shenzhen put in place a "Regulation on Building Energy Savings", and standards for energy saving buildings have been designed and implemented. In 2008, the share of newly constructed buildings achieving national standards for energy-efficiency reached 100 percent, placing Shenzhen among the first few cities in China achieving this target. The national average is a much lower 71 percent. The Shenzhen municipality also mandated that at least 10 percent of buildings constructed each year should comply with national green building standards. By enforcing energy efficiency regulations, energy saved in the building sector accounted for 49 percent of the annual energy conservation target for the whole municipality, which is 830,000 tons of SCE.

4) *Circular economy.* Shenzhen is the first among Chinese cities to issue a series of local regulations, technical standards, and fiscal incentives to promote cleaner production and usage of reclaimed water and solar energy. These efforts were led by the Shenzhen Economic Special Zone Circular Economy Promotion Code, which was enacted in 2006. Municipal level and district level institutions were established to govern the development of the circular economy. In 2005, the intensities of $SO_2$ and COD emissions were 0.88 and 1.13 kg per ten thousand yuan, respectively. These intensities are much lower than the 5.0 and 4.0 national eco-city standards. In 2007, the Shenzhen Municipality was designated as one of the "National Pilot Cities for Circular Economy" by NDRC, MEP, and other line ministries.

### Challenges

Shenzhen has made notable progress in increasing the coverage of green space, introducing energy efficient buildings, and improving resource efficiency. However, compared to national eco-city standards, Shenzhen's performance still lags in certain areas, such as reuse of industrial water (only 42 percent in 2005 compared to the 80 percent standard), use of reclaimed water (only 1 percent in 2007 compared to the 30 percent standard), sewage treatment rate, etc. These areas must be prioritized given their importance to ensuring sustainable water resources in a city with severe water shortages. The Shenzhen municipality is also paying increasing attention to renewable energy, and its importance to ecological development. Shenzhen is expected to begin formulating new energy development plans, but the detailed planning is only in the early stages.

### C.Case 3: Eco-City Development in Yangzhou, Jiangsu Province

### Introduction

Yangzhou is located in the Yangtze River Delta, Jiangsu Province, and has a population of 1.2 million. It is a populous tourism city famous for its history, culture, and scenic landscape. Yangzhou municipality developed its "Yangzhou Eco-City Construction Plan" in 2000 with the aim to be recognized as a national eco-city by 2020. It was the first eco-city plan approved at the national level by MEP in 2003. A comprehensive and detailed indicator system including over 80 indicators covering socio-economic and environment aspects was proposed to guide the planning, construction, and management of the eco-city's development. In addition, the government organized a steering committee and a special office to oversee planning, construction, and project implementation. In December 2003, MoHURD recognized Yangzhou as a "National Garden City" in view of its achievements in urban afforestation and greenery. In March 2006, MEP recognized Yangzhou as a "National Ecological Demonstration Zone". Yangzhou was also awarded a "United Nations Habitat Prize" for effectively protecting the ancient city and improving the city's habitat environment. In 2007, MoHURD recommended Yangzhou as a pilot "National Ecological Garden City".

### Key Features

1) *Energy efficient buildings.* In 2006, Yangzhou issued its "Notice on Further Promoting Innovation of Wall Material and Implementing Building Energy Conservation". The city also requested that newly constructed buildings comply with the requirements of the "Jiangsu Civil Thermal Environment and Energy Saving Design Standards". In 2007, Yangzhou issued a document on "Strengthening the Application of Solar Water Heating Systems". This document requested that new residential buildings having less than 12 floors, and projects to renovate and expand existing buildings, should integrate and support installation of solar thermal water systems.

2) *Water efficiency.* In the water sector, Yangzhou issued its "Programs for Establishing a Water-Saving City" in 1998. Groundwater exploitation was controlled by implementing permits for drilling, reducing the urban groundwater exploited to 4.50 million tons/year in 2004 from 13 million tons/year in 1998. From 1998 to 2004, the industrial water recycling rate also rose from 28.6 percent to 75.98 percent, which is close to the 80 percent required by national eco-city standards. Water consumption per unit GDP also fell from 280 tons to 150 tons (same as national water efficiency standards). In 2005, Yangzhou was recognized as a "National water-saving city".

3) *Energy efficiency and clean energy.* In 2007, Yangzhou released a policy on "Implementation of Energy Conservation and Emissions Reductions in Yangzhou". The city implemented projects to replace energy-intensive equipment and products with more efficient technologies, and enforced quotas on energy consumption among enterprises. Yangzhou also established a special development fund, and supported preferential tax policies and land use to promote the installation of LED and the development of the photovoltaic industry. Over 50,000 municipal LED lights were introduced in the urban city for street lighting and landscape lighting. Annual power savings of 13,600,000 kWh are expected along with energy savings of 1710 t SCE. Yangzhou also employed household subsidies to promote the use of clean energy, such as the combined straw-methane application, in rural areas.

4) *Waste management.* The municipality of Yangzhou required that all developments zones, industrial parks, and industry centers in the city develop plans to construct sewage treatment plants. The old sewerage network was rebuilt and upgraded in the old urban area. At the same time, sewage treatment plants were constructed in villages and towns. 13 new plants were

built in 2007. As a result, Yangzhou's sewage treatment rate reached 83.6 percent in 2008, up from 14.4 percent in 2000. An industrial solid waste disposal center was constructed in 2007. This center includes the integrated processing system for industrial sludge, integrated treatment of hazardous waste, a landfill for industrial and hazardous waste, leachate treatment equipment, and other facilities. In 2007, Yangzhou achieved a comprehensive utilization rate of industrial waste of 81.9 percent.

5) *Circular economy.* In 2006, city authorities developed the "Yangzhou Circular Economy Construction Plan". Three industrial chains were targeted to adopt the principle of "reduce, reuse, and recycle" in Yangzhou's economic development zone: the thermoelectric industry, photovoltaic-LED industry, and the thermoelectricity-cement industry. In recent years, Yangzhou municipality mandated that all enterprises pass the clean production inspection test, a key indicator when attracting investment. 188 "cleaner" production projects have thus far been implemented in the economic development zone. These projects are expected to save 230,000 tons of water and 100,000 tons of SCE each year. In 2008, the Yangzhou economic development zone was approved as a National Eco-Industrial Demonstration Park.

### Lessons Learned

As a historic city facing preservation pressures, Yangzhou needs to devise incremental and innovative measures to improve the living environment of its old areas. A waterfront redevelopment undertaken between 2002 and 2007 with the support of Germany demonstrated that small-scale, innovative techniques and improved management could improve water quality. This project illustrated how local residents can participate in the redevelopment process of historic urban areas, particularly through public consultations. Raising public awareness of environmental protection and ecological development is also important. As a starting point, Yangzhou municipal government has established its "Methods of Environment-friendly Rewards in Yangzhou", which aim to recognize collectivities and individuals who contribute to environmental protection.

## D.Case 4: Eco-City Development in Huaibei, Anhui Province

### Introduction

Huaibei city's ecological development was driven mainly by a desire to address its severe environmental problems linked to its mining sector, mainly by adopting various remedial measures. With substantial mineral reserves, Huaibei city relies on coal industries to power its economy. Huaibei city is one of the ten largest coal exporting cities in China. The city's power industry is currently the third largest in Eastern China, and accounts for 70.8 percent of the city's total industrial output, and 37.4 percent of its total GDP. Five decades of coal mining has resulted in a sharp decrease in mineral reserves and, more importantly, threats to its environment and sustainability. Huaibei has fewer than 200 days per year in which ambient air quality meets or exceeds China's National Ambient Air Quality Grade II Standard, which is much lower than the 300 days required by national eco-city standards. Emission intensity of COD, energy consumption per unit GDP, and water consumption per unit GDP are all unsatisfactory compared to national standards. In 2009, Huaibei was identified as one of 44 "resource-exhausted" cities in China. To improve this situation, Huaibei began to develop the "Huaibei Eco-city Construction Plan" in 2004. A steering committee responsible for governing eco-city development was also established.

### Key Features

1) *Recovery of degraded land.* In recent years, urban planning in Huaibei has emphasized reclamaiming subsidence areas linked to extensive coal exploitation. The subsidence area in Huaibei has reached nearly 130 $km^2$, and is increasing by 5 $km^2$ each year. Huaibei

commenced land reclamation of subsidence areas in the mid-1980s, and various remedies have been developed to address different scenarios. The city plan clearly indicates that subsidence areas in the central urban zone should be strictly protected and reserved for greenbelt, wetland, and water uses. The plan indicates that subsidence areas on the fringe of the urban built-up area can be reclaimed for urban roads, public facilities, and industrial park construction, assuming compliance with special regulations on building heights and building standards. Proper engineering measures must be used for all construction. These subsidence areas are also suitable for urban park development. To-date, about 54 percent of subsidence areas have been reclaimed, and the central government has recognized Huaibei as a "Land Reclamation Demonstration Area".

2) *Building sector.* Huaibei municipality issued regulations promoting "Energy-saving Management of Civil Construction" that mandate that all newly constructed buildings conform to energy efficiency standards. In addition, Huaibei has promoted using waste materials in building construction. For example, industrial wastes have been utilized as materials for manufacturing buildings. Currently, more than 80 percent of the total multi-storey brick-concrete structures in Huaibei city make use of coal gangue sintered bricks. A high share of buildings also make use of wall frame structures built from fly-ash autoclaved aerated concrete blocks.

3) *Water efficiency.* Huaibei issued regulations and applied industrial water quotas to promote water conservation and management. Measures include coal mine water purification treatment, recycling of cooling water, promotion of water saving irrigation, and renovation of water supply networks to prevent leakage. About 70 million $m^3$ of water was projected to be saved from these measures. Rainwater was collected and restored in river and subsidence areas for industrial use. In 2006, Huaibei was recognized as "National Water-Saving Pilot City by the Ministry" of Water Resources.

4) *Energy efficiency.* Huaibei issued a series of regulations to assess, monitor, incentivize, and promote energy savings in industrial development. Energy saving in industrial development was achieved by renovating existing equipment and using residual heat. Coal-bed methane was utilized as domestic fuel gas. The yield of coal-bed methane is projected to reach 20 thousand $m^3$ by 2015. In rural areas, renewable energy was promoted through, inter alia, solar water heaters, energy efficient stoves, rural biogas digesters, solar greenhouses, and solar heating. In 2008, Huaibei launched a program entitled "Energy-saving and Emission Reduction Family Community Action" to raise public awareness. Publicity wall charts were exhibited in the community. 50 families were recognized as having "energy-efficient homes."

5) *Circular economy.* In January 2008, the city of Huaibei was confirmed in China's second group of pilot cities with circular economies. In May 2008, Huaibei municipality issued "Regulations for Promoting Circular Economy Development in Huaibei", which established supporting funds and preferential tax policies targeting key enterprises and projects. Huaibei has extended industrial chains in recent years to develop intensive coal processing, and has implemented a series of major projects linked to a circular economy. The largest operation, the Huaibei Coalification - Salinization Integration Project, will invest 40 billion yuan and is beginning to take shape. 12 enterprises from Huaibei's key industries (i.e., coal, textile machinery, electric power, printing and dyeing, and light industry) were identified as pilot enterprises to achieve comprehensive pollution control, mainly to institute clean production and reduce $CO_2$, $SO_2$, and other pollutants. Comprehensive utilization of coal gangue, mine tailings, and smelter slag has been also improved.

Table A2.1: List of Selected Eco-City Initiatives in China

| No | City/County | Location | Urban population | Eco Awards by MoHURD | Eco Awards by MEP | Key Initiatives |
|---|---|---|---|---|---|---|
| 1 | Qingdao | Largest industrial city of Shandong province | 2,760,000 | National Garden City;<br>Pilot of Ecological Garden City | National Environmental Protection Model City;<br>National Eco Demonstration Area | "Eco-city construction plan" in 2003, with a focus on Jiaozhou Bay coastline protection; "Seawater Desalination Industry Development Plan of Qingdao" in 2005: water supply from desalination will account for one fourth of the city's total water demand by 2010; A new eco-city with an area of 75 $km^2$ targeting high end and green industry is planned to construct in Northern part of Qingdao. |
| 2 | Rongcheng CLC | Shandong province | 675,000 | National Garden City | National Environmental Protection Model City;<br>National Eco City | "Eco-city Construction Plan" in 2004; Promote use of solar energy and insulation materials in buildings; construct large scale wind farms in coastal areas. |
| 3 | Miyun County | Northeast Beijing | 150,000 | | National Environmental Protection Model City;<br>National Eco County | "Minyun Eco-city Construction Plan" in 2005, with a focus on water resource protection, development of eco-agriculture and eco-tourism; 10% revenue was set aside for eco-county construction each year. |
| 4 | Weihai | Shandong province | 4,100,000 | Pilot of Ecological Garden City | National Environmental Protection Model City;<br>National Eco Demonstration Area | "Weihai Eco-city Construction Plan" in 2005; Plan for comprehensive management of watershed pollution. |
| 5 | Hangzhou | Capital of Zhejiang province | 4,100,000 | Pilot of Ecological Garden City | National Environmental Protection Model City | "Hangzhou Eco-city Construction Plan" in 2003; "Regulations on Establishment of An Ecological Compensation Mechanism" in 2005: ecological compensation fund was established; "Energy Conservation Plan of Hangzhou" in 2007: proportion of solar energy and renewable resources use in new buildings will reach 25% by 2010. |
| 6 | Suzhou | Historic city in Jiangsu province | 2,400,000 | National Garden City;<br>Pilot of Ecological Garden City; | National Environmental Protection Model City;<br>National Eco Demonstration Area | "Eco-city Construction Planning Framework" in 2003; "Suzhou Circular Economy Development Plan" in 2004. |
| 7 | Shaoxing | Historic city in Zhejiang province | 640,000 | National Garden City;<br>Pilot of Ecological Garden City | National Environmental Protection Model City | "Eco-city Planning Framework" in 2002; Water Conservation Plan: leakage rate of water supply network decreased to 4.94% in 2008; "Regulations On The Implementation of Circular Economy". |
| 8 | Jiangyin CLC | Jiangsu province | 550,000 | - | National Environmental Protection Model City;<br>National Eco-city | "Jiangyin Eco-city Construction Plan" in 2005; Special funds on energy-saving and circular economy development were established in 2007. |

| No | City/County | Location | Urban population | Eco Awards by MoHURD | Eco Awards by MEP | Key Initiatives |
|---|---|---|---|---|---|---|
| 9 | Taicang CLC | Jiangsu province | 290,000 | - | National Environmental Protection Model City; National Eco-city | “Cyclular Economic Development Plan of Taicang City” in 2004; “Taicang Water-saving Plan (2008-2020)”; Construct sewage treatment plant in every town and small sewage treatment facilities in remote villages; Reform of water management system, i.e., set up water investment company |
| 10 | Guiyang | Capital of Guizhou province | 2,300,000 | - | - | “Guiyang Master Plan of Circular Economy and Eco-city” in 2003; “Regulation on Construction of Circular Economy and Eco-city” in 2004. |
| 11 | Chengdu | Capital of Sichuan province | 4,400,000 | - | National Environmental Protection Model City | “Eco-city Construction Plan” in 2007; “Opinions on Development of Circular Economy” in 2005; “Implementation of Clean Production Programs” in 2006 |
| 12 | Wanzhou District | Chongqing municipality | 660,000 | - | - | A new city with 14 $km^2$ was constructed for migrants after the Three Gorges reservoir was launched; “Implementing Opinions on Circular Economy”; “Comprehensive Work Programs of Energy-saving and Emission Reduction”. |
| 13 | Beichuan County | Sichuang province | 85,000 (planned) | - | - | Reconstructed in new site after Wenchuan Earthquake according to MoHURD’s eco city standards. |
| 14 | Zhuzhou | Hunan province in central China | 800,000 | - | - | National Pilot of Comprehensive Reform on Constructing Resource-saving and Environment-friendly Society in 2007 (Changsha, Zhuzhou and Xiangtan); “Opinions on Priority Development on Urban Public Transport” in 2007: promote energy-efficient and new energy vehicle; Implementation of sulfur dioxide emissions permits system; Strategy of circular economy. |
| 15 | Sanya | Tropical tourism city in southern Hainan province | 250,000 | National Garden City | National Ecological Demonstration Area | “Sanya Eco-city Construction Plan” in 2009; “11th Five Year Plan of Building Energy Conservation”: promoting Integrated Solar Hot Water System and solar lighting. |
| 16 | Guilin | Famous tourism city in Guangxi province | 600,000 | National Garden City; Pilot of Ecological Garden City | National Environmental Protection Model City | “Guilin Ecological Construction Plan” under preparation |
| 17 | Wuhan | Capital of Hubei province | 6,600,000 | - | - | National Pilot of Comprehensive Reform on Constructing Resource-saving and Environment-friendly Society in 2007; Green public transport development: promote use of liquefied petroleum gas motor vehicles, update vehicles using CNG engine and Euro 4 standard engine; develop trolley buses, BRT and urban rail; “Wuhan Water-saving Plan (2002-2010)”; “Medium &Long term Plan of Circular Economy”. |
| 18 | Huanren County | Historic city in Liaoning province | 300,000 (total population) | - | National Ecological Demonstration Area | “Huanren Eco-county Construction Plan”: focus on circular economy, eco-tourism, use of wind power and hydro power. |

1. Applying on a pilot basis the emerging "city-wide" methodology for accessing Carbon Finance.

2. The report focuses only on new city developments; retrofitting existing urban areas is not being addressed.

3. It needs to be noted that this approach is a "work in progress" and its application to Tianjin serves as an initial case study to demonstrate the potential benefits of capturing carbon finance potential at the city-scale.

4. McKinsey & Company, Preparing for China's Urban Billion, 2009.

5. UNFPA, The State of the World Population 2007: Unleashing the Potential of Urban Growth, 2007.

6. Shlomo Angel, Stephen C. Sheppard and Daniel L. Civco, The Dynamics of Global Urban Expansion (Washington D.C.: Transport and Urban Development Department, The World Bank, 2005).

7. David Dollar from the World Bank, Eco-Cities: An Integrated Platform from Energy Efficient Buildings to Sustainable Urban Planning, presentation at the Fifth International Conference on Intelligent, Green and Energy-Efficient Building & New Technologies and Products Expo, Beijing, March 27-29, 2009.

8. East Asia Urban Unit of the World Bank, The Spatial Growth of Metropolitan Cities in China: Issues and Options in Urban Land Use, March 11 2008.

9. China's arable land per capita peaked in 1965 at 0.19 hectare, but this had fallen to 0.1 hectare by 2003, which is less than half of the world's average of 0.23 ha. Since then, the available arable land in China has decreased further about 10 percent to 121.7 million hectares in 2006.

10. It was estimated that each year, 1.5 million farmers lost their farmlands in the process of urbanization during the last decade. See: Lu, C.H., Li, X.B., Tan, M.H., 2003. China's farmland changes and trends: a scenarios analysis. In: Economic Transition and Sustainable Agricultural Development in East Asia. International seminar 20–22 October, 2003 in Nanjing, jointly organized and sponsored by Nanjing Agricultural University, Wageningen University, and IFPRI.

11. World Bank, Stepping Up: Improving the Performance of China's Urban Water Utilities, 2007.

12. East Asia Region Poverty Reduction Unit of the World Bank, Mid-Term Evaluation of China's 11$^{th}$ Five-Year Plan, December 18 2008.

13. Ecological Civilization, China Daily, October 24 2007.

14. Ministry of Environment Protection. The State of Environment in China in 2008. June 5 2009.

15. World Bank, World Development Indicators, 2008.

16. World Bank, Cost of Pollution in China, 2007.

17. Yusuf and Saich, China Urbanizes: Consequences, Strategies and Policies, the World Bank, 2008.

18. World Bank, Cost of Pollution in China, 2007.

19. Interview of QIU Baoxing, Vice Minister of Ministry of Housing and Urban-Rural Development, on First China Urban Public Transport Week and Non-car Day, October 11 2007, www.mohurd.gov.cn.

20. State Council's Explanation on "National Code on Energy-Efficient Civil Buildings", September 2008, www.people.com.cn.

21. State Council's Explanation on "National Code on Energy-Efficient Civil Buildings", September 2008, www.people.com.cn .

22. China's State Council, China's White Paper on Energy Situation and Policy, 2007.

23. Yusuf and Saich, China Urbanizes: Consequences, Strategies and Policies, the World Bank, 2008.

24. www.c40cities.org.

25. Nicholls, R. J. et al. (2008), "Ranking Port Cities with High Exposure and Vulnerability to Climate Extremes: Exposure Estimates", OECD Environment Working Papers, No. 1, OECD Publishing.

26. This concept was put forward by Hu Jintao, General Secretary of the Central Committee of the Communist Party of China (CPC),during the fifth plenary session of 16th Central Committee of the Communist Party of China (CPC) in October 2005.

27. This concept was put forward by Hu Jintao, General Secretary of the Central Committee of the Communist Party of China (CPC), at the 17th National Congress of the CPC in 2007.

28. China's 11th Five-Year (2006-2010) Plan for National Economic and Social Development, National Development and Reform Commission, 2006.

29. For example, a 30 percent reduction in water use per unit of industrial value added by 2010, 60 percent comprehensive utilization rate of industrial solid waste by 2010, 120 million hectare arable land by 2010, 10 percent reduction of major pollutant emissions, and 20 percent forest coverage rate.

30. The Ministry of Land and Natural Resources (MLNR) regulates the national consumption of agricultural land through a quota system. Quotas for the conversion of agricultural land into 'construction land' are distributed from central government to local governments every five years. Provincial governments distribute their quotas to municipal governments which, in turn, allocate parts to district, county, and county-level city governments.

31. For localities that fail to meet the agreed targets, the head of the government and other responsible officials will not be rewarded and promoted (even demoted in serious cases) even if performance in all other aspects meet the criteria for reward and promotion. See: East Asia Region Poverty Reduction Unit of the World Bank, Mid-Term Evaluation of China's 11th Five-Year Plan, December 18, 2008.

32. As stressed in the National 11th Five-Year Plan.

33. Remarks of Chinese President Hu Jintao, collective study of the CPC Central Committee Political Bureau, September 29, 2005.

34. The "ecological city" concept was first introduced to China by UNESCO's intergovernmental Man and the Biosphere Program in 1971.

35. Average forestation coverage of built-up area of Chinese cities in 2007 is 36.64 percent. See: 2007 National Urban Environment Management and Comprehensive Treatment Annual Report, MEP, 2008.

36. Average water body quality standard meeting rate of Chinese cities in 2007 is 86.50 percent. Ibid.

37. Average domestic solid waste non-toxic treatment rate of Chinese cities in 2007 is 67.58 percent. Ibid.

38. MoHURD, National Standards for Eco-Garden City, 2004.

39. For example, public green space per capita should reach 7.5 $m^2$, 8 $m^2$, 9 $m^2$ for cities with, respectively, more than 1 million people, between 0.5-1 million people, and less than 0.5 million people; these rates are 7 $m^2$, 7.5 $m^2$, and 8.5 $m^2$ for cities in northern region, respectively.

40. MoHURD, National Standards for Garden City (revised), 2005.

41. MEP, National Environment Protection Model City and Model District, 1997.

42. MEP, Indices for Eco-County, Eco-City and Eco-Province (revised), 2007.

43. For example, according to the eco-city standard by MEP, energy consumption ≤0.9 (ton SCE per 10,000 RMB GDP); fresh water consumption ≤20 ($m^3$ per 10,000 RMB industry VA).

44. For example, according to eco-city standard by MEP, COD emission <4.0 (kg per 10,000 RMB GDP); $SO_2$ emission <5.0 (kg per 10,000 RMB GDP).

45. Average urban sewage centralized treatment rate of Chinese cities in 2007 is 51.95 percent. See: 2007 National Urban Environment Management and Comprehensive Treatment Annual Report, MEP, 2008.

46. Average industrial solid waste treatment rate of Chinese cities in 2007 is 92.26%, and hazardous industrial solid waste treatment rate is 94.71percent. Ibid.

47. For example, MoHURD requires a 70 percent sewage treatment rate, while MEP requires a higher 85 percent. MoHURD requires per capita urban public green space of 12 $m^2$, while MEP requires a lower 11 $m^2$.

48. QIU Baoxing, MoHURD, Guidelines for Reconstructing Eco-city after Earthquake, 2008 International Forum on Urban Development and Planning, June 19 2008.

49. Cities that are pushing the eco-city agenda include Shanghai, Tianjin, Harbin, Chongqing, Changzhou, Chengdu, Qinhuangdao, Rizhao, Guiyang, Tangshan, Xiangfan, Changchun, and Changsha, among others. Provinces such as Hainan, Jilin, Shanxi, Fujian, Shandong, Anhui, Jiangsu, and Zhejiang have also set the goal of building Eco-provinces, and started the planning process. See: report from People's Daily Online.

50. 2013 is the year when the construction of start-up area is expected to be finished.

51. SSTEC Standard for Green Building Evaluation (SSTECAC).

52. Green trips refer to non-motorized transport, i.e. cycling and walking, and trips on public transport.

53. The percentage of employable residents in the Eco-city that work in the Eco-city

54. Tianjin City Master Plan (2005-2020).

55. Tianjin 11th Five-Year-Plan for Economic and Social Development (2005-2010).

56. State Council: Approval of Tianjin Binhai New Area Master Plan ([2008]26).

57. National 11th Five-Year-Plan for Economic and Social Development (2005-2010), National Development and Reform Commission.

58. Tianjin Municipality Master Plan (2004-2020).

59. Tianjin Binhai New Area City Master Plan (2005-2020).

60. Tianjin Binhai New Area 11th Five-Year-Plan for Economic and Social Development (2005-2010).

61. Population in 2004.

62. Eco2 Cities: Ecological Cities as Economic Cities, World Bank, 2009.

63. Tianjin City Master Plan (2005-2020).

64. The Spatial Growth of Metropolitan Cities in China: Issues in Urban Land Use. World Bank 2008 (Draft).

65. In 1994, the average FAR of 612 Chinese cities nationwide was 0.264 while Hong Kong SAR, China was 1.6-10 and Japanese cities were 0.5-20 across different land uses. Today, it is not uncommon to find much higher FAR in Chinese cities. In Tianjin, the maximum FAR is around 1.8 in most residential areas. See A. Bertaud (2007), Preliminary Draft Report on China Land Use Efficiency, World Bank, for a detailed discussion of floor area ratio and land use efficiency in China.

66. Eco2 Cities: Ecological Cities as Economic Cities, World Bank, 2009.

67. Eco2 Cities: Ecological Cities as Economic Cities, World Bank, 2009.

68. Bylund, Jonas R. What's the Problem with Non-Conventional technology? The Stockholm Local Investment Program and the Eco-cycling Districts. European Council for an Energy Efficient Economy, & Author, 2003

69. Ibid

70. Ibid

71. http://www.hammarbysjostad.se/frameset.asp?target=inenglish/inenglish_model.asp

72. Karolina Brick, Barriers for Implementation of the Environmental Load Profile and Other LCA-Based Tools (Stockholm: Royal Institute of Technology, 2008).

73. Eco2 Cities: Ecological Cities as Economic Cities, World Bank, 2009.

74. Presentation by IPPUC (Institute for Research and Urban Planning of Curitiba). 2009.

75. Ducom, Estelle. 2008. Tama New Town, West of Tokyo: Analysis of a Shrinking Suburb.Landscape and Urban Planning. Elsevier.

76. Energy intensity is a measure of the energy efficiency of an economy calculated as units of energy/ unit of GDP.

77. Commercial buildings include primarily office buildings, schools, hospitals, shopping malls and warehouses.

78. Source: Fridley, D., N. Zheng, and N. Zhou (2008). Estimating total energy consumption and emissions of China's commercial and office buildings, LBNL-248E, Lawrence Berkeley National Laboratory, 2008.

79. The percentage reduction is based on nominal calculated average building energy use measured as $kWh/m^2$.

80. SSTEC Standard for Green Building Evaluation (SSTECAC).

81. National Standards for Garden Cities, Ministry of Housing and Urban-Rural Development (MoHURD), revised version in 2005.

82. Examples include Residential Building Code (GB 50368-2005), Design Standard for Energy Efficiency of Public Buildings (GB 50189-2005), Design Standard for Energy Efficiency of Residential Buildings in Hot Summer and Cold Winter Zone (JGJ 134-2001), Civil Building Energy Conservation Regulations (2008), and Code for Acceptance of Energy Efficiency Building Construction (GB 50411-2007).

83. Source: State Council's Explanation on "National Code on Energy Efficient Civil Buildings", Sep. 2008 . http://env.people.com.cn/GB/7727144.html.

84. As of May 2009, there are 21 LEED certified buildings in China and 158 buildings registered or pending.

85. Source: Evan, M. (2009) Building Commissioning: A Golden Opportunity for Reducing Energy Costs and Greenhouse Gas Emissions. Report for California Energy Commission.

86. The Seasonal Energy Efficiency Ratio (SEER) is defined by the Air Conditioning, Heating, and Refrigeration Institute to

rate the efficiency of air conditioners. The higher the SEER rating of a unit, the more it is energy efficient. The SEER rating is the Btu of cooling output during a typical cooling-season, divided by the total electric energy input in watt-hours during the same period.

87. Source: Efficiency 2.0. Behavior as a Resource.

88. Tianjin Beitang Heat and Power Plant is located in the north of Tanggu district with a total heating area of 35 million $m^2$. The pre-feasibility study and site selection have completed and the EIA is ongoing.

89. Tianjin Beijiang Power Plant is located in the south of Hangu district with a total heating capacity of 1920 t/h. Incorporating functions of power plant, desalination and condensed sea salt production, it has already begun construction and the first phase of 2 × 1000MW unit, and is expected to be put into production by the end of 2009.

90. SSTEC is located in the central and northern coastal geothermal filed.

91. Road Energy Systems consists of a layer of asphalt concrete that has a closed system of pipes running through it to absorb the sun heat. The road energy system will be piloted in certain public building in the start-up area of SSTEC, which is the first experiment of such a system in China.

92. Source: Jing, F. and T. Yu (2008). "Half of New Buildings Fail Energy Standards", China Daily, Jan. 2008.

93. Source: Langdon, D. (2007). Cost of Green Revisited: Reexamining the Feasibility and Cost Impact of Sustainable Design in the Light of Increased Market Adoption.

94. See Chapter II for definition.

95. The KPI is >80% f all trips are included, i.e., also those entering or leaving SSTEC.

96. SSTECTransport Sector Plan.

97. The Tianjin Municipal transport plan calls for a green transport share of 80 percent which would imply that SSTEC would achieve a 10 percentage point increment over other practices in Tianjin Municipality.

98. Green trips refer to non-motorized transport, i.e. cycling and walking, as well as trips on public transport.

99. SSTEC Transport Sector Plan.

100. The metro line will be extended into SSTEC within 3 years, to be completed by 2011.

101. This figure has been provided by SSTEC transport planners as part of their core baseline data. It does, however, conflict with other data sources from UITP regarding walking and cycling mode shares in Shanghai (see Table 4 below). This highlights the importance of accurate data when dependency for decision making is so high.

102. It is important to note that given inconsistent apportionment of taxi journeys across base cases, caution is required when directly comparing mode percentiles, due to the high volume of taxi journeys across Chinese cities.

103. Given the significant percentile of walking and cycling trips in Chinese cites compared to those in the West, analysis of SSTEC's planned target against achievements in European, American and, Australasia is not relevant.

104. Note that the reported mode share differs from that used by SSTEC transport planners and reported in Table 2.

105. 2001 Urban Transport Fact Book.

106. These are discussed in detail in Chapter II.

107. To date, no micro-simulation of any traffic intersection has apparently been undertaken, though detailed designs have been submitted. There will be a need for such simulations in the future. As VISSUM has been used for modeling the SSTEC area, VISSIM should be employed to undertake the necessary micro simulations.

108. Six-station and eight-station options were originally considered, with the eight station option now preferred. Modeling shows that the eight-station option will significantly increase the number of 'green' trips undertaken.

109. In the road design drawings, the tramway is shown on one side of the right of way. If this solution is adopted, it is important that the tramway be located on the side of the right of way closest to the adjacent residential development. This will minimize passenger walking distances to access the tram, and avoid the need to cross a main road (even though, in most cases, there would be a grade separated crossing).

110. A recent comparative cost analysis in Gold Coast, Australia on LRT and BRT mass transit options along the same 17 km corridor indicated capital costs of AU$175.5M for BRT and AU$251.3M for LRT. Total operating and recurrent costs were assessed at AU$13.6M and AU$22.9M, respectively, for BRT and LRT. Queensland Transport: TransLink 2005.

111. Single direction passenger trips range from 2,500 to 6,500 per hour, depending on the route; the capacity of the total network is 14,500 passengers per hour. According to the master plan, 3 LRT depots (1 per SSTEC phase) will be located in industrial areas. Land will be used above the LRT depots. Though this is a good idea, depot strategies should be finalized once operational transit planning is completed. If depots are poorly sited in relationship to operational demands, increased running and operational costs may ensue.

112. Bicycle storage facilities and bicycle parking areas will be provided at key interchanges and major stations. Bicycle rental stations are also being considered.

113. In developed countries, providing public transport infrastructure in new communities early encourages public transport use and tends to reduce desires for a 'second car'.

114. Similar phasing issues relate to parking strategies and vehicle emission control strategies. Low targets for initial implementation may appeal to communities and developers alike, but engender low environmental benefits which are hard to boost in the future.

115. Best practice examples include: Bad Ischl, Barcelona - Trinitat Nova, Gyo˝r, Tampere - Vuores, Trnava, Tübingen – Derendingen, and Umbertide.

116. It is apparent that property developers are applying significant pressure to the planning process to ensure that opportunities for real estate sales are not inhibited, particularly in the early stages. The perception is that environmentally-beneficial constraints will impact the desired lifestyle of potential purchasers, at least in the early stages of development, thereby reducing the number of potential buyers. In particular, parking strategies and the roll-out of the public transport system may be at some risk.

117. Source: Australian Government Department of the Environment, Water, Heritage and the Art.

118. Transportation services are best planned and coordinated at the highest possible level. In Chongqing, a recent government initiative introduced a new municipal mega-department responsible for integrated service planning and operational management of the city's LRT company, BRT Company, and bus services.

119. Tianjin's 160 $m^3$/year includes water transfers from other regions (World Bank: North China Water Study, 2005).

120. The treated water quality for Hangu (2003) is turbidity NTU 0.41; COD/mg/l 1.7; bacteria count: 1; residual chlorine mgl/ l 0.73.

121. Reclaimed water will meet the GB T 18920-2002 standards. The plan will include a possible desalination plant to further improve the reclaimed water for landscaping and irrigation.

122. In fact, the KPIs have already influenced the design of the Hangu Yingcheng wastewater treatment plant, which is in the early stages of construction and financed by the World Bank. The original design was for discharge standard Class 1B, which since changed to Class 1A.

123. As the bulk of drinking water is produced from surface water disinfection, using chlorine only will not be sufficient. Disinfection by ozone, part of the water treatment process, will guarantee the elimination of some risky pathogens like cryptosporidium, which can survive chlorination.

124. The tailing of a high pressure steam turbine with a back pressure steam turbine can be more feasible than running a desalination plant. This option needs to be examined.

125. Being a coastal city it is expected that the wind will change its direction between day and night. Despite the fact that the treatment plant is located inland which is downstream from the city relative to the favorable wind direction during the day it is expected to be a source of nuisance during the night. Thus the proposed odor treatment and control system need to be well maintained.

126. See the Alliance to Save Energy's 2007 Watergy Handbook for more discussion on barriers and opportunities for tapping water and energy efficiency in water utilities at: http://www.watergy.net/resources/publications/watergy.pdf.

127. The private sector can also provide valuable competitors to operate water systems in a city. Involvement of private operators can be contracted under different setups: service contracts to manage specific works or operations; management contracts; operating contracts; lease contracts; and long term concession contracts. More details on Public Sector Participation modalities can be accessed at the World Bank PSP Toolkit.

128. The service provider can be a private company (UK, France, Germany, etc.), a public utility (Germany, South Africa, Australia) or the municipality (Cairo, Jordan, France, Germany). In some cases, multifunction utilities may evolve to offer water, electricity, and other utility services. This depends on the scale of the various industries, and the benefits of achieving synergies between the various utility services. Moreover, public utilities may outsource some or all of their operations to increase their efficiency.

129. Solid waste management in many medium sized cities can account for 40 to 50% of the total municipal budget.

130. $11^{th}$ Five-Year National Environment Protection Model City Assessment Indicators, MEP, 2006.

131. It is also lower than forecasted in Table 3 Eco-City which may reflect some planning inconsistencies.

132. Ton = metric ton.

133. Hoornweg, Dan; Lam, Philip; Chaudhry, Manisha. Waste management in China: Issues and recommendations. Urban Development Working Paper No. 9; World Bank. Washington, DC. December 2005.

134. The estimated gross generation rate, assuming that most materials recovered for recycling occurs prior to landfill, is 1.37 kg/ capita / day for permanent and temporary residents.

135. The KPI value shows 0.8 kg/ capita / day by 2013. These forecasts appear to have been derived from two different sources, so the basis for the projections may be different. Nonetheless, while the specific forecasts differ, the objective for a reduced generation rate are similar and should be viewed in this manner.

136. Most recyclables recovered by waste pickers are collected before the waste reaches a disposal site.

137. The forecasted recyclables that would be recovered by the informal sector were assumed to be the same both with and without the implementation of the planned waste reduction measures. While there would likely be a difference under the two approaches, it is assumed that the differences would be relatively small.

138. 80 percent of the population participates in neighborhood community associations; City of Yokohama (2008) Proposal for Eco-Model Cities.http://www.city.yokohama.jp/me/kankyou/ondan/model/> (accessed February 2009)

139. City of Yokohama Resources & Wastes Circulation Bureau (2006) Yokohama G30 Plan –Verification and Next Steps. <http://www.city.yokohama.jp/me/pcpb/keikaku/G30rolling/> (accessed February 2009)

140. Data in one planning document reports that the moisture content in the waste discarded in Tianjin in 2003 amounted to 58%. As stated above, this information must be viewed as an indicator rather than as an absolute; but as an indicator, the moisture level is much higher than is desirable for waste combustion, unless a supplemental fuel is used.

141. Welsh School of Architecture. Solid waste pneumatic collection system in the historic centre of Leon (Spain) http://www.cardiff.ac.uk/archi/programmes/cost8/case/waste/leon.html.

142. Iriarte, Alfredo; Xavier Gabarrell; Joan Rieradevall. LCA (Life Cycle Assessment) of selective waste collection systems in dense urban areas. Waste Management Number 29 (2009). Pages 903-904.

143. Jackson, Stephen B. Independent Research Project: An in-depth report on the development, advancement, and implementation of pneumatic waste collection systems and a proposed program for practical evaluation of such a system in terms of waste disposal parameters, engineering design, and economic costs. Independent Research Report, June 24, 2004.

144. Al-Ghamdi, Saeed, Abdullah; Abu-Rizaiza, Asad Seraj. Pipeline transport of solid waste in the Grand Holy Mosque in Makkah. Waste Management &Research. 2003. pages 474 -479.

145. Appropriate Disposal of Waste. Environment Bureau. Osaka, Japan. http://www.city.osaka.jp/kankyojigyo/english/waste/waste_04.html

146. Tianjin currently has two transfer stations with a combined capacity of 1,550 tpd. There are also a reported 237 small transfer stations in Tianjin, of which 189 are in the central city. These small transfer stations apparently are used to consolidate waste collected in carts into trucks. Specifics on the transfer process were unavailable.

147. Hoornweg, Dan; Lam Philip; Chaudhry, Manisha. Waste management in China: Issues and recommendations. Urban Development Working Paper No. 9; World Bank. Washington, DC. December 2005.

148. Peterson, Charles (moderator / presenter) Workshop – Composting of Organic Waste. World Bank. June 24, 2008. http://go.worldbank.org/5ZGV8EM1V0.

149. Methane is a greenhouse gas with a Global Warming Potential that is 21 times greater than carbon dioxide.

150. The GEF study for SSTEC, for example, focuses only on a few specific components and does not cover opportunities such as waste reduction; landfill gas capture and fuel switch for vehicles.

151. www.c40cities.org

152. Attribution of emission reductions for shared resources, such as a landfill serving multiple cities is important to ensure the critical causal link between the city's action and its GHG impact.

153. For example, a correlation exists between GHG emission reductions and increasing density of population, but the quantification of such benefit is complicated and is currently not included in the methodology.

154. The current set of assumptions includes activity-based baselines and is not adjusted for interactive effects between policy and technology interventions across sectors. As a simplistic approach, the emission reduction potential could be discounted by 20% to account for the cross-effects, potential double counting, leakage and uncertainty due to use of estimation approaches and lack of monitoring rigor.

155. For further information, refer to State and Trends of the Carbon Market, 2009.

156. The Commercial Agreement is confidential and was not accessed for the preparation of this report.

157. Of SSTEC's total $34km^2$ land area about 2/3rd are located in Hangu District and 1/3rd in Tangu District.

158. Keppel intends to maintain an equity share of about 50% in STEC and is seeking international investors to co-invest in STEC. Keppel has signed a Memorandum of Understanding with the Qatar Investment Authority with the objective that the

Qatar Investment Authority takes a 10% ownership stake in STEC.

159. TECID will transfer land for the development of the Eco-city to the JV Company as its equity contribution. STEC will contribute its equity in cash.

160. In terms of the urban infrastructure to be constructed and operated in SSTEC, the arrangements in the urban public transportation sector have not yet been finalized. It is anticipated that TECID's scope of business will encompass investment and construction of certain transportation assets. TECID's scope of business does not include roads, which are the responsibility of the JV Company.

161. The Commercial Agreement specifies that the JV Company receives 62% of the utility connection fee, which is RMB 500/$m^2$ charged based on the floor area of properties, for the construction of the agreed infrastructure.

162. The total available land is 34.2 $km^2$, of which about 25 $km^2$ is available land (in light of water bodies, embankments, etc.). 53% of the 25$km^2$ can be sold as construction land.

163. In the start up area, it is RMB 600,000 per mu; for the rest RMB 635,000/mu.

164. Most land in the eco-city is state owned land, except 1 $km^2$, which is privately owned.

165. The figures do not yet include transportation investments in SSTEC.

166. Eco2 Cities: Ecological Cities as Economic Cities.

167. C40 Cities: Buildings Best Practices (www.c40cities.org/bestpractices/buildings/melbourne_eco.jsp.)

168. Eco2 Cities: Ecological Cities as Economic Cities.

169. According to the National Standards for Ambient Air Quality GB3095-1996, ambient air quality functional zones are divided into 3 categories (from high to low): Class I areas including nature reserve zone, scenic spots and other special protected areas should meet Grade I standard; Class II areas including residential district, mix-use district, cultural district, general industrial district and rural areas should meet Grade II standard; Class III areas including specific industrial district should meet Grade III standard. SSTEC belongs to Class II area.

170. National Standards for Eco-Garden Cities, Ministry of Housing and Urban-Rural Development (MoHURD) 2004.

171. Indices for Eco-County, Eco-City and Eco-Province. Ministry of Environmental Protection (MEP), 2007.

172. 11th Five-Year National Environment Protection Model City Assessment Indicators, MEP, 2006.

173. China's 11th Five-Year (2006-2010) Plan for National Economic and Social Development, NDRC.

174. Tianjin Eco-city Planning Guideline, January 2008.

175. Tianjin Eco-city Planning Guideline, January 2008.

176. Beijing 11th Five-Year Plan (2006-2010) for Environmental Protection and Ecological Construction

177. 2013 is the year when the construction of start-up area is expected to be finished.

178. National Standard GB3838-2002 divides water bodies into 5 categories, and each category should meet corresponding grade of surface water quality (from high to low). For example, Class IV water bodies, including general industrial water and recreation water without direct contact with human bodies, should meet Grade IV; Class V water bodies including agriculture water and general landscape water, should meet Grade V.

179. Indices for Eco-County, Eco-City and Eco-Province. Ministry of Environmental Protection, 26 December 2007

180. Tianjin 11 Five-Year (2006-2010) Implementation Plan for Water Pollution Prevention and Treatment.

181. In 2007, 75 percent of the river length under nation control in Tianjin city reached the standard, 33.3 percent of the river length under nation control in Binhai reached the standard. The quality of water body reach the area standard in 2010 and 2015 in "The framework of Ecological city construction plan Tianjin"; The water quality of Haihe river and other landscape water body In Tianjin city have to reach level V, and no less-V water body in other area was approved in "Tianjin 11 Five-Year (2006-2010) Implementation Plan for Water Pollution Prevention and Treatment".

182. In 2007, 51 percent of the river length, 79.4 percent of the lake area, and 88.5 percent of reservoir content reached the National Standard. In "Beijing 11th Five-Year Plan (2006-2010) for Environmental Protection and Ecological Construction", the water quality of the central city and new developing area should meet the National Standard in 2010.

183. 2007 National Urban Environment Management and Comprehensive Treatment Annual Report, MEP, 2008.

184. http://www.eedu.org.cn/Article/ecology/ecoappliacions/ecosafety/200708/15157.html.

185. National Standards for Eco-Garden Cities, Ministry of Housing and Urban-Rural Development (MoHURD), 2004. In 2004, based on the "National Standards for Garden City", MoHURD proposed a higher-level "National Standards for Eco-Garden City".

186. Indices for Eco-County, Eco-City and Eco-Province. Ministry of Environmental Protection, 26 December 2007

187. National Standards for Eco-Garden Cities, MoHURD, 2004.

188. Tianjin Eco-city Planning Guideline, January 2008.

189. National 11th Five-Year (2006-2010) Plan for Forestry.

190. SSTEC Standard for Green Building Evaluation (SSTECAC).

191. Technical Manual for Green Building Evaluation (MoHURD,2007).

192. National Standards for Garden Cities, Ministry of Housing and Urban-Rural Development (MoHURD), revised version in 2005.

193. National Standards for Eco-Garden Cities, MoHURD, 2004.

194. Indices for Eco-County, Eco-City and Eco-Province. Ministry of Environmental Protection, 26 December 2007

195. National Standards for Eco-Garden Cities, MoHURD, 2004.

196. National Standards for Garden Cities, Ministry of Housing and Urban-Rural Development (MoHURD), revised version in 2005.

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