世界未来委员会
World Future Council

北京交通大學
中国城市研究中心

Host Institution：Beijing Jiaotong University China City Research Center
World Future Council

China Urban Development Review

Special Edition of Green Cities

Editor-in-Chief: Kui Feng
Xuedong Yan

Associate Editors: Mingmei Zheng
Boping Chen
Huanying Yin

This report was published by the China Environment Science Press

Beijing Jiaotong University China City Research Center

Editorial Director：Jingli・Sun
Tel：+86-10-51684602
Email：sunjl@bjtu.edu.cn
website：http://ccrc.bjtu.edu.cn/

World Future Council

Contributing Editor：Ying・Zhou
Tel：+86-10-65008172
Email：info.china@worldfuturecouncil.org
Wechat：

content

Foreword 1

Preface 3

Chapter One: Energy 6

Vancouver 100% Renewable Energy Strategy 7

1. Background 7

2. Manager Thoughts and Decision-Making Processes 9

3. Measures and Solutions 10

4. Effects 23

5. Remarks and Inspiration 25

Dunhuang: Moving Forward to 100% Renewable Energy City 28

1. Background Information 28

2. Development Concepts for Urban and Energy Development 31

3.2 Urban Renewable Energy Development Planning 33

3.2 Problems and Challenges 33

3 Three Stages of Urban New Energy Construction 35

3.2 2009: Building 1 million KW Solar Power Bases 35

3.2 2011: Building A National New Energy Demonstration City 36

3.2 2015: Building 100% Renewable Energy City 37

4. Organizational Management and Safeguard Measures 39

5. Implementation Achievements 40

6. Inspiration and Suggestions 42

Chapter Two: Water Resources 46

Water Management in Seoul 47

1. Background 47

2. City Manager's Thoughts and Decision-Making Process 55

3. Measures and Solutions 57

4. Effect 65

5. Inspiration and Suggestions 66

Water System Management and Practice in Chizhou City 69

1. Background Information about Chizhou City 69

Chapter Three: Waste Resources 92

Solid Waste Management in Berlin 93

Classification and Reduction of Urban Living Garbage and Kitchen Waste Disposal in Yantian District of Shenzhen City 109

Establish Improved Management Mechanism 116

Chapter Four: Urban Ecosystem 121

The Management and Practice of Urban Ecosystems: A Case Study of Zhuhai City 122

1. Background Information of Zhuhai City *122*
2. Thoughts of City Managers and Decision-Making Process *125*
3. Countermeasures and Solutions *127*
4. Implementation Achievements *137*
5. Inspiration and Suggestions *138*

OVERVIEW: Build Regenerative City, and Develop Green Urbanization 141
1 International Background on Regenerative City Development 141
2 The Concept of theRegenerative City and its Key Objectives 142
3 Problems to Be Solved During Construction of Chinese New-Type of Green Urbanization 144
4 The Effect of Regenerative Cities Development on the New Green Urbanization 145
5 Methods to Develop Regenerative City 148
5.1 Strengthen the Efficient Utilization and Recycling of Resources 148
5.2 Promote Material Circulation within Urban and Regional Eco-systems 149
5.3 Optimize Urban Spatial Structure and Layout 149
5.4 InnovativeInvestment and Financing Mechanismsfor Sustainability 150
6 Policy Recommendations on Regenerative City Development in China 151
6.1Set up Developmental Vision and Strengthen Leadership 151
6.2 Encourage Cities to Actively Innovate Across Fields of Industry 152
6.3 Strengthen the Formulation of Urban Environmental Standards and Guidelines 153
6.4 Implement a strategy based on open development to attract the active participation of the whole society 154
6.5 Strengthen Coordination among Urban Sectors 154
6.6 Further Strengthen International Cooperation 155
7 Conclusion and Prospects 155

Epilogue 159

Foreword

Why Do We Review?

China is undergoing one of the fastest and largest urbanization processes in the world. This process has two facets, one is the incremental expansion of urban populations and cities, which characterizes China's urbanization, while the other is that urban quality is increasingly gaining people's attention. Specifically, with regard to the differing gauges for measurement sweeping the nation. These measurements increasingly define what is a *good* city, and those are *not so good*, and how to improve them both. Put it another way, the term 'city' has become a hot topic, repeated in thousands of workshops, seminars, disertations, and academic publicaitons, sparking the fire of debate and innovation.

Accordingly, there are many questions that have been on my mind since my partners and I began the *China Urban Developent Review*, which is, is it really necessary to do this? Why and what do we review? Who should review exactly? And how is the review done?

In answer to the why-question, first, we review in order to learn and to reflect. Second, we feel obligated and excited to join in these lively dicussions on China's urbanization, making our voice heard, and making contributions that will grow with our beautiful cities. These contributions are from our heart, simple, but real.

Nevertheless, we believe it is necessary to offer different, innovative, and valuable suggestions, rather than sticking to the cliché. Accordingly, we pose the following questions:

What do review? We review the most outstanding urban development cases, as we believe real cases are as important as theoretical guidelines, with the theortical guidelines appearing, and being applied, in the practical, real-world, cases. Thanks to our partners, who are active key players representing a wide range of different parties, such as UN bodies, The World Future Council, universities, high-ranking officials, and urban planners, related cases become more accessible to us, and we are excitedly happy to share those cases, and outcomes, with the public.

So by whom should reviews be conducted? Well, policy makers, urban designers, experts, scholars, journalists, and so on forth, are all welcome to be our guests and give their opinions. Anyone who has a deep, balanced view on urban development is expected to join us. It is very likely, and hopefully, that Ebenezer Howard or Jane Jacobs will appear on our writers' list in future.

How to review? We believe a critical and unbiased view is the most important way toreview. Our articles incorporate international and comparative perspectives in order to give a more comprehensive picture of the situation. It does not need to be too complicated, instead, informing readers of the situation in other countries and places is more than sufficient. Further, we would like to stimulate our readers, releasing their imagination to ponder and comtemplate situations and solutions.

In short, we are humble learners who wish to call together observers to review the

urban development process, and we want to be advisors and facilitators for urban development through collecting cases and igniting people's passion for improving our cities. We live and work in cities, there is no reason to sit and do nothing when our cities deserve more care. Even a tiny change could make a huge difference. Spring arrives, sweeping away the gloom of winter, and bringing the earth back to life. Looking outside our windows in Beijing, we see the city turning green and alive before our eyes, and we are honored to release the China Urban Developent Review in this beautiful season. We hope it will inspire and enlighten us, and lead us toward a more promising tomorrow.

Preface

Sustainable development has become a focus of the international community. The United Nations issued the 2030 Sustainable Development Agenda in September 2015. This is the first global development oriented agenda following the UN Millennium Development Goals. It not only pointed out the direction and the blueprint for countries' development and international cooperation in the coming 15 years, but also established an index system of sustainable development, and clarified the approaches necessary to realize the Sustainable Development Goals. As the Rotating Presidency holder of G20 2016, China formulated the Action Plan to Implement the 2030 Sustainable Development Agenda and adopted Sustainable Development and Climate Change as the core issues of 2016 at the G20 Hangzhou Summit. The parties have reached a consensus on the action plan, which implements significant demonstration and roles for implementing SDGs. The Chinese Government also released the China Country Action Strategy on Implementation of the 2030 Sustainable Development Agenda, which is not only a specific action of China's response to the G20 Action Plan but also a strategic measure for China to lead the promotion SDG. At the same time, this countries action strategy will be the guideline for implementing the SDG and will provide reference to other countries, especially those developing countries, in order to promote the implementation of SDG.

The Fourth Conference of 12th Chinese National People's Congress implemented the 13th Five-year Plan for national Economic and Social Development Guidelines (hereinafter referred to as the "guidelines") on March 16th, 2016. The guideline was officially issued on March 17th, 2016. In order to build a well-off society, this long guideline discussed Chinese economical and societal development for the next 5 years with 66,000 words, in 20 chapters. Compared with previous five-year plans, green development became the main focus of this guideline through major target definition, elaboration in each section, and the chapter -Speed Up Improvement of Ecological Environment. To attain the new goal of the well-off society, the guideline establishes and implements a new development theory of innovation, coordination, green development, openness and sharing. Among them green development is a necessary condition for sustainable development, and also a significant reflection of people's pursuit for better life. Development in next five years must adhere to the basic state policy of resource conservation and environment protection, sustainable development and civilized development on improving production, wealthy living and good ecology. This is in order to speed up resource conservation and environmentally friendly society, with a new pattern of harmonious development between human and nature, which will promote a beautiful China construction, and contribute to global ecological security.

Cities are the new hot spots of environmental change. They are the leading growth centers of population, consumption, resource use and waste. In cities, everything is closely connected. So problems tend to multiply, but so can solutions. More than half of global population is an urban citizen. According to UN projections, 70% of humanity will be living in cities by 2050. Green development is vital to global emissions reduction and societal sustainable development. Urbanization is an inevitable development stage for industrializing countries worldwide. Presently the urbanization rate is 75% in Germany. According to the green city promotion experiences in Germany, the most important point is overall systematic green city planning,through key projects implementation in urban sectors and implementing their successful experiences in ecosystems, energy, water, wastes, traffic, etc. to be replicated and promoted in broader areas. China is also in a significant period of urban development transformation. How to plan the future cities intelligently, how to lead urban sustainable development, and how to refer those successful urbanization solutions from home, and abroad, for scientific and healthy development of the cities has become a major issue for the Chinese national economy, system innovation, and structure adjustment.

In the face of opportunities and challenges in China, and referencing international urbanization processes, it is quite clear that each city needs its own unique solution. Urbanization is a systematic project, no matter the specific situation of the city, systematic methods should be applied to solve the problem. This should prioritize the difficulties for cities in development in the sectors of ecology development, urban energy, resource, and green traffic etc. There are a lot of excellent solutions in the process of urbanization. Each successful case depends on proactive governmental decision-making, appropriate technical methods, efforts of the business community and social supports. Among them the replication and promotion of technical solutions itself is rather easy compared with policy development and commercial environment cultivation. Government decision-making is the primary part forgreen urban development. Managers‘ wise decisions regarding city problems can include gathering elements like technology, finance, human resources, etc. which forms a benign development for the city. As an international non-government organization dedicated to the promotion of global sustainable development policies, World Future Council expects that the successful case studies in city energy, water resources, waste management and urban ecosystem can be helpful for stakeholders during process of urbanization and green city development. This is done through clear elaboration of the proposed cities‘ difficulties and challenges before action, deep analysis of city managers‘ thoughts on the problems‘ solution, and presentation of government management experiences and prior effectively demonstrated projects. It is further expected to refine the forward-looking vision of green city governance and development for the readers, and to provide a reference for city managers, in stimulating new thoughts for city planning

designers, and provide deeper reading materials for the public, which would generate societal contribution to green economic and social development.

This book has incorporates sincere trust and extensive sharing from many partners. Thanks cordially go to the authors who provided materials, and hard work that went into the cases of this report, and special thanks to Beijing Jiaotong University Urban Research Center and the HALO fund for their kind support.

Due to the diversity and system characteristics of the green city concept, as well as the connotation limits of oureditors, this book will inevitably be critiqued. Readers‘ criticism and corrections are highly appreciated and we will improve this book in the follow-up reports of the series. We hope that this book can cause social concern and resonance, and jointly promote green, low-carbon, circular city development.

Chapter One: Energy

Cities, which account for 60% to 80% of global energy consumption, are the leading actors in the transition from fossil fuels to alternative energy sources. Preventing climate change requires real energy revolutions and shifting towards greater efficiency and renewable energy use. Local actions include setting targets for renewables or for CO_2 reduction, urban planning, building regulations, tax relief, financial assistance, and municipal purchases and investments. Some cities have been trailblazers, for instance in initiating 100% renewable city, mandating solar water heaters in new buildings, providing subsidies for installations of solar panels, and in financing construction of wind farms and smart grids, which promote urban energy structural transition from both supply and demand side.

Vancouver 100% Renewable Energy Strategy

Filippo Boselli[1], Yin Huanying[1]

Abstract: Vancouver is well known globally for its ambition to become the greenest city in the world by 2020. Vancouver launched the 100% Renewable Energy Strategy in 2015, with the aim of transforming the city´s current energy supply system to one based entirely on renewable energy, including the transportation and building sectors. The author provides an overview of what the 100% renewable energy commitment means and how it was developed, followed by a description of the implementation approaches and some key requirements that should be considered when developing such a strategy.

Keywords: Vancouver, 100%Renewable Energy, building and transportation

1.Background

With 605,000 inhabitants, Vancouver is the most densely populated city, the largest in British Columbia Province and ranks 8th in Canada. Including its metropolitan area, the city reaches a population of more than 2 million inhabitants. As such, Vancouver is the third largest metropolitan area in Canada, and plays a major economic role within the country. Vancouver‘s port is the largest in Canada, in port volume measured in metric tons of cargo; Vancouver leads the harbour rankings on the North American west coast. In total, the city had a GDP of US$ 109.8 billion in 2014, and a $44,337 GDP per capita. Vancouver has only three large industrial facilities, a handful of medium-sized industries, and myriad of light-industrial and small and medium enterprises. In the past 25 years, Vancouver‘s population has grown by 34%, with jobs increasing by 30%. Over the same time, Vancouver‘s carbon emissions has seen a net reduction of 7%, and are expected to keep falling.This evidences that the city can continue to grow, and be economically strong, while reducingthe cities‘ carbon pollution output. Over the next 35 years, the city‘s population is expected to grow by about 30%—that is another 170,000 people—adding 32% more jobs. Additionally, close to 400,000 additional people travel to or through the city each day.

[1]Filippo Boselli: Climate,Energy and Urban Policy Officer of World Future Council

Yin Huanying: Senior Project Expert of Word Future Council China Program

Figure 1 Street view in Vancouver

In 2014, Vancouver had a total energy consumption of 59.3 million GJ, causing 2.8 million tonnes of CO_2 emissions. In 2014, the city covered about 69% of all its energy needs through fossil fuel resources and about 31% from renewable energy sources. The predominant form of renewable energy is large hydro, which is not surprising given the mountainous morphology of the province. Fossil fuels are mostly used for building heating (especially natural gas which makes up about 46%of the energy supply of the city) and for transportation (mostly gasoline and diesel).

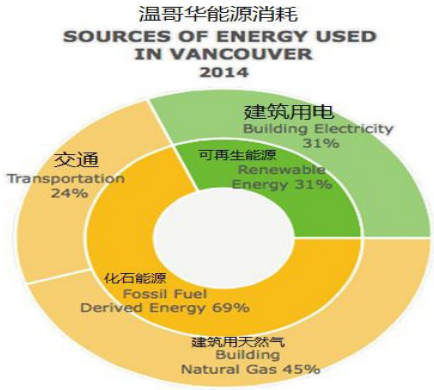


Figure 2: Source of Energy Used in Vancouver in 2014

In the energy sector, Vancouver‘s key challenges are as follows:

1.1 The Consequences of Continuing to Use Fossil Fuels

The effects of climate change are already being felt. The year 2014 was the hottest year on record. Burning fossil fuels worsens air quality, directly impacts human health, accelerates the loss of natural habitats, and affects agricultural production, among other things. The release of carbon dioxide through fossil fuel use is affecting Vancouver and its surroundings through sea level rise, more frequent and more severe heat waves, increased frequency and severity of storms, increased winter rainfall, summer droughts, and less snow. These changes will continue to worsen in the near future. There is a need to not only take action to prevent this (climate mitigation), but also prepare for it (climate adaptation).

In 2008, 55% of Vancouver‘s emissions came from buildings, mainly heating by natural gas, 37% from transportation and 8% from emissions created at landfills from solid waste. As much as 39% of emissions reductions are projected to come from provincial regulations in British Columbia, including regulations on vehicle fuel efficiency and greening of the power supply. The rest includes: 24% from green buildings, 22% from green transportation, 11% from renewables, and 4% from zero waste. This means Vancouver´s work with green buildings and renewable sources for heating will be crucial.

The city of Vancouver, both the government and the people, wanted to actively contribute to solving climate change and take responsibility in solving this problem. The 100% RE plan was a very practical and concrete solution to effectively diminish the amount of CO_2 the city produces.

1.2 Population and Urban Growth

The world‘s population continues to increase, with most of that growth taking place in urban environments. Cities are the engines of the global economy and are responsible for about 70% of the world‘s greenhouse gas emissions. The benefits that fossil fuels have brought over the past 100 years can no longer be relied upon to continue into the future—in fact, to continue to improve the standard of living for everyone in Vancouver, the city must transform so that it derives 100% of its energy from renewable sources.

1.3 Fossil Fuel Divestment and Renewable Energy Investment

The movement by pension funds, private equity, academia, and some governments to withdraw investments in companies that extract fossil fuels is one of the fastest divestment movements in history. A proposal from the federal government to build a new pipeline from Alberta to Vancouver would have increased seven times the amount of tar sounds passing by Vancouver. This would have been extremely dangerous for the city, its natural environment, and the citizens of Vancouver who could not directly benefit from it. Some entities are removing financing from fossil fuel extraction companies on moral grounds, while for others it is seen as the prudent long- term investment decision.

2. Manager Thoughts and Decision-Making Processes

Vancouver is one of a few cities around the world, where the environmental agenda has become a unifying principle and main project of the city. After decades of work with the environment, starting with the cancellation of a massive freeway project in the 60s, and continuing with Transit Oriented Development (TOD) and an early climate plan (1990), Vancouver has now launched a comprehensive action plan to "become the greenest city in the world". The Greenest City 2020 Action Plan, approved in 2011, is inspiring not only because it sets high goals across the board of urban sustainability, nor because it is integrated throughout the departments of the city, but because it shows that it is possible to quickly achieve improvements.

Due to the highly competitive, highly mobile modern world, the elements that make a community healthy also make it wealthy. Functionally, a compact, efficient city with a light environmental footprint is cheaper to run and easier to maintain. The world is moving away from fossil fuels.The transition is not about austerity or making sacrifices; it is about growing a city that better meets human needs. A renewable future will enrich society with new opportunities in many areas of life. Vancouver has all the conditions necessaryto successfully derive 100% of its energy from renewable sources before 2050.

Vancouver is building on 25 years of action and success to tackle climate change for the benefit of all the people who live in, work in, and visit Vancouver, and for the benefit of the world. Vancouver, a city of 605,000 people and with an area of 115 sq. km, is already a world leader in the development of complete, compact, and liveable communities. Further, many of these already have greenhouse gas emissions per person amongst the lowest in the developed world. Vancouver, serviced by a clean and reliable electrical system, which also powers much of the city‘s transit system, is primed to capitalize on the electrification of both its buildings and its transportation system.

Investment in renewable energy projects (excluding large hydro) jumped by nearly 17% in 2014 compared to 2013; 2014 also saw an all-time high in the capacity of wind and solar power installations: 20% higher than in 2013. The technological and business transformation of energy efficiency, conservation and management, coupled with new renewable energy generation is set to define the economy of the future. The Renewable City Strategy positions Vancouver to increase its economic diversity for a stronger, more resilient economy. A healthy environment is essential to attracting and retaining the very best minds, establishing Vancouver as an innovation hub with high and inclusive employment, and positioning Vancouver in the vanguard of long-term economic stability and success. The City of Vancouver can be the catalyst for change through its own internal operations, as well as public pilots and demonstrations. Ensuring that the city‘s neighbourhoods, communities, buildings, transportation system, businesses and individuals embrace renewable energy will mean a better, healthier quality of life for Vancouverites today and into the future.

Vancouver‘s energy supply is currently 31% renewable, with the remaining fossil fuel portion dominated by natural gas, for space heat and hot water, and gasoline for personal and light-duty vehicle use. Vancouver‘s energy use, and the resulting greenhouse gas emission, is dominated by buildings and transportation. These two sectors are the focus of the Renewable City Strategy.

3.Measures and Solutions

3.1 Goals and Approaches

In 2015, the City Council unanimously voted for Vancouver to shift towards 100% renewable energy. The later published Renewable City Strategy 2015-2050 document further outlines the city‘s transformative pathway through2050. The strategy was

developed in consultation with multiple local stakeholders and experts, and it follows a rather practical approach in terms of its implementation. Two goals are at the centre of the strategy document:

- 100% renewable energy use until 2050, and
- A minimum of 80% reduction of greenhouse gas emissions by 2050,

compared to 2007 levels.

To achieve the ambitious goal of 100% renewable energy, the Renewable City Strategy visualises a pathway to eliminate fossil fuels by following a threefold approach of reducing energy use, while increasing use and supply of renewable energy.

The threefold approach includes three key objectives:

1) Reduce Energy Use.

Advance energy conservation and efficiency programs, which are the most cost-effective way to a renewable energy future. E.g., increase building insulation requirements or improve bike network

2) Increase the Use of Renewable Energy.

Switch to renewable forms of energy that are already available, and make improvements to our existing infrastructure to use it to its fullest potential. E.g., switch to an electric vehicle or expand the number of buildings connected to the Southeast False Creek Neighbourhood Energy Utility

3) Increase the Supply of RenewableEnergy.

Increase the supply of renewable energy and build new renewable energy infrastructure. E.g., increase the amount of rooftop solar power generation or supply more biofuels for transportation

The city plans to double the use of renewable energy until 2050, while it also increases energy efficiency, reducing its total energy demand by 3.4 million GJ, which is equivalent to about 5% of the city‘s total annual energy demand from 2014. In order to increase the supply of renewable energy, Vancouver plans to expand respective infrastructure and seeks to increase rooftop solar power generation as well as the use of biofuels in the transportation sector. The extensive expansion of renewable energy is also understood as an opportunity to achieve a strong and sustainable economy while enhancing the liveability in the city. This motivation is summarised in the Vancouver‘s mission —*to create a great city of communities that*

cares about its people, its environment, and the opportunities to live, work, and prosper.‖

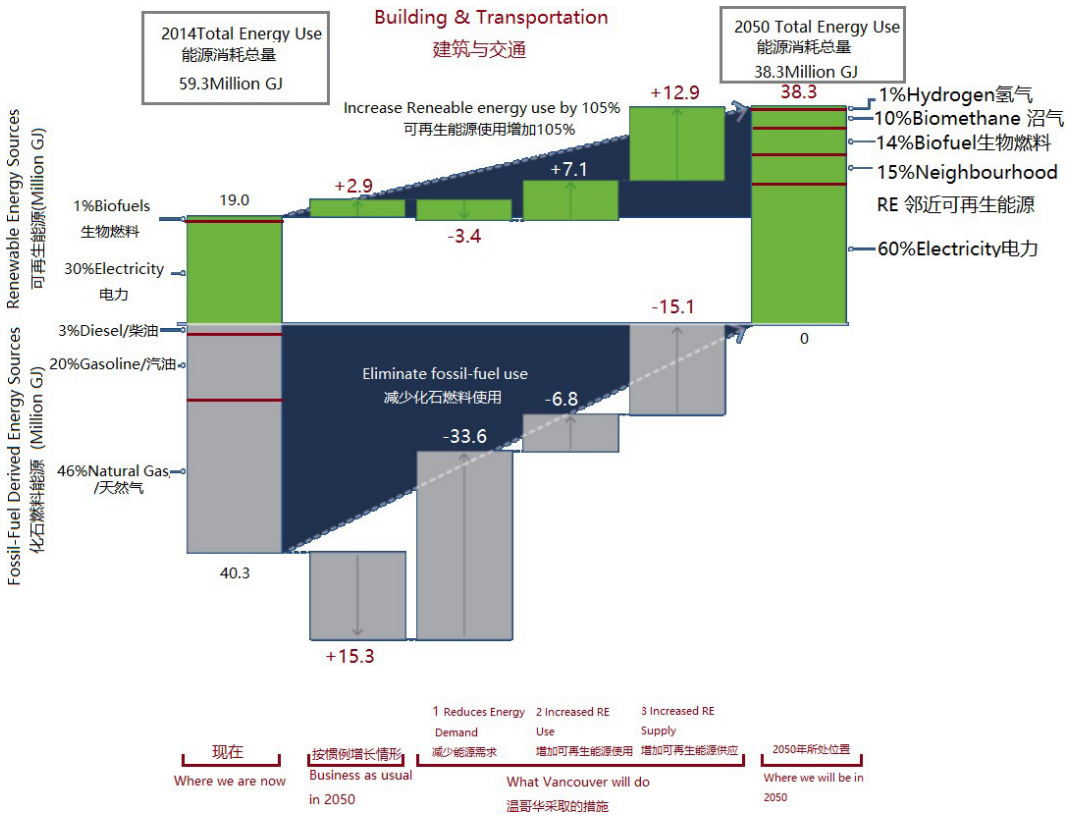


Figure 3: Goals and approaches

The Renewable City Strategy sets the direction for Vancouver to achieve its 100% renewable energy goal. It is not intended to be a detailed roadmap or technology guide, but instead is a foundation for more detailed planning and budgeting. Project and technology support that result from the Renewable City Strategy will be assessed to ensure that the route followed is technically, economically and socially responsible. The Renewable City Strategy proposes a viable route to using 100% renewable energy—it is not the only route to that success.

With this strategy document, Vancouver underpins its aspirations of being a leader in urban sustainability. Alongside, the Renewable City Strategy Vancouver has several other policies in place complementing its transformative and progressive pathway in terms of environmental and climate policy. These can be clustered under the three pillars of sustainability/environment, social and economic. Building the centre of these three pillars, the Renewable City Strategy is not only the continuation of the Greenest City 2020 Action plan, but also complements the Vancouver‘s Health City Strategy and the Vancouver Economic Action.

More specifically, since 2009, Vancouver has been working on its Greenest City 2020 Action Plan, that was adopted by the City Council in 2011, and was followed by the implementation of so-called Priority actions that are also summarised in implementation update reports. In 2012, Vancouver published its Climate Adaptation Strategy,which aims to ensure the city‘s liveability and resilience in the face of climate change. In order to achieve the energy targets of the Renewable City Strategy and the Greenest City 2020 Action Plan, Vancouver developed its Neighbourhood Energy Strategy.This strategy includes the reduction of carbon emissions, the reduction of fossil fuel dependency, ensures affordable energy prices, and incorporates the implementation of the 100% renewable energy target before 2050 by expanding renewable energy systems throughout Vancouver.

Figure 4: Greenest City Event

3.2 Governance and Coordination Mechanism

In terms of political coordination, Vancouver perceives regional, provincial and federal policy coordination as key for success in achieving the 100% renewable energy target. On the regional level, Metro Vancouver is providing central strategies in the context of the 100% target, such as the Regional Growth Strategy, the Integrated Air Quality & Greenhouse Gas Management Plan, and the Integrated Solid Waste & Resource Management Plan. On the provincial level, coordination is required between BC Climate Action Plan, BC Energy Plan, BC Bioenergy Strategy, and the BC Air Action Plan in order to support the 100% renewable energy transformation pathway. Finally, the Federal Government needs to improve its actions towards 100% renewable energy, since, so far it only has policies in place referring to infrastructure planning and funding to support renewables. More specifically the three levels of coordination include:

- ***Regional Planning***

The City of Vancouver cannot act in isolation when transitioning to using 100% renewable energy. Metro Vancouver‘s most important strategies to respond to regional growth, and support the use of renewable energy, are the Regional Growth Strategy,

the Integrated Air Quality & Greenhouse Gas Management Plan, and the Integrated Solid Waste & Resource Recovery Management Plan.

- ***Provincial Policy***

The Provincial Government of BC has a number of plans that support the development of 100% renewable energy resources.These include the BC Climate Action Plan (successor under development), BC Energy Plan, BC Bioenergy Strategy, and the BC Air Action Plan. The City of Vancouver encourages the Provincial Government to continue with these commitments, devote additional resources to the transition, and accelerate the pace of change.

- ***Federal Policy***

The Federal Government‘s most relevant policies related to renewable energy are currently limited to infrastructure planning and funding. There is need for more explicit federal policies and programs to support renewable energy, energy efficiency improvements, and the pricing of carbon pollution.

3.3 Respective Solutions

3.3.1 Challenge 1: Meet the Building Heating Needs Through Renewable Energy

As highlighted earlier, about 45% of the entire energy demand of the City of Vancouver comes from heating buildings (space heating plus hot water). All of this demand is currently met through natural gas. The challenge is to shift this and use renewable energy sources instead. In summary, the current energy plan proposes the following key measures:

PRIORITY 1: Reducing Building Energy Demand

Reducing the energy demand of buildings is the key priority for Vancouver. It is estimated that citywide building energy demand could be reduced by about one-third from 2014 levels by adopting zero-emission buildings, requiring buildings that undergo retrofit to attain a similar level of performance, and connecting buildings to neighbourhood renewable energy systems. Of that energy demand in 2050, about 70% can be met through renewable electricity (both on-site and grid supplied) which constitutes about a 15% increase in building related electrical demand compared to today; about 10% of building energy needs will be met through bio-methane and 20% through neighbourhood renewable energy systems.

Key interventions to reduce energy demand of buildings include:

Intervention 1: Improve New Building Envelope Performance

Once constructed, building envelopes last a long time before they need significant updates or retrofitting. While lighting and appliances can reasonably be expected to change every 10 years or so, buildings do not have their windows changed or walls re-insulated nearly as often. Ensuring that buildings meet zero-emission standards from the time they are built is the most effective way to ensure that buildings use as little energyas possible. A zero-emission building, one that emits no greenhouse gases from the energy it uses, is only viable if it is very energy efficient. With energy use substantially reduced, a zero-emission building can meet its energy needs through either on-site generation or connection to an off-site renewable energy source like a neighbourhood renewable energy system or the electrical grid.

Ultra-energy-efficient buildings afford owners and occupants much lower electrical bills, avoid fossil fuel bills altogether, and do not overly burden the electrical grid. The use of electrical (resistance) heat only makes sense when buildings meet ultra-efficient standards, and in most circumstances, heat pumps provide a better alternative to resistance heat. As new and retrofitted buildings start to incorporate more effective energy conservation principles—such as solar shading and solar orientation considerations—and the ability to generate their own power, the urban landscape will change. Building and neighbourhood design has never been static, and new designs will have to manage aesthetic appeal while incorporating design principles that support reduced energy use and increased energy generation, allowing buildings and neighbourhoods to cope better with a changing environment.

Intervention 2: Implement Building Envelope Performance Retrofits

Buildings not originally built to zero-emission standards will undergo some form of retrofit before 2050. Retrofits are likely to take place for one of two reasons:

1. Part of the building has reached the end of its useful life (such as the lighting, the heating system, or the roof).

2. The building owner feels that the building is in need of an update to be more appealing to buy or rent, reduce occupant energy bills, etc.

In the first case, lighting, appliances, and similar components are replaced much more often than major components like walls, roofs, or windows. For components that are replaced sooner, larger market forces outside those specific to Vancouver, or even BC, are shaping efficiency improvements. The technology is improving rapidly and is easy to update—all you have to do is plug it in! Lighting, although not as easy to replace as appliances, is relatively simple to upgrade, and with advances in LED technology, LEDs can be expected to meet almost all lighting needs by 2050.

For major components that have reached, the end of their useful life and which are replaced less frequently, it is possible to use natural building renewal cycles to meet zero-emission standards more quickly. When a building undergoes a major retrofit,

the elements being replaced will have to meet the standards required of a new building.

When building retrofitting is desirable rather than essential, the City will foster voluntary retrofitting or mandate only modest retrofit requirements to encourage building owners to undertake retrofits that achieve energy reductions. In the case of existing buildings, a retrofit would require connection to a neighbourhood renewable energy system in high-density neighbourhoods, or use of a heat pump or on-site renewable energy generation for low-density areas.

Intervention 3: Update Building Equipment Performance Requirements

As with building envelopes, developers should install the most efficient building equipment available at the time of construction or upgrade to that standard at the time of retrofit—acting in the timeliest fashion secures the most improvement. However, envelope upgrades are a higher priority than building equipment upgrades, since equipment upgrades are less enduring and realize smaller gains in overall energy performance.

PRIORITY 2: Increase Building Renewable Energy Use and Supply

Energy efficiency improvements alone are not enough to achieve a renewable energy future; buildings must switch the sources of energy they rely on from fossil fuels to renewable sources. Many options to produce renewable energy at the building level already exist and include:

1) **Photovoltaic (PV) Systems:** A residential solar energy system uses solar modules, made up of photovoltaic (PV) cells, to harvest the sun‘s energy and convert it to electricity.
2) **Solar Hot Water Systems:** Solar thermal collectors circulate a fluid, which is heated by the sun‘s radiant energy. The heated fluid can then provide space heating, although it is more common to use these systems for hot water.
3) **Wind:** Small wind turbines can produce enough energy to partially meet the electricity needs of a home.
4) **Heat Pumps and Geo-exchange**: Heat pumps are devices that can take heat from the air or ground and use it to provide space heat or hot water. Geo-exchange systems, sometime also called geothermal heat pumps or ground-source heat pumps, use the heating or cooling properties of the ground that make a basement warmer in the winter and cooler in the summer to cool or heat buildings as required.
5) **Neighbourhood Renewable Energy Systems:** In neighbourhood renewable energy systems, a neighbourhood energy centre generates heat that is piped to local buildings for space heat, hot water, and, in some cases, cooling. This eliminates the need for each individual building to have its own boiler, hot water heating, and in some cases cooling equipment, and is more efficient.

6) **Waste as an Energy Resource:** Some waste streams, such as wood and food scraps can be used to generate energy.Anaerobic digesters produce bio-methane from food scraps and clean wood combustion systems produce heat. Liquid waste can also provide a renewable source of energy. The City already uses sewage heat recovery in its Southeast False CreekNeighbourhood Energy Utility to provide heat and hot water to buildings in and around the Olympic Village. Non-renewable materials and mixed solid waste streams will continue to be actively managed for the most responsible outcomes, but they will not be considered as inputs to the long-term renewable energy system of our future.

Key interventions to implement priority 2 include:

Intervention 1: Power Industrial Facilities through Renewable Energy

The City will continue to preserve its industrial land to secure the long-term economic strength of Vancouver. Because of significant roof space and underutilized land area, such land has the opportunity to become a significant renewable energy hub through local and on-site generation. The price of land, and its prominence on a business‘ balance sheet, is an important factor in moving Vancouver businesses to be more renewable. Vancouver cannot geographically expand any further—it is bound on all sides. With land at such a premium, land values have been rising for the past decade and this trend is unlikely to change. Vancouver currently has little large or heavy industry, but that which does exist serves regional, national, and international markets. Changing transportation patterns coupled with less favourable land economics are likely to mean that these heavy industries will have relocated outside the city by 2050.

The use and generation of goods and energy for the industrial sector in Vancouver is driven by the large number of light to medium industrial enterprises that service the city, for which there is an incentive to remain close to their customers and not relocate out of the city. These businesses are the focus of preserving industrial lands within the city. Light to medium industry tends to own or lease its equipment, which is the primary driver of energy bills, as well as owning or having signed long-term leases for their premises. These businesses will become more energy aware as the cost of fossil fuels rises and that of renewable energy drops; and as they start to identify new business models driven by energy efficiency and renewable energy opportunities.

Intervention 2: Provide New Neighbourhood with Renewable Energy Systems

The City‘s *Neighbourhood Energy Strategy and Energy Centre Guidelines* set the long-term vision for the development of neighbourhood renewable energy systems in Vancouver with a focus on the following areas of opportunity:

• Conversion of the existing Downtown and Hospital´s steam heat systems from fossil fuels to renewable energy sources.

• Establishment and expansion of systems to serve high-density areas in the Downtown, Cambie Corridor, River District, and Central Broadway areas that are undergoing rapid development.

• Expansion of neighbourhood energy systems to replace the boiler equipment in existing gas-heated buildings.

Intervention 3: Expand On -Site Renewable Energy Generation

Areas with low population density—those with a lot of single-family homes or low-rise condominiums and apartments—do not require enough energy to merit being connected to a neighbourhood energy system. As such, low-density development must have its heating needs (for both space and hot water) met by renewable electricity from the grid or from on-site renewable energy generation. On-site renewable energy generation is more applicable in low-density circumstances since there is space available within the property to generate enough electricity and/or heat to meet the demand of a zero-emission building. On-site renewable energy generation can come from solar power or solar thermal, heat pumps (that would likely use grid-supplied electricity), or perhaps in some cases on-site wind generation.

With the anticipated improvements in building efficiency and an already effective and clean electrical grid, the need for on-site rooftop solar power generation will likely be determined by the market price of the technology, the cost to produce electricity, and the larger system needs of the electrical grid. The widespread use of solar panels is not necessary to meeting the City‘s renewable energy goals, but can give the public and businesses the opportunity to meet their own energy needs, earn income through the sale of excess power, and contribute to moving towards a renewably powered future. On-site generation can also allow buildings and neighbourhoods to be more resilient to disruption and outages, particularly during extreme weather events.

Intervention 4: Increase Overall Renewable Grid Electricity Supply

With current building practices, Vancouver‘s demand for electricity would be about 10% higher in 2050 than it is today, with a 25% increase in fossil fuel also expected. However, through energy efficiency and conservation efforts, the direction outlined in the *Renewable City Strategy* allows Vancouver to make much wider use of renewable electricity to eliminate fossil-fuel use completely, while only increasing electricity demand by about 20% above current levels. Across the province, there is a need to increase grid-scale renewable electricity generation, not just for Vancouver. BC Hydro—the sole electrical utility supplying Vancouver—is legally required to develop an *Integrated Resource Plan* to detail its plans for meeting customer demand over the coming 20 to 30 years. The City‘s goal to move to 100% renewable energy is consistent with many aspects of the *Clean Energy Strategy* section of *BC Hydro’s 2013 Integrated Resource Plan*. New market-ready, utility-scale wind and solar technologies can compete on cost with large-hydro power. Grid-scale renewable

electricity generation of the future should be brought into service, as it is needed, to enhance system reliability, particularly in light of a changing climate, while also maintaining affordability.

Current regulation allows for up to 7% of the electricity used in Vancouver to come from non-renewable sources. The City will work with its utility partners to find ways to address that non-renewable portion, but in the event that the electricity supplied to Vancouver is not 100% renewable, the City of Vancouver will investigate how to secure renewable electricity from other sources.

As there are increases in both on-site electricity generation and new grid-scale generation, the electrical grid will have to adapt; the electrical grid will need to become ‗smart' to manage these new ways of generating and distributing electricity. The smart grid will not only better meet customer needs, but is also imperative to managing emerging technologies like energy storage, electric cars, the ‗home ecosystem', and on-site power generation distributed throughout the city. A smart grid is more reliable, more resilient when things go wrong, and more adaptable to the future demands on the electrical system.

3.3.2 Challenge 2: Moving Towards 100% Renewable Energy Transportation

Transport in Vancouver contributes to about 24% of the entire energy demand and it is currently almost fully dependent on fossil fuels. The challenge will be to transform the currently fossil-fuel dependent transport system into one powered entirely by renewable energy. These are the top priorities (and respective key interventions) needed in order to achieve this transformation.

Priority 1: Reduce Motorized Transportation Demand

Reducing the demand to move using motorized vehicles is one of the key strategic interventions that the City of Vancouver is prioritizing. Key interventions to achieve this target include:

Intervention 1: Land-Use and Urban Design As Tools to Promote Sustainable Transport

Urban planning has a key role to play in reducing the need to move and travel long distances, as well as in favouring certain modes of transport over others. For example, creating dense, compact and mixed-use development means creating neighbourhoods where offices and houses co-exist, and where people can simply walk or cycle to work. A key priority of Vancouver is people-centred development that promotes walking, cycling, and that avoids unnecessary sprawl. Planning that gives more space to pedestrians and to cyclists, rather than cars, is another example of how urban planning can influence transport choices. Similarly, creating priority lanes for public transit can have similar impacts on how people decide to move throughout the city.

Intervention 2: Promote Walking and Cycling

Walking will continue to be the city‘s top transportation priority. Almost every journey has a walking component to it at some point. For short trips, walking is the best option for people and the environment, additionally, businesses benefit from passing customers. Vancouver‘s grid network, good urban planning, and pleasing urban design mean walking trips are often direct, convenient, and interesting. As part of its *Transportation2040* efforts, the City will address gaps in the walking network, improve sidewalk connectivity, create more temporary and permanent public spaces, and maximize accessibility for those with visual or mobility impairments.

Cycling creates no emissions, is inexpensive, improves health, and allows easy access to much of Vancouver. Also, it is often the fastest way to get around for short-to-medium length trips, with many destinations accessible by bike within 20 minutes.

There is also increasing evidence that cycling, similar to walking, is good for local businesses.

To reach a wider audience, the City is focusing on building a direct, intuitive network of routes that efficiently connect destinations and are comfortable for everyone, including families with children, the elderly, and novice riders. Providing more secure, convenient, and abundant parking and end-of-trip facilities, like showers and change rooms, is also important, as is promotion and education to encourage cycling as an everyday, normal activity.

Figure 5 Residents with bicycles

Priority 2: Increase Use of Renewable Transportation Options

Intervention 1: Increase Public Transit Use

The city‘s compact urban form is complemented by Vancouver‘s comprehensive public transit system. A large portion of the transit service in Vancouver is already

electrified—the SkyTrain, Canada Line, and trolley buses—but there are still diesel bus services on many of the cities routes. Meeting the City‘s 100% renewable energy goals will require expanding the trolley network and/or converting these non-electric routes to other renewable fuel sources.

Figure 6 public transit in Vancouver

Intervention 2: Increase Shared Vehicle Journeys

Car sharing is a membership-based service that gives access to a fleet of cars that can be rented. Car sharing allows people to go car-light or even car-free and save money compared to owning their own vehicle, yet still maintain the flexibility of car ownership. People often have multiple memberships to meet their exact journey needs based on whether they need a quick one-way trip or a particular type of vehicle. A single car share vehicle can replace up to 11 personally owned vehicles, freeing up road space for other uses. The already significant ability of car sharing to cut energy demand from transportation is further enhanced through the potential to use renewably powered cars in car sharing fleets.

Intervention 3: Increase Renewably Powered Personal Vehicle Choice

With the exception of the electrified SkyTrain, Canada Line, and trolley buses in Vancouver, today‘s transportation system is almost exclusively based on the combustion of gasoline and diesel. The transportation system of the future will have a greater range of energy sources and vehicle types than are common today.

The transportation system is expected to evolve so that most short-distance and local journeys will be made on foot or bike, most longer trips by transit, and remaining trips by electric vehicles of various types, depending on the needs of the journey. Electric vehicles already have ranges that are ample for peoples‘ everyday use. If drivers need to make longer journeys that cannot be served by the range of battery technology or where battery technologies are not cost efficient, alternatives like hydrogen and sustainable biofuels will need to be considered. Plug-in hybrid electric vehicles, already available today, combine a battery and a regular engine, so that for short

distances the car acts like an electric vehicle; if the battery runs flat, the regular engine takes over.

For those people who regularly travel long distances, renewable fuel solutions will come from sustainable biofuels and renewable hydrogen fuel cell vehicles.

Similar solutions can also be expected for larger vehicles like buses and trucks.

It typically takes between 15 and 20 years to see significant changes in automobile fleets, and about the same amount of time again for technologies to be adopted into widespread society. This means that although vehicles tend to be changed every seven to ten years, action must be taken now, particularly to support market-ready technologies

Intervention 4: Increase Supply of Renewable Transportation Fuels

The _hierarchy of fuels' establishes the ease with which new renewable fuels can be adopted. For mobile uses, liquid fuels are preferable since they are more easily transported and handled during refuelling. However, with improvements in battery and charging technology, electrification is becoming an option for more vehicles, although the ease with which electric power trains can be used decreases as vehicles get larger.

- **Electricity Supply**

Electricity generation in BC is required by law to be at least 93% clean,thougha move to 100% renewable electricity would secure further environmental benefits. Current and anticipated future electrical generating capacity in BC is able to meet the increased demand that electrification of the transport system would create; but ensuring that local electrical systems are able to meet the needs of electrified transportation is important. There will be a need to ensure that the vehicle-charging infrastructure is available for people to recharge their vehicles, particularly through personal home and workplace charging. Plug-in hybrid electric vehicles will mostly use only electricity when driving in the city; electric vehicles will only use electricity.

There is still a need to develop charging infrastructure, and ensure that a network of fuelling stations exists for drivers to top up with biofuel when needed. This diversity leads to shared infrastructure needs and increased resilience so the vehicles are not tied to a single fuel source.

- **Sustainable Biofuel Supply**

Sustainable biofuels can be produced from wood, grass, plants, and even algae, with different technologies at various stages of development. There is the potential to develop significant sustainable biofuel production throughout the Pacific Northwest

and central Canada. It is important to ensure that the feedstocks used to make the biofuels are sourced responsibly, most preferably from what is currently considered the waste stream (e.g., agricultural waste). The supply of sustainable biofuel feedstocks, typically canola in Western Canada, is more than sufficient to meet near-term local requirements since much of the current production is exported. The diversity of feedstocks and agricultural methods that can be used to produce biofuels limits any potential impacts to food supplies and pricing, since with the right regulation biofuel production should not complete with food production.

- **Bio-methane Supply**

Technology, such as anaerobic digestion, produces bio-methane from food scraps, and the material left over from that process is used in the production of compost and fertilizer. Bio-methane is currently in limited supply in BC since there are few sites producing it. However, as the need to replace natural gas grows, demand is expected to increase. Production increases will likely be met by landfills, anaerobic digesters (which take organic waste like kitchen scraps and yard trimmings to make bio-methane), and waste water/ sewage treatment plants. As waste diversion programs take effect and better ways to use the waste stream are implemented, bio-methane production from landfills is expected to decline, while anaerobic digesters will increase production volumes.

- **Hydrogen Supply**

Hydrogen is in plentiful supply since it is the major constituent of water. However, the majority of hydrogen used today comes from natural gas. Using renewable electricity to electrolyze water could produce clean hydrogen in the quantities needed. A move to increase hydrogen use will require new fuelling-station infrastructure, which would be similar to the gas stations of today.

4. Effects

4.1 Key Economic Benefits

Investment in a renewably powered economy is an investment with lasting returns.

Within the next fifteen years, global investment in clean energy is expected to constitute almost three quarters of total global energy investment; in fact, Canada already has more jobs in clean energy than in oil and gas. Renewable energy technologies like wind and solar generation and home battery storage are rapidly dropping in price at both the industrial and home scales.

This is creating new business models where individuals and neighbourhoods are no longer passive consumers, but are actively producing, using, and selling their products and services, including the energy they generate.

In summary, the city aims at achieving four key economic benefits through this new strategy:

a) Support innovators through business and technology research, incubation, acceleration, and demonstration
b) Actively work with businesses to increase the use of renewable energy
c) Target key events and organizations that represent clean tech and renewable energy to strengthen Vancouver‘s economy
d) Attract ‗green capital‘ and enable more innovative financing mechanisms.

4.2 Benefits to the Environment and Human Health

Energy production often causes direct and indirect costs and benefits for the energy producer and society. Usually, external impacts of energy production are not taken into account, i.e. externalized.These costs can arise, for example, from the detrimental effects of air pollution or from the negative effects global warming induced by GHG emissions. The inability of the market to put a price on environmental and health impacts of technologies is often called market failure. Several studies have also tried to describe the link between CO_2 emissions with the social cost of their impact on climate change(these are called SCC, i.e. social costs of carbon). Given the low GHG emissions of renewable energy options their SCC is usually lower than fossil fuel options. Furthermore, combustion of fossil fuels and biomass often causes emissions of particulates and gases which have health impacts. These imapacts on health have also been monetized and considered by many studies. Other effects include impacts on water, land use, soil, ecosystem and biodiversity.

A comprehensive study completed in Germany(Krewitt & Schlomann, 2006) tried to evaluate the external costs for different electricity generation technologies and showed that RE options have significantly lower external costs compared to fossil fuel options.

The emissions of NOx, SO_2, PM and NMVOC(non-methane volatile organic compounds) tend to be much higher for coal, oil, lignite and natural gas than for non-cumbustive renewable energies in terms of grams emitted per kWh energy produced. Biomass is still cause of concern given that it emits very high level of pollutants. Drastic increases in RE deployment such as hydro, wind, and solar would significantly lower these emissions and therefore have major health benefits.

Another study (Rashedi, Sridhar & Tseng, 2013) developed an Eco-indicator which calculates life cycle impact based on 11 categories that incorporate carcinogens (C), respiratory organics (RO), respiratory inorganics (RI), climate change (CC), radiation

(R), ozone layer depletion (OL), eco-toxicity (E), acidification/eutrophication (A/E), land use (LU), minerals (M) and fossil fuels (FF). The overall eco-impact comparison is shown in Figure where every technology is arranged with highest value indicating comparison to that of the lowest value. For example, an oil plant contributes almost 154 times eco-impact of the hydrokinetic plant to generate every 1 kWh of electricity.

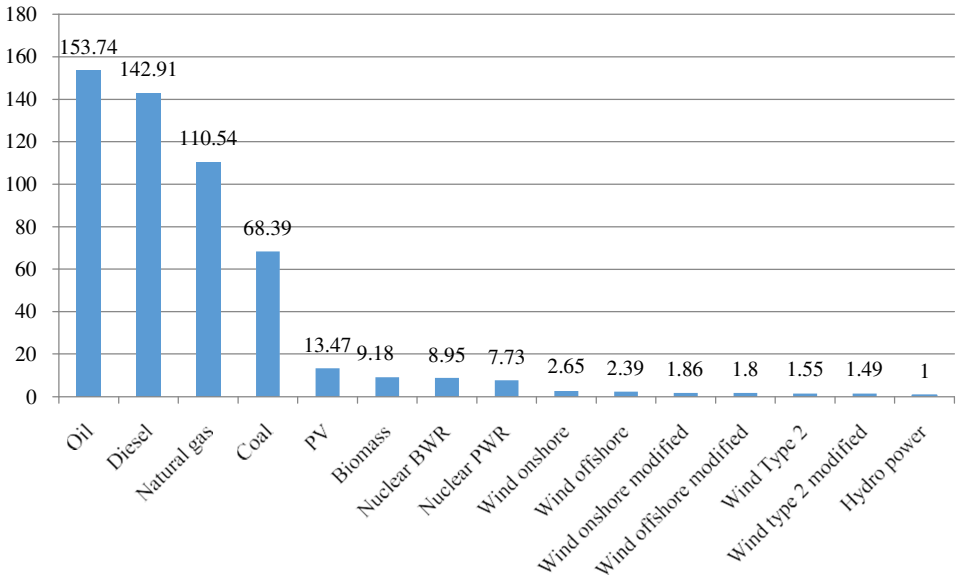


Figure **3**: Total Eco-impact values derived from life cycle impact assessment of major power generation technologies (Data from: (Rashedi, Sridhar & Tseng, 2013)

5. Remarks and Inspiration

The following key success factors are very important transferable elements that can play a vital role when applied in any other context.

5.1 Political Will and Solid Governance

The Renewable Energy Commission was launched by the Mayor Greg Robertson and wasunanimously approvedby the City Council. It is significant to have a committed and ambitious political leadership driving change forward. Solid governance at the regional, provincial, and federal level is also crucial for the successful implementation of the 100% renewable energy strategy.

5.2 An Inclusive Consultation Phase and Plan Development

A key success factor of the strategy is the fact that The *Renewable City Strategy* is based upon best practices from around the world, as well as local expertise, and public input. Key inputs include:

- The Renewable City Action Team, made up of representatives from environmental and civil society non-profit organizations, academia, regional and provincial government, the business community, and local utilities.

- International thought leaders and peer organizations such as the City of Stockholm's *Roadmap for a Fossil Fuel–Free Stockholm2050* and the City of Copenhagen's *CPH 2025 Climate Plan*.

- Members of the *Carbon Neutral Cities Alliance* (an organization that comprises the world's 17 leading cities taking action on climate change), who reviewed and provided feedback on initial drafts of the *Strategy*.

- Delegates from international organizations in attendance at the *Renewable Cities Global Learning Forum* held in May 2015.

- In 2015, the City held the *Bright Green Summer*, a series of events and engagements. Outreach included public presence at Pacific National Exhibition showground, Doors Open Vancouver, Pop-up City Hall, downtown block parties, and Vancouver Public Library summer reading events; a micro-conference; and a survey through the City's *Talk Vancouver* platform, which collected feedback on renewables from 850 people, 76% of whom supported the direction the City is taking in its climate action work.

- The City also retained a world-leading energy system consultancy to investigate and analyze the technological, financial, and behavioural feasibility of adopting renewable energy technologies.

1) Strong Advocacy and Engagement

By actively pursuing renewable energy in all areas where the city exercises some control, and through advocacy and partnership with agencies in the areas where the city has little or no control, the city of Vancouver will create an environment that fosters inclusiveness and innovation. To achieve a 100% renewably powered future, the city of Vancouver will have to further build on its already strong organizational capacity, not only for the city's own operations but also to lead and guide the wider public and business communities. There is also the need to ensure renewable, clean, green, and emergent technologies are readily available and that people have what they need to implement them. The city can educate and empower people and businesses to directly engage in energy production and conservation, while itself leading both locally and internationally. Vancouver has a long history of supporting climate action, from the *Clouds of Change* reports in 1990 to the *Community Climate Change Action Plan* in 2005 and the *Greenest City 2020 Action Plan* in 2011, and now the *Renewable City Strategy*. These plans were built with strong support from the public, businesses, and governments, as well as partnerships with local utilities, the development community, academic institutions, and non-profit organizations.

2) A Comprehensive , Cross-Sectional and Detailed Roadmap

Another key success factor of the Vancouver 100% Renewable Energy plan lies in its very comprehensive, all-inclusive and detailed roadmap that was established to guide the transition forward and to understand the wide range of benefits that such a transition entails. This was key to align different interests and ensure that all different stakeholders and city departments would work together cohesively. This ensures unity, which accelerates the transition considerably.

3) Public Acceptance

Another key success factor was the vast acceptance of the 100% RE target among the people living in Vancouver. As reported by the Vancouver City Councilor Andrea Reimer, there is widespread support in the city for the 100% RE vision. This means that citizens are very committed to actively contributing to the achievement of this target. In only one year, in 2015, the CO_2 emissions in the city decreased by 7%. Most of this drop is due to a change in thebehaviourof its people. Many people became more responsible and started to consume less energy, as they felt committed to contribute to the achievement of the 100% RE plan, which also includes a need to decrease energy consumption. The Vancouver case shows the importance of having people on board and how their commitment is indeed crucial in the achievement of real change.

Reference:

1. Renewable City Strategy: our future to 2050, http://vancouver.ca/green-vancouver/renewable-city.aspx
2. Vancouver Greenest City, http://wwf.panda.org/wwf_news/?212273

Dunhuang: Moving Forward to 100% Renewable Energy City

Hu Runqing[2]

Abstract: Dunhuang City in Gansu Province is a famous historical and cultural city, and its development orientation is to become an international famous tourist culture city. There are abundant solar and wind energy resources in Dunhuang City. The first large scale PV power station in China was built in Dunhuang and the PV market developed very quickly in the years afterwards. Dunhuang launched construction of New Energy Demonstration City in 2011 and worked on developing 100% Renewable Energy City Concept in 2015. Concepts of city energy development have been designed and advanced. With this progress, Dunhuang is moving forward to 100% renewable energy city step by step. Dunhuang's renewable energy development is a typical case of a energy transition from the supply side with rich natural resources.

Keyword: Dunhuang city, new energy city, 100% renewable energy city, development concept

1. Background Information

1.1 Overview

Dunhuang City is a strategic passage on the ancient Silk Road and also an oasis city on the Gobi Desert, located in the west of Gansu Province, andon the westernmost end of the Hexi Corridor. The cityis in jurisdiction of Jiuquan City, Gansu Province, encompassing31,200 square kilometers, including 9 towns and 56 administrative villageswith a total population of 200,000.

[2]Hu Runqing,
Associate Researcher of Energy Research Institute, National Development and Reform Com mission

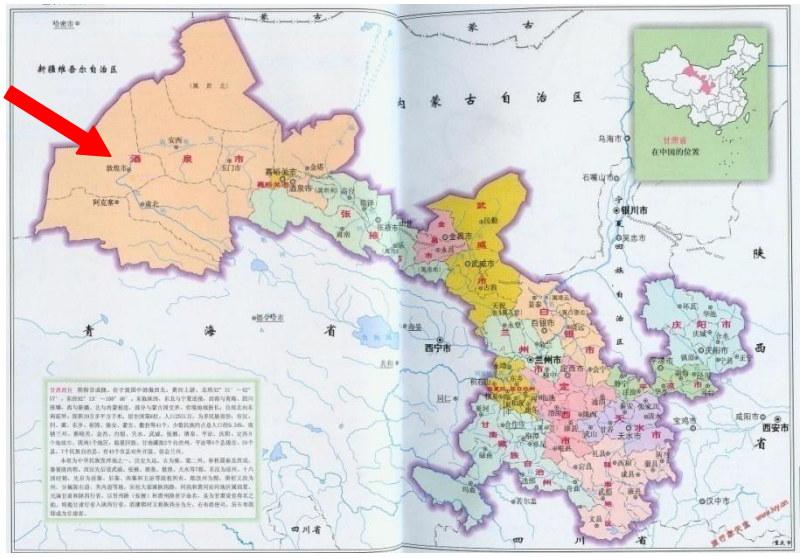


Figure 1 Dunhuang location

In 2015, Dunhuang City registered a GDP of 11.2 billionRMB, up 12% over the previous year. Its total investment in fixed assets amounted to 21.0 billion RMB, general financial revenue **1.2** billion RMB, urban per capita disposable income 28,000 RMB and rural per capita net income 14,200 RMB. Moreover, the city had a general income of 6.3 billion RMB from receiving 6.60 million tourist arrivals.

Historically, Dunhuang was a junction wherethe frontier culture of the Silk Road,Oriental and Western civilizations met, an unparalleled land of Buddhist art and even the brightest pearl on the ancient Silk Road. Nowadays, it‘s an important node city for the One Belt and One Road initiative, and has been included into the first group of historic, cultural, and outstanding tourist cities for China. Its cultural tourism resources including Mogao Caves, Mingsha Mountain, Crescent Spring, Jas Dan Demon City, Yumen Pass and Yang Pass are renowned both at home and abroad and the tertiary industry, led by tourism, accounts for over 50% of the city‘s economy. With the cultural industry‘s value added occupying a share of 8% in 2013, cultural tourism has been identified as a prime industry supporting and driving economic transition, enriching the people and strengthening the city.

Figure 2 Dunhuang Mogao Grottoes(left) and Singing Sands Mountain(right)

Rich in wind and solar energy resources, Dunhuang has devoted years to the promotion and application of renewable energy, and is included in the first group of New Energy Demonstration Cities, the first 1,000MW PV power generation demonstration base, the national sustainable development pilot area, and the circular economy demonstration zone of Gansu Province. One third of its economic aggregate has been shifted to new industries, with priority given to clean energy and circular utilization of resources.

1.2 Energy and Resource Conditions

Short of fossil energy resources, Dunhuang relies heavily on external supplies of coal, oil, and natural gas. However, the city can develop and apply renewable energy on a large scale thanks to the possession of abundant solar and wind energy resources, as well as desert and semi-desert land resources, and excellent transmission capacity of the power grid.

Solar energy: Included in Class I regions with the most abundant solar energy resources, Dunhuang enjoys 3,257 hours annually and 8.9 hours daily of sunshine on average, with an annual solar radiation quantity of 1,754 kWh/m^2.

Wind energy: The all-year-around-windy city is developing its North Lake Region, which is a part of theGobiDesert with 980 square kilometers available for development. The northernareahas a higher elevation than the south, but the total area is almost equal between the two parts. Average wind speed is 6.9 m/s at 70 meters high.

Geothermal energy: Geothermal resources in Andun Basin are mainly geothermal water at a mid-low or low temperature,butthewater at 1,600 meters undergroundcan reach 52℃. The landscapes of Dunhuangaregenerally the Gobi desert and oases.

Land resources: About 3,500 square kilometers of the Gobi desert can be used to build wind power plantsand PV power plants, withthe potential installed PV power capacity of100 million kW.

1.3 Energy Supply and Demand

Dunhuang City is short of fossil energy resources and therefore, relying on the imports of coal, oil, and natural gas. PV power generation has developed rapidly since 2009. In 2015, newly installed PV power capacity was 340MW, with a year-on-year growth of 110%; cumulative installed capacity amounted to 0.583 million kW, which has increased 80% over the previous year. Without any coal-fired power plants established in Dunhuang,electricity is generated from water and PV. Driven by PV power development, the city has witnessed a swift growth in electricity generation, up to 640 million kWh in 2015, with a year-on-year growth of 88%. Annual electricity generation exceeded annual consumption for the first time and electricity was generated entirely from renewable energy.

Table 1 Yearly Generation and Consumption of Electricity in Dunhuang

	Unit	2011	2012	2013	2014	2015
Installed PV Capacity	10 MW	2	13.3	16.3	32.3	66.3
Annual Generation	100m kWh	0.5	1.2	2.03	3.4	6.4
Annual Consumption	100m kWh	3.27	3.9	4.61	4.83	5.31

In 2015, Dunhuang's energy consumption amounted to 819,300 tons of standard coal equivalent, a year-on-year increase of 7%, with 8% from local hydropower and PV power and the rest from imported fossil energy. The consumption was basically the same including coal, oil, and natural gas (see Figure 3). That is to say, Dunhuang is basically self-sufficient in terms of electricity, but relies on imports of other energy resources.

To be more self-sufficient in their energy supply, developing and utilizing the abundant solar and wind energy resources is an inevitable choice for the city's sustainable development.

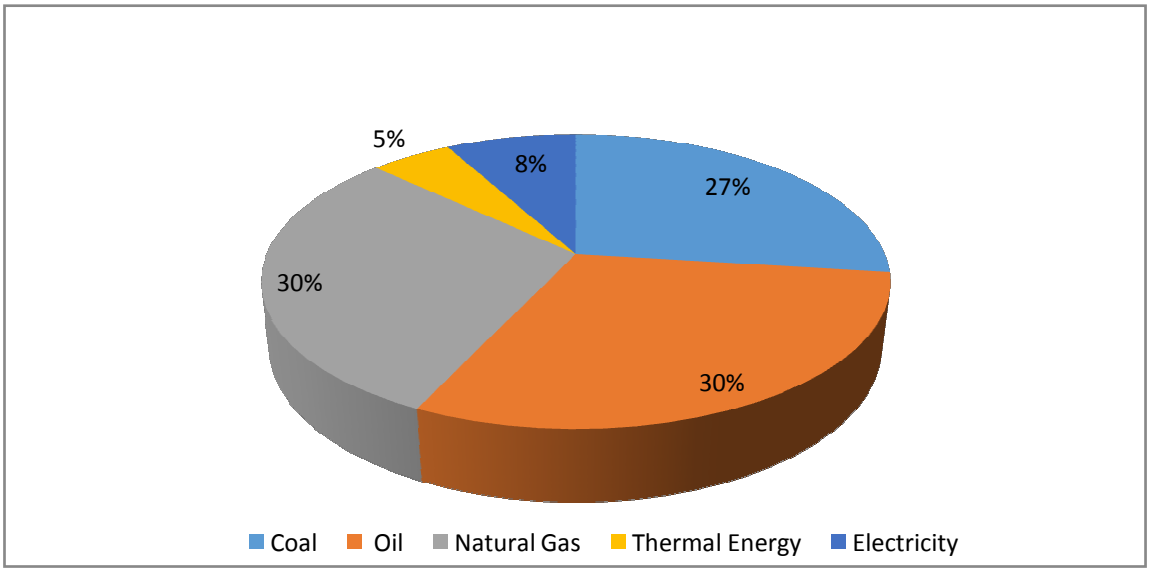


Figure 3 Energy Consumption Structure in Dunhuang, 2015

2.Development Concepts for Urban and Energy Development

2.1 Urban Development Orientation

In September 2013, President Xi Jinping brought forward the strategic conception of jointly building a Silk Road Economic Belt during his visit to Kazakhstan. During the Third Plenary

Session of the Eighteenth Central Committee, the Central Planning Committee or Chinese People‘s Congress made a strategic arrangement for promoting construction of the Silk Road Economic Belt and forming an all-round open pattern. Dunhuang is expected to build itself into an world renowned city for cultural tourism through cultural revitalization, establishment of a modern cluster of cultural industries, and constructing a strategic platform for introducing the Chinese culture to the west, and in order to integrate into the construction of the Silk Road Economic Belt.

Figure 4 Street view in Dunhuang

Challenges remain in various aspects as to the construction of a world-reknown city forcultural tourism, which includes protecting world cultural heritage and building eco-buffer zones when the ecosystem is vulnerable and water resources are limited. Other obstacles include the late start-off of natural, historical, and cultural resources in developing and overcoming the discordance between industry patterns, economic goals and natural resources, small economic aggregate and population, inefficient financial support, backwardness of urban infrastructure, immature urban functions and relatively low population quality. All of those are obstacles that block Dunhuang‘s development.

Building Dunhuang into an internationally famous city for cultural tourism must be based on its resources, as well as the four major principles, including environmental protection, optimizing capacity, practicality, and urban beautification. Instead of simply imitating development models of some developed regions and large-scale city construction plans, we must, bearing in mind the limited environmental capacity, initiate a new development model that is self-driven, rapid-growth-based and cultural-tourism-industry-oriented, and explore an effective approach for resource branding, brand marketization, market capitalization and capital internalization. Therefore, city development, industry growth, and market expansion can be facilitated.

The government of Gansu Province issued, in March 2014, the *Outline of Plan for Construction and Development of the International Famous City of Cultural Tourism of Dunhuang*, defining the overall position and requirements for the city‘s development, in order to exert all efforts to develop Dunhuang and coordinate the overall strategy.

- Dunhuang is a restricted development zone where the ecosystem must be protected, and industries and projects must meet the standards of low energy consumption, recycling, lessening emissions and zero pollution.

Dunhuang‘s development positioning and planning takes place at the provincial level, which makes the city more confident and determined indeveloping renewable energy. The uniqueness of Dunhuang‘s nature, geology, culture and economic development drives the city to develop new energy, focusing on wind and PV power, in order to achieve green development. Transferring to anew national energy demonstration city promotes the goal of tourism, and further strengthens the national policies on encouraging sunrise industries.

3.1 Urban Renewable Energy Development Planning

Since 2009, which marked the start of China‘s large-scale PV power plant development, Dunhuang‘s urban energy development has been through three stages:

1) **Building a Million KW Solar Power Bases**: the goal was to realize more than one million KW capacity of wind & PV power plant, of which the electricity would be transferred to the grid. While the focus was on green power generation and power transference, consumption was neglected to some extent.

2) **Building a National New Energy Demonstration City:** The strategy was to promote the large-scale application of various renewable energy technologies in cities, with the aim to raise the share of renewable energy in total energy consumption to above 28% by the year 2020. Importance was attached to local production and application of renewable energy on the consumption end, especially the development and utilization of distributed projects in urban built-up areas. Only the locally consumed green electricity generated by large-scale wind power plants and PV power plants was counted.

3) **Building a 100% Renewable Energy City:** The guideline was to significantly increase renewable energy‘s proportion in urban energy consumption (including electricity, heatingpower and vehicles‘fuel) through policies and regulations of energy conservation and renewable energy development. The expected goal was to make Dunhuang a 100% renewable energy city.

3.2 Problems and Challenges

As the first group of new energy demonstration cities, Dunhuang is facing a number of problems and challenges, of which some are unique in Dunhuang, while the others are common problems in new energy cities.

1) Unique Energy and Resource Conditions and Contradiction Between Demand andSupply: Dunhuang is lacking in conventional energy supply and thus relies heavily on imports. It was even entirely dependent on importing resources (including energy, oil and electricity) before the new energy city was built. In the meantime, Dunhuang has abundant solar and wind energy resources, desert land resources, huge potential for PV power, which means that local energy generating should be turning to solar energy, wind energy, and other renewable energy resources. When the central government started to promote the large-scale application of PV power stations in 2009, Dunhuang seized the opportunity by winning the first PV concession bid project, and pursuing the construction

of 1 million KW PV bases. Meanwhile, driven by local economic growth, a substantial increase was achieved in the local energy supply rate and its renewable energy-generated electricity-to-electricity consumption rate. **In relation to energy demand**, the tourism city has a population of 200,000, with electricity consumption of 550 million KWH or below, or 1 million tons of standard coal equivalent or below. As its energy consumption capacity is limited, electricity generated by the rapidly growing PV projects is transported out largely through power grid. **In terms of the balance between supply and demand of energy**, quantity of renewable electricity in Dunhuang was bigger than the city‘s consumption, and its solar abandonment rate reached 32% in 2015. Therefore, the National Energy Administration (NEA) ordered to halt the PV power station construction projects in 2016 across Gansu Province. While the abandonment of solar power is increasing, Dunhuang remains heavily dependent on the import of coal, oil, and electricity. How is it possible to remove the contradiction between energy supply and demand in Dunhuang? How is it possible to solve the problems in grid connection and consumption of PV power? How is it possible to meet the demand for all kinds of end-use energy (electricity, thermal energy and transport fuel)? How is it possible to balance the supply and demand among different types and quantity of energy? These are the challenges that Dunhuang has to face in energy production.

2) **Understanding of the HighratioRenewable Energy GoalNeeds to be Improved Gradually.** In the early stages of new energy city construction, the goal of high ration renewable energy was understood as the renewable energy share in the total energy consumption,which includes both the locally consumed and outwardly transported PV generated electricity. However, Dunhuang later realized that high ration renewable energy refers to the consumption of renewables in that it incorporates significant use of non-fossil fuel generated energy including electricity, thermal power and vehicle fuels – a rather huge challenge that the city did not foresee initially.

3) **Some Renewable Energy Technologies Need to be Improved in Ways of Feasibility and Economic Cost.** Though renewable electricity hascome to maturity technically and economically due to the policy support and large scale deploy of wind power, PV power, and hydro power plants, the technological development path for renewables-based heating is still unclear. Some technologies such as solar heating water systems or geothermal energy heating are basically ready to be commercialized, though the implementation of those technologies are limited in many ways, such as on rooftops or ground areas, which makes it difficult to achieve large scale implementation in cities. Electric heating technology by renewable energy (with wind and solar energy abandoned) is mature, but cannot be applied on a large scale, because the supporting policy incentive system has not yet been established. Vehicle fuel generation by renewable energy is confronted with the greatest challenges, such as the high cost of electric cars. Moreover, vehicle biofuel also faces big problems and challenges when it comes to resources and technologies.

4) **Energy Planning Needs More Support of Authoritative Data of Energy and Renewable Energy.** As a fourth-tier city, Dunhuang encounters problems in collection and organization of energy consumption and renewable energy data when formulating

development plans for new energy city, and the comprehensive plan for becoming a high renewable energy penetration city. China's statistical system only covers large-scale energy consumption data, without distinct data on consumption of hot water by scattered users, building heating, and small industrial boiler usage. Statistical information covers large-scale wind power and PV power, but not distributed renewable energy power projects and non-commercial utilization projects (solar thermal energy and geothermal energy). Authoritative data support for urban energy plans is also insufficient, as there are no statistical agencies and personnel coordinating and managing the collection of data on energy production, consumption, and renewable energy use invarious sectors and fields.

5) **State Policy Support and Guidance are Needed.** Dunhuang City is enthusiastic about its new energy city construction, which meets the internal requirement of building a low-carbon and environment-friendly city. However, as some local cities' capability and finance are limited, the central government is expected to issue targeted incentive policies so as to provide technological and financial support for building capacity and infrastructure of new energy cities.

6) **Local Technical Support is to be Improved.** As a fourth-tier city, Dunhuanghas lack of of technical support skill and thus, relies heavily on external professional research teams' support of overall construction planning, design, operation, and management. It also has significant weaknesses in new energy publicity, talent training and capacity building, and is faced with deficiency of financial and human capital. Therefore, the city is actively seeking support from expert teams at home and abroad. In 2015, it was listed as one of the China-Germany Renewable Energy Demonstration Cities. Experts from Germany and China are playing an increasingly important role in building Dunhuang into a 100% renewable energy city.

3 Three Stages of Urban New Energy Construction

3.2 2009: Building 1 million KW Solar Power Bases

Dunhuang's renewable energy development starts with the construction of large-scale PV power stations, based on its abundant solar and wind energy resources.

In 2009, construction of China's first 10 MW grid-connected franchised PV power generation demonstration project began, kick-starting PV development in Dunhuang, and even China. In May 2010, the General Office of the State Council proposed in the *Suggestionson Supporting Economic and Social Development in Gansu* to ―build solar power generation demonstration bases above 1 million KW with the priority given to Dunhuang.

The city's PV market has developed rapidly since 2009. By the end of 2015, the installed capacity of grid-connected PV power had reached 663,000 KW and registered an installed capacity of 969,000 KW in Dunhuang.

Grid connection and consumption must be assured in order to push forward the construction of large PV power bases. Thus, Dunhuang has made great efforts to construct a power grid.

Up to the end of 2015, the city had built up one 750KV, two 330KV, and thirteen 110KV transformer substations so as to relieve the pressure on green electricity exportation.

3.2 2011: Building A National New Energy Demonstration City

While pushing forward PV power base construction, Dunhuang also recognizes that large-scale PV power construction can effectively raise green electricity proportions; however, integrating PV power into the medium and high voltage grid contributes little to local energy consumption, which remains heavily dependent on fossil energy.

Therefore, the city proposes to build itself as a new energy city and promote the application of distributed renewable energy. It completed the formulation of the *Plan for New Energy City Development in Dunhuang*as early as 2011. In June of the same year, the NEA approved the *Plan* to support the city in building a state-level new energy demonstration city, and Dunhuang was listed in the first group of national new energy demonstration cities.

According to the *Plan*, Dunhuang would facilitate the application of various new energy technologies to urban electricity supply, thermal energy application, heating and building energy conservation, with a focus on various patterns of solar energy usage. It would attach importance to construction of projects including electricity and heat supply by solar energy, urban micro grid, integrated application of solar PV and heat to buildings, electric cars and large-scale PV power and wind power for local electricity supply, and strive to meet the goal that renewable energy production should exceed urban energy consumption by 2015.

New energy demonstration city construction was an important project in renewable energy construction during the 12th Five Year Plan period. According to the 12th Five Year Plan for renewable energy, 100 new energy cities, focusing on distributing renewable energy should be built by the year 2015. In 2012, the NEA set out in this respect, defining the general guidelines, basic requirements, and assessment indicators. According to NEA documents, new energy demonstration cities are cities that take full advantage of local abundant solar energy, wind energy, geothermal energy, and biomass energy resources in urban energy development and utilize renewable energy in a high proportion. Theoverall requirement for China‘s new energy demonstration cities is that renewable energy utilization should account for more than 6% of urban energy consumption, and more than 2 renewable energy technology application indexes should be attained.

Based on the city‘sabundant solar and wind energy resources, the objective set in the initial *Plan of New Energy City Development in Dunhuang* is ―striving to make renewable energy production exceed urban energy consumption by 2015, which is basedon large-scale PV base construction. After the NEAreleased its general guidelines for the new energy demonstration city construction project, Dunhuang made an adjustment, incorporating the concept of renewable energy consumption on a local scaleand its proportion in energy consumption. The new objective is:

- By the year 2015, renewable energy production, particularly solar and wind energy,

should reach 2.20 million tons of standard coal equivalent, or nearly three times the total consumption of energy. Regarding Dunhuang, energy consumption is approximately 780,000 tons of standard coal equivalent, and as forecasted, local consumption of renewable energy should then reach 213,100 tons of standard coal equivalent, or about 27% of total energy consumption.

- By the year 2020, renewable energy production, particularly solar and wind energy, should reach 6.06 million tons of standard coal equivalent, or nearly five and a half times the total consumption of energy, which is equivalent to 1.1 million tons of standard coal. Local consumption of renewable energy should reach 239,200 tons of standard coal equivalent, or about 28% of total energy consumption.

According to the plan, the installed capacity of large-scale PV power plants and that of wind power plants would amount to 3 million KW by 2015, and 7 million KW by 2020, respectively, and either of them would account for more than 85% of renewable energy production. As for new energy demonstration city construction, renewable energy projects are under construction, however, little consideration is given to consumption. Coordination between renewable energy system, energy conservation, conventional energy system and urban planning and construction system is to be improved.

3.2 2015: Building 100% Renewable Energy City

The ―100% Renewable Energy Regions‖ project was initiated and funded by the German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU), with the aim to provide help to selected regions that are willing to make long-term efforts to transform their energy supply to renewable energy and ultimately meet the 100% goal. By the end of 2014, there had been more than 130 counties, towns, and regions in Germany already setting up such a development goal.

100% renewable energy refers to energies, including electricity, heating power and traffic fuel, that are generated entirely from renewables.

The German city Frankfurt is a global trailblazer for low-carbon and 100% renewable energy development. Based on a detailed feasibility study, in 2015, the city approved the ―General Plan on Frankfurt 100% Climate Protection, setting goals of decreasing energy consumption by 50%, greenhouse gas emission by 95%, and going 100% renewable energy by 2050. Other developed cities such as Hanover and Vancouver have also promoted the goal of 100% environmental protection and 100% renewable energy. The international experiences and endeavors have made Dunhuang more determined to realize low carbon and renewable energy development.

In January 2015, Dunhuang was listed as one of the ―China-Germany Renewable Energy Demonstration Cities, and began planning and researching implementation of 100% renewable energy cities with the support of German and Chinese experts. Currently, efforts are underway to study and draft the *Comprehensive Energy Plan for 100% Renewable Energy City of Dunhuang City*. The *Plan* will present detailed analysis and studies on the current status and trends of energy production, consumption and delivery in Dunhuang City. This

analysis will include the production potential and trends of renewable energy, demand for end-user energy in each field and of each variety (electricity, heat and vehicle fuel), equipment and efficiency of energy conversion and production processes, path and capacity of import and export of electricity and energy, and the complete the urban energy balance sheets for 2015 and 2020. It will further promote planning guidelines, key work projects, and work elements for the 100% renewable energy city construction.

To meet the 100% renewable energy goal, priority should be given to the following work:

- **Emphasize the Construction of Large-Scale Renewable Energy Bases on the Production Side:** Build 1 million KW state-level solar thermal power demonstration bases, 2 million KW large-scale leading PV power bases and 2 million KW new-type wind power bases; promote greater efforts to develop distributed energy and ensure 100% satisfaction of renewable energy consumption demand in Dunhuang.
- **Build Export Channels Vigorously on the Energy Delivery Side and Improve Local Distribution Network:** Build a renewable energy heating network, and achieve complete renewable energy heating in urban areas; build a renewable energy transport network and speed up deployment of charging pile networks to ensure steady promotion of renewable energy traffic in Dunhuang.
- **Perform Energy Management on the Demand Side:** Manage energy demand in the fields of industry, building and traffic, shift from extensive to precision energy management, and, improve energy utilization efficiency through technological and administrative approaches.

According to preliminary research, Dunhuang will be able to reach 100% renewable energy for electric power and thermal energy around 2030, but it‘s faced with great technological and economic challenges regarding generating traffic fuel completely from renewable energy.

- **100% Renewable Energy for Electric Power:** Installed capacity of PV power and wind power is growing rapidly in Dunhuang. The city is rich in solar and wind energy resources, and local renewable energy electricity can meet its demand completely. Challenges lie mainly in the economic cost of flexible promotion schemes.
- **100% Renewable Energy for Heating:** Renewable energy heating technologies are mature, including heating by solar energy, geothermal energy, and renewable energy electricity. Heating has great potential for energy conservation, and implementation of energy conservation and efficiency measures may cut down demand for heating energy. Major challenges lie in heating for rural areas and scheduling for implementation of energy measures.
- **100% Renewable Energy for Transport Fuel:** Energy transition in the traffic system is faced with great challenges. Available technologies include electric cars and electric gas fuel, but with challenges in maturity and economical efficiency.

4. Organizational Management and Safeguard Measures

4.1 Strengthening Organizational Leadership

To strengthen the organizational leadership of national new energy demonstration cities, Dunhuang establishes the ―Leading Group for State New Energy City Construction of Dunhuang City led by the Executive Vice Mayor and consisting of major principals from all relevant departments. The Leading Group coordinates new energy city planning and construction as a whole, arranges major problems in development, resolves and implements in a detailed manner new energy city construction tasks, builds an assessment indicator system for new energy cities, incorporates them into the social management and comprehensive governance accountability mechanism for examination, and ensures the implementation of all tasks related. It has an office and several members transferred from relevant departments and is funded by the municipality.

4.2 Intensifying Policy Support

Dunhuang should build a powerful policy support system and incorporate new energy city construction ideals into its long-term economic and social development plan. In order to do this it needs to establish special funds for new energy city construction so as to assure the implementation of key project construction and operation and maintenance capital; strengthen overall planning of special funds for new energy city construction across the city, increase investment to new energy utilization for urban infrastructure, and optimize information technology-based capital structure; establish a sound mechanism for communication and connections between banks and enterprises, make the best use of clean energy investment and financing platforms, improve diversified investment and financing mechanisms, and attract and encourage participation of diversified social capital.

4.3 Innovating Management Assessment Mechanism

Dunhuang should strengthen objective assessment management, and build a scientific and effective integrated performance appraisal system; establish a classified accountability system for program implementation objectives, and take implementation of new energy city construction programs as important content for assessing the government performance of Party and government leaders at all levels; enhance supervision and inspection so as to ensure people are benefited; formulate the *Performance Assessment Indexes and Management Measures for New Energy City Construction of Dunhuang*, establish annual and monthly assessment mechanisms, detail assessment objectives, and ensure steady construction of new energy cities.

4.4 Speeding Up Project Construction

Dunhuang should give priority to promoting the application of co-generation, distributed PV and photovoltaic/thermal integrated buildings, water source heat pump and new energy

automobiles; amend and improve measures for management of government-funded new energy projects, formulate relevant enforcement regulations, strengthen whole-process managementof projects, regulate planning, design, project examination and approval, promote purchasing by invitation to bid, assessment, acceptance, operation, and maintenance impovements, improvement mechanisms for project supervision and performance evaluation, ensure quality of project implementation, and improve the all-round benefits of government investment. All accountability departments should assign work according to their respective responsibilities, analyze progress of work, make clear stage objectives and construction scheduling, and speed up the establishment and construction.

4.5 Strengthening Publicity and Promotion

Dunhuang should popularize and apply the latest research achievements, products and successful application cases regarding new energy cities, and establish typical models; conduct publicity and experience activities through leadership training, community service and other platforms so as to popularize new energy city knowledge and expand its influence; guide relevant enterprises, social organizations, experts, scholars, and citizens to participate in new energy city construction, and build a favorable atmosphere of social support for it.

5. Implementation Achievements

5.1 Overall Progress and Achievements

Dunhuang works on both production and consumption of energy, according to its energy supply and demand, and renewable energy characteristics. Its renewable energy industry is diversifying in —highlighting priorities and emphasizing multiple kinds of energy. At present, 1 million KW photovoltaic power bases have been built, solar-thermal power demonstration projects have been launched first, wind power base construction in North Lake region has started, export channels for new energy electricity have been opened, and the cities‘ largest new energy industry park is under development, and a diversified distributed energy system is under construction.

Various energy forms complement each other in consumption and renewable electricity, solar heating, and geothermal heating and cooling are applied in a large scale.

A PV power industry park, with the largest linked area coverageand the most installed capacity in China, has been built up, and the grid-connected electricity generated by renewable energy exceeds 1 million KW.

Up to April 2016, Dunhuang consumed the renewable energy equivalentof 227,100 tons of standard coal, accounting for more than 20% of total energy consumption. The application of renewable energy may reduce SO_2 emission by 595,000 tons.

5.2 Advancing New Energy City Construction in All Fields With Priority Given to Application

Urban Construction. Across Dunhuang there are nearly 10,000 solar water heaters installed in newly built residential communities, with an area of 505,000 square meters covered by the solar hot water supply. There were 20 electric and solar paneled vehicles purchased for urban police patrol and tourists‘ sightseeing in scenic spots. Further, on urban city roads, street lamps, billboards, and traffic lights have been replaced by solar powered units, and over 500 solar street lamps have been installed.

Residents’ Life. The water source heat pump project has been initiated, using water tanks owned by supply companies as heat storage facilities, for heating and cooling office buildings, apartment buildings, and near-by commercial residences, with a total coverage of 200,000 square meters. Dunhuang Academy, Mogao Hotel, and Dunhuangfarm apartment buildings all get heating or cooling services through ground-source heat pump technology.

New Countryside Construction. Dunhuang has launched rural solar housing, rural street brightening, and rural solar bathroom demonstration projects, and installed 1,300 solar insecticidal lamps in rural areas. It plans to combine organic agricultural production with the new energy industry, perform solar transformation on linked pieces of sunlight greenhouses in rural areas, build up more than 8,000 mu (about 533 hectares) of distributed PV agricultural greenhouse demonstration zones, and increase rural income further while supplying electric farming greenhouse rolling machinse and auto control devices of agricultural greenhouses.

5.3 Sticking to Promotion by Projects and Popularizing New Energy Technology Application Comprehensively

Popularizing Solar Hot Water Application Projects in an All-Round Way. Dunhuang has installed large-scale solar hot water systems on rooftops of eligible hotels, restaurants, dormitory buildings, and residential communities in order to provide domestic hot water and reduce consumption of fossil energy focusing on natural gas.

Advancing PV Power Station Construction. In 2009, China‘s first 10 MW grid-connected PV power generation concession bidding demonstration project was implemented in the PV power industry park of Dunhuang. Thus, kicking off PV power project construction in the city. By the end of 2015, registered capacity of PV power generation had reached 969,000 kW, and 663,000 kW of grid-connected PV power projects had been built up. It is projected that Dunhuang‘s newly increased installed capacity of PV power projects will reach 1 million kW during the 13th Five-Year Plan and its installed PV power capacity will reach 2 million kW by the end of 2020.

Launching Solar-Thermal Power Generation for the First Time. Construction of two solar thermal power plants is under way, with an estimated future output of 20,000 KW. In 2014, the Shouhang Energy Saving Company started construction of a 10 MW Tower-type Fused-salt Solar Thermal Power Demonstration Project. It is the largest single tower-type

fused-salt solar thermal power project in China, whose solar thermal power stations are expected to generate electricity around the clock after completion. In 2015, the 10 MW Linear Fresnel Solar Thermal Power Project, the largest grid-connected project of its kind, was initiated. In addition, early preparations are made for several other projects, including the 9 MW Dish-type Solar Thermal Power Demonstration Project, 50 MW Slot-type Solar Thermal Power Project, and a 3×50 MW Solar Cogeneration Demonstration Project.

Carrying Forward Demonstration of Comprehensive Distributed Solar Energy Application Steadily. Dunhuang has carried out township-level solar energy micro-grid demonstrations and solar energy heat comprehensive utilization projects, accumulating valuable experience necessary for the construction and commercial operations of distributed PV power stations. Under the support of the Asian Development Bank (ADB), the city implemented in 2014 the Qili Town, Qinjiawan Rural Solar Energy Comprehensive Utilization Micro-grid Demonstration Project, installing a distributed roof-top PV system for 50 rural households, and providing them with green electricity through a ―centralized peak load regulation and household metering‖ system. The Rural Solar Heating/Heat Storage Project provides electricity and heat for factory-styled agricultural land and countryside tourism parks through solar PV power generation, solar thermal collector heating, and concurrent heating by electric boilers.

Advancing Construction of the Development Platform with Full Strength. Approximately 250 million RMB has been spent on building infrastructure of the PV electricity industrial park, infrastructure improvements regarding the provision of water, electricity, transportation, telecommunications, natural gas access services, and the zero emission PV electricity expo park service center. Through its new energy science popularization hall, application and demonstration of new energy technologies and products are displayed fully to both Chinese and foreign tourists. Accordingly, the PV electricity park was built into an AAA-class scenic spot based on an industry-and-tourism combination, as a new energy science popularization and education and training base. The service center is free of emission thanks to the adoption of renewable energy and energy saving technologies, such as ground-source heat pump, solar thermal collector, PV tile, solar cell module, and glass curtain wall.

Demonstrating and Generalizing PV Agricultural Greenhouses. Dunhuang has built up distributed PV agricultural greenhouse demonstration zones, with an area of over 8,000 mu (about 533 hectares), covering centralized and linked rural sunlight greenhouses across the city. As a result, rural income has increased, while electricity demand of facilities, such as the agricultural greenhouses‘ mat-rolling machines and auto control devices is satisfied.

6. Inspiration and Suggestions

6.1Broadening the Mind for New Energy City Development

Dunhuang‘s new energy city construction starts with the building of large-scale PV power station projects, goes through simultaneous promotion of energy production and consumption,

and is in the process of further developing renewable energy application, city planning, andoverall planning of the construction, transportation and industry sectors. The theory and guidelines concerning energy development are continuously adjusted and improved in order to solve development problems. At present, the city isstriving to be 100% renewable as quickly as possible.

Changes in the city‘s urban energy development ideology are an important reference factor for other cities. Most new energy demonstration cities are implementing renewable energy projects, where coordination between renewable energy, energy conservation, conventional energy systems, urban planning, and practical construction systems needs to be improved. Accordingly, focus should shift from urban energy construction, to how to promote and assure urban sustainable development with renewables energy. Renewable energy development ideology and thought processes need to be expanded.

According to the on-going national new-type urbanization work, and the energy revolution thought, advanced by President Xi, consideration of new energy city‘ work should encompass:
1) New energy production: large-scale production of renewable energy in cities; 2) Energy consumption concepts and systems: Well performing urban planning, coordinating energy development with planning and construction of traffic and industry, building a sound local consumption system, advocating new-type energy consumption concepts, and providing better conditions for consumption of renewable energy; 3) Energy technology improvements: Supporting the demonstrative implementation of new types of renewable energy technologies, including micro-grid, regional energy station, low-energy and net zero energy consumption buildings and etc.; 4) Publicity and education: Improving education to raisepublic awareness and behavioral pattern.

6.2 Putting Forward Bigger Stage Goals of Development

According to China‘s assessment indicator system for new energy demonstration cities, the new energy demonstration city refers to a city whose new energy consumption accounts for 6% or above in its total energy consumption, and has two or more renewable energy technologies meeting the standards. However, cities like Dunhuang, which have high feasibility of developing renewables and have surpassed the national average in ways of renewable energy implementation, are likely to lose the momentum and direction for further development after meeting the national standards. From the perspective of the global energy transition trend, that new energy consumption reaches 6% is merely a minimum standard for a new energy city, far behind the goal of high ratio of renewable energy (above 60%). In the meantime, new energy city construction is a long-term, continuous task, which means cities at different stages of development should follow different objectives.

It‘s suggested that China should implement the concept of a star rating mechanism for new energy demonstration cities, with goal setting at 6%, 13%, 25%, 50% and 80% respectively, with new energy cities accredited with one to fivestars, so as to guide cities to set up goals according to their development stages that are based on resources, applicable conditions, and

to move towardbe considered a high renewable energy city.

6.3Providing Particular Support to Local Capacity Building

As a fourth-tier city, technological support in Dunhuangis rather weak. As developmental thought of new energy cities improves, Chinese and foreign experts provide quite important professional and technical support on energy planning, technical scheme design, and the promotion of new energy city concept. In Europe, important support for new energy city development also includes local capacity building and provision of consultation services to local governments.

However, the Chinese government has yet to promulgate incentive policies for new energy city development, and is restricted by the lack of overall support and governance. Recognizing the importance of sustainable development and the vital role played by renewable energy development in city development and economic transition, many cities have formulated development plans, but the implementation is restricted due to weak governance ability. New energy city capacity building should include planning, implementation, consultation and information monitoring, which may be facilitated through establishment of alliances, associations, or business cooperation.

References:

1. Zhao Tingqian: Chinese Cities Are Moving Forward to 100% Renewable Energy Supply System—Practices and Challenges, Workshop on Sino-German New Energy Demonstration Cities, Germany, May 2016
2. Fraunhofer Institute Germany, Initial Achievements of Energy Plan Formulation of Dunhuang City, Sino-German Workshop of Cooperation on Renewable Energy, Dunhuang, April 26, 2016
3. Declaration for Sino-German Cooperation on New Energy Demonstration Cities Construction Project, Dunhuang Energy Bureau, January 2015
4. General Office of People‘s Government of Gansu Province, Outline of Plan for International Cultural Tourism City Construction and Development in Dunhuang, March 18, 2014, http://www.gansu.gov.cn/art/2014/6/11/art_4364_180033.html
5. Reply of the National Energy Administration to New Energy City Planning of Dunhuang City, Gansu Province, National Energy Administration, 2011
6. Dunhuang City: Dunhuang New Energy City Development Plan of Gansu Province, 2011

Chapter Two: Water Resources

Water connects many issues in urban systems. How well we use, manage, waste, or pollute water can determine the sustainability of acity‘s environment. Cities are facing water shortages, falling ground water levels, and system weakness in urban rainwater drainage and flooding.

In the face of water shortages, cities are increasingly taking responsibility for water management. Some cities link water systems with regional nature conservation, for example by protecting forests, wetlands, and catchment areas vital to local water supply and biodiversity. Cities increasingly engage in storm water management, rainwater collection, water quality improvement, recycling, and desalination.

Water Management in Seoul

Young June CHOI[3]

Abstract: The city of Seoul, in Korea, has experienced rapid urbanization in last 60 years. It contracted the deterioration of regional water circulation system and other urbanization diseases, at the same time as it was classified as an international first-class metropolis. To change this situation, through political and technical efforts, the Seoul City Government constructed an effective and sustainable urban water resources management system and encouraged awareness of production of resources and energy instead of treatment of the urban water resource system.

Keywords: water circulation system, storm water management, smart water grid, sustainability, Seoul

1. Background

1.1 Introduction

Seoul is the capital of South Korea, and it is also the largest metropolis of South Korea. Seoul was called WiryeSeong, during the Baekje period, serving as its capital from 12 CE to 475 CE, and it was called Namgyeong during the Goryeo Dynasty. Since Seoul became the capital of the Joseon Dynasty in 1394, Seoul has served as the political, economic, social, and cultural capital of Korea. Between the mountains, numerous ranges and hills sprawl like fingers towards the city center. The Han River runs through the center of the city. (Office of Waterworks, 2008).

About 24% of the population of Koreais concentrated in Seoul. As the land surface of Seoul is relatively small to accommodate for the large population of Seoul, Seoul‘s urban growth pattern has consisted of urban sprawl caused by the low-income residents of Seoul. This spread has been towards cheaper residential areas located on the higher ground of Seoul. Urban sprawl towards the high ground posed a challenge to water supply management in Seoul.

Currently, Seoul is a metropolis containing a population of 10 million people. It is a city that has experienced an unprecedented growth in a very short period of time.

[3]Young June Choi, Director of Bureau of R&D for Water, Seoul Water Institute, Seoul Metropolitan Government

1.2 Seoul's Water Environment and History

The first modern drinking water treatment plants were constructed and operated since December 9, 1903, when Emperor Gojong of the Korean Empire issued a license for construction and management of waterworks to C.H. Collbran and H.R.Bostwick, from the United States. Korean Water Works Co. took over the license on August 1905 and began managing Seoul's waterworks. In August 1906, Korean Water Works Co. began the construction of a basin for slow sand filtration at the Ttukdo Water TreatmentPlant, supplying 12,500$m^3$of water to 125,000 residents in Seoul upon its completion in August 1908.

Ttukdo Water TreatmentPlant marked the beginning of modern waterworks in Korea, as well as for the city of Seoul. Introduction of modern waterworks system provided improved sanitation and convenience, as well as increased life expectancy for the citizens of Seoul, who were greatly exposed to waterborn diseases before. Modern waterworks also provided revolutionary changes across various sectors in Seoul, such as the daily lives of the citizens, industry, and urban disaster management.(Office of Waterworks, 2009).

In 1910, The Japanese Empire took control of Seoul's waterworks when it assumed control of Korea's sovereignty and administrative control through its colonization. Despite the change of hands, the increasing population of Seoul, and the recognition of the convenience and sanitation of waterworks in Korea led to an increased demand for improved waterworks in Seoul. The colonial authority of Seoul expanded Seoul's waterworks infrastructure through 3 stages, until Korea's independence in 1945. As a result, the number of taps in Seoul increased from 4,000 in 1912 to 21,121 in 1930 and to 61,970 by 1945.

Once Korea regained its independence from the Japanese Empire in 1945, the Office of Waterworks in Seoul assumed the control of the abandoned waterworks administration, and began an autonomous management program. During this time, Seoul Waterworks focused on expanding its water production capacity to meet the surging demand for water in Seoul. The outbreak of the Korean War in 1950 however destroyed most of Seoul's waterworks infrastructure. During the war, which lasted for three years, 30-90% of the treatment plants in Seoul were destroyed, and 90% of Seoul's communication facilities were damaged.

In 1954, the Korean Government, with the aid of the UN,began repair and restoration of the waterworks facilities. The project took about five years. Notably, the second watertreatment plant at Guui was constructed in 1956, soley an effort of Korean technicians. By 1960, the expansion and refitting of waterworks infrastructure in Seoul led to an increase of water supply from 59 liter per capita to 163 liter per capita.

In the 1960s and 1970s, the Korean government actively pursued a Five-Year Economic Development Plan. As a result, Korea experienced rapid industrialization

and urbanization, which led to an explosive population growth in Seoul, and consequently led to an exponential increase of water demand in Seoul. An urgent need for the expansion of water facilities soon became apparent, and water supply needed to be increased accordingly.

Seoul‘s population increased dramatically, from 2,450,000 in 1960 to 8,370,000 in 1980, an increase of 282,000 people on average every year. During this period, Seoul madegreat efforts to expand the facilities and enhance the capacities of waterworks. By the 1980s water supply became stable. This was a result of the expansion of water production facilities and the slowdown of population growth in Korea. The water distribution rate exceeded 90%, and the amount of water supplied per person on a daily basis neared 400ℓ.

During the 1980s and the 1990s, the main issue for water policy shifted from quantity to quality. Due to increased awareness worldwide of environmental issues, coupled with Seoul‘s successful efforts to stabilize the water supply, there were growing concerns over water pollution. In Seoul, the frequent pollution of the Han River, Seoul‘s main water source, occurring from urbanization and industrialization led to new discourse over maintaining the quality standard of the water source. As the Office of Waterworks‘ credibility diminished from water pollution in local streams, the quality standard of tap water became a national issue in Korea. (Office of Waterworks, 2009).

In the 2000s, the efficiency of the system became an important policy goal, and decreasing NRW (Non-Revenued Water) became a major issue. This in turn was proposed as a management index for all waterworks projects. As a result of efforts in technology, policy, and management, Seoul‘s NRW reached 5% in 2015, achieving one of the lowest NRWs in the world.

In 2016, Seoul introduced and focused on ‚sustainability‘ as its new policy goal. This goal was created in order to participate in the global efforts to achieve the Sustainable Development Goals (SDGs) launched by the United Nations.

1.3 Problem Statement

A comparison of average monthly precipitation shows that climate change had a noticeableeffect on the precipitation patterns in Seoul.

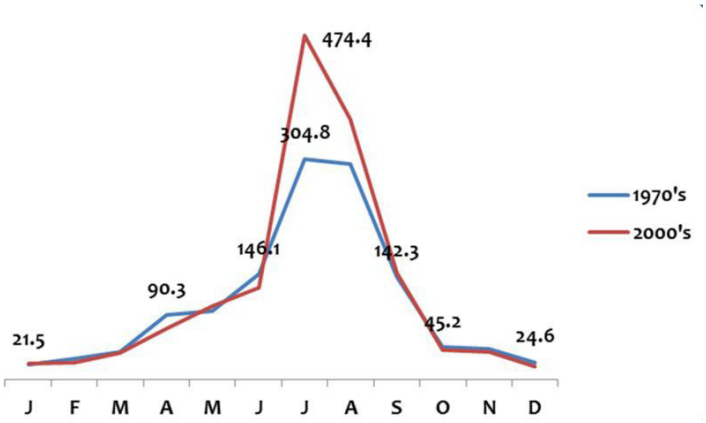
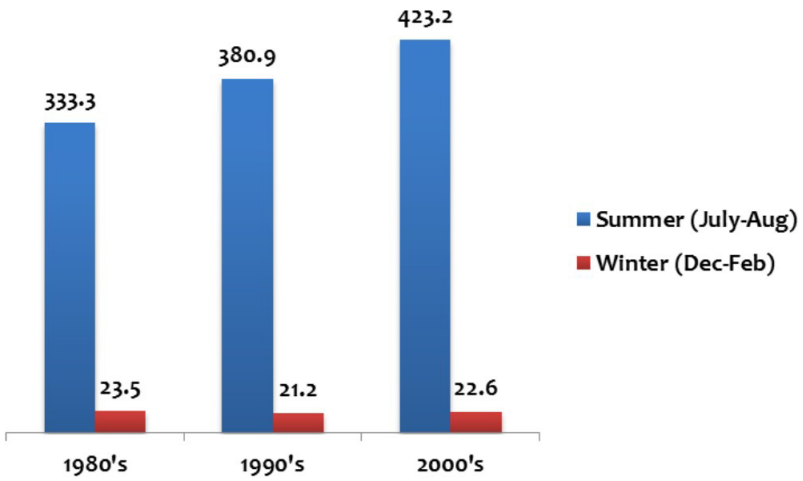


Figure 1. Changes in Monthly Precipitation Patterns

Approximately two thirds of the yearly precipitation is concentrated in July and August, the rainy season of Korea, and the concentration of rain and the volume of precipitation are increasing (Figure 1). In addition, precipitation decreased during winter and spring, which are relatively dry seasons in Korea (Figure 2). Such changes in precipitation patterns can make it difficult to use water resources for two reasons. First, difficulty arises from floods in the summer (Figure 3), and second, from droughts in the spring and winter.

In 2015, Seoul had suffered droughts for three years in a row.

For the decade from 2004 to 2013, the average discharge flow from Paldang Dam, which accounted for most of the flowof the HanRiver, was 613 CMS[4]. Accordingly, the water intake of Seoul for tap water production accounted for about 6% of the total flow. In early 2015, when the drought continued for three years, the discharge of Paldang Dam dropped from 240 CMS to 124 CMS, to80 CMS in the fall, and eventually to50 CMS in November.



[4] CMS or cubic meter per second is used for measuring flow rate.

Figure 2. Changes in Precipitation Patterns According to Season

Figure 3. Flooding in Gwanghwamun in Summer of 2010 (left) and Overflowing of Cheonggyecheon Stream (right) (Choi, 2016)

If the flow rate of the Han River decreases to 50 CMS, the water intake of Seoul for tap water production per day accounts for 71% of the total flow rate of the Han River. If this had continued for a few weeks more, Seoul would have faced a state of emergency. Although Seoul was able to avoid such state of emergency in 2015, Seoul regards that similarly severe droughts are possible in the future. Therefore, diversification of water resources, water conservation, and contingency plans in case of extreme situations must be considered when devising a water policy.

Climate change also greatly affects the water quality of the Han River, the only water source of Seoul at this time. Although physicochemical water quality parameters are gradually improving thanks to the efforts to enhance water quality, biological and ecological shifts are increasing due to climate change and increase in human activities. Algae blooms, as well as new microorganisms, such as pectinatellamagnifica, and antibiotic-resistant bacteria are increasingly appearing in the Han River.

Water demand in Seoul is mostly for domestic use (87.3%). Water demand arising from agricultural and industrial usages are very low (0.7%).(Figure 4).

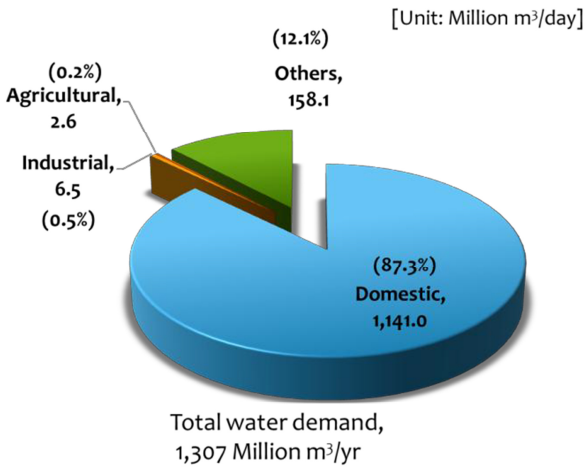


Figure 4. Seoul's Water Demand Use (Choi, 2016)

Therefore, the main target for water resource management in Seoul iswater supply for domestic use. Accodringly, the two main axes in Seoul's water resource management are demand and supply management of drinking water, and urban drainage based on sewage treatment and water reuse.

As discussed above, Korea's economic growth achieved after the Korean War, starting in the 1960s and increasing through to the 1990s, along with urbanization and industrialization, led to rapid population growth. This led to an exponential increase in water demand. To address such a surge in water demand, Seoul focused its efforts on production and supply of tap water and a quantitative expansion of wastewater treatment and urban drainage systems.

Now that all urban infrastructures related to water resources arefully constructed, the focus of budget operations and policies is on the maintenance of its infrastructure systems. To efficiently manage the urban water cycle system, including drinking water and wastewater, wastewater management system and waterworks system must be integrated.

In the past, the process for tap water production was called ‚water treatment', and the process for treating and discharging treated wastewater was called ‚sewage treatment'. Now, water treatment and wastewater treatment must be seen not only as the treatment of polluted water, but also seen as production processes for new types of resources. In this respect, Seoul's water resource system should take an approach called the *Water-Energy NEXUS*. Recently, deterioration of utilities and systems built in the 1970s and 1980s has become severe, and the number of disasters and accidents caused by climate change has increased. Therefore, the *Water-Energy-Risk NEXUS* approach, which offers broader perspectives, should be the starting point for discussions on water management.

From the 1960s and through the 1970s and 1980s, urban environmental problems also surged in Seoul (Figure 7)due to rapid urbanization (Figure 5), industrialization, and population growth (Figure 6). However, despite the surge of urban environmental problems, government policies in Korea focused on development and expansion. Therefore, it was difficult for the central government to consider the environmental problems and water quality. This approach to environmental issues coincided with the general sentiments shared and accepted widely by the public of Korea at the time. Accordingly, urban development focusing only on growth caused serious environmental problems, as well as problems for sustainable development.

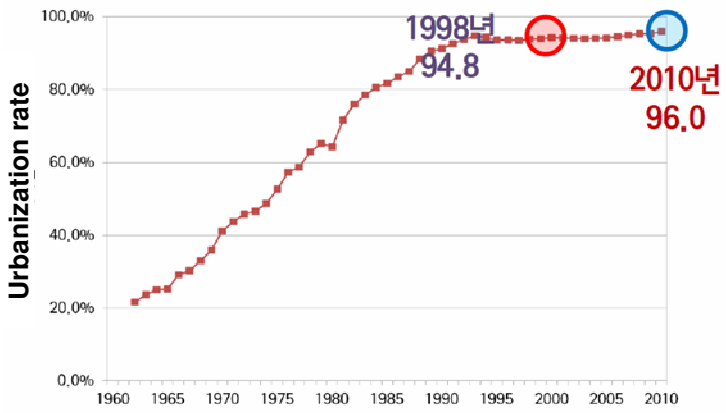


Figure 5. Changes in Seoul's Urbanization Rate (Kim, 2012)

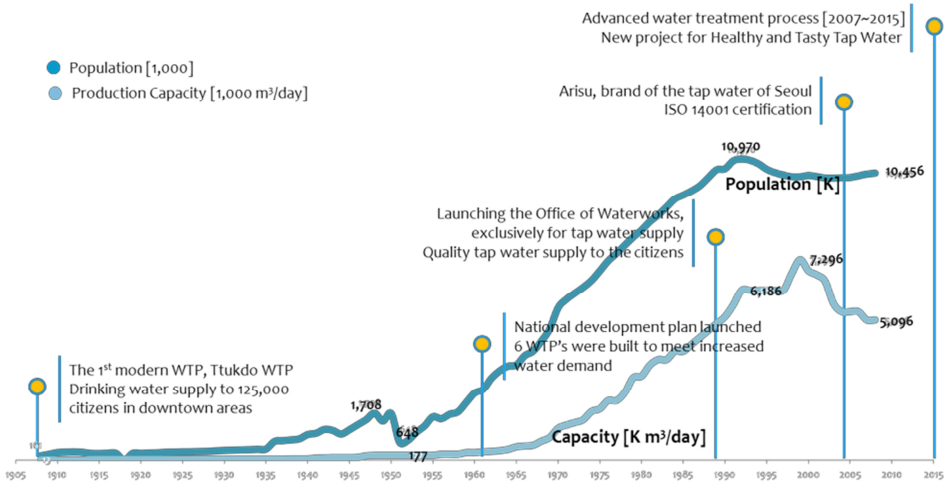


Figure 6. Changes in Seoul's Population and Production Capacity of Tap Water(Choi, 2016)

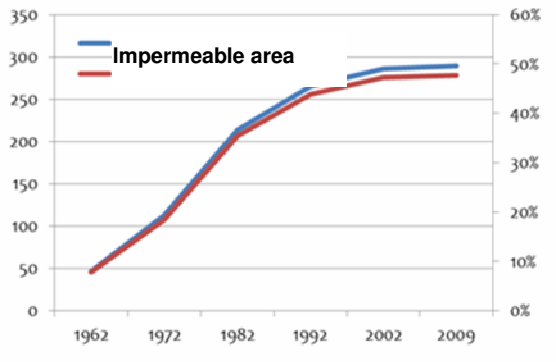


Figure 7. Changesin Seoul's Impermeable Area and Rate(Choi, 2015b)

It takes a much greater effort to restore a destroyed environment than conserving the environments or resources already present. As the interest and understanding on environmental issues and sustainable development increased among the public and the central government, the city of Seoul put in a lot of effort on restoring Seoul's environment. Through these efforts Seoul managed some successes in improving the water quality of the Han River, the air condition of Seoul, as well as expanding green areas in Seoul. (Figure 8).

Figure 8. Before(https://goo.gl/KlIR0v), During and After (http://goo.gl/Pa1OR2), and After the Restoration of Cheonggyecheon Stream(http://goo.gl/Pa1OR2)

2. City Manager's Thoughts and Decision-Making Process

Water problems in cities are not limited to water as a physical objective. Urban water problems contain various factors of consideration, such as technical, social, economic and environmental factors. In order to resolve urban water problems effectively, it is necessary to approach each issue in a multi-dimensional method. Moreover, to deal with water challenges in cities, it is necessary to have the cooperation and participation of different stakeholders'. However, Seoul's problem-solving structure in regards to water issues is limited in a way that technical and policy stakeholders are the primary participants. There are two reasons for such a limitation. First, the water business is allowed toonly local governments and K-Water, a public company dealing with water. Secondly, operation by the public sector was inevitable because urban infrastructure such as wastewater treatment and urban drainage systems requires large-scale projects and largebudgets. Therefore, in a megacity such as Seoul, to address water problems, participation of stakeholders, such as citizens, society, and people from economic sectors, is essential.

Construction and operation of urban infrastructure, including water and sewage systems, requires enormous finances and long periods of time. Therefore, plans, designs, construction, and operation of the urban infrastructure must not be distorted by political and economic intentions. However, the reality is that, it is not easy to plan, design, construct, and operate the management system of urban water resources with a long-term strategy in mind. In addition, a shift is required in the divided administrative structure[5], which was built in a time of development and expansion, to an integrated structure, which is required in the new era of efficient operation and management. Therefore, the city is having difficulties in establishing efficient management systems of urban water resources.

2.1 Possible Solutions

Now that Seoul is fully equipped with urban infrastructure, it now needs an organization with comprehensive functions that can take an integrated approach to urban water problems to efficiently manage water resources. In another words, to avoid overlapping functions of organizations and a silo mentality in organizations, an overall organization is needed that can approach water problems in an integrated way, such as a Water Authority or Water Basin Committee. Such an organization will conduct mediation within a city as well as between cities, regions, counties, and related agencies, and will cooperate with them. Because the central government

[5]In the era of development and expansion,sewage and waterworks authorities separately planed, designed, and constructed necessary facilities for each sectorto secure the quantity of urban infrastructure related to water resources.As it turned out, this separate approach was more efficient in terms of speed. Therefore, an authority for waterworks (Office of Waterworks of Seoul Metropolitan Government) and an authority for sewage (Department of Water Cycle Safety) took charge of waterworks and sewage administrationrespectively.

ministries such as the Ministry of Environment and the Ministry of Land, Transport and Maritime Affairs have clear limitations in its capacity and its willingness to mediate among regions, it would be ideal to establish this comprehensive organization through discussion among local governments.

As discussed so far, planning, designing, constructing, and operating urban infrastructure, especially water resource management facilities, requires a systematic and long-term approach. To do so, long-term plans and methods to secure a budget to support the plans are required. For example, in the United States, improving aging water infrastructure will require a budget of about 1 trillion USD over the next 30 years, and 44% of its water infrastructure will require a major overhaul as its lifespan has already elapsed and the infrastructure is in a very poor condition. (Morrow, 2016). Korea‘s water infrastructure is also facing the same problems as the United States. In 2012, out of 647 water treatment plants in Korea, 210 facilities, or 32.5% of the total number of water purification facilities, has been operational for more than 30 years, and thus faces problems from aging. In terms of capacity, out ofthe total 5,932,170,000 m^3/year, 9,770,000 m^3/year (38.9%)is produced from a very poor, aged state. In addition, 47,714 km (26.6%) of waterworks pipes out of 179,159 km of pipes were reported built more than 20 years ago. (Kim Jingeun, 2016). As for the sewage pipes of Seoul, at the end of 2014, out of the total 10,572 km,or 5,400 km (51.2%), were reported used for more than 30 years. (Kim Jaeseop, 2016). To repair and improve such aging urban infrastructure, an astronomical large budget, long-term plans, and execution of such plans for a substantial period of time are needed.

In response, realistic and accurate long-term plans must be proposed with full consideration of experts. In addition, plans should include finances, such as fees, taxes, and financial plans, such as setting up a water fund, as well as technological and engineering plans.

2.2 The Decision-Making Process

The overall process for major decision-making related to water resource management is as follows:

Local governments draw up detailed and local plans, and related departments within the central government approves the plans. The central government establishes long-term plans at the national level. Such adecision-making process is not much different from that of administrative tasks generally performed by civil servants. Civil servants and experts are principal agents of decision-making. Therefore, this decision-making structure, and process, has a limitation that citizens and other stakeholders regarding water resource management policies cannot easily participate in the policy development process.

To overcome this limitation, all local governments were institutionalized to create a waterworks evaluation committee that includes experts, citizens and other

stakeholders in order to receive more comprehensive advice and opinions regarding waterworks policies. However, the process of creating a comprehensive policymaking environment is still insufficient.

City Councils decide and monitor matters related to policy execution, and budgets and accounts.

The lack of waterworks expertise shared by both the local and central governments will most likely have a negative impact in creating an effective and progressive water resource management. In particular, the gap of administrative and technical expertise caused by the mass retirement of the baby boomer generation within the governments will cause difficulties in creating an efficient water resource management for the time being. In addition, the short department turnover period of public servants in the Korean governments is regarded as one of the primary reasons behind the difficulty in achieving policy continuity and fostering technical expertise.

In order for decision-making in water resource management to be more efficient and sustainable, it is necessary to create an institutional structure that allows for various stakeholders to participate in the decision making processes, and ensures that policies and decisions are carried out continuously without interruption. Additionally, there should be an institutional structure to prevent wasteful behaviors in policymaking and implementation, such as scrapping policies or modifying the direction of the policies because of political orientation. It is also essential, in order to ensure an efficient and sustainable water resource management, to build an institutional structure that fosters continued communication between the implementing agents of the policy, and the citizens and stakeholders that will be affected by the policy.

3. Measures and Solutions

3.1 Policy and Regulation

The expansion of impermeable areas due to urbanization is one of the factors that makes urban drainage management difficult. These difficulties could be managed by utilizing porous pavements or rainwater infiltration facilities. In order to expand rainwater infiltration, Seoul adopted theLow Impact Development (LID[6]) consultation process, which regulates the private and public constructors to procure a certain degree of rainwater collection feature into the constructed buildings and urban infrastructure.

[6] To keep the state of water cycle changing due to development similar to a pre-development state as much as possible by using environment-friendly method. Design and design techniques to keep natural facilities and hydrologic functions similar to the hydrologic characteristics before the urbanization regarding problems occurred by hydrologic characteristics, which is changing because of urbanization. [US EPA] (Ministry of environment, 2013)

Seoul currently provides assistance for the expansion of rainwater harvesting facilities. For example, private home owners that build rainwater harvesting facilities in their houses are subsidized by the Seoul government for up to 90% of the construction cost. Seoul is also considering a policy that will reduce its water tariffs for consumers that reduce water usage by either utilizing rainwater collection, or by utilizing graywater.

In addition, Seoul supports rainwater collection pilot project villages by providing rainwater collection, infiltration, and utilization facilities at a neighborhood level (Department of Water Cycle and Safety, 2016). Seoul also holds an annual Water Cycle Expo and public debates to ensure open communication with its citizens regarding Seoul‘s water policy, and to discover possible policies that Seoul may consider implementing.

3.2 Technical Solutions and Examples

3.2.1 Urban Water Resource Management for Flood Preparedness:

In order to address problems related to drainage such as flood and stormwater drainage, Seoul extended the probability of precipitation for the design and operation of its urban drainage system from 10 years to 30 years[7]. In addition, stormwater retentionbasins are installed on pre-existing pipelines to address problems regarding urban drainage system. In addition, retention basins for combined sewer overflows (CSOs) are installed in wastewater treatment facilities to address water quality problems caused by non-point sources of water pollution in cities.

As of 2016, the total capacity of rainwater storage tanks in Seoul is 254,480 m^3, and the city is planning to double the capacity by 2021 (increasing the capacity ro253,475 m^3). Since 2013, Seoul has implemented the Total Maximum Daily Load (TMDL). The pollution loading by CSOs reaches 60% of the total pollution emission. To keep this at an acceptable level, Seoul is pushing ahead with a plan to gradually expand the capacity of CSOs‘ stormwater retention basins from the current capacity of 11,700 m^3 to 235,700 m^3 by 2024. CSOs occurring during heavy rainfall are stored in the CSOs retention basins installed in underground reservoirs. Stored CSOs are then transferred to wastewater treatment plants, and it is processed once the weather conditions improve.

3.2.2 Securing Alternative Water Resources for Drought Preparedness and Establishing a Sustainable Water Cycle System:

Seoul supplies its tap water through reservoirs systems. The purposes of operation of water reservoirs are to utilize energy efficiently to supply tap water, and to build a consistent drinking water supply system.

[7] Currently branch lines should be designed in preparedness of five years of rainfall frequency and main lines 10 years. The years will be extended to 10 years for branch lines and 30 years for main lines when designs are developed.

As of 2016, Seoul operates102 reservoirs, with a total capacity of 2,420,000m^3. With this capacity, Seoul is able to provide drinking water to its citizens up to 17 hours without tap water supply from connected water treatment plants. Of course, if water is rationed to the population in emergency, Seoul will be able to supply water for much longer. City of Seoul aims to expand its reservoir capacity to ensure 24 hours of uninterrupted water supply to its citizens, and it will construct two more reservoirs to add 18,300m^3 to its water supply capacity.

The Han River is the primary source of drinking water for Seoul. Although the Han River provides plenty of water, it is vulnerable to droughts and contamination; adequate risk management plans are required to mitigate these risks. It is worth noting that the Han River experienced a severe drought in between 2013 and 2015, and in November 2015 the discharge from Paldang Dam, which accounts for most of the Han River‘s flow, fell to 50CMS. If the flow of the Han River is 50 CMS, Seoul‘s water intake for tap water production accounts for 71% of the total flow of the Han River. Therefore, securing alternative water resources is a very real and urgent issue for Seoul. The city of Seoul regards water reuse as a valid water source alternative. Water reuse includes rainwater harvesting, graywater use, and wastewater reclamation. Although Seoul‘s water reuse rate was about 4% in 2010, the city is planning to increase this figure to 14.4% of the total water capacity, or 1,454,097,000m^3/year, by 2020. Seoul will increase the reuse rate of rainwater from 393,000 m^3/year in 2010 to 2,400,000 m^3/year in 2020, wastewater from 2,837,000 m^3/year to 18,351,00 m^3/year, and sewage from 47,266,000m^3/year to 188,069,000 m^3/year (Kim et al., 2013).

As for ground water, out of 160,000m^3/day of groundwater discharge generated from subway and others, only about 67% (11,000m^3/day) was utilized in 2015. Approximately 94% of this water is used for maintaining streams, and the rest is used for buildings and landscaping.

3.2.3 Securing the Water Quality to Cope with Climate Change:

Climate change causes problems in water quality too. The average water quality of the Han River has improved; however, urbanization and population growth have led to eutrophication. Additionally, rising temperature and flow rate reduction, caused by climate change, led to harmful algal blooms. Seoul operates an algae alert system to effectively respond to water quality problems caused by algal blooms (Table 1). In 2015, algae warnings were issued for 89 days in upriver areas including source water protection areas, 112 days in downriver areas, and 19 days in source water protection areas in the Han River.

Table 1. Warning Level According to the Algae Alert System

Warning level	The number of blue-green algae cells [Cell/mL]
Watch	1,000 or more

Warning	10,000 or more
Massive outbreak	1,000,000 or more

There are two ways to respond to eutrophication and algal blooms: one is a removal of the cause, and the other is treatment after the outbreak. To get rid of the causes of eutrophication and algal blooms, the WWTPs for reducing nutrients, including total phosphorus and total nitrogen, are being built and operated in Seoul. Seoul carried out projects to constructed advanced treatment processes from 2004 to 2014. With the projects, complete waste-waterplants to remove the total phosphorous, with a total capacity of 4,370,000m^3/day, are installed. However, the project‘s purpose was to reduce the total phosphorus concentration of effluent of treatment plant to 2.0 mg/L. To meet the tightened water quality standard (total phosphorus 0.5 mg/L), Seoul planned to build tertiary total phosphorus treatment facilities. The construction for these facilities is currently underway, and when the construction is completed in 2018, the total treatment capacity of Seoul will be 1,750,000m^3/day.

To control drinking water quality after algae blooms occur, Seoul built advanced water treatment facilities, with a total capacity of 380,000 m^3/day, at the six water treatment plants from 2007 to 2015. As a result, citizens are able to use clean and safe tap water without being affected by algal blooms. The advanced water treatment technology adopted by Seoul is based on post-ozonation and a granular activated carbon (GAC) adsorption process. The current purpose of the advanced water treatment process is to remove the taste and odorgenerated by algal blooms. However, the process can also be used to control toxin and micro pollutants such as PPCPs and EDCs as well. Currently, optimization research and development are underway to improve the efficiency of the advanced water treatment processes.

A decline in microbiological water quality must be addressed in order to manage Seoul‘s water resources. In addition to the control of algal bloom, Seoul is conducting research studies on new micro organisms, occurring with algal blooms, such as pectinatellamagnifica. Due to societal changes such as urbanization, population increase and aging population, coupled with misuse and abuse of PPCPs, antibiotic resistant bacteria (ARB), though rare, has occasionally been detected in streams in the Southern Korean Peninsula. Seoul is undertaking basic research on this matter.

3.2.4 Water-Energy-RiskNexus:

In the case of the United States, 3% of total energy use goes to the operation of waterworks and sewage systems. (Fillmore, 2010) In Korea, energy used by the water sector was 1.02% of total energy use in 2013. (Choi, 2015b) In Seoul, the water sector used around 1.7% of the total energy use (Figure 9).

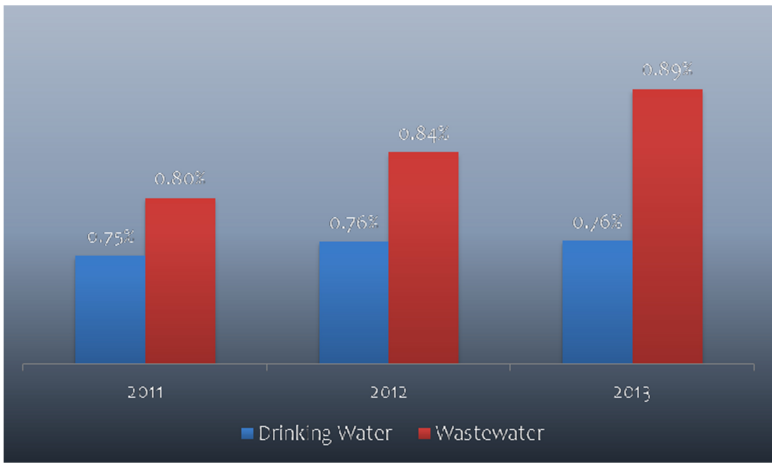


Figure 9. Energy Use Rate of Seoul's Water Resources Sector(Choi, 2015b)

As shown above, water and energy are inseparable, and they have an effect on each other because of their mutual dependence. For example, energy generation, such as livestock farming, biofuel production, extraction of oil and gas, and cooling of thermal power, uses a large amount of water. Conversely, extraction, transfer, treatment, and use of water resources to satisfy water demand in cities require a large amount of energy. (USGAO, 2012)

For sustainable water resource management, Seoul is making a number of efforts to establish anefficient Water-Energy NEXUS. The most notable aspect of this is the renewable energy sector. The total energy generation capacity of solar power generating facilities, built at the six water treatmentplants in Seoul, is 11,810 kW (Figure 10).

Figure 10. Photovoltaic Power Generation Module Installed on the Top of Sedimentation Basin at a Water Treatment Plant in Seoul[8]

Seoul has many hilly areas. Seoul utilizes small hydropower plants to take advantage of its distinct topographical characteristics (Figure 11). Seoul has a plan to increase the capacity of small hydro powerplants to 680kW by 2016. The city also plans to procure the total capacity of 2,930 kW from its geothermal system.

[8] http://image.fnnews.com/resource/media/image/2013/07/31/201307310320077671_l.jpg

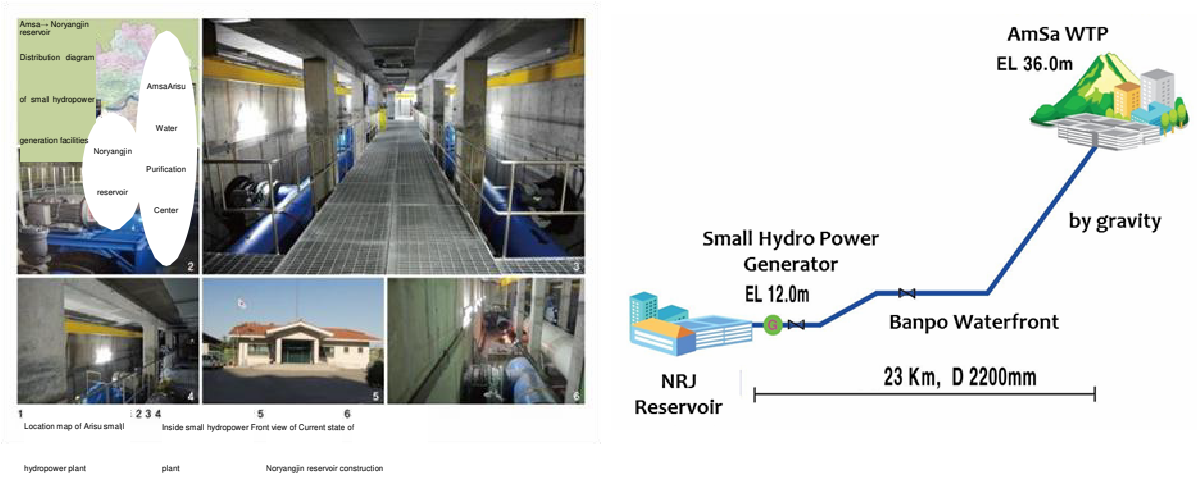


Figure 11. Seoul Small Hydro Power Plant(left) and Schematic Diagramof the System (right)[9]

Wastewater mainly consists of organic substances. Therefore, it can be said that wastewater itself is an energy source. There are many energy self-sufficient wastewater treatment plants operated in Europe.

Seoul‘s wastewater treatment plants produce energy in a variety of forms. Energy generated in the wastewater treatment plants come from bio-gas, wastewater heat, sludge, photovoltaic power, and heat from processes.

Bio-gas is utilized in the greatest numberof ways. The amount of bio-gas used for cogeneration is 8.9 MW, liquefied natural gas(LNG) output is 16,000 m^3per day, and compressed natural gas (CNG) output is about 4,000m^3 per day. The amount of bio-gas generated from food waste is 9,300m^3. The capacity of small hydropower generation using waterfall of the effluent from the wastewater treatment plants is 0.5MW. Dried sludge can be used as fuel for thermoelectric power plants, and approximately 43,000 tons of dried sludge is produced per year. Photovoltaic power generation using the top of settling tanks in wastewater treatment plants are being attempted to make use of the large surface area available on top of the settling tanks, and its power production capacity is about 5MW (Table 2).

Table 2. Seoul’s Sewage Treatment Facilities’ New Renewable Energy Output

Energy	Project	Capacity [TOE]	Economic feasibility [10^3 USD/yr]

[9] Left: http://www.energy.co.kr/images_atl/000/000/007/000000007597/000000007597-0001.jpg, Right: https://seoulsolution.kr/sites/default/files/images/image00003(8).jpg

Bio-gas	Cogeneration plant (8.9 MW)	Electricity: 56,390 MWh/yr	11,898	4,526
		Heat: 66,924 Gcal/yr	6,692	
	City gas	LNG: 16,000 m^3/day	5,507	1,749
	Vehicle fuel	CNG: 4,000 m^3/day	1,377	182
	Food waste treatment	Bio-gas: 9,303 m^3/day	1,596	530
Effluent flow	Small Hydropower	Electricity: 0.46 MW	384	122
	Wastewater Heat	Heat: 95 Gcal/hr	35,157	1,386
Dried Sludge	Fuel for Thermal Power Generation	43,000 ton/yr	12,900	391
Space	Solar PV	Electricity: 5 MW	1,253	50
Waste Heat	Drier, boiler		2,057	
Total			78,821	8,936

Resource recovery from wastewater is also being attempted as a pilot project. Phosphate is considered extremely valuable as it is closely related to food resources. Seoul developed a technology that can recover phosphorous from wastewater, and completed verifying its uses as fertilizer. Now, Seoul is undergoing a feasibility study with the fertilizers from the recovered phosphorous.

3.2.5 Smart Water Grid:

Smart City is another functional objective that Seoul is pursuing. While there are varying definitions of a Smart City, it can be defined as an efficient city system based on ICT. Seoul‘s water system is one of the important elements of a smart city.

Although it is not yet implemented in the field due to economic and societal concerns, Seoul completed developing the Integrated Smart Metering System, and has passed a number of pilot projects.These efforts were recognized by the International Water Association, and the Integrated Smart Metering System was awarded the Project Innovation Award in 2012. In addition, citizens in general, as well as system operators, can check the water quality of tap water of Seoul anytime and anywhere. This is done through a real-time water quality monitoring system, also known as Seoul Water-Now system, installed in 2007 and opened to the public since 2011 through preliminary operations (Figure 12). Furthermore, by integrating the water pressure monitoring systems, flow, water levels, and image monitoring system in the field, and operating them integrally, Seoul has completed the first stage of the smart water management system (Figure 13).

Figure 12. Water Quality Monitoring System of Seoul's Tap Water. Seoul Water Now System

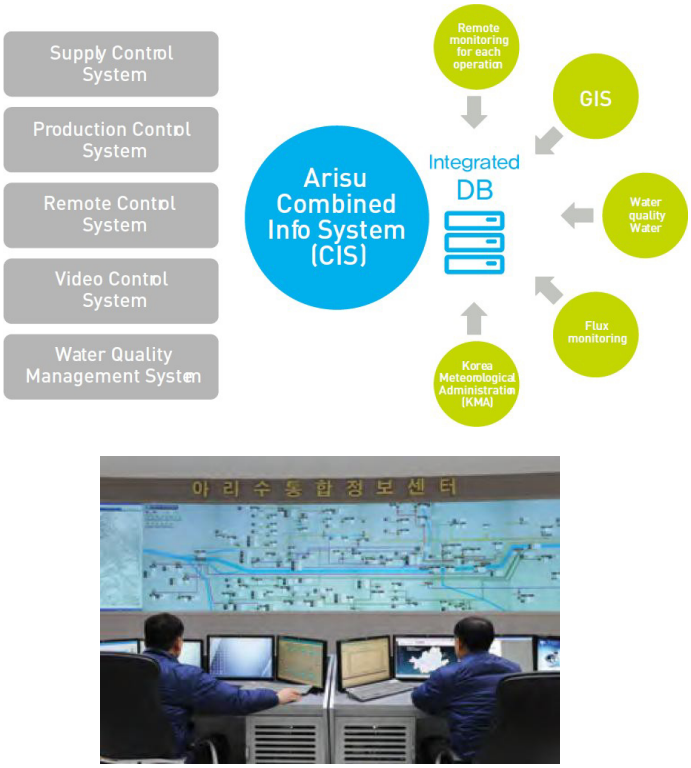


Figure 13. Composition of Seoul Waterworks Integrated Management System (left) and Integrated Information Center (right)

In order to ensure that a city's water resource system is sustainable, an integrated management system is needed. To achieve this, integration of urban energy and water resources based on Water-Energy Nexus are needed, and a management system must be established.

In terms of integrated management of a city's water resources, Nexus should notbe limited to water and energy, but it should also include risk management. In Seoul, a

research on disaster management system concerning water resource management is currently going underway in order to expand the scope of urban water management to include energy and safety.

4. Effect

Water resources are simultaneously economic goods and public goods; it is an essential element for life and all people should be able to use it without discrimination.

Across the ages and in all countries of the world, in order to build an urban community, water resources enough to support the people in the community was neccessary.

In this sense, efficient and sustainable urban water resource management has a significant effect on environment, society, economy, and all other areas.

In regards to the environment, a city can secure resilience and sustainability of its environment by restoring and sustaining a healthy water cycle system.

Seoul maintains the sustainability of its water environment by returning used water resources to a natural state as much as possible through wastewater works and treatment systems. Seoul is also improving the resilience of the urban environment by improving the energy self-sufficient wastewater treatment system in Seoul, and as a result mitigating the problems arising from carbon emissions in Seoul.

To secure a satisfactory supply ofwater is essential factor in realizing urban water welfare. Seoul made technological, and as well as policy, efforts to build a system that allows all citizens access to water resources as a fundamentally necessary right, without economic and social discrimination. This system created a foundation for justice and livable environments in Seoul where citizens can sustain free and safe lives.

As discussed above, Seoul made technological, as well as policy efforts to establish an efficient and sustainable urban water resource management system. By doing so, Seoul raised awareness for the concept that an urban water resource system is not only a treatment system, but also a production system of resources and energy. This means that, on top of the reliability of urban water resource system, the efficiency and economic feasibility should be both the purpose and the objective of the system as well. Seoul‘s water system is achieving enormous economic effects through direct energy generation, as well as energy-saving and resource recovery.

In addition, it should be noted that the social utility gained by securing a safe and reliable water resource, in both quality and quantity, have an immeasurable value.

5. Inspiration and Suggestions

Seoul's water management policy was focused on the quantity of water resources during its early stage of urbanization and growth period. As Seoul entered a more stable phase in its development, it focused its efforts water quality. After the city managed social and economic stability, Seoul focused its efforts towards improving the efficiency of the water production and its supply system.In the future, the main objective of Seoul's urban water resource management will be ensuring sustainability of its operations.

Sustainability of a city can be secured only when social, environmental, and economic conditions are met. Meeting each conditions guarantees resilience, self-reliance, and social justice (Figure 14). The city's sustainability is achieved when these results are manifested at the same time (Figure 15).

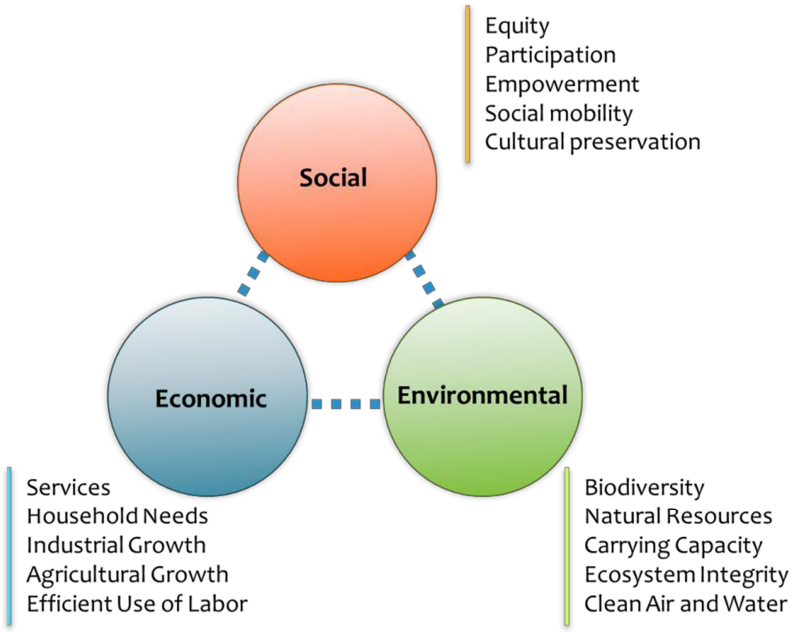


Figure 14. Conditions and Details for Sustainability (Choi, 2016)

Figure 15. Correlation Between Sustainability and its Components (D'Amato, et al., 2016)

The establishment of a sustainable urban water management system is one of the major issues for Seoul. However, it is also an issue for humanity, which has to be carried out in other cities, countries, and all over the world.

The strength of Seoul's water management system is the broad spectrum of its technical and policy experience, and achievements, accumulated over a relatively short period of time (roughly 50 years, from the 1960s to today).

Seoul is making efforts to share such experiences and achievements with other cities around the world and further develop them together. Through collaboration with other cities, Seoul's experience and achievements will undoubtedly obtain a greater value for the city and the world at large.

References

Fillmore, L., 2010, **Sustainable Treatment: Best Practice from the Strass imZillertal Wastewater Treatment Plant**, Water Environment Research Foundation

Morrow, M., 2016, **America's Water Infrastructure Is in Need of a Major Overhaul**, Fox Business, http://www.foxbusiness.com/features/2016/01/28/america-s-water-infrastructure-is-in-need-major-overhaul.html

United States Government Accountability Office, 2012, **Energy-Water NEXUS: Coordinated Federal Approach Needed to Better Manage Energy and Water Tradeoffs**, Report to the Ranking Member, Committee on Science, Space, and Technology, House of Representatives

Kim Yeongran, 2012, **Urbanization's effects on water cycle and the current condition of Seoul**, 2012 Water Cycle City forum

Kim Yeongran, Hwang Seonghwan, SimJuyeong, Kim Ayeong, 2013, **Seoul's water reuse management plan**, The Seoul Institute

Kim Jaeseop, 2016, **Seoul, put 306.9 billion won in expanding immediate sewage maintenance**, Gukjenews(http://www.gukjenews.com/news/articleView.html?idxno=442987)

Kim Jingeun, 2016, **Management of waterworks facility assets and tap water causticity**, Ministry of environment water pipe network causticity management experts forum Department of Water Cycle Safety, 2016, 2016 Major performances reports of 268th Regular meeting of the municipal assembly

Office of Waterworks, 2008, **A hundred years history of Seoul's waterworks(1908~2008)**, Seoul Metropolitan Government

Office of Waterworks, 2009, **white paper of Office of Waterworks Seoul Metropolitan Government – Arisu, 20 years of challenges and vision**, Seoul Metropolitan Government

Wikipedia, 2016, **Seoul Metropolitan Government**(https://ko.wikipedia.org/wiki/%EC%84%9C%EC%9A%B8%ED%8A%B9%EB%B3%84%EC%8B%9C)

Choi Young June, 2015a, **Water-Energy NEXUS in Seoul**, The 7th World Water Forum, Daegu, Korea

Choi Young June, 2015b, **Seoul's water management policy**, Seoul Solution(https://goo.gl/TpjHVY)

Choi Young June, 2016, **Sustainable Water Management of Seoul, International Forum on Urban Policy for SDG's**, UNESCAP, CityNet and Seoul Metropolitan Government, Seoul, Korea

Ministry of environment, 2013, **Manual for Low Impact Development (LID)technique application for environmental effects evaluation**

Water System Management and Practice in Chizhou City

Zou Tao[10]

Abstract: As one of the pilot sponge cities in China, for over a decade, Chizhou has studied the solutions needed to fix the problems existing in the urban water system. We have realized our set goals through many kinds of projects and administrative measures, including policy-making, mechanism-coordination, as well as inspiring measures. This article focuses on the Qingxi River regulation project, which focuses on the comprehensive improvement of the river's water environment. The project links up the water system of main urban areas as well as sponge city demonstration areas construction. Finally, we discuss a series of relevant supporting measures as examples, analyzing the experience of related issues of the management of city water system and putting forward some suggestions.

Keywords: Urban water system, Management, Practice, Chizhou

1.Background Information about Chizhou City

1.1Brief Introduction

Chizhou is located in the southeast of Anhui province, separated from Anqing by a river. Chizhou adjoins Huangshan in the southand Jiujiang city in the southeast, which belongs to Jiangxi province. To the north and northeast, the city borders Wuhu, Tongling, and Xuancheng respectively. As one of the most important port cities, Binjiang is also a famous and historical provincial and cultural city. Chizhou is also an indispensable part of 'Two-Mountain, One-Lake' tour site (Referring to Mount Huang,Mount Jiuhua and Taiping Lake). Covering an area of 8,272 square kilometers, Chizhou has a population of 1.62 million, and administrates 4 counties: Guichi, Dongzhi, Shitai, and Qingyang.

Chizhou is well-known for its beautiful eco-environment and is thus touted as 'Natural Oxygen Bar'. Here, forest coverage reaches 60%, and the water quality of the main rivers achieves excellence, and so does the annual air-quality. In built-up urban areas, the green coverage rate has reached 43.4%, green land rate of 38.4% and per capita public area of 13.1 m^2.Such fine environmental quality, which is one of the best among central and eastern regions, makes Chizhou a suitable place for living.

This region belongs to warm and humid subtropical monsoon climate, with warm weather, four seasons, and abundant rainfall. The southern mountains framework, consisting of Mount Jiuhua and Guniujiang (a famous mountain) and others in the southeast, is a component part of mountain areas of southern Anhui

[10]Zou Tao: Director of Ecological Division of T-H-U-P-D-i

province. The central parts are hilly-regions and northwest zone consists of river delta polders, which are low and flat, with criss-crossing rivers and lakes. Influenced by east China monsoon and southwest warm and humid airflow, Chizhou is moist and rich in rainfall, with an annual average rain volume of 1400mm to 2200mm. Besides, the total water resources volume reaches 6.37 billion m^3, accounting for 11% of the whole province‘s rainfall.

There are three major river systems and ten rivers in this area, thereinto, the part of Yangtze River, which flows through Chizhou, is as long as 162 km, while Qiupu and other 6 rivers pour into the Yangtze River. As a typical agricultural and water conservancy metropolitan center, Chizhou owns 377 small and medium-sized reservoirs,15 polders each of which is over ten thousand mu while 63 polders each over one to ten thousand mu, and 56 watergates linking the river.

Figure 1 a View in Chizhou City

Water systems in main area of Chizhou are well developed, and the waters are wide. The Yangtze River flows towards east through the north of this area, in the south there are lakes and wetlands including the Moon Lake, Qishan Lake and the Heaven Lake. Baiyang River pours into the Yangtze River through the west while Qingxi River crosses the region from the south to the north, and Pingtian Lake is placed in the centre. All of this reflects a unique city structure: near the rivers and lakes, while surrounded by the mountains and waters[1].

Since Chizhou resumed its regional system in 1988, it has been prioritizing eco-development and has made great strides in that area. In 1997, Chizhou City was listed as one of the pilot area programs, by the State Development Planning Commission (SDPC), for carrying out ‒China‘s Agenda 21‖.The 1998, it was billed, by the United Nations Environment Programme (UNEP), as one of the six key institutions to implement the capacity building programs mentioned in the agenda. In 2000, the city was approved to be a National Ecological Economic Zone by the State Environment Protection Administration (SEPA). Four years later, in 2004, it became one of the three comprehensive demonstration bases for ecological construction in Anhui, and in 2008, it is initiated the Habitat Scroll of Honor Award of Anhui‖. Just one year later, the city was dubbed a National Garden City by the Ministry of

Construction[2]. At the end of 2012, Chizhou's Heaven Lake District became one of the first cities to be named as a "National Green Ecological Demonstration Area''. One year later, Chizhou was billed as "National Forest City,'' as well as awarded „the Habitat Scroll of Honor Award in China". Most recently, in 2015, it became a 'Sponge City' pilot area.

1.1 Accounts of Difficulties and Challenges the Urban Water System Faces Before this Case's Implementation

One of the biggest problems the city now faces is the extremely uneven space-time distribution of water resources. Although the city is abundant in the average annual rainfall, rainfall mainly concentrates during April to July, andannual change is variable.Meanwhile, rainfall variesgreatly in different areas.The hilly regions are drier than the polders.[3] Since the uneven space-time distribution of rainfall, Chizhou is frequently suffering from drought and flood. There is even record of several such disasters in one year. According to statistics, since the establishment of P.R.C, on average, flooding in this city happens once every 3-4 years,and drought once 5-6 every years[4] which has hindered the city's socioeconomic development.
The long-term water system issues faced by Chizhou include the following four challenges.

1.1.1 River andLake Water System's GradualSolation and Fragmentation

Historically, Chizhou was surrounded by water, and the water systems linked up with each other. When flood periods came, the rivers and lakes joined, while they were separated only in the dry season.[5] After liberation, Chizhou, without urban flood-control facilities, suffered from Baiyang River flooding form the inside and river water intrusion from the outside. As the land flooded, traffic was disrupted, people had to row in the street, and oncomelania was everywhere, making the residents suffer from diseases and waterlog.

After the establishment of P.R.C, Chizhou strongly promoted water conservancy construction. In the 1960s, in order to prevent schistosomiasis and kill oncomelania through reclamation projects, Chizhou built Baiyang River dyke, Pingtian Lake dyke, and Chengqu River dyke in the east, north, and west, respectively. The route of Baiyang River's merger into the Yangtze River was changed. The merger no longer took place downstream from the Yunzifan dyke, but around the mountain of the western city. The old path became an urban inland river, named the Qingxi River. Enlargement of the water courses of Pingtian Lake, led to the east and south parts becoming South Lake and Qishan Lake. The original connected natural water system, gradually became separate water systems we know today as: Qiupu River, Baiyang River, Qingxi River, Pingtian Lake and South Lake.

In the 1980s and 90s, due to road construction and urban development, the Qingxi River was cut off in the South Gate Roundabout, resulting in Lake Road, Qiupudong road, Baiya road, and Qingfeng road, which were further cut off

from the hydrological cycle, becoming „stagnant water".

During the flood season in 1983,1996 and 1999, when Chizhou suffered from above-averageflooding, Pingtian Lake, which can store 75km^2 of outside water, diverted the floodwater into the city, forming a world of waters and causing gigantic losses. People no longer lived near the river, and were even afraid of it. The problem of excess waste and pollution of the water, as well as the contradiction between flood and land for local people, had restricted the economic and social development of the city.

1.1.2 Urban Water Bodies' Contamination and Water-Quality's Deterioration

There was a time when aquaculture was the main characteristic of city water. People put excessive organic feed into the lake. Meanwhile, with the growth of the population, mismanagement to city planning and residents' low environment consciousness, sewage and garbage were all poured into the lakes and rivers, further polluting them. As a result, the original beautiful and clean waters became heavily polluted.

On the other hand, urbanization reduced the natural ecological buffers. The erosion of the surface by the early rains caused non-point source pollution. Sometimes, certain sections of the river's water quality exceeded class IV, even class V levels of contamination. Seasonal water shortages inseveral urban riversand insufficient flow decreased the ability of the stream's self-purification. The numerical value of the main characteristic contaminant trended to increase year by year, and the risk of water quality deterioration became higher and higher[6].

1.1.3 Serious Water Shortage Lead by Bad Water Quality and Single Reserve Water Sources

According to the water consumption situation, the guaranteed rate of water supply was too low. Further, there existed a problem with water shortage caused by bad water quality. Although there were large volumes of source water, water supply in Chizhou depended mainly on surface water, which was greatly affected by runoff variation. Meanwhile, with the lack of reserve water sources, once minimum flow or pollution appeared, water supply would be interrupted. It showed that the problem of water pollution was serious, and that water shortage due to bad water quality was obvious.

Pingtian Lake was the only reserve water source region in Chizhou city. The pollution in this basin did not come from industry, but from residents' life,agricultural non-point sources, such as livestock and poultry farming, and aquaculture. Serious pollution of Pingtian Lake influenced the security of the urban water supply. It was necessary to take effective measures to restore the lakes ecology, strengthen the construction of water conservation, and reinforce the protection of water source field.

1.1.4 Urgent Developmentof City Drainage Standards

The acceleration of urbanization, serious ground-hardening, and encroached river regulation and storage weakened the regulatory functions of the natural system and caused water logging. While the imperfect urban drainage system and the low drainage pipe-network construction standard made it hard to drain the water off quickly. Waterlogged areas in the central region were up to 228 sites, and the old town location was the most serious place of pooling. Chizhou City was threatened by both floods from Yangtze River‘s natural cycle, and from the seasonal flooding of the river‘s upper reaches. On one hand, the Yangtze River level raised the downstream section. On the other hand, the flash floods from the upper reaches of the river, without effective control, made the disasters of the downstream areas heavier.

2 Administrators’ Thoughts and Decision-Making

2.1 Urban Managers’ Thinking about the Urban Water System

Closely linked to the stage and the level of the regional socioeconomic development, urban water systems require complicated system engineering that involves many aspects.

Since Chizhou resumed its regional governance system in the 1980s, politicians of every session of the party committee and level of the government have been emphasizing development of foundations and long-run developments, based on the location‘s original healthy ecological environment. In the early 1990s, Chizhou proposed such thoughts as, “You cannot manage the city if you cannot keep good waters and hills”. At the end of 1990s, the message became, “Base on blue hills and clean waters, to develop ecological economy”. During the period of the 10th Five-Year Plan, Chizhou established the strategy of “Constructing the city with the ecological concept”, while the 11th Five-Year Plan, “Develop without sacrificing our ecology”.In 2012,Chizhou came up with the planof building an Ecological Civilization Demonstration City. With Chizhou‘s ecology taking aprominent position, clearer direction and more positive effects began taking place.

With the guidance of “Ecological concept” strategy, the encouragment and support of relative national departments, as well as the promotions and suggestions of the Municipal People‘s Representatives, Chizhou, after analyzing and reconsidering the problems of urban water system objectively, has been positively tackling the challenge.

2l.l Facing the Renovation of Qingxi River

The problems of river siltation, serious pollution, and squalor of Qingxi River were described at the second session of the first Municipal People‘s Congress of 2002. Local deputies highlighted the issues of improving the Qingxi River, which, as the only bill of the session, drew attention of the committee and the government. After the council, the government listed the comprehensive renovation works of Qingxi

River as the No.1 program in Chizhou, and planned to fulfill the task in 3 periods, within 3 years, with an investment of 0.3 billion yuan[7].

2.2 Deep Reflection on Problems Lead by Lake and River System's Isolation and Encroachment

In 2008, Chizhou scholar Tan Jiasheng and others delivered an essay called *Development of Dyke-building and Its Impact on Ecological Environment in Chizhou Prefecture of Anhui Province in Modern Times*[8]. In this text, the author deeply analyzed the pros and cons of polders' development, which had risen since the late Qing Dynasty and early Republic China.

On one hand, the behavior changed the appearance of the intertidal zone and improved the eco-environment. However, on the other hand, the polders caused major problems. The polders dictated the water's flow and the river-width was narrowed, causing frequent flooding.As the river changed course, it began to become silted, leading to the unbalance of aquatic eco-system. This article used historical records to analyze the problem of eco-safety caused by lake-river system change, and criticized the enclosure movement for urbanization, which resulted in the further shrinkage of area for the fragile natural water systems. This shrinkage in turn lead to further developmental imbalance. Other authors from the Chizhou water authority demonstrated that the research on this issue had to be discussed in the relative administrative departments. One year later, Chizhou put forward a comprehensive water environment remediation plan. The plan would includere linking of original river system in main urban area, increasing remediation efforts on the city's main water system, and improving flood prevention standards.

2.3 Combine with New Ideas to Explore Innovative Systematic Solutions

Realizing improved environmental regulation of the river environment and re-connection of the natural river systems would allow Chinato put forward various targets and measures for building "sponge cities". Facing the historic opportunity, Chizhou city set a new goal; Build into a new model for the small and medium citiesand play a demonstration role for the Bin Jiang port cities. Zhao Xinqun, Party Secretary of Chizhou, said that we would promote the quality of urban construction on the basis of our own needs, using the advanced principle of "sponge city" development and construction. We would especially include this idea, and relative technical concepts, into the planning for construction. We would also blend the "sponge city" principles into the strategy of building an ecological city, and include it into all aspects of urban construction and management[9] .

However, director from Urban-Construction and Environment, Resource and Science Department, Zhu Lin, believed that the building of sponge city, which is a complex undertaking, should be considered further. For urbanized areas, comprehensive management to rain-flood not only relates to the traditional construction of water pipelines, but also impacts the coordination among the city's

development patterns, programming, and land utilization. Chizhou is now striving towards a new direction to systematically solve this problem.

2.2 Proposed Solutions

2.2.1 Restore the Watercourses to Maintain the Health of the River's Ecosystem

Maintaining the river's health is an logical progression of the water-regulation ideas and concepts. A healthy river means a complete hydrological cycle, sufficient amounts of water in the system, restoration of natural hydrological flows, and good water quality. Additionally, the condition of river-bank and river-bed should be returned to a natural state, further helping to returning the ecosystem's natural stability and gradual changes. Finally, focusing on providing the conditions for a return of native plants and animals, especially aquatic life, should be abundant and various.

The socio-economic value of healthy rivers lies in meeting the needs of life surrounding the river system. The visual target Chizhou wants to reach is clean rivers, green banks, and beautiful city. Meanwhile, residents can feel the beautiful artistic conception, as the poet Libai described in his poem: "The water of Qingxi River can purify my heart, because the color of the water is totally different from the others."

Figure 2 Water View in Chizhou

The main task of river restoration is to improve the hydrologic and ecologic conditions. This will be accomplished by maintaining the natural water volume of the rivers through water resource dispatching, improving the river's water quality through proper sewage disposal and wastewater discharge controls, and finally, restore the cities rivers and ditch networks to keep vertical and horizontal waterways open, in order to avoid stereoplasm and singleness of riverbed materials, which will benefit the growth of aquatic plants and fish habitat.

2.2.2Link-up Water Systems, Integrate Demands and Do Well on Water Problems

In order to make Chizhou, a thousand-year old ancient city, reflect its former beauty, described as, "A city of landscape, a landscape of city, " the following steps will be taken: link up the river and lake system, improved hydrological

environment, and insistence on the new concept of “restoring the river morphology, cutting-through the drainage, improving the ability of flood-control and security,bettering the river-lake water quality, and creating a tourist environment”. This process will rely on innovative planning and construction systems, involving multiple departments, and taking engineering measures to renovate the Qingxi River. Combining these steps with river-lake water systems cutting-through and renovation, we intend to promote the river‘s natural abilities of flood-control, ensuring water security, and improved water environment. This will further help to realize the controllability, usability, and transferability of water quality and water volume, and advance the development of urban ecological water conservation in the city.

Abandoning the traditional planning concept of cutting through river-lake systems, Chizhou integrated the complex demands of water conservation, municipal works, tourism, traffic and landscape. With the targets of fully utilizing water sources, improving on water problems, and creating a suitable city for residents and tourism, Chizhou came to the conclusion of linking-up the river-lake, integrating scenic spots, building nodes, rebuilding the bridge and returning aquaculture to lake, in order to make the urban water alive, flowing and attractive.

2.2.3 Break Through Traditional Flood Management Ideas, and Build a New Model of Sponge City

Ecological construction has been the focus of Chizhou City‘s work in the long term, while the construction of sponge city complements the general idea of an ecological Chizhou. As the first national pilot area of the state ecological economic demonstration region, Chizhou‘s construction has been devoted to maintaining the ecological sensitive areas of rivers, lakes, wetlands, ponds, and ditches. The plans take advantage of linking up a natural drainage system, improving the capacity for self-repair of the ecological system, and keeping the city‘s water environment healthy. The superior natural environment in Chizhou, which are mainly hinterland forests and wetlands along the river (characterized by the suitable climate, undulating terrain, and developed water systems) are abundant ecological sources. The natural conditions, together with Chizhou‘s continuous protection and conservation plans make the region a natural location for the sponge city framework.

Figure 3 Garden in the City

In building the sponge city concept must overcome the problem of drainage and flood-prevention during the annual flood season, as well as waterlogging during rainy seasons. Chizhou must solve these problems by breaking through the traditional rainfall-flood management concept of "draining is the first task". Therefore, Chizhou has proposed using sponge-city construction to find solutions to the main problems concerning the water-environment in the Binjiang port cities. The contradiction between environmental protection and the city's development, the matters of integrating urbanization and sponge-city concepts, and the issues between monitoring and controlling the water environment, must be reconciled to realize an orderly sponge-city construction plan.

3Countermeasure and Solutions

3.1 Government Administration and Mechanisms-Coordination

3.1.1 Representatives of People's Congress Actively Supervise and Leadership Attention

In 2002, under the strong appeal and suggestion of all representatives, the project of comprehensive renovation of the Qingxi River was listed as the No.1 bill in the second session of the first Municipal People's Congress of Chizhou. Although Chizhou was just established as a prefecture level of city at the beginning of the century, all future actions were to be undertaken and financial resources were fragile. Even with these constraints, municipal leaders paid close attention to the implementation of the bill, raised money, and decided to continue with plans to renovate the river, devoting ¥300 million over three years to the project.

With active supervision of the deputies from two sessions' municipal party committees and the unremitting endeavor of the municipal government, finally the staged achievements on comprehensive renovation were gained. In order to recreate the landscape as described in Libai's poem, "The water of Qingxi River can purify my heart, because the water colors is totally different from the others". In 2013, the municipal government invested heavily in the river and began the new round of water environment renovation.

As for the proposition of constructing a sponge city, the government set up a high-level group to form a comprehensive management pattern. The mayor put in charge, the vice-mayor-in-charge managed the specific issues, and the head of department implemented the program, to ensure the effective advance of the sponge city's construction.

3.1.2 The Government Organizes, the Experts Lead, Departments co-operate, and the Public Participates

Chizhou emphasized the direction of the experts very much during its work on

realizing the sponge city urban water system management. During the demonstration of the comprehensive renovation project of water environment in the central urban area, the municipal committee and government, proposed to further improve the ecological efficiency, the landscape efficiency, and the social efficiency without destroying the original urban ecology.They also hired many famous state and Anhui experts to investigate on-site. Finally, the experts formulated plans and targets for comprehensive renovation, put forward feasible solutions, and thus provided strong foundations and guarantees for the work. Meanwhile, the government took public opinion seriously,in accordance with the principle of the government organizing, the experts leading, departments co-operating, and the public participating, planning at a higher starting point, publicizing the scheme through networks and soliciting opinions from all circles of society.

3.3 Fully Play the Role of PPP Project (public-private partnership)

Chizhou main citysewage treatment and drainage facilities purchasing service PPP project (integration between sewage factories and sewer networks), which was called Chizhou PPP wastewater project, was the first one contracted among the 30 PPP projects proposed in 2004 by the Treasury Department. It was also the one listed as pilot project both by the Treasury Department and the Ministry of Housing. The Ministry of Housing strongly promoted the privatization of sewage pipe network and the combination between wastewater factories and the sewage pipe network, which further allowed for a breakthrough on the Chizhou project. This project relied on previous experience to find solutions for the difficulty of financing and application of social capital.[10]

Left: Go to Shenzhen Water Group to investigate the construction of urban drainage facilities

Right: Chizhou city sewage treatment and drainage facilities purchasing service tender

Figure 4. Relevant activities for Chizhou water management

The current situation of sewage disposal facilities in the main urban area of Chizhou city, and the requirements of “integration between sewage factory and sewer networks”, demands the creationof PPP adopting the combination of franchised business and government purchasing services.

3.2 Contents on Formed and Supported Policies, Regulations and Planning

3.2.1 Creating a Local Policy Environment Led by Ecological Civilization

Under the firm leadership of the committee and the government of Anhui province, and based on the guideline of "transforming comprehensively, accelerating emergence, flourishing the city, and enriching the people", Chizhou is vigorously implementing the developmental strategy of, "building the city with the eco-concept, developing the city through industry, flourishing the city by tourism, stimulating the city through commerce, and putting the city on the map with culture", and further strives for promoting the economic, political, cultural, social, and ecological development. In March 2002, Chizhou promulgated the *Decision on Accelerating Ecological Civil Construction,* which focused on the topic of five systems: eco-environment, industry, habitat, culture and rules. These decisions included requirements on the formulation of 40 indexes, 16 supporting policies, evaluation system, the requirements of paid-use resources and ecological compensation, and marketization mechanism, among others. Most of the 13 total items were detailed during this process. The *Decision* has specifically put forward the targets and measures related to urban water system management.

For example, during the construction of the Sponge City, Chizhou introduced incentives of up to ¥30 million for the development and construction of alow-impact rainwater system, to mobilize social capital investment in sponge city construction.

3.2.2 Scientific Planning, Guiding, and Advancment of Multi-Professionalism

In the early phases of implementing comprehensive renovation of the water environment, Chizhou emphasized the systematic participation of scientific experts specializing in water conservation, environmental conservation, and housing.

For the sponge city construction project, Chizhou has prepared and approved, the *Three-Year Implementation Plan on Sponge City Construction Pilot in Chizhou(2015-2017).* This process included the revision of a series of related sub-plans, and included the sponge city construction ideas from the comprehensive plan. These included planning for prevention of land erosion, green land creation, and the environmental renovation of Pingtian Lake and Qingxi River. What was particularly noteworthy was that the new Heaven Lake district was described as a "State Green Ecological Demonstration Region", one of only eight in China, and the only in Anhui Province. The plan prepared and approved the general planning mechanisms, and controlled detailed planning such as: architecture, municipal administration and energy according to green energy specifics, ecological and low-carbon concepts, and established the, *Indicator system and technical implementation guidelines on Chizhou Heaven Lake Green Demonstration District.* This plan included technical guidelines for low-impact implementation and gathered further experience for urban ecological construction of Chizhou.

3.2.3 Actively Introducing Social Capital,and Recommendations for A Demonstration Project

The relative departments in Chizhou have realized that the Sponge City project, in accordance with the Equator Bank Principals, was the focus of bank support projects, and can make use of the private capital directly, along while also incorporating social capital. Under the influence of the first nationally contracted PPP demonstration project, the Chizhou sewage treatment and municipal drainage facilities service project, and in order to get rid of the market access restrictions and develop the relationship between the government and private market, Chizhou Development and Reform Commission drafted and presented to the government. *Implementation Measures of Government Purchasing Service from Social Forces.* The commission also promoted pilot demonstrations of private investment projects. Four private enterprises have now been introduced and 4 additional projects implemented, including the chosen Chizhou sewage treatment and municipal drainage purchasing service PPP project(the second phase), and Chizhou Pingtian Lake and Qingxi River upstream line project, which have been presented to the D.R.C(Development and Reform Commission), and will be opened for social investment.

3.3 Key Technologies and Solutions in Engineering Practices

33.1 Renovation Project of the Qingxi River

Interconnect and Dredge the Rivers, and Restore Its'Natural Forms. Over the years, the city directly intercepted many river channels to build roads, causing five water courses to be interrupted. These interruptions to the Qingxi River‘s formed scattered ponds and destroyed the continuity of the natural river, affecting the smooth flow, and reduced the water surface area of the city. The renovation program planned to interconnect all river-filled roads, construct bridges, clear up garbage along the river, restore the original watercourses, and dredge and purify the entire riverbed.

According to the current situation, the planning committee wants to keep the natural water courses along upper segments of the South Outer Ring. This can be accomplished by maintaining the natural features of the river, such as natural embankments, slopes and step-shape. These improvements are beneficial for the natural hydrological cycle, including the containment of floodwater and silt, as well as their infiltration into natural water courses. Cultivating water plants, water bamboo plants, and other native species on and by the shore can help stabilize riverbanks through plant roots, as well as provide natural habitat for aquatic life forms.

Located in the city center, the river-section between the South Outer Ring and Baiyalu Bridge is composed of a widewater-way, surrounded by heavy traffic and dense buildings. It is an entertainment district for living, sightseeing, and leisure. It is necessary to protect the river banks in to maintain the structural integrity of the city roads, bridges and maintain landscape construction to stabilize the riverbanks, prevent erosion and provide water access for public activities.

Maintaining the shorelines the original direction, maintaining or widening water areas, as well as keeping a reasonable water-depth through dredging can create

conditions for boating and other water activities. The bank revetment was built using compound sections anda ladder type layout in order to meet the hydrophilic requirements necessary to manage dry and flood season water level flucuations. The bank revetment was constructed with dry stones, a small amount of cement mortar, or cement concrete, to ensure the natural exchange between soil, water and river, with part of the river using the gentle slope section into the riverbed. Aquatic plants are distributed on the sloping surface to provide for wildlife habitat. Downstream of Baiyalu Bridge is the administrative section of the city, and the two banks are decorated with green. The is agentle slope, and planted with turf and bushes, which naturally extend to the water‘s surface, and integrate the water with forest grass, preserving the natural feeling even though it is a highly developed residential living area.

Intercept Sewage and DivertWater to Control Pollution. Without sewage treatment facilities in Chizhou‘s main urban areas, the main pollution sources of Qingxi River came from industrial wastewater, domestic sewage, and street runoff. During the non-flood period, the water of the Qingxi River poured into the Yangtze River directly, while needing the help of pumping stations when in flood season. The polluted wastewater caused serious corrosion to the pumping equipment. The planning department decided to set up storm water sewage pipes on both banks of the Qingxi River to collect runoff, as well as build a sewage-treatment factory that can treat 40,000 tons wastewater daily. It is located near the Baisha pumping station. The future target is to build a wastewater treatment plant capable of treating 80,000tons daily to bring the wastewater discharge up to modern standards, and provide the capacity necessary for the sewage produced by Chizhou.

Divert the Water Into the City to Strengthen the Self-Filtration Capability of Water Body. Anatural body of water has the capability to self-filtrate. According to the planning ideas of, “renovate the water with a dynamic approach, dilute the wastewater with the clean water, fill up the dry rivers with rich ones,and improve the water quality”, diverting the water into the city and promoting the water flow of the whole river will help improve the self-filtrationand dilution capacity of the water body, as well as improve the water environment.

Qingxi River basin has an abundance of annual rainfall, and has traditionally had had fine water quality. The water quality of feed water here can reach the standard of class II to III throughout of the year, and thus is suitable to be diverted. Chizhou planned to build a dam at Yunzifan, which was upstream of the Qingxi River, and set up a control gate, regulating and controlling the volume of water diverted in to the city.Meanwhile,various measures were taken to eliminate the breeding environment of the oncomelania, as called for the in the water conservancy requirements. After the implementation of sewage disposal processes, and re-diverting of natural water flows, the project aims to reintroduce native fish, shrimp, and other aquatic fauna into the river in order to re-build aneffective food-chain, which will help to lower water pollution, filtrate the water body, and improve water quality.

The Qingxi River goes through the city center from south to north. The river‘s urban area, is 15km long with the varying width of 50-80m, is a closed water body. This section‘s water level is maintained around 7.60m and 8.10m by locational management at Xinghua Village, the South Lake, Baisha, and three drainage-pumping stations. Located in the eastern suburbs of the city, Pingtian Lake, whose inflow water area is 75km², covers an area of 11-12km², and its water level is controlled between 10.80m and 12.10m. The South Lake, which is situated to the south of the city‘s old district, is divided into several segments, with most of the parts being fish ponds, lotus ponds and paddy fields. They are all connected through culvert pipes. Heaven Lake is linked with the Qingxi River through several drainage ditches.

The comprehensive renovation project of Chizhou‘s water environment is also called project “3538”, and includes linking-up the three water systems (Pingtian Lake, South Lake, and the Qingxi River), integrating five scenic areas (Bolangping Lake), establishing the three nodes (Qishan canyon), and rebuilding eight bridges (Wanluoshan Road Bridge, among others). The project will also artificially renovate the bodies of water that make up the Qingxi River and South Lake. This will be done by increasing the strength of the river‘s flow, improving the river‘s natural filtration systems, supporting the recovery of the natural ecological environment of the South Lake Wetlands, maintaining the diversity of animal and plant species, building a water sightseeing route around Pingtian Lake, South Lake and Qingxi River, and form tourism resources with unique characteristics.

Link Up the Existing Water Systems. Make use of the current advantages of the river-lake water network to link up the water systems. First, excavate and connect the natural river courses, and thread the urban rivers and lakes together, as can be done via the reconnection of Pingtian Lake, Qishan Lake and Qingxi River, etc. Second, build a diversion canal to divert the water of Baiyang River into the Qingxi River, allowing the river to flow again. Third, link up Pingtian Lake with the Fengshou Lake water system, leading to inter-basin water transfer.

Renovate the River Courses. Comprehensively renovate the Qingxi River and relevant riverbanks, de-silt and protect masonry along the river, place stones and plant willow trees segmentally, and set up hydrophilic platform and cruise terminal to encourage hydrophily, ecology, and diversity.

Return the Aquaculture Ponds to Lake. Excavate the former breeding ponds, restore the Qishan Lake, East Lake and South Lake wetlands, and build 134km^{2}ecological wetland park. Meanwhile, the municipal government must introduce control measures on the Qingxi River and Pingtian Lake‘s waterlevels. They must also lawfully and scientifically control water levels and water quality to guarantee naturally occurring ecological water cycles.

Drain and InterceptSewage. Set up storm water and sewage pipes according to the principle of rainwater and sewage diversion, providing for the correct drainage of sewage and rainwater to ensure the rain waterflows enter into the river, and sewage into the sewage treatment plant to eliminate pollution sources.

Perfect theTraffic. Renovate or construct eight bridges over the linking-up river

courses that can meet traffic demands, as well as respect the landscape and deep cultural heritage of Chizhou.

IntegrateTourism Resources. Build a 20km-long water sightseeing route around Pingtian Lake, South Lake and Qingxi River, combining the beautiful natural scenery with the rich cultural landscape, and build nodes like Qishan canyon, the Sports Exhibition Center, the shiplift, as well as integrate the multi-plescenic areas throughout the river‘s areato develop tourism resources using the area‘s unique characteristics.

3.3.3 The Main Measures to Building a—Sponge City

Chizhou selected the core area of the central city, which stretches over 18.5 square kilometers, as the sponge city demonstration region. This area covers the old city (10.68 km²) and the Heaven Lake New district (7.82 km²)[11].

Strategically, Chizhou is concerned with synthesizing the urban fabric and the underlying infrastructure construction of the project, analyzing the various low-impact development measures, and identifying the applicable measures to realize sponge city construction. According to the general target of “Taking the national medium and small-sized new sponge cities as the new model”, sponge city construction in Chizhou city will set the example for all the Binjiang port cities,which have sound ecological foundations and serious water environment problems. In addition Chizhou will establish, *the technical guidelines to sponge city construction,* this will include the following measures: the use of GIS spatial geographic data analysis, hydrological watershed modeling, analysis of the rainfall data of Chizhou in the past 30 years, and establishment of the annual runoff volume goals in Chizhou pilot areas.

Performance appraisal will be based on the construction requirements of the national sponge city planning, and the standardized planning of Chizhou‘s sponge city construction. Chizhou will focus on solving the problems of waterlogged areas in the sponge city, improving black and smelly urban water bodies, water security, renovation of the aquatic environment, early rainfall pollution, wetland protection and so on. By 2017, the demonstration city is required to achieve the following goals: Waterlogging prevention duration of 30 years, urban flood-prevention of 100 years; standard-reaching rate of flood prevention dyke reaches 100%, drainage of 80%, and improvement of the water quality in drinking water source areas to 80%; detention rate of rainfall of 10%, water area rate of 11%, and utilization of rainwater resources reaching 3%. In the light of international experience, fragmentation of project should be avoided so as to reach these goals. Therefore, through scientifically evaluation of the overall costs of economy, ecology, and politics, Chizhou formulated scientifically based, clean, and systematic solutions to separate the sponge city pilot regions into four catchment areas for further study.

In accordance with the technical specifics of the sponge city construction that aims to “reduce emissions at the source, control the process and govern systematically”, as well as in accordance with the concrete water-system structure, and the comprehensive

treatment methodology applied to the Qingxi River (from source to the end), Chizhou divided the demonstration regions into four areas: old-city rebuilding area (combined system and overflow-control + sponge city), Guanhuzhao Dyke area (black and smelly waterbody + sponge city), Huijing area (original architecture rebuilding + sponge city), and the Heaven Lake new area (new-city development + sponge city). The *Enforceable Scheme on Sponge City Construction Project in Chizhou* synthesized the building areas and public architectures, city roads, parks, municipal pipe network systems, waterlogging regions, black and smelly water bodies, and determineds the rainfall control targets in various areas.

3.4 Achievements of Implementation: Environmental, Economic, and Social Benefits

3.4.1 Palpable Effect of Comprehensive Water-Environment Renovation and Water-System Linking-Up Project

Since 2003, the Qingxi River has been a beautiful landscape passing through Chizhou‘s main urban area. Through the achievement of many project goals, the targets of clean water, green banks and pretty city have been achieved.

After the implementation of the comprehensive renovation project, the three water systems: Pingtian Lake, South Lake and the Qingxi River have been threaded together with the new, 150 km^2 urban public green space, greatly improving the urban ecological environment and increased thecity‘s image. Qingxi River, Pingtian Lake, South Lake and so on, which are lakes in the main urban area in Chizhou, formed a beaded pattern, and constitute Chizhou‘s most essential natural environment resource. The water system covers a wide area accounting for 1/10 of Chizhou‘s urban area[12].

The concrete results of the many projects are as follows:

Enhanced Capacity forFlood-Prevention and Safety. Connecting the river-lake water system in Chizhou‘s urban area, along with the renovation of Qishan Lake, South Lake, and newly excavated water courses have accomplished several important goals. The projects have expanded the total area of flood storage and regulation, facilitated interbasin water transfer, improved the discharge capacity of drainage channels, increased the project benefit of the drainage pumping station, and decreased flood damage in the city. During the flood season in 2010, Chizhou‘s main urban area suffered from heavy rain which happened only once in twenty years but resulted in no waterlogging, demonstrating the benefit of flood prevention and safety measures undertaken by the city authorities.

Improved Ecological Environment. By dredging the channels and improving engineering measures, ecological-protections, restoration of wetlands and the pertinent riverbanks, the project area has been greatly improved. Other, non-engineered, measures of restoring aquiculture to lake, managing water resources uniformly, helped to greatly reduce sources of pollution, and strengthened the body of water‘s capacity for self-filtration.. Excavating the naturalwater courses and

diverting the original water sources helped to promoted the flows of the Qingxi River,

South Lake, Qishan Lake and Fengshou Lake. In addition, the new water flow revitalized the water quality, restored the natural ecological environment, and created conditions for the living and reproduction of diverse species. Since the end of 2010, more wild ducks and white swans have been living near the Pingtian Lake, South Lake and Qishan Lake than ever before, becoming part of the city‘s beautiful scenery.

Created an Environment for Tourism, Recreation, and Living. The interconnected water systems helped to reduce the problems of serious pollution and ecological degradation caused by the separation of the natural water system, but also degradation in the combined Chizhou with five surrounding regions. Linking the scenery of Qishan Lake, Pingtian Lake, and Qingxi River with each other, this renovated interconnection reflected the artistic conception of “a city in the landscape and a landscape in the city”, and created an environment for tourism, recreation, and living.

Inheritedthe Historical Culture of Chizhou. As an ancient, thousand-year old city, Chizhou‘s natural water system had numerous links with its historical culture. Reconnecting the water system not only connected the various cultural relationship residents have with the water as seen in the media. The media‘s portrayal helped to unify urban management and environmental protection. It also shows the deep relationship between the people who have historically lived in Chizhou and how the natural scenery and cultural landscape reflecting deep cultural characteristics of mountains and rivers.

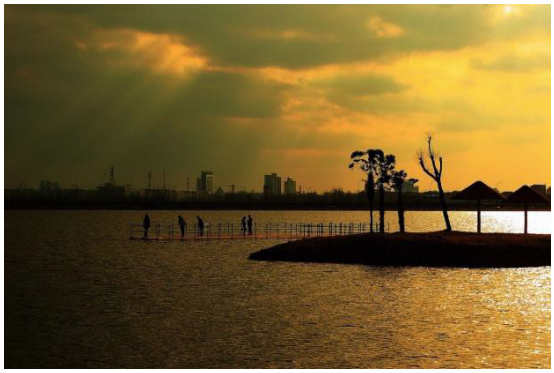


Figure 5 Water View in Chizhou City

3.4.2 The Cconstruction of the Sponge City Develops Order, With Enormous Expected Benefits

The cities fine planning and technical approach accelerated the construction of the Sponge City pilot areas. To date, the government has directly invested in 55 projects, totaling ¥1.432 Billionin 2005, with the projects under construction covering a catchment area of 2.3 km², while finished projects cover a 0.76km² area . The ¥650 millioninitial capital, already invested in 2005 (not including investment on real estate) included ¥80 million from central funds, ¥520 million from local financial funds, and ¥50 million from social investment.

Chizhou was determined to prioritize the projects of eliminating black and smelly water bodies at the Chizhou First Middle School, Santaishan Park, Qishan Avenue, and the South Lake as the first sponge city demonstration projects. In terms of construction management, Chizhou laid out "61+1" programs, broken down into three categories: sponge city control systems, planning systems, and investment and finance systems. As for financial channels, Chizhou made full use of innovative financial tools in the projects that utilized PPP financing. In 2015, the drainage company has invested ¥37 million on drain pipe network construction. In 2016, with the sponge city construction as the focus of the work, together with removal of black and smelly water, Chizhou implemented projects in renovating sewage-interception dry pipes of the Qingxi River, remedying initial rainwater problems and improving standards and reforming sewage factories, the investment of which were estimated to be about ¥588 million.

During the construction of Chizhou's sponge city, the experience tried to extrude "five simultaneously":

First, highlight ecologicalization and the role of natural detention/ retention accumulation. Construct Pingtian Lake wetlands of about 4.36 km² in the urban centre as a flood detention area, to protect the city's originalrivers, lakes, wetlands, ponds, ditches and so on. Chizhou also built an ecological conservation system to promote the city's natural accumulation, natural infiltration, and natural filtration capacity.

Second, highlight modularization and the infiltration function of the sponge city. Promote the integration of "block, line, and point". 75 out of the 117 projects (7 categories), totaling investments of ¥21.16 billion, are under construction. The resulting storage capacities of these three "sponge" projects, located at Qishan Avenue, Chizhou First Middle School, and Santaishan Park reaching 3065,2274 and 3887 m³, respectively.

Third, highlight improvements in efficiency and function of drainage networks. The implementation of the PPP at the city's sewage treatment plant and municipal drainage facilities, has helped to interconnect the city's waterways. A complete survey of Chizhou's pipeline network can be done quickly via GIS mapping. Allowing the city to more quickly dredge the 655 km of storm sewers, 11,800 inspection pits, and 54,900 gutter inlets. The dredging process cleared out 3017.2 m³ of silts, completed over 80 engineering transformations, and eliminating 20 of the city's 25 waterlogging areas. Chizhou also retrofitted 60 kilometers of storm water and sewage diversion piping networks in the historical districts, and newly built or rebuilt 15 km of pipe networks.

Fourth, highlight engineering and the retention and regulation functions of the river and lake. The water safety engineering and water environment improvement project that has already been implemented has led to further interconnectedness of the four water systems: Pingtian Lake, the Heaven Lake, Qingxi River, and Fengshou Lake.

Fifth, highlight professionalism and the primary function of the private market. In 2015, Chizhou introduced two PPPs, the Shenzhen Water (Group) Co., Ltd. (SZWG), and the Chizhou Drainage Company. The city invested 3.9million yuan to

acquire advanced CCTV pipeline robot survey vehicles, as well as large repair cars, improving the emergency response capabilities. In response to the major rainstorm events, the three advantages of a professional team, facilities and techniques were on display, emergency flood operations resolved many waterlogged points and eliminated the phenomenon of "city of the sea".

It is estimated that the project of the sponge City, after completion, is expected to improve 34 old districts and reduce the annual average flood losses of 36.5 million yuan. The annual savings of tap water will reach 2.0313 million yuan, land value-added benefit 200 million, more than 4000 related jobs will be created, pollution load reduction rate will reach over 50%, and the up-to-standard rate of city inland-river will reach 100%. Sponge city construction is very important for improving the bearing capacity of Chizhou and creating a beautiful and more sustainable city. Sponge City developments can improve the quality of the city, enhance social cohesion, promote harmony between humans and water, and produce huge social, economic and ecological benefits. In civic terms, sponge-city construction will help transform the old districts, rebuild and widen Lake-View Park, the Moat Ruins Park, and Santaishan Park, reconstruct the Street Garden, improve living quality, and expand the public open space area, to meet the public demands for leisure space and environment.[13]

It is worth mentioning that in 2016 Chizhouwithstood the test of a rare flood event. The rare flooding event, cause by unusually heavy rainfall did not affect Chizhou or its residents, due to Sponge City development projects. The city's implementation of the Sponge City designs south of Qishan Avenue, the playground of Chizhou first middle school, the sidewalks of Chiyang Road, the motor vehicle lanes of Baiya road, demonstrated fine water-absorption properties and drainage during the heavy rainfall event. Large areas of the city, which are normally waterlogged following such a rain event were not negatively impacted, further demonstrated the capacity of Sponge City in flood-prevention safety.

4 Inspiration

4.1 Highlights of the Case

4.1.1 Creating a Sound Soft Environment Under the Guidance of Eco-Civilization and the Concept of Ecological City Construction

In recent years, Chizhou has demonstrated that the city must engage the three natural resources which define the city's experience: ecology, Jiuhua Mountain, and the Yangtze River. These three natural resources will help Chizhou builda happy and prosperous economy, elegant environment, harmonious society, and well-off life for its inhabitants[14]. The eco-civilization and the concept of sustainable city construction provide both firm and proven examples of sustainable urban water system management and realize the target of constructing a "Sponge City". We should take the path of sustainable development based on the evidence of Chizhou's green

hills and clean waters. All segments of society have reached a consensus this path of future development will be beneficial to realizing the relevant targets of water system management.

4.1.2 Urban Water System Management Orientation Which Combined Closely with Historical and Ecological Views

The historical and ecological views in Chizhou inhabitant‘s mind is reflected in the comprehensiveness, entirety, and systematic nature of the water system management strategies. Recalling ancient poetry and remembering the polders and the river between them laid the foundation for fully realizing and accepting the various problems of the city's water system. Compared with the people in other regions, Chizhou‘s inhabitants are more likely to understand the important significance of watershed management, and water patterns, in a larger area for local flood problems. This is why, in a very short time, Chizhou was able to achieve the goals of river renovation and natural water system interconnection, by utilizing fundamental basics of the “Sponge City” planning and developmental framework.

4.1.3 Maintain Long-term Policy Orientation and Persistently Move Forward

Through many years of water management in Chizhou, there have been no great changes in general policy orientation. Both the city committee and the government have been adhered to the goals and tasks of comprehensive city management. The city government will not rest after new achievements. Their response is to propose new and higher requirements and try to realize new achievements in city planning and development. From the environmental remediation of the rivers, to the comprehensive management of the larger river systems, and the building of sponge city urban improvements, Chizhou has never stopped innovating. Long lasting policy direction is very important for the realization of all kinds of sustainable management objectives.

4.1.4 Fully Use PPP Pattern to Deal With the Relationship Between the Market and the Government

Chizhou‘s development pattern will play an exemplary role for the reform of the national municipal sewage pipe network as well as wastewater factories. The highlights of this pattern includes the following 5 aspects: the government attached great importance to the Sponge City improvements, the city carried out the market-oriented management based on the integration between sewage factory and sewer networks, the sewage pipe network adopted the government purchasing service pattern, the SPV introduced a mixed ownership system, and the bids were made public to demonstrate competition in the market. After the implementation of the PPP Pattern, Chizhou has succeeded in revitalizing the years‘ stock assets and relieved the government‘s debt burden. Through the pattern of private enterprises implementing professional services (third-party governance) and the government purchasing

services, the relationship between public and private investment has changed. Now the public sector can focus their resources on the supervision of the private sector.

4.2 Advice on Popularization

Historical and geographical conditions have provided Chizhou with great advantages in urban water management. It is also the sound governance that makes it possible for a rapid and virtuous transformation of this resource management. Although there are maybe similar conditions in other areas, it differs greatly in historical identity. Therefore, we need grasp the following points from the case of Chizhou:

1) Political leaders and planners must take new perspectives into consideration to create sound environmental policy.
2) Pay attention to leading professionals, respect scientific law, solve problems practically, compile planning with open system, construct with open procedure, and manage with open mode.
3) Fully make use of PPP and other economic patterns to mobilize the enthusiasm of the private market, establish a communication platform mechanism and coordinate the stakeholders.
4) Ensure the long-term timelines in policy orientation.

Bibliographies:

1.Fang Shuxiang. *Measures and Benefits of River-Lake Interconnection in Chizhou Urban Areas[J] .Jianghuai Water Resources Science and Technology,*2011,03:7-8.

2.Gaomei. *The Pattern of Ecological Civilization Construction In Chizhou and Its Experience. [J]The Construction of the Old Revolutionary Area,*2013,22:15-19

3.Peng Wenji. *Countmeasures and Solutions of Water Sources Management in Chizhou[J].China Water Conservancy,*2010,11:42-43.

4.Wangying, Fang Shuxiang. *Analysis on Effect of Water Conservancy Construction of Chizhou during the 11th Five-Year Plan[J].Jianghuai Water Resources Science and Technology,*2012,06:7-8.

5.Lu Taozheng. *Analysis on Comprehensive Renovation of Water Environment in Chizhou[J].Modern Agricultural Technology,*2012,01:257-260.

*6.*Zhou Lingyun. *Chizhou Building Sponge City*[J].*Green Sight,*2015,09:27-32.

7.Sun Guangmin. *Environment Renovation and Ecological Restoration of Qingxi River in Chizhou[J].Jianghuai Water Resources Science and Technology,*2006,02:5-6.

8.Tan Jiasheng, Fang Xiangming. *Development of dyke-building and Its Impact on Ecological Environment inChizhou Prefecture of Anhui Province in Modern Times* [J]. *Anhui Agricultural Science,*2008,26:11470-11472.

9.Wu Shengyou, Reporter Wuhao. *Pilot Construction of Sponge City(N).China County Economic News,*2015-06-25002.

10.Li Xinbing. *Analysis on Features, Types and Operation of PPP Pattern and Cases in Water Project[J].China Municipal Engineering,*2016,01:42-45+93.

11.Liu Hongwei. *Sponge City Construction Pilot–Tech-Geeks‖[N].China Construction News,*2016-05-12001.

12.Jijie, Zhubin. *Research on Development of Water Tourism in the Main City Area of Chizhou*[J].*Journal of Chizhou College,*2015,03:85-89.

13.Liu Hangbo. *Ecological Chizhou for the Dream of Sponge City[J].China Biding,*2015,21:12.

14. Huang Wensheng, Hu Yuping. *Research on Countermeasures about how to play well with the cards —ecology, Mount Jiuhua and the Yangtze River‖ for Chizhou[J]. Anhui Agricultural University Journal(Social Science Edition),*2013,01:37-40.

Chapter Three: Waste Resources

Waste management is a city‘s need to deal with its waste in a sustainable way. Reducing flows to minimize waste is a key strategy. And converting waste into sources is also vital. Waste is increasingly used by cities as a resource, delivering bio-gas, district heating, fertilizer, and recycled goods.Circular economy promotion, legal regulation, as well as the sustainable operation mode involving participation of social parties are key factors in the success of urban waste management.

Solid Waste Management in Berlin

Yin Huanying[11]

【**Abstract**】Germany has an advanced solid waste management system. It is based on the laws and regulations of waste management, and this article will systematically introduce
These management ideas, policies and economic instruments, technical schemes, operation modes, and implementation effects for waste disposal utilized in Berlin. Combined with the successful practices in Berlin, this paper will also put forward concrete suggestions on the popularization of city solid waste management.

【 **Keywords** 】 city garbage in Berlin; resourcization; producer responsibility; Greenpoint Organization; circular economy

1 Background Introduction of Berlin

Located in northeast Germany, Berlin is surrounded by the state of Brandenburg, with the Spree river pouring into the Havel river mouth. It has a long history of 750 years, and became the new capital of Germany in 1991. Covering an area of 89.2 thousands square kilometers, with a population of 3.5 million and urban length of 234 kilometers, Berlin is the largest city in Germany, as well as the political and economic center. Originally, Berlin was divided into 23 districts, then in January 2001, the implementation of administrative reform merged the 23 districts into 12. Each area was subdivided into partitions, representing the traditional urbanized places. After the administrative reform, the reorganization of local government was still ongoing. At present, the 12 districts are combined, and there are 96 local governments, with each branch consisting of a number of sub-districts.

As surbanization and industrialization advance, the number of cities and the population are increasing. Accordingly, municipal solid waste pollution has become one significant environmental problem that the government pays attention to. In the mid 1980s, many cities in Germany, including Berlin, disposed their garbage in the same manner as many of the world's previously industrializing cities. The garbage was either burned or buried, which caused the landfills to be unable to accommodate the growing city garbage, and increased water and air pollution.

[11]Yin Huanying: Senior Project Expert of Word Future Council China Program

Figure 1 Waste Treatment in Berlin

2 The Thinking and Decision-Making Process of the Administrators

Germany is a resource-poor country, this caused the government‘s transformation in dealing with the waste, and that the waste should be a kind of resource that can be recycled. This realization led to the closed cycle of the materials: "from cradle to grave and to cradle again", and promoted the emergence of the idea of circular economy and its implementation. The whole evolution of relevant laws and regulations in the field of solid waste treatment perfectly reflected the solutions of city garbage disposal:

The first issue of “*Law on Waste Disposal*” in 1972 marked the start of Germany‘s exploration on circular economy. After World War II, Germany‘s economic recovery and development led to rapid growth. But, this caused industrial and personal garbage to increased exponentially. Before 1972, the nation disposed of garbage mainly through stacking or burning, and until the 1970s, there were 50,000 dumpsites in Germany (Western Germany). Most of which were under disorganized management. In order to normalize waste disposal, shut down the unreasonable waste-yards, and improve the environmental quality, thevery first issue of “*Law on Waste Disposal*” determined several key principles on water disposal. These included harmless treatment, the division of responsibilities, polluter pays, and starting the terminal treatment of waste discharge.

In 1973, Germany became aware of, due to the oil crisis in western countries,the resources and energy contained in waste. And in 1975,the Germany government published its first national plan on waste management which included the following targets: The priority order of waste disposal is "prevention-reduction-recycling"; share the costs according to concrete situations of disposal after the polluters paid. This plan led the transformation from waste disposal to waste economy.

With more and more garbage, in 1986, the German government issued “*Law on Waste Disposal*” based on the amendment to the law of 1972, setting out the principles of precaution-first, and recycling the disposed waste, as well as, for the first time, stipulating the responsibilities of product manufacturers. Thus,

developmental direction was changed, with the view of "[h]ow to deal with the garbage" upgraded to "[h]ow to avoid the production of waste and how to recycle it ". On this basis, the German government passed the *Packaging Regulations*, stipulating the responsibility, as well as the goal of recycling various packages.

In 1996, the German government passed a new "*Law on Circular Economy and Waste Management*" ("*Circular Economy Law*" for short), upgrading waste disposal to a fully developing circular economy, and establishing supporting legal systems. This was the first time that the concept of circular economy appeared in the national laws.

From the *"Waste Disposal Law"* of 1972 to the *"Circular Economy Law"* of 1996, the German government formulated all the laws on waste, in order to adapt to the household nature of waste during different periods and their differing requirements. The idea of waste disposal in Germany transformed from "terminal treatment - recycling– avoiding waste-production" gradually to "avoiding production - recycling - terminal treatment." This was especially due to the implementation of the *"Packaging Regulations"* of 1991 and *"Circular Economy Law"* of 1996, which further established and affirmed this idea.The formulation and implementation of the *"Circular Economy Law"* has led the comprehensive treatment of German domestic waste to a new turning point -- the beginning of circular economy. This is a law that fully reflects the reduction, resourcization, and harmlessness of the waste, and that is in accordance with the requirements of sustainable development. It also emphasizes that waste disposal aims to achieve a wholly virtuous cycle of resources, environment and economy, and is no longer just simple disposal of garbage.

These new ideas on garbage management strictly stipulated the principles of waste disposal: First, reduce as much of the waste as possible during the production and consumption periods. Second, as for the produced waste, maximize its recycling in a harmless way, including the reutilization of energy. Third, dispose of the inevitably produced, and unable to be recycled, waste in an environmentally compatible way.

The principles of the developing circular economy in Germany are as follows:

First, the principle of producer responsibility, which means the one who produced the waste is responsible for recycling. For example, car-manufacturers have duties to recycle scrapped cars and bear the cost of disposal. Therefore, this causes the manufacturers to pay attention to environmental protection from the start, taking the future issue of recycling scrapped goods into account.

Second, there is principle of self-regulation. The government encourages industrial companies and subsequent cycles to implement the "*Circular Economy Law*" willingly. For example, the beverage packaging industry in Germany specifies 72% of the packaging material must be utilized twice.

Third, and finally, there is transparency principle, in which the manufacturers have the responsibility to disclose the production processes of commodities in order to give consumers the right to choose goods.

3 Countermeasures and Solutions

3.1 The Formulation of Laws and Regulations on Waste Disposal

The establishment of laws and regulations is an important vehicle for promoting domestic waste management. There are many laws and regulations on waste management in Germany. Many of which involve technical aspects, some of these laws are as follows:

The first published "*Waste Disposal Law*" in 1972 required the shutdown of unattended garbage dumps and set up centralized dumps strictly supervised by the government. It also stipulated for the construction of garbage-disposal stations, in order to carry out waste incineration and landfilling. After the oil crisis, Germany started to obtain electrical energy and heat energy from waste incineration.

In 1986, The German government promulgated a new "*Law on Waste Prevention and Management*", establishing the principles of waste-reduction and recycling preceding waste disposal, and clarifying the obligations of oil enterprises in that they should recycle waste oil from consumers and deal with it in an environment-friendly way. This was the embryonic form of the famous "Extended Producer Responsibility"(EPR), which aims at solving the problems of waste reduction and recycling.

The "*Packaging Regulations*" passed by the German government in 1991 set out two-phase targets for mandatory circular utilization of packages to recycle them. It stipulated that extending the principle of "polluter pays" in the environmental economics to the field of production and consumption. Therefore, the producers, packagers and sellers of goods that have entered the market are responsible for the recycling of, and packing of products. The core thought is "producer responsibility". This principle, not only, solved the problem of recycling and disposal of garbage produced by consumption, but more significantly, encouraged producers to reduce garbage at the source through price leverage. For example, using improved technology to reduce the amount of raw materials, used recycling materials, simplifying the product package, and so on, in order to promote an environmentally-friendly development. The"*Packaging Regulations*" initiated consequential provisions on recycling, reutilization, and utilization ratio of waste packaging. The production enterprises must entrust the relevant companies, (Green Dot Company below), to collect and dispose of waste and pay for it, unless they could provide evidence of their own recycling. According to this regulation, Germany ensured the status of Duales System Deutschland GmbH（DSD Company, the Green Dot Company. This company is in charge of collecting and disposing of waste packages printed with the "Green Dot". However, it does not dispose waste itself, but rather allows packaging waste sorting and processing companies to carry out this process by signing a contract with them.

Figure 2 Green Dot

The last amendment to the *Packaging Regulations* came into effect in May 2005, and clearly stipulated that implementing a mandatory deposit system for the disposable of beverage packaging. In addition, Germany has also promulgated the "*Commercial Garbage Ordinance*", "*Scrap CarsOrdinance*", "*Electronic Waste Regulation and Battery Regulation*", adapting laws to deal with different types of garbage and specific technical requirements.

After a series of experiments in the main field, in 1996, the German government proposed the "*Circular Economy Law*", transforming waste disposal into, and developing, a circular economy. The law has had a wide impact, and has transformed the German recycling economy. It is a programmatic regulation on the development of circular economy and waste disposal in Germany. The act defined some principles of waste disposal. First, is the principle of polluter pays. Second, before recycling and disposal, reduction is the top priority factor. Third, incineration and recycling are in the equivalent positions, and which one to choose must be in accordance with the specific circumstances. Fourth, producers are responsible for the garbage produced by their products. Fifth, promote the privatization of waste disposal. These rules are complemented by a number of more detailed regulations, such as the *"Biological Waste Regulation", "Landfill Regulations", "Sludge Disposal Regulations", "Regulation on the Approval of Garbage Transportation", "Enterprise Regulations on Professional Waste Disposal "*. After promulgation on October 6, 1996, these laws have undergone several revisions.The most recent revision was on August 11, 2009 and the revised law came into effect on March 1, 2010.

There were many strict management rules during the implementation of "*Circular EconomyLaw*",and especially the "*General Rule for Waste Technical Reference*" and the "*General Rule forResidential Living Garbage Technical Reference*". The former explained the relevant technical indicators of the garbage stacking, chemical / physical / biological disposal, garbage incineration and the storage of high-risk garbage, whilethe latter made a detailed specification on the removal, utilization, and disposal of domestic refuse. It is worthwhile tonote that the "G*eneral Rule for Residential Living Garbage Technical Reference*" was formulated during a period of rapidly increasing domestic and untreated garbage harming the environment. Therefore, it stipulated that since June 2005, untreated garbage from residential households was strictly forbidden from entering the landfill.

3.2 Waste Management Institutions

The waste management institutions in Germany are divided into five levels: country, state and federal, region, city and county, and community.

The GermanEnvironmental Protection Department, as well as its professional institution— The Federal Environment Protection Agency, is the top management organization for waste management. It is responsible for the promulgation of laws, international cooperation, and the scientific research projects.

The federal and state department of the environment, the corresponding regional authorities, and the State Administration for Industry and Commerce, are senior management authorities, which are responsible for the implementation of relevant laws and regulations;

The regional waste management agency belongs to intermediate level, and is responsible for the approval of specific waste disposal projects.

Thewaste management authorities ofcity and county are primary waste management organizations, and are in charge of the whole process of garbage collection, transportation, processing and disposal. The community is the basic unit of garbage collection.

The waste management authority of Berlin is the Berlin Municipal Planning and Environmental Protection Bureau.

3.3 Supervision-Mechanism

As for producers and sellers, according to the regulations, manufacturing enterprises, which create over 2000 tons of hazardous waste every year, have an obligation to submit a garbage disposal program to the Health Supervision Department for supervision.The manufacturers cannot carry out production and sales activities unless they can prove to the supervising institution that they are able to recycle end-of-life products. These enterprises must ensure control of the generation of as much of the waste as possible during the production process, as well as to have measures to effectively recycle waste and not harm the environment. Certain products cannot be produced and sold unless the garbage they produce can be utilized and disposed of according to regulation specifics. All enterprises must have a device to separate garbage, placing the waste products of paper, glass, plastic, metal and others separately, in order to ensure that all the waste can be reused to the greatest degree.

Since the 1970s, Germany has begun to organize an environmental police force to supervise the implementation of its environmental laws. Environmental police, who are public officers of the Police Department in the Federal Interior Ministry, belong to a specific branch of the police force. The number of posts is decided according to specific circumstances. For the city residents, they must accept the supervision of the environmental police in their daily life. First, the environmental police will supervise the garbage problems in residential areas. If waste there is misplaced, the police will notify the Housing Management Department and Waste Disposal Department for an immediate disposal. Second, the police, on a weekly basis, randomly check the

situation of waste classification inthese areas, sometimes even rummaging through the garbage, to ensure correct garbage classification. Usually, residents of the same building share one garbage station, in which, if the environmental police find a huge amount of incorrectly classified garbage, the station will be closed in order to rectify the situation. Meanwhile, the police will inspect the cleanliness of dustbins placed by the roadside.

3.4 Major Policy Instruments

The major policy instruments of waste management include tax revenue and non-tax revenue, such as environmental tax, garbage disposal fees, financial subsidies, producer responsibility (product fee), deposit refund system, etc.

（1）**Environmental Tax.** Regarding environmental policies in Germany, with the energy tax reform as a core interest, the Ecological Tax Reform Act is a typical example of environmental tax. Its main target is to reduce energy consumption and environmental pollution, as well as to improve the employment rate. Although this tax policy raised the price of energy, it steadily promoted the application of economic stimulus measures in the field of energy. Germany encourages power-generation by waste incineration, and recycling, through a variety of tax incentives.

（2）**Garbage Charging System.** Division of the responsibility of waste processors is according to the "Polluter Pays" principle.Therefore, the government and individuals have their own responsibilities, as well as pay relevant fees.This forces residents and producers to increase investment in recycling and disposal of the waste, reducing waste generation from the source, and encouraging residents to consciously adhere to the principles of waste recycling and reutilization. The garbage fee is not only one way to raise waste treatment costs awareness, but also shows that the garbage producers using waste disposal facilities (including waste transfer stations, landfills, waste incineration plants) are not exempt from the corresponding fees.

As for waste disposal fees concerning residents, each city in Germany has different methods. Generally, there are three categories for the collection of residents waste disposal fees:

1. Charge according to the garbage container / metering: Charge a certain amount every year according to the capacity of the garbage bins, for instance, the annual charge amount is about 360 Mark for a 90 liters of trash bin. In addition, certain cities installed micro-chips in the garbage cans (boxes), which can identify and automatically measure the amount of waste discharged by the residents and send the data to the computer in the driving room of garbage collection car as charge voucher.
2. Household charging: taking the household as a unit, and pay the annual fees according to the housing area accounting.
3. Combination of the base with the metering charging:pay fees in accordance with the family population, and then on this basis, pay the extra processing costs according to

the capacity of different bins and collection frequency.

The local public waste management service units charge this fee, and the local governments or municipal governments supervise collection. In Berlin, BSR implements the household charging, and the collection of monthly waste disposal fees.

（3）**Product Fee Collection.** This is an important part of garbage fees policy in German. Product cost is a front-end economic means of the environmental management, and its directly related legal concepts include "producer responsibility" and, or, a "national responsibility system". The product cost requires the manufacturers to be responsible for the entire life cycle of its products. The imposition of the product fee helps prevent manufacturers from using too many raw materials, promotes the innovation of production technology, and raises funds for garbage disposal. In terms of packaging waste recycling, charging according to the packaging materials, weight, quantity, and other characteristics, promotes the saving of raw materials and reduces excessive packaging.

（4） **Deposit Refund System.** The last amendment to the "*Packaging Regulations*" stipulated that carrying out a compulsory deposit system for disposable beverage packaging. Stating, if the containers of liquid beverage cannot be recycled, the buyers must pay a minimum deposit of 0.25 Eurosfor each container, and when the capacity isover 1.5 liters, the buyers need to pay 0.5 Euros. The deposit is refunded only if the container is returned by the requirements of the "*Packaging Regulations*".

（5）**Financial Subsidies System.** The German government encourages the development of environment-friendly industries, such as waste incineration through cash subsides, state secured loans, or tax preferences. For instance, if the enterprises build environmental protection facilities, they will get preferential pricing for the lands they need.

3.5 Operation Mode

There are three management modes of garbage disposal:

1. Government Administration

In some cities, the governmental Sanitation Departmentis responsible for the management and disposal of the municipal household garbage, such as Berlin. But after reform in 1994, Berlin established a public enterprise BSR, which was owned by the Berlin government. This company sets up a management committee, the administrative committee, and the supervisory board. The management committee consists of government senators, and represents the government‘s interest. Members of supervision board are elected from the municipal bureau and the company‘s employees. The council is in charge of daily management. Further, the company is

operated in a wholly market-based manner. Its accounting is done independently and it is responsible for its own profits and losses. In addition to the 19% of the value-added tax reduction or remission by the government, the company has no additional financial subsidies. The waste disposal fees paid by the residents are its main source of revenue. BSR‘s disposal of nearly one million tons garbage produced by Berlin household and enterprises every year, and cleaning 136 square kilometers of street in Berlin, is their most significant task.

2. Enterprises Operation Mode

Private enterprises can also operate collection, transportation, treatment, and disposal of municipal garbagethrough coordinating and cooperating with the DSD Company.

Manufacturers and distributors of sales packaging participate in a binary recycling system of DSD, and pay DSD "green Dot" fees. DSD pays for the collection, classification, and recycling near the households, delegates waste disposal, and utilizes the company to collect, clear, sort, and recycle the garbage. The sellers supply the retailers with packaged products. Consumers put the used empty packaging in DSD‘s collection containers after use. Waste management firms collect and sort the packaging waste, which is then forwarded to recycling plants. Used packaging is turned into secondary raw materials and new products in the course of recycling.

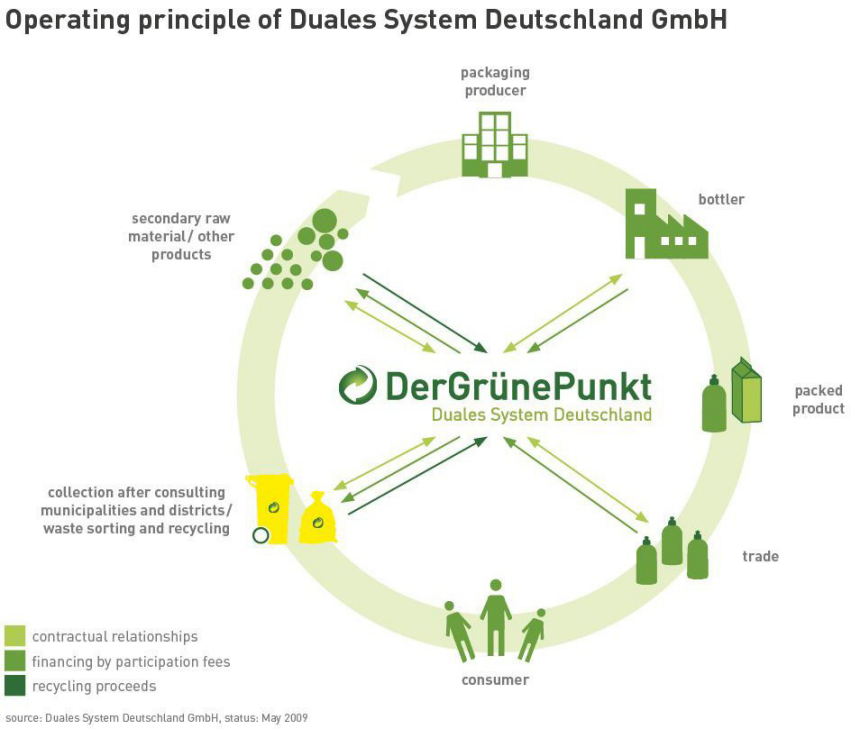


Figure 3the Operation Mode of Greenpoint Company

3. PPP Pattern

Private sectors cooperate with the government to dispose of the garbage. For

example, they can operate the garbage incineration plants in the form of an equity cooperation.

3.6 Garbage Management

3.6.1 Garbage Classification

Classification and collection is the most important step in the treatment of garbage. On this basis, what needs recycling, or what needs burning and sending into landfill can be determined. Berlin is implementing fine classifications for garbage, making an effort to realize waste reduction, increasing recycling, and reducing the proportion of landfill disposal to meet the legal requirements of restriction.

According to the production sources, the categories of the garbage in Berlin include: household garbage, mainly coming from private families; trade garbage, produced by enterprises and coming from service-providers, retailers, and small-sized companies; commercial garbage, produced by small-sized enterprises, sales shops, service companies, public organizations, or industrial enterprises; bulky waste, coming from private families; street refuse, including vehicle tire grains, damaged pavement, withered leaves, and driftings and in winter.

Consumers in Germany generally sort their sales packaging into three classifications: 1. Paper/cardboard. 2. Lightweight packaging (aluminum, tinplate, plastics, composites). 3. Glass. In paper sorting plants, the waste paper mixture is separated into the different categories before being forwarded to the paper-mills. Lightweight packaging is also separated into different materials and consigned to the relevant industries for recycling. Glass is transferred directly from the bottle banks to processing plants, where impurities are removed and the glass is crushed and sorted according to color. The glass granulate is then used to produce new bottles and jars.

Figure 4 Waste Bins on theStreet in Berlin

3.6.2 Garbage Collection

Generally, garbage is collected through the following ways:

Household garbage is collected and transported regularly by the Public Waste Utilities Department with standard containers for further treatment. All households must participate and pays waste collection fees.

Trade garbage is collected together with household garbage. In Berlin‘s central residential areas, small enterprises usually share waste bins with the residents living the same building.

Commercial garbage is usually collected with large and small-sized containers by small enterprises, service companies, public institutions, industrial enterprises themselves, or by the professional companies they have contracted with. The garbage is then transported to the disposal sites and disposed of together with the household garbage.

Bulky waste is collected and transported by BSR for recycling and disposal, but the company usually charges for it. Private bulky items can also be sent to the city recycling-sites in person for free.

Street refuse is collected and disposed of by road sweepers of BSR.

3.6.3 Garbage Recycling

Taking the recovery and recycling of the waste into prior consideration is the key policy of Berlin‘s waste management program. At present, Berlin is developing towards a method of resources management that promotes efficient material recovery, energy recovery, and the recycling of secondary raw materials. As for bio-degradable paper, and biological trash coming from household and municipal services, the recycling strategies of BSR are as follows: Biological waste is collected and processed separately, which can reduce the bio-degradable waste that will otherwise go into the landfill；Increase the recovery of materials like paper, glass, plastic and metal, etc； Enhance the conversion of garbage into energy and climate protection activities. Regarding the recycling of packaging garbage, according to the “*Packaging Regulation,*” and based on the principle ofextended producer responsibility, producers are responsible for the garbage they produce during its entire life cycle. However, for small manufacturers and distributors, it is a big burden to build an independent recycling and disposal system. Therefore, in 1990, under the support of the German Federation of Industry, the German Industrial and Commercial Association, 95 companies in the retail, consumer, and packaging industries established the DSD company (Green Dot Company), which is a non profitable private joint-stock enterprise. This companyis mainly targeting packaging waste, forcing the producers and sellers to bear the responsibility of recycling products packaging and reducing cost through the establishment of a binary recovery system.

The "Green Dot" trademark licensing strategy applied by DSD plays an important role in limiting and reducing the waste of packaging materials. The manufacturers, transporters, agents, and whole salers of each package have to pay the

corresponding license fee to DSD, in order to get the right to print the "Green Dot" trademark on their products. The license fees are calculated according to the material, weight, and number of packages. In order to reduce the "Green Dot" license fee, enterprises will try to improve and optimize the product packaging, which will promote the significant reduction of the packaging waste, and therefore save resources. Residents can enjoy free removal of the garbage if they throw the waste printed with "Green Dot" into the special dustbin. But, if they put this kind of garbage into the other waste barrels, they have to pay additional garbage fees. At present, over 90% of German packaging is printed with the "Green Dot" logo. Of the billions Euros of "Green Dot" fees DSD annually receives, about 20 Euros are paid per person per year for the processing and recycling of packaging waste.

The recycling mark "Green Dot" of DSD is only used on disposable sales packaging, while reusable packaging, like beer bottles, needs to be recycled and reutilized through paying a deposit instead of using the mark. Since DSD members have paid for the packing materials, not only is there no fee, but there are also professionals coming forward to recycle the packaging materials. If the consumers don‘t classify the packaging waste, dustbins will need to be cleaned more often, thus, the consumers will need to pay more fees for the waste disposal, and they will also face punishment for lacking of correct garbage classification. This is an effective measure of the "Green Dot" system, which encourages the consumers to recycle packaging materials.

Light packaging in Berlin is collected with yellow dustbins, or yellow bags, by the companies entrusted by the DSD system operator.

3.6.4 Processing Technology

After classification, the unrecyclable waste is disposed of mainly through the following three ways:

1. **Mechanical Treatment and Incineration.** This process generates energy and remotely provides heat supply. Mechanical and physical stabilization treatment (MPS) and mechanical treatment are environmentally friendly.These innovative methods of solid waste treatment require the separation of the combustible part from the bio-degradable part through waste classification. Screening out the bulky and unavailable waste, which will be crushed by the crushing machine, is also required. Black metal will be screened out among the waste crushed through the magnetic separation method, and then the organic part, and high calorific value part will be selected through a rotary screen. After pre-treatment, most of the waste can be used to produce Derived Fuel Refuse (RDF), and only a small fraction of the remaining materials needs final disposal.
2. **Composting or Fermentation.** Perishable organic waste is turned into a compost after stacking or high-temperature fermentation. These methods can be used in farmland. Additionally, methane gas, produced by the fermentation of organic

waste can reach 98% after purification, treatment and concentration. Then the gas will enter gas supply system and provide fuel for the BSR waste collection vehicles, which need natural gas for power, or it will enter the city gas network.

3. **Landfilling.** Landfilling is the last choice in Berlin's waste management policy. According to German law, only waste containing less than 10% combustible materials can be buried. Pipes are laid under the landfill sites to collect combustible gas produced by refuse degradation for further utilization, such as electric generation, gas supply, etc.

At present, Berlin has built 15 recyclable waste stations, one transit distribution center, one waste disposal center, four disposal factories for waste classification, and three waste landfill sites, which constitute the waste disposal system of the whole Berlin.

4 Implementation Achievements

In accordance with the requirements for the protection and utilization of renewable resources, Berlin has had tremendous success in implementing a waste classification system, and in forming a Solid Waste Economy or Circular Economy. Classified waste has become an important source of energy carriers and secondary raw materials. For example, among all recycled plastic waste, 40% was sorted strictly according to categories. Producing one ton of plastic with new materials cost 1200 to 1400 Euros, while producing with recycled plastic waste only costs 500 Euros. Compared with the original recovery, renewable raw materials appreciated three to four times in value. It can thus be seen that the afore mentioned legislation and requirements haveled to the formation of an ecological waste economy industry, the turnover of which reached 200 billion Euros. The industry production value has grown by 14% annually, creating jobs for around 250,000 people.

In 1992, Berlin produced 2.594×10^{6}t waste (including recyclable waste quantity and waste disposal quantity). In 2012, the amount of waste generated decreased to 1.481×10^{6}t. This is 43% lower than that produced in 1992. Regarding this change, 79% of the waste came from households, the remaining 21% from the business sectors (includingstreet refuse). The highest proportion of the waste categories was plastic (23%), followed by paper (20%), and food waste (15%).

Since 1990, the waste disposal quantity in Berlin has been constantly declining (See Figure 2). In 1992, waste disposal quantity reached 2.325×10^{6}t. In 2012 the waste disposal quantity was 8.57×10^{5}t, a reduction of about 65%. This reduction is attributed to the separate collection of recyclable waste, like paper, organic garbage, light packages, and glass. From 1992 to 2012, the amount of garbage collection and utilization in Berlin increased significantly, with only 2.69×10^{5}t waste recycled in 1992 to 6.24×10^{5}t in 2012. Further, the recycling rate increasing from 10.4% to 42.1%. In looking at the collection and recycling of glass, Berlin has realized the classified collection of glass in the whole city, and household apartments are equipped with green or brown containers with wheels for collection. Additionally, there were about

6000 public glass bottle recycling stations where people can dispose of other old glass articles. The waste coming from these containers and stations was collected and recycled by different types of companies. In Berlin, about 7.0×10^{4}tof glass was collected annually, (20kg per person), and the recycled glass accounted for 90% of the new produced glass.

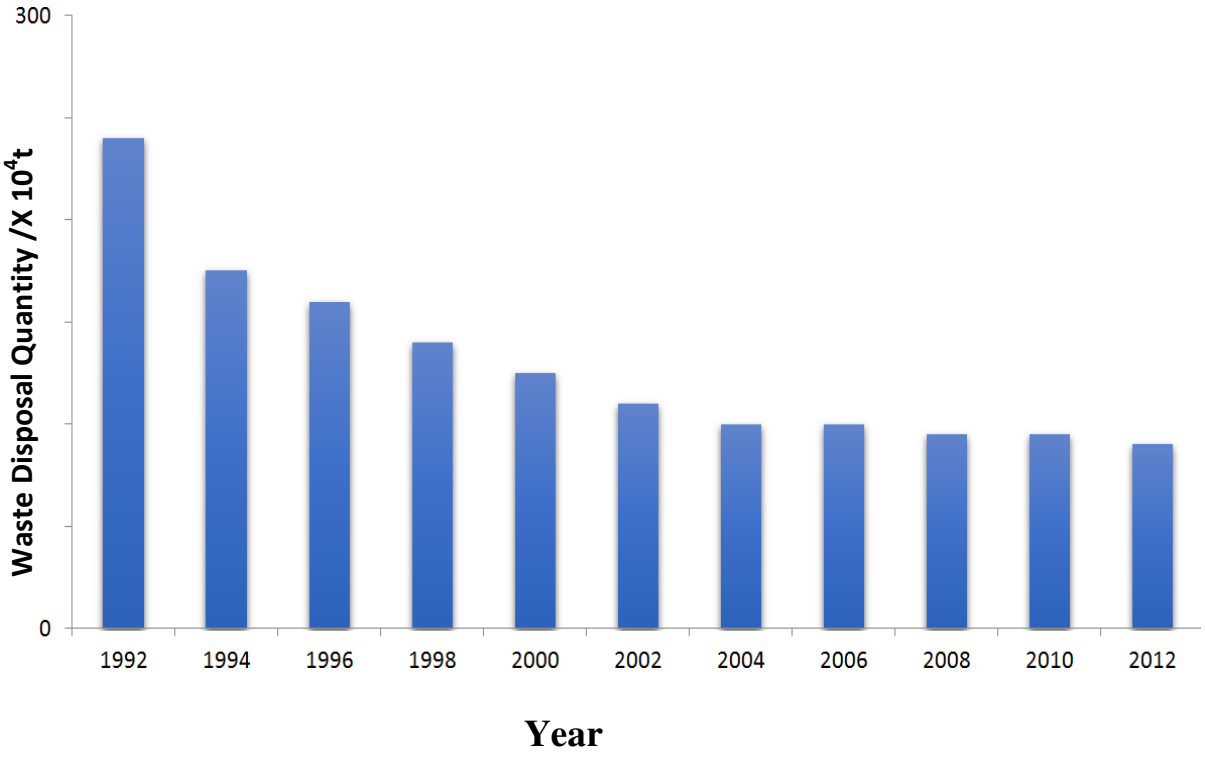


Figure 3. Waste Disposal Quantity in Berlin(1992 – 2012)

Berlin's garbage management strategy is not only limited to the safe disposal of waste, but also focuses on climate and resource conservation. Further climate and resource conservation is bolstered through the production of electric heatingby burning steam, generating power through landfill gas, mechanical and physical stabilization treatment, and producing combustible materials and fuel through mechanical treatment, etc. Accordingly, Berlin has recovered a lot of energy and reduced the impact on the climate. The study showed that in 2010 Berlin reduced greenhouse gas emissions by about $9.0\times10^{5}tCO_{2,}$ through waste management (incineration power generation, composting and fermentation of biogas utilization, landfill methane collection and utilization). Through measures as the optimization of different types of garbage disposal, improving the sorted collection of recyclables and organic garbage from the household and commerce, promoting more efficient recycling of materials and energy, and forcing the government agencies and public groups to follow the environmental protection standards when formulating rules to products and services, greenhouse gas emissions will be further reduced by, as is expected, about $2.48\times10^{5}tCO_{2}$ equivalent. Therefore, the improvement of Berlin‘s garbage disposal will reduce greenhouse gas emissions by an estimated

$1.148\times10^6 tCO_2$, and promote the realization of the goal of climate protection in Berlin, and reduce environmental impact.

5 Implications and Suggestions

(1) Laws and Regulations Go First

The establishment of laws and regulations is an important method to successfully promote effective municipal waste management of Germany. Further, Comprehensive improvement to these laws is the key point of the German experience. Governments at all levels should formulate feasible regulations and exercise strict supervision, especially in the details of execution. These details should be regarding the requirements of waste classification, recycling, as well as how to classify waste, and so on. The successful disposal of municipal waste in Berlin, domestic garbage becoming raw materials, and the ecological waste economy becoming a major industry all depends on the enforcement of laws and regulations.

(2) Mechanisms of Supervision and Implementation

In order to realize the environmental benefits of solid waste management, it is indispensable to build strong supervision mechanisms instead of relying solely on the individual and enterprise's self-consciousness. It is under mandatory administration and supervision that Berlin can guarantee that garbage-collection and disposal produces no secondary environmental pollution. For enterprises, strict supervision and management links the environmental-management target with the economic benefits, therefore changing the enterprise's environmental behavior through altering the production cost, and thus incorporating the environment management into its framework.

(3)Economic Instruments

Economic instruments are effective methods to solve the problem of waste classification and recycling. Among the waste management policies in Germany, "Producer Responsibility" is the key to a successful circular economy policy. As for the Domestic Waste Charging Institution, the fee for mixed garbage that is not properly classified is often higher than that of other types of garbage. This stimulates people to classify the garbage more precisely. By comparison, garbage classification and recycling pilot work has been launched in many cities worldwide, but recyclable and unrecyclable duster bins throughout the streets did not play the role of classification, and people didn‘t make any distinction what they put in each bin. Therefore there is only a formalistic effect rather significant change. According to data and research in other developed countries, the economic instruments of garbage fees and deposit refund have dramatic effects on waste reduction and classification, and the experience deserves continued study.

(4)Propaganda and Education

Strengthening environmental awareness, participation of citizens, and promoting garbage reduction and classification is important. As the premise of recycling, garbage classification is a meticulous and complicated job. Therefore, it‘s necessary to launch content-rich and diversified public educational activities about garbage classification, and vigorously disseminating the relevant knowledge to promote the cultivation of people's consciousness of conservation. Congruently, guiding the public to implement minimalist lifestyle will help carrying forward the fine tradition of thrift.

(5) Social Participation

The Green Dot operation mode innovated by DSD is the key to the successful reduction, recycling, treatment, and utilization of waste packaging. We can also see the importance of establishing social participation mechanisms. In order to change the current situation of municipal garbage management, it is necessary to change from government monopolized urban garbage treatment, and allow state-owned and private enterprises to take a wide part in the disposal and processing of municipal garbage. Therefore forming a waste-disposal pattern of the government support, enterprises leading, and the public participating, in the whole process. This will allow for therealization of domestic waste resource utilization, promotion of the development of an ecological waste industry, and lead toa beautiful, clean, and ecological friendly living environment, which incorporates resource recycling, green energy, and sustainable development.

Bibliographies:

1. http://www.gruener-punkt.de/en.html
2. waste policy: http://www.bmub.bund.de/en/topics/water-waste-soil/waste-management/waste-policy/
3. data on the environment 2015:http://www.umweltbundesamt.de/en/data
4. Chenjie, Pang Chensheng, Zhang Ruijiu.*Analysis on the Management and Comprehensive Disposal of Solid Waste in German Cities(2).Energy Conservation and Environment Protection 2008.*
5. Tan Lingzhi, Wang Guoyou.*Management Policy on Municipal Solid Waste Incineration in Germany, World Environment*,2006(3):40-43；
6. Shao Jingbang.*Current Situation and Development Trends of DomesticWaste Disposal in Germany*, http://wenku.baidu.com/link?url=Ih3yib0Mojbngr3mUpenifpC4IDuS H5_-boTNB0Evo29MFAQiwIhl2jBoXrYruaBMma0eCpHzv9dfa0MNoRsOwrB MIlFXn-cYc01zEEieQ3
7. Li Huayou, Xiao Xuezhi. *Analysis on Management Policy of Municipal solid waste in Germany*， *Environment Protection* ,2003.5 p58-61

Classification and Reduction of Urban Living Garbage and Kitchen Waste Disposal in Yantian District of Shenzhen City

Zhang Zhenshan[12] Ye Haofeng[13]

Abstract: Shenzhen Yantian District won the 2014 annual "Chinese Habitat Environment Award". And this is the only Chinese city winner for a garbage disposal project. This paper introduces details on the innovative practices in Yantian regarding urban garbage classification and reduction, as well food waste treatment and summarizes its successful experiences. It will be a very good reference in the field of urban wastes disposal.

Keywords: urban waste resources, kitchen waste, garbage classification, waste reduction, Yantian.

1. Background

Shenzhen is a coastal metropolis in Southern China, adjacent to Hong Kong, and located in the Tropic of Cancer (113°46'-114°37'E and 22°27'-22°52'N). It lies in the south of Guangdong province and on the east bank of the Pearl River Estuary. Shenzhen adjoins Daya Bay and Dapeng Bay in the east, the Pearl River Estuary and Lingding Bay in the west, and the Sham Chun River and Hong Kong in the south, all while bordering Dongguan and Huizhou in the north. The city covers an area of 1991 square kilometers, and had a permanent population of 11.3 millionat the end of 2015, which is rapidly increasing. As Shenzhen develops economically and urbanizes, more and more people have been attracted to the city. Further abundant rainfall, wet days, and annual average temperature of 22.4℃, create a very hospitable subtropical oceanic climate. Shenzhen produced over 20000 tons of garbage daily (not including construction waste), 15800 tons of which are incinerated or buried, 3600 tons of paper waste that is recycled, and an additional 2000 tons of kitchen garbage.

Located to the east of Shenzhen city, Yantian is 12 kilometers far away from the urban centre. Covering an area of 72.63 square kilometers, its east-end is Bei Zaijiao beach which adjoins the Longgang District, while its west-end is Wutong Mountain which adjoins the Luohu District. In the south, Yantian is adjacent to the New Territories of Hong Kong, and in the north, Longgang District. At the end of 2012, Yantian had a permanent population of about 212,000,of which 50,000 are permanent households. Yantian is famous for its port, one of Chinaho international deepwater ports, its beautiful natural landscape of Sanzhou-tian, the cultural landscape of the

[12]Zhang Zhenshan: Program Manager of UN Habitat China Office.
[13] Ye Haofeng:Urban Management Bureau, Yantian District, Shenzhen City

Sun Zhongshan uprising, the OCTEast (Overseas Chinese Town) tourism project, and its famous–ast (Overseas Chinese Town) tourism to Yantian, and its famous sites, has exceeded 10 million per year.

Figure1 Birdseye View of Yantian

Although with a small population, Yantian has been, like other districts, suffering from the pressure of increasing garbage due to recent urbanization and development. As a tourism hub, along with the permanent population, Yantian attains a far higher per capita volume ofwaste production than an average city of equal size. Although geographically small, Yantian has difficulty in dealing with the garbage centrally. Yantianh geographically small, Yantian 50 square kilometers, but only about 23 square kilometers are available for development, or habitable use. This relatively small amount of utilizable land has a large effect on Yantian, because even though the region is seriously lacking waste disposal facilities, there is still no land available for the construction of large waste disposal stations. The surrounding area also lacks developable land and therefore makes it difficult for Yantian to centrally manage its waste. Residents have a high demand an ecologically friendly environment, while maintaining alow tolerance for garbage disposal facilities. Further, Yantian also has a problem with mixed garbage in the dustbins, which can cause decay of kitchen waste and food garbage, can produce unwanted sewage and odor during collection, transportation and processing, and finally can pollute the surrounding environment for the second time. In this regard, residents here yearn to solve the problem, but waste treatment facilities are "NIMBY (Not In My Back Yard) facilities." This low tolerance for waste treatment facilities previously made it difficult for Yantian to solve some of its waste management problems.

The inevitable course to properly manage waste disposal is to implement reduction and resourcezation through garbage classification. The government of Shenzhen attaches a high importance to garbage management and promotes it as a practical part of people‘s lives. The party committee and government of Yantian describes waste disposal as the key link for further ecological development, formulating work programs based on the region‘s situation, and launch waste classification and reduction programs, as well as implementing a hazard-free treatment of kitchen wasteplan. Accordingly, these plans have had significant effects,

and this essay will further introduce the details of Yantiance successful experience in waste reduction, classification, and kitchen waste treatment.

1.1 Waste Reduction and Classification

As a tourist area, Yantian produces 260 tons of garbage averagely per day, with kitchen waste (including kitchen garbage) accounting for 1/3, 200 tons of which are treated through incineration, while the remainder is treated by kitchen waste disposal factories. Meanwhile, garbage production is increasing at an average rate of 8% annually.The contradictions between waste growth, waste reduction, and recycling are increasingly distinct, while the search for solutions has become a worldwide process. Through years of experimentation, Yantian previously succeeded in reachinga "zero increase" of garbage incineration, and even had a year of "negative growth of waste" in 2015.

In 2014, Yantian also was awarded the annual "China Habitat Environment Award", which is the only Chinese related award for garbage disposal.

In order to further improve waste reduction and resource utilization, the Urban Management Bureau of Yantian carefully analyzed and researched, and finally implemented the reduction, classification, and resourcization of the waste system, because there were no suitable centralized processing points in the district and surrounding areas.

Figure 2 Training on Waste Classification

Many developed countries like the United States, European Nations, and Japan have already adopted waste classification systems. Although their methods were different, they all achieved positive results. Annual waste yield in Tokyo, Japan in 2008 declined by 50% compared to 1988. Taipei city began a pilot program of household garbage classification in 2000, and implemented compulsory classifications in 2005, thereby reducing waste by 59% as of 2010. China of iusepment, or at garbage classification did not obtain ideal results due to the following reasons: First, there is already a waste recycling system in China, recycling waste that can be reused as resources like plastics, paper products, metal etc. Second, the urban transportation and disposal system has some flaws, in which the classified

garbage cannot be relevantly treated, but instead is taken to the landfill sites or incineration plants. Therefore, the methods of classified collection, transportation, and processing must be incorporated into the waste classification system.

Figure 3 Waste Bins at a Community

Accordingly, Yantian connected the three links of front-end classification, mid-end collection and transportation, and the terminal treatment.They then built systems of classified collection, transportation, and resource processing of low-valued recyclable materials and hazardous waste. They further, vigorously recycled low-valued recyclable materials, like scrap fabric and glass, and implemented special recycling processes of bulky garbage, flowers and orange plants abandoned after New Year, and landscaping waste. Therefore improving the resource utilization of classified garbage and making great achievements in reducing waste.

The detailed measures include the following:

First, vigorously promote "Resource Recycling Day", which will lead to the positive participation of the residents in furthering waste classification. Increase publicity by having regular activities in different communities and residential quarters, villages, and in the city, every Saturday. Incentivize proper disposal, by the way of prizes, in order toform good habits of storing recyclable materials temporarily in home and disposing of them properly on "Resource Recycling Day." This will help lead to a recovering system for recyclable materials that isscalable, economically viable, and high-efficiency.

Figure 4 Yantian Resource Recycling Day

On May 14th, 2016, Red-Vest Team appeared in Yi Haicheng square, the team was composed of 80 parent-offspring volunteers coming from 36 families. They promoted environmental protection knowledge regarding "Resource Recycling Day", and recycled scrap metal, waste paper, waste plastics, waste glass, waste fabric and so on there. It was through these practical deeds that more and more residents got to learn about waste classification and recycling, and their awareness rate and participation rate in the reduction and classification of the living garbage dramatically improved. On the spot the environmental protection volunteers positively disseminated polices, laws and knowledge about garbage classification, guided the public to throw the waste into the relevant dustbins, and attracted their participation into the activity by the way of exchanging prizes with harmful waste and recyclable materials. Especially the parent-offspring volunteers, ignoring the morning rain, still took part in the activity . Children learned relevant knowledge from books on site, and the loud reading voice attracted passing citizens to join "Resource Recycling Day" and study the classification of garbage.

Second, carry out the disposal work of bulky old furniture and implement the resourcezation of landscaping waste. In accordance with the practical situation, entrust professional companies to collect bulk wooden waste, scrap wooden furniture, and landscaping waste for centralized crushing and then reuse them as accessories of kitchen waste disposal. As of August 2016, bulk wooden waste and scrap wooden furniture had been reduced by about 1706.43 tons and landscaping waste reduced by 674 tons across the whole region.The effective front-end reduction and classification has laid a fine foundation for non-hazardous disposal and resource utilization of garbage.

Third, promote the work of collecting and transferring hazardous waste,such aswaste batteriesand waste fluorescent tubes. Establish a network on regulatory recycling and comprehensive utilization of waste batteries across the region. Launch a special recycling service concerning waste batteries to reclaim these batteries and fluorescent lamp, and at the same time, carry out harmless treatment and resource utilization of both. As of now, 849 battery boxes, 115 lamp tubs boxes, and 733 recyclable-products and harmful-materials containers have already been placed in all residential quarters, working places, and various public places in order to guide the residents for disposing of their waste in the proper manner.

Wutong Court is the first housing estate in Yantian that has realized garbage classification, and the project has been highly recognized. A row of waste bins are placed in the open places in the court, with those for kitchen garbage equipped with display screen and card-swiping area. Every family participating in the waste classification has a card. When the residents throw kitchen garbage, they can punch their own cards, and data will be displayed on the screen and taken as the basis for prizes exchange.The pattern of residential waste reduction and classification has changed from the original manual registration to intelligent classification management.

Fourth, develop special recycling and disposal programsconcerning flowers and orange plants thatare abandoned after New Year. Implement free recycling of abandoned flowers and orange plants through temporary governmental disposal sites and municipal garbage company collection services (Village Cleaning Enterprises are responsible for the villages in the city). Accordingly, this past Spring Festival, about 2000 flowers and orange plants were properly disposed of, and further used to demonstrate the basics of kitchen waste recycling, reducing an amount of 20 tons. Among the plants, the well-growing ones were maintained and eventually returned to the nursery for further use, while the poorly maintained plants' fruits were used as raw materials of kitchen waste, and their leaves and branches were disposed of harmlessly as landscaping waste.

Fifth, implement special recycling and disposal work for scrap fabric. Build channels of recycling and introduce recycling enterprises. For example, Sheng Donghua Environmental Protection Co., Ltd, which has its own sorting places and recycling channels, placed over 120 special recycling barrels for scrap fabric in residential quarters. At the same time, the company equipped more than 80 660-litre recycling boxes in refuse transfer stations and residential districts, further improving the level of resource utilization of scrap fabric in the city.

With the purpose of strengthening supervision of the enterprises that are managing waste reduction and classification, it is necessary tomake records of the persons responsible of the classification and regularly submit the relevant information about waste type, quantity, transport method, whereabouts, and so on within the scope of responsibility. From January to August in 2016, the whole region reduced, incinerated, and harmlessly disposed of 4874.68 tons of urban household garbage (including 1706.43 tons of bulky old furniture and wooden waste, 674 tons of landscaping and greening garbage, 50.1 tons of scrap fabric, 1239.85 tons of glass, 10.3 tons of hazardous refuse, 21 tons of abandoned flowers and plants, and 1173 tons of kitchen garbage from residential quarters). With the growing population and increasing waste volume, the amount of incinerated of household garbage did not grow, and waste reduction and resourcezation work achieved obvious effects.

1.2 Kitchen Waste Treatment

Although with a small population and small area, Yantian is a major coastal tourism site. These conditions have made it a better experimental field for testing a waste reduction and classification system. In March 2012, Yantian formally launched this pilot project, disposing kitchen waste, which is the most difficult job in garbage disposal, and properly implemented it.

The Shenzhen average proportion of food waste in the garbage is about 18%. Every day 28 tons of kitchen garbagein residential quarters, out of 200 tons of living garbage incinerated in the region are not sorted out. Together with the 60 tons of food waste collected and processed, the total amounts reach 88 tons, accounting forover 1/3 of the 260 tons of daily household refuse, which makes it very difficult to dispose. Kitchen waste is highly perishable, and it will, if without enclosed transportation,

cause secondary pollution to the environment. Even if it can be burned in the incineration plants, large amounts of diesel will be needed for combustion. What is worse, pig farmers from surrounding cities purchase part of the food solidsat very low price, and waste edible oil enters an underground recycling and processing market, bringing significant risks of drainage oil being used again.

During the implementation of waste reduction and classification, the first disposal of food waste was expected to have a significant impact. Accordingly, the high rate if collection and the integration of processing of food waste not only eliminated the biggest destructive fact or to the environment waste not on, but also, in a socially responsible manner, prevented the hazardous practice of using drainage oil.

To enhance effectiveness of treatment of kitchen waste, Yantian seriously urged franchising enterprises to optimize the process route, and to constantly improve environmental protection facilities processes in disposal of sewage, stench etc. The city of Yantian also carried out a publicity campaign and daily law enforcement, expanded the scope of the collection of kitchen waste, and took the lead in uniformly collecting kitchen waste from public catering units. This further improved the enthusiasm of waste classification within the cities catering units. As of August this year, Yantian had signed 734 contracts regarding the collection of kitchen waste, with the active cooperation of sub-districts and member units. Overall, the signing rate reaching 91.7%.The work covered all large-medium catering service enterprises in the area, the region, and also gradually including farmers‘ markets, supermarkets, and fruit stores along the street into the classification, collection, and transportation waste disposal system. According to the statistics, the region collects about 50 tons of solids and 10 tons of oily water daily, which was all appropriately disposed of.

To consolidate the achieved effects, Yantian has been continually strengthening supervision and management on kitchen waste, especially regarding the linkages of front-end classification, collection and treatment, data delivery through regulation of the Internet of Things and third party regulatory enterprises. Yantian also helped organize law-enforcement teams of sub-districts to launch the “One-Hundred-Day Campaign” that was meant to eliminate illegal collection of kitchen waste, in the course of which the illegal collection of food waste and “drainage oil” was effectively eliminated. During this campaign, 629 law-enforcement officials were called and 154 law-enforcement vehicles were used, carrying out special actions for 4 times. Further, the task force investigated 427 restaurants that produced kitchen waste, patrolled the roads over 240 times, garbage transfer station 80 times, and even seized 9 vehicles on-site.

In order to further improve the waste reduction and classification system, and in consideration of the long-term development needs of urban sanitation, based on the principle of saving land and reasonable layout, the district committee and government is pursuing new projects to dispose of of non-hazardous treatment of kitchen waste. These projects include the construction of crushing and gas-makinglines for biomass materials, bio-diesel feedstock oil, landscaping waste and bulky scrap furniture, as well as supporting facilities for the disposal of waste gas and sewage water. In accordance with the project goals, the average daily disposal amounts of kitchen

waste (including drainage oil) are around 200 tons, with the products out puts being biomass materials and bio-diesel feedstock oil. Additionally, the project is expected to effectively eliminate all the food waste (including drainage oil) generated in Yantian District after completion.

Since the implementation of the pilot program of waste reduction and classification in 2012, Yantian has, adhered to the principles of "government lead, public participation, enterprise involvement, and technology supportn 2012, es were used, carrying out specther, they have actively innovated and chased their policy goals, and eventually succeeded in the integration of disposal of waste classification and kitchen refuse, particularly regarding the reduction, resourcization and harmless disposal of said waste. They have accordingly been recognized for their achievements. The kitchen waste disposal project in Yantian Districthas won the 2013 annual "Livable Environment Award in Guangdong Province", and "China Habitat Environment Award" at the end of 2014. Also, Yantian was identified as the only pilot unit of food waste treatment in Guangdong Province.

The summary of the successful experience of Yantian on garbage classification and kitchen waste disposal is as follows:

Establish Improved Management Mechanism

In order to improve the construction and management of garbage classification and reduction of kitchen waste, the local government established a leading group with the mayor as the head, the relevant district leaders as deputy heads, and the leaders of government departments and sub-districts as committee members. The city also set up a system of joint conferences to work on garbage reduction and classification and non-hazardous treatment of kitchen waste, formulated the "*Implementation Plan on Creation of Waste Reduction and Classification Work*" through research, defined the overall objectives of the project, implemented phase steps and measures of success, and launched a work mechanism featuring all-level action focusing on of clear division of responsibilities, coordination, collaboration, comprehensive advancement.

Meanwhile, in order to ensure the effective implementation of various regulations on waste reduction and classification, and to improve the work level, Yantian formulated the "*Comprehensive Evaluation Methods on Waste Reduction and Classification in Yantian District*", in order to assess and check the relevant enterprises that have been contracted for waste reduction and classification.

In accordance with the principles of "overall planning, scientific implementation, fanning out from points to areas and gradual promotion", and based on the created demonstration units (residential quarters) on waste reduction and classification over the years, in 2016, Yantian selected 42 large-scale residential properties to participate in a new project.Garbage was divided into four categories: recyclable products, hazardous garbage, kitchen garbage, and others, and then sorted. The daily waste classification work was launched in "Internet Plus" mode, and residents were encouraged to actively participate in the waste classification through receiving free "degradable garbage bags", "scanning card" and participating in a "prizeexchange ".

Other residential quarters and the region's institutions carried out garbage classification in accordance with the "Four Small (refers to bin for small scale garbage) and OneLarge" pattern, with daily supervision.

Introduce Market Mechanisms

In addition, during the project, Yantian has also fully introduced market mechanisms, vigorously played the role of social capital, combined government investment in infrastructure with investment in enterprise equipment and technology, actively explored efficient and feasible way of commercial operation, strengthened market operation of urban living garbage disposal, directly reduced government investment, and promoted waste reduction and classification as well as sustainable development. In the process, it also paid high attention to the positive participation of sub-districts, schools, communities, enterprises and institutions, property companies, social organizations and residents of the region to cultivate their environmental awareness and ideas to further promote the construction of ecological civilization.

EnhancePublic Participation

In order to encourage public participation, it is essential to increase public of knowledge about waste reduction and classification, food waste treatment regulations and technology relying on the carriers such as television, radio, new media, large column advertising, community windows and so on, to createa strong atmosphere of public opinion, and improve public awareness of waste reduction and classification. It is also important to motivate the participation of sub-districts, communities, enterprises, property companies and social organizations to spread the message. In terms of the choice of waste disposal places, scientific principle should be followed, and it is also needed to solicit ideas of the district deputies, CPPCC members, community work stations of the sub-districts, residents of the region, and news media, so as to effectively incorporate both the public and private sectors. During the processing of the project, Yantian introduced market mechanisms, emphasized the role of social capital, and combined government investment in infrastructure with enterprise capital in technology and equipment, to effectively inform the public.

Figure 5 Waste Classification and Reduction Campaign in Yantian

Prize Guidance

Further it is important to incentivize recycling to help the public form good habits of storing recyclable materials temporarily in home and disposing of them properly on "Resource Recycling Day", so as toestablish ascalable, economically viable, and efficient system for recyclable materials.

Through the various methods described above, and the adhering to the proper methods of garbage disposal and classification, Yantian has succeeded in reaping the economic and social benefits of garbage reduction and classification.

Innovation of Working Methods

Through innovation and experimentation, from the pilot program to the promotion, garbage classification and reduction (including kitchen garbage utilization) in Yantian Districthas gone through–three Transformations based on the "Four Relying-On" system.

First, the "Four Relying-On" system including:

(1) Relying on "FineClassification" of Property Management Department. Taking advantage of the chance of meeting with residents, the property companies can deliver special kitchen garbage bags door-to-door to publicize the knowledge of waste reduction and classification. Setting IOT (Internet of Things) service station, and all-weather collecting, as well as scanning automatically for registration; at the same time, there is designated responsible person to guide residents' correct classification disposal; Franchised enterprises send personnel with special training certificates to go on duty in the public canteens and staff cafeterias, and on-site guide the fine classification of garbage to ensure the effective follow-up collection and processing.

(2) Relying on "Harmless Degradation" Based on Scientific and Technological Innovation. Harmless Degradation is a Process of extracting and attaining dehydrated oil from kitchen oil-sewage through oil-water separator, and then refining bio-diesel. This is done through using SZ Resell. technology regarding "oil-water separation and high-temperature biodegradability". After this process the separated water can be poured into municipal sewer networks, and the kitchen solids would be degraded and then reused, while the remaining 15% of the degraded materials would be further used for producing organic fertilizer or bio fuel rods.

(3) Relying on “Zoning Processingn On the Basis of Existing Facilities. Zoning Processing is the Procedure of Effectively and Efficiently Using Existing Facilities and Networks to Dispose of Waste. Due to Yantian Districtd be further used lack of centralized processing places, it is critical to utilize existing facilities. This can be done through upgrading spare infrastructure in the original sanitation base, constructing scattered front-end disposal stations of kitchen waste in certain

areas, and then through collecting and transporting the waste by air-tight environmental vehicles to the terminal factories for disposal. This would allow for the avoidance of using new lands and reduce the influence of the transportation costs, leaks, and smells during the transportation process and subsequent environmental damage.

(4) Relying on "Market operation" of Professional Companies. Market operation is the incorporation of private companies in helping the public become more aware, and more efficient, in disposing of their garbage. This can be accomplished through adopting a pattern of combination between high-tech (like IOT) and commercial operations. These linkages will encourage residents to participate in waste reduction and classification through returning bonus points that can be redeemed for prizes. This will further build scale, economic, and efficiency in managing recyclable materials, while greatly improving the work efficiency, and helping to realize a "zero increase" of garbage incineration.

Second, the “Three Transformations” are as follows:

Transform “Mixed Collection and Transportation Into “Front-End Classification”. The fundamental problem with reduction and classification of urban household garbage lies in mixed-waste disposal. The source of this problem is in there residential quarters, villages, large food streets, and restaurants. In order to rectify the problem,it is essential to implement preliminary classification in those districts. Accordingly, many districts chose to promote by stages, and from easy to hard, through various forms and methods. In 2016, based on the created demonstration units (residential quarters) of waste reduction and classification over the years, Yantian selected 42 large-scale residential properties, in which the garbage was divided into four categories. These categories were: recyclable products, hazardous garbage, kitchen garbage, and others, the daily waste classification work was launched in "Internet Plus" mode, and residents were encouraged to actively participate in the waste classification through receiving free "degradable garbage bags", "scanning cards" and "prizeexchanges". Other residential quarters, and the region's institutions, carried out garbage classification in accordance with the " Four Big and One Small" pattern, accepting daily supervision, and attracting public participation through redeeming gifts with bonus points. Meanwhile, regarding the Yantian seafood streets, sanitation vehicle teams and other regional catering stores, Yantian implemented the kitchen waste solid-liquid separation process and reduction through the measures of incentive and constraint, to link front-end classification with processing, and consequently realized waste reduction and classification from the source.

Transform “Simple Disposal”Into “FineUtilization”. Before the project, most restaurants and canteens would sell their kitchen waste directly to pig-farmers, and kitchen garbage, hazardous garbage and low-value recyclable materials were mixed with other garbage and then transported from refuse transfer stations to incineration

plants for incineration .In addition, without efficient scientific utilization techniques, and proper enforcement, the front-end waste classification cannot avoid the following waste mixture. In order to prevent this, Yantian put the fine utilization of resources as the target, scientifically designed the processing links, built a disposal system of classified transportation and resourcization of low-valued recyclable materials, hazardous waste, depth recovered scrap fabric, glass and other low-valued recyclable materials, and further launched a special recycling project of bulk garbage, abandoned flowers and orange plants, and landscaping waste. Finally, after centralized crushing, the waste is reutilized across different waste areas. Concurrently, it also strengthened the supervision, and enforcement, of processes to promote waste disposal and resource utilization.

Transform "Centralized Processing" Into "Zoning Processing". Without appropriate centralized processing sites, it is necessary to adopt zoning processing. This means relying on the existing small and medium-sized sanitation infrastructure, such as transfer stations and sanitation tool rooms, it means further building front-end treatment stations of kitchen waste equipped with oil-water separator,high temperature biodegradation machines and so on. This, more local, zoning processing will promote the harmless disposal of kitchen waste coming from large restaurants, food street, and industrial zone canteens, as well as reduce nearby residential kitchen garbage. Figures show evidence that solid kitchen waste can be degraded after high-temperature treatment by 85%, leaving only 15% residue, and the liquid can be completely dehydrated. This can help to effectively avoid secondary pollution caused by the kitchen waste transfer processing, effectively reducing waste and improving the harmlessness of waste disposal.

Through the above "three transformations", Yantian has made significant improvements in classification and disposal of living garbage, in finding waste disposal solutions featuring low-investment, land constrained areas, and in having rapid success. This is in accordance with the practical situation, or "Yantian Pattern" of waste reduction and classification, as well as the non-hazardous treatment of kitchen waste. At present, Yantian is leading the city in this job. Yantianardous treatment of kitchen waste. At present, Yantian is leahey have fully affirmed Yantian's work in integrating the forces of government, enterprises, and society. Further they have praised Yantiann integratin exploring the commercial pattern of household garbage disposal, and finally obtaining positive results on waste reduction and classification, and the harmless treatment and resource utilization or waste. They also required promotion to improve the citizens' awareness of waste classification and the innovative environmental protection work to enhance the city's ecological civilization level.

Chapter Four: Urban Ecosystem

Wide ranges of ecosystem services come from the natural spaces in, and around, cities. The breadth of ecosystem services provided by nature is often undervalued. They clean the air and water, reduce noise, temper floods, sequester CO_2, provide water and food, regulate the local climate, provide renewable energy and conserve biodiversity. They can also increase physical and psychological wellbeing.

Some cities have started to safeguard biodiversity and ecosystem services – for the benefit of current and future generations – by preserving and recreating greenbelts, natural parks and waterways, and generally prioritizing nature protection during development.

The Management and Practice of Urban Ecosystems: A Case Study of Zhuhai City

Li Hailong[14]

Abstract: Zhuhai is an experimental field of ecological civilization. She has inherited the idea of coordinated development between ecological protection and social-economic construction for a long time. Furthermore, Zhuhai has ensured and promoted city‘s ecological environment through scientific urban planning, sound legal systems, strict environmental protections and policies indevelopment and management, as well as the advanced notion of a garden city, an ecological city, and a forest city. In addition, she has vigorously developed multiple promotion and optimization programsregardingecological systems. Accordingly, Zhuhai has realized her potential and capacity for economic development, in accordance with retaining good-quality natural environment. The exploration of urban ecosystem management in Zhuhai isan important reference for other cities in China.

Key words: Urban ecosystem; management; practice; Zhuhai

1. Background Information of Zhuhai City

1.1 Brief introduction

Located in the southwest of the Pearl River Estuary in Guangdong Province (**See Figure 1**), Zhuhai faces Hong Kong and Shenzhen across the sea to the east, and borders Macauto the south, Xinhui and Taishan to the west, and Zhongshan to the north. It covers an area of roughly 1,732.33 square kilometers inhabited by a permanent population of 1.6341 million (2015). The city has a pleasant climate, with the monsoon season alternating between winter and summer, a high temperature all year round and little differences in yearly and daily temperatures. Zhuhai‘s climate is further affected by

Figure 1. Geographical Location of Zhuhai.

[14] Li Hailong, Doctor of Human Geography of Beijing University; Deputy Director of Eco-City Planning and Construction Center,Chinese Society for Urban Studies; Deputy Secretary General of Eco-city Studies Committee; and Director of Office of Europe-China Eco-Cities Link (EC-LINK) Project, Ministry of Housing and Urban-Rural Development.

the surrounding South Subtropical and Tropical Transitional Oceanic Climate zones. Zhuhai is honored as the "City of A Hundred Islands", with the largest area of sea, the largest number of islands and the longest coastline in the Pearl River Delta area.

The beautiful coastal city has various types of ecosystems, including mountains, hills, plains, forests, farmland, rivers, lakes, mud flats, coastal zones, ocean and islands, covering multiple types of landscapes and great ecological diversity, with a unique natural environment where cities are located around mountains, rivers are crisscrossed, and the mainland and islands face each other. There are four river networks in the area. These networks include: (Hutiaomen-Yamen Channel, Huangyanghe-Jitimen Channel, Xilihe-Modaomen-Kuanhekou Channel and Lovers Road Coastline) from the south to the north, and six mountain clusters (Phoenix Mountain Cluster, Black and White General Mountain Cluster, Dahengqin Mountain Cluster, Huangyang Mountain-Guogai Mountain-Daling Mountain Cluster, Yanlang Mountain Cluster and Gaolan Island Cluster) from the east to the west. The river frameworks and mountain clusters are overlapping and interspersed. Early in 1991, Zhuhai was included in the "National Top Forty Tourist Destinations", and the only one relying on the overall urban landscape.

Zhuhai is among the best Chinese cities in terms of air quality, though located in the Pearl River Delta, one of the three most air-polluted regions in China. In 2015 statistical data suggests the city had 323 days of good air, and ranked ninth in the seventy-four key cities in air quality. Meanwhile, its GDP grew by 10.0%, it ranked top in the Pearl River Delta region. Zhuhai proves through facts that a favorable eco-environment is one of the best public products, as well as the most universal welfare for the people.

Zhuhai has a significant focus on preserving ecology in its region. It has highlighted the significance of "ecology" since the beginning of planning for both the Hengqin New Area and the Western Center City. For instance, the Western Center City has been positioned as a high-end accumulation area for Macau-Hong Kong-Guangdong Cooperation, with a productive service center arising on the west bank, and an emerging service area for transition into the special economic ecological and livable demonstration zone, with an additional emphasis on the importance of being "ecological and livable". Since its construction in December 26, 2010, the Western Center City has been following the ecological concept-determined development pattern, retaining natural landscapes but also implementing a scientific and reasonable urban layout.

1.2 Difficulties and Challenges

Since it's founding in 1979, Zhuhai has always stuck to the coordinated development between eco-environmental protection and social and economic construction. The border, fishing village is now a well-ordered modern coastal garden city with a

vigorous economy, tidy appearance, fresh air, moderate population, unimpeded traffic and a beautiful environment. It has won the first titles of “National Garden City”, “National Ecological Demonstration Zone‖, “National Model City for Environmental Protection”, “National Ecological City” and “National Ecological Garden City”, as well as UN-HABITAT “International Award for Best Practices to Improve the Living Environment”. However, environmental and economic development of the city has not always been so smooth.

Initially, Zhuhai‘s Special Economic Zone encompassed only 6.81 square kilometers. In 1984, it was expanded to 121 square kilometers, when the extensive exploitation threatened the eco-environment. However, the government of Zhuhai, reaching for green prosperity, voted down 67 heavily-polluting industrial projects, ordered 32 projects to be readdressed, closed down more than 40 stone pits and dismantled all big smokestacks in urban areas, at a price of billions of RMB. This was a bold choice for Zhuhai, considering the city only had “one store, one traffic light and one road” at the time.

Since the implementation of reforms and the opening-up of policy, cities at the Pearl River Delta promoted endogenous (Foshan and Zhongshan) and exogenous (Shenzhen and Dongguan) industrialization processes, with a focus on labor-intensive manufacturing, economic prosperity through extensive utilization of land, poor-quality urbanization, which led to heavy polluting to the environment and sharpening of social conflicts. However, Zhuhai choose a differential development path and thus, takes the lead in raising the environmental protection standard and project admittance, avoiding waste of land resources and eco-environmental deterioration, and meets the goal of harmonious development between man and nature.

While economic development of the Pearl River Delta imposes great pressure on its environmental capacity, Zhuhai has build urban landscapes where mountains embrace the sea, islands face the continent and the sea melts into the sky. It is advantageous, in this beautiful environment with abundant resources, to demonstrate the potential and capacity of economic development, which further owes thanks to its long-term adherence to the strict protection of urban ecosystems. But along with rapid development, the city will also face huge potential pressure from the ecosystem because as the population increases rapidly, city size grows, and the shortage of land resources becomes grows, it will create a bottleneck problem hindering its development. A question of fundamental importance is how to sustainably protect the favorable urban ecosystems.

2. Thoughts of City Managers and Decision-Making Process

2.1 City Managers' Thoughts on Urban Ecosystem Problems

Zhuhai is endowed with super excellent eco-environment. As the saying goes that "above the sea is the sky and under the sky is Zhuhai", the city is ringed on three sides by the sea, where mountains embrace the sea, islands face the continent and rivers and lakes are crisscrossed. All the managers in Zhuhai have been concerned with what path should be followed to develop and build in an environmentally friendly manner.

The CPC Committee in and government of Zhuhai City affirmed the concept of sustainable development in that "industrial development should not proceed at the expense of the natural environment and economic development shall not proceed on the premise of eco-environmental sacrifice". The city seeks the possession of both "golden wealth" and "green wealth" and is working hard to enable that people have access to the huge wealth brought forth by industrial civilization, as well as a green, environmentally friendly, homeland. This idea is clarified in the principles of simultaneous planning, implementation and development of economic construction, urban construction and environmental construction, reasonable layout of urban-rural planning, construction and management, supporting functions and beautiful environment; matching between population growth and economic development and combination with population quality improvements, and combination between development of high-tech industries, with high added value and low energy consumption, and improvement of economic quality.

After that, CPC Committee and government of Zhuhai City have stuck to the concept of ecological protection and environmental construction whenever adjusting urban keynote and function layout.This has been done according to the historical background and development conditions of the city, and improved the concept over time through exploration and practice. Fortunately, the city maintains green mountains, clear waters, blue skies, white clouds, and fresh air.

2.2 Solution Ideas and Decision-Making Process

The development of Zhuhai adheres tothe core strategy of "urban planning first, priority to environmental protection, infrastructure-oriented planning and adherence tolaws and regulations". Guided by this strategy, Zhuhai makes urban plans by utilizing its' late start advantages, scientific analysis, by sticking to policy optimization, by implementing institutional innovation and eco-environmental management innovations which follow the sustainable development concept, and has accordingly had fruitful results.

Early in the second round of overall urban planning in 1987, Zhuhai established the

goal of developing a "modern coastal garden city", and emphasized strengthening urban design in greening and providing environmental protections, they then adjusted urban layout and implemented environmental function divisions to manage these goals. During the third round of overall urban planning in 1992, the city advanced the principle of "sticking to simultaneous planning, development of economic construction practices, urban construction and environmental protection". They further planned to remove polluting industrial projects and exercise strict control over the approval of polluting projects. In 1998, Zhuhai's urban development goals reloved around, "implementing the overall strategy of sustainable development" and "building Zhuhai into a coastal garden city and modern special economic zone".The Fourth Congress of the Communist Party of Chinafurther emphasizedthe promotion of coordinated development of ecological protections and economic construction.

When it comes to the 21st century, Zhuhai has established a preliminarily pattern of coordinated development between the environment and the economy. At the end of 2004, the city issued the "*Eco-City Construction Plan of Zhuhai*", incorporating environmental protection performance examination into the examination of the performance of Party and government leaders in each district and each economic function zone. This further proved the determination of the CPC Committee and government of Zhuhai to follow the path of sustainable development. At the beginning of 2006, Zhuhai formally established the goal of building the "most livable, most business-suitable, and most charming" coastal scenic city, and to achieve further progress in urban planning and construction in accordance with the spatial strategy of "stretching to the east, expanding to the west, strengthening the functions of coastal areas, improving the natural environment, building beautiful coastal landscapes, and developing the functions of islands".

At the end of 2008, the State Council approved the "*Outline of the Plan for the Reform and Development of the Pearl River Delta (2008-2020)* ". Zhuhai then defined the goal of "building a new special ecological economic zone and striving to be a scientific development demonstration and core city on the west coast of the Pearl River Estuary". The goals further proposed improving patterns of traffic in the city, and strengthening the principle of mutual benefits between economic development and environmental protection, using better materials, improve environmental and societal regulations, and utilize the advantages of brand, geological position, eco-environment, development space and science, education and humanity, and build a charming and competitive modern regional core city on the west coast of the Pearl River Estuary which focuses on a developed economy, sound ecology and social fairness. The city promulgated multiple policy measures, such as promoting transportation development, integrating industrial parks and strengthening ecological construction.

Up to 2015, Zhuhai had completed the formulation of the fifth urban master planning session and presented the urban development goal of "building, together with Hong

Kong, an international metropolitan area and a sample of Beautiful China as a new special zone based on ecological civilization and a scientific development demonstration city". The further stipulatethe need to advance new-type urbanization and upgrade urban development concepts through reasonably controlling growth boundaries and construction, by designating cultivated land and ecological red lines, promoting optimization of urban spatial structures via inefficient utilization of land, promoting coordinated urban and rural development, establishing an urban-rural integrated public service facility system and exploring integration of multiple regulations.

For over 30 years, Zhuhai has successfully stuck to the concept of sustainable development without environmental sacrifice, carried out urban construction, economic development, environmental protection, and sustainable construction, and further promoted the coordination of developing the economy, society and environment. It has been among the best cities in the Pearl River Delta regarding environmental quality and among the least intensive in exploitation of land. In terms of ecological civilization, Zhuhai has undoubtedly chosen the right path in maintaining green mountains and clear waters at the expense of low-end economic development.

3. Countermeasures and Solutions

3.1 Government Management and Coordination Mechanisms

3.1.1 Establishing a spatial pattern of development and protection through conceptual spatial development and overall planning.

For over 30 years, Zhuhai has adjusted their urban keynotes and functional layout eight different times. Since the initial planning stage, it has established green, intensive, and efficient development concepts and implemented grouped urban forms based on the organic integration of nature and city. The "*Urban Master Plan of Zhuhai City (2001-2020)* (hereinafter referred to as *Master Plan*) ", revised in 2015, integrates ecological construction and green space system planning via advanced concepts, and promotes the harmonious integration of urban construction and ecosystems, from the perspective of ecological regulation and urban green land construction. The "*Master Plan*" establishes an eco-space layout strategy of "connection between the east and the west, the land and the sea, and causeway dredging", it also divides Zhuhai into different types of ecological function zones, and thereby, provides a scientific basis, and administrative means, for protecting regional ecological security, promoting reasonable utilization of resources, conserving the ecosystem and improving environmental conditions. In relation to ecologically degraded urban areas, it requires intensifying the governance, restoring the damaged ecosystems, and maintaining regional ecological security patterns.

In line with the "*Master Plan*" that focuses on an urban eco-space layout, the "*Conceptual Plan for Urban Spatial Development of Zhuhai (2010-2060)*" (hereinafter referred to as "*Conceptual Plan*") emphasizes the ecology-first concept, shows respect for existing natural environments including mountains, water, shorelines, and wetlands, and further attaches importance to the construction of road greenbelts, water greenbelts, and urban parks at all levels, and implementsan ecological pattern based on integration of natural systems and artificial systems. On this basis, the city demarcated an ecological control line encompassing more than 1,006 square kilometers, or about 58% of its land area, to protect ecological open space covering 70% of the city's land area. The "*Conceptual Plan*" finalizes the layout plan, identified as the primary plan of Zhuhai, at the end of 2015, in the "*Decision of the Standing Committee of the People's Congress of Zhuhai City on the Conceptual Plan for Urban Spatial Development of Zhuhai*".

3.1.2 Safeguarding and propelling eco-environmental construction through sound laws and regulations

Since the National People's Congress granted Zhuhai a Special Economic Zone in 1996, Zhuhai has formulated five fundamental laws and regulations—"*Urban Planning Regulations of Zhuhai City*", "*Environmental Protection Regulations of Zhuhai* City", "*Land Management Regulations of Zhuhai City*", "*Population Planning and Management Regulations of Zhuhai Special Economic Zone*", and "*Road Traffic Management Regulations of Zhuhai City*", legalizing "five unities" for land management, "eight unities" for urban construction management and "eight not-allows" for environmental protection, and incorporating the consensuses that all citizens "shall not strive for temporary development at the expense of environment", and "should degrademountain and water resources in the process of urban development" into laws and regulations. As a result, they built a sustainable legal environment for the city and carried out gradual implementation of the legislation inecological construction and environmental protection.

Subsequently, Zhuhai has promoted ecological civilization construction by formulating and promulgating appearance and environmental health management regulations, drainage regulations, forest fire prevention regulations, parks management measures, urban greening measures and greenway management measures according to geological characteristics, and based on existing environmental protection regulations. Guided by the national ecological civilization strategy, Zhuhai approved, in 2013, the "*Regulations on Promotion of Ecological Civilization Construction in Zhuhai Special Economic Zone*", setting up a stage goal of building a national eco-city. The further confirmed to designate 4 areas as first-class ecological function zones, 12 as second-class ecological function zones and 86 as third-class ecological function zones, and implementing measures to control exploitation in prohibited regions, exploitation in restricted regions, in key regions of development,in preferred development regions, and in defining the ecological control line. These regulations laid a solid foundation for optimizing and improving the urban spatial

development pattern, and ensuring urban ecological security in Zhuhai.

Till 2015, Zhuhai had promulgated and revised 17 local regulations and 12 government regulations. These encompassed planning layout, industrial development, land exploitation, law enforcement and investigation and pollution abatement. These laws and regulations laid a solid legal foundation for eco-environmental oversight, promoted long-term advantages in implementation of ecological civilization concepts, and helped to blaze a sustainable development road.

3.1.3 Implementing strict environmental protection policies and exploitation management policies so as to protect urban ecosystem

Under the guidance of the overall plan, Zhuhai has only carried out strict ecological protection and construction projects. According to its ecosystem characteristics, the city will build one state-level, one provincial-level and six municipal/county-level natural reserve areas. At the same time, it will plan and designate nine forest parks and build 19 countryside parks.

In relation to coastal eco-environmental protection, Zhuhai has planned to strengthen the protection of its natural resources, including mangrove forests, Chinese swamp cypress forests, and near-shore mud flats through ecological construction. Zhuhai will further build itself into a city of coastal wetland conservation, the largest in the Pearl River Delta and the most famous across China. This will be done through strengthening the protection of typical wetland ecosystems, with the focus on Qi‘ao Island, Modaomen Estuary, Jitimen Estuary, Qianshan Estuary and tidal flat wetlands. This will be done specifically through maintaining natural native vegetation, such as mangrove forests and horsetail beefwoods, restoring degraded wetland ecosystems, and improving their eco-environmental service functions and values.

While implementing projects that promote ecological protection and construction, Zhuhai has also raised requirements for approval of industrial projects. Early when the special economic zone was founded, Zhuhai advanced the development concept of “not developing polluting, high-energy, or high-raw-material-consuming industries in downtown area”. In 1998, in their environmental protection regulations, the Standing Committee of the Municipal People‘s Congress stipulated that exercise of strict control over the construction of high-resource-consuming and heavily-polluting projects was necessary and that they would not approve any other heavily-polluting project in downtown area. They also stipulated the prohibition on use of coal, heavy oil, or plastics as fuel in downtown area. In its revision, in 2009, the regulation sticks to, and details, the requirements of strict admittance, and stipulates environmental impact assessments, and investment promotion pre-appraisal mechanisms, must be usedin the decision-making process. Late-starting advantages are being accumulated as legislation is adopted to control admittance, and promote Zhuhai as a city with high environmental quality standards, with the least intensive exploitation of land, and the smallest layout of low-end industries in the Pearl River Delta.

3.1.4 Building urban green space through implementing the garden city, ecological garden city, and forest city ideas.

Zhuhai has playeda leading role in China in building urban green space. It was included in the first group of national garden cities early in 1992, and became the only Nationally Designated Eco-Demonstration Region with a city‘s name in 2000. Zhuhai was further included into the first group of “Ecological Garden Cities” in May 2016. Now, the city is striving to build a national forest city.

The “*Overall Plan for Forest City Construction of Zhuhai City (2014-2025)*” advances the concept of building “a beautiful Zhuhai surrounded with mountains, sea and forests” and the general layout of “four zones, five centers, ten cores, a hundred corridors, a hundred islands, and a hundred villages”, it also establishes the priority of projects focusing on ecology, industry, and culture, with the aim to establish a national forest city and build a livable environment on the basis of analysis of the city‘s eco-environmental characteristics. It also presents short, mid, and long-term objectives, in order to raise the forest coverage rate to 37.93%, and raise the urban green coverage rate to 49.96%, which is necessary to attain national forest city indexes and be considered a national forest city by the year 2017.

Taking the actions of “city of parks, colorful ribbon, a-thousand-mile green corridor and ecological river network” as an opportunity to build a national forest city, Zhuhai is committed to building 52 parks with metropolitan characteristics, seven forest and countryside parks, 315 community parks and 1,430 kilometers of ecological corridors. They are also committed to building up one state-level forest park, two state-level wetland parks, two provincial-level wetland parks, realizing full service coverage in the 500-meterradius of urban community parks, constructing an urban eco-environment where “cities and forests are interlaced”, and letting every citizen enjoy the forest.

3.2 Key Technologies and Schemes of Project Practice

3.2.1 Building community parks

Zhuhai is promoting community park construction in order to build a more beautiful eco-environment. Since 2012, Zhuhai has made the most of the idle land left by rapid urban development and built 284 community parks, covering an area of 2.12 million square meters, across the city, with almostone park built per community. As a result, green space has become the first choice of citizens in exercising and having rest areas near their homes.

Zhuhai follows four concepts in building community green space. The first is that “citizens have the final say about what kind of parks will be built” —small-sized, open, nearby, multi-functional and ecological parks are built according to citizens‘ demand, and are installed with physical fitness facilities, pavilions, book bars, coffee shops,

stores, showers, and restrooms,which are accordingly quite popular among the citizens. The second is to “build parks near citizens‘ homes” so that they can reach the parks in a fifteen-minute walk, and an emphasis on green, low-carbon fitness network for all people. This is established due to the parks beingconnected seamlessly with the greenway network, and the slow-traffic system. The third is to “build quite different parks in a way different” and establish planning and construction standards from perspectives of land use, examination and approval, capitalization and standardization of construction. The fourth is to “let citizens share and manage the parks”—makingcommunity parks incubators of self-governance and innovation at a basic level. Where the sites are managed, activities are conducted and order is maintained by citizens and regulations are formulated by and for the citizens.

Nowadays, Zhuhai also features a mass sports areas represented by Dajingshan community park, a coastal romance zone represented by the coastal community park, an ecological forest and vegetables garden represented by Meihua city park, a commercial and bazaarzone represented by Changping community park, a history themed region represented by Beishan community park, and an urban-rural integration area represented by Lianquan community park (**see Figure 2**).

Figure 2. Community Park Examples in Zhuhai.

Construction of community parks improves urban eco-environment and promotes intensive utilization of resources and guides healthy lifestyles, encourages recreational and sports activities, and improves people‘s opinions and warms their heart. Therefore, Zhuhai was awarded the 2014 Award for a Livable Environment Examplein Guangdong Province.

3.2.2 Establishing an urban greenway network

As an international common practice with functions, in both ecological protection and leisure and entertainment, the greenway plays an important role in preventing flood and fixing soil, cleaning water sources, purifying air, relieving landscape fragmentation, providing passage for animals, improving environmental quality, restricting un-ordered extension of cities and protecting local cultural heritage.

Zhuhai has taken the lead in formulating the "*Overall Plan for Urban Greenway Network of Zhuhai City (2010-2020)* ", requiring greenway network to be built near mountains, waters and woods, and according to local conditions to; not to confiscate land, dismantle houses or cut down trees; to display ecologicalization, localization and diversification; and to form a spatial structure of "four verticals, two horizontals, two rings and six islands" by virtue of distribution of city clusters, ecological patterns and the layout of natural and human landscapes (**see Figure 3**). The city plans to build a greenway network 1,003.02 kilometers long[错误！未定义书签。].

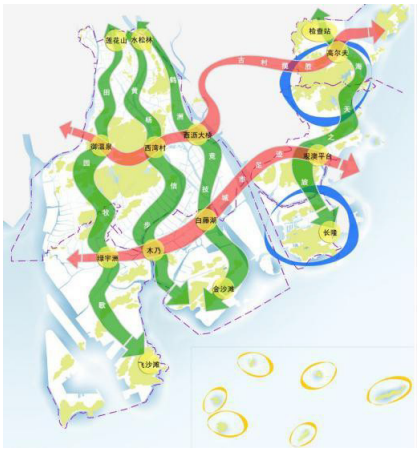


Figure 3. Spatial Structure of Greenway in Zhuhai.

Since the launch of the greenway network construction in 2010, Zhuhai has created greenway "excitements" on the basis of upholding nature and in combination with construction of urban squares, park green spaces, entertainment and sports sites, public transit hubs, human nodes and post houses, and making the best of integration, excavation and improvement of existing resources inside and outside cities (**see Figure 4**). This has been done with the aim of attracting more people to use the greenways through providing citizens with good wide-open space for recreation, fitness, and outdoor activities. By the end of 2015, the city had built up 896 kilometers of greenway and constructed 48 post houses at all levels.

Greenway "Excitements" in Zhuhai.

In 2016, Zhuhai plans to build "upgraded" greenways to make the best of all its functions and improve its effects. The city also plans to link all kinds of interest nodes through construction of "city of parks", "happy villages" and "ecological river networks". This is with a focus on community sports parks, waterfront parks and forest parks. In addition, Zhuhai has formulated the "*Beautiful Zhuhai—A Thousand Kilometer Greenway Action Plan*", stating that efforts will be made to build anecological landscape forest belt, an urban greenway, a healthy footpath, a avenue and passage with rural characteristics, a system of one thousand kilometers of greenway, create another green ecology brand, and promote the establishment of a national forest city from 2016 to 2018.

3.2.3 Designatingan ecological control line.

An Ecological control line is a control limit for urban development boundaries designed with the center on key ecological elements. This is done in order to guarantee urban ecological security and optimize structural layout of urban space, and on the premise of respect for urban and rural natural ecosystems and reasonable environmental carrying capacity.

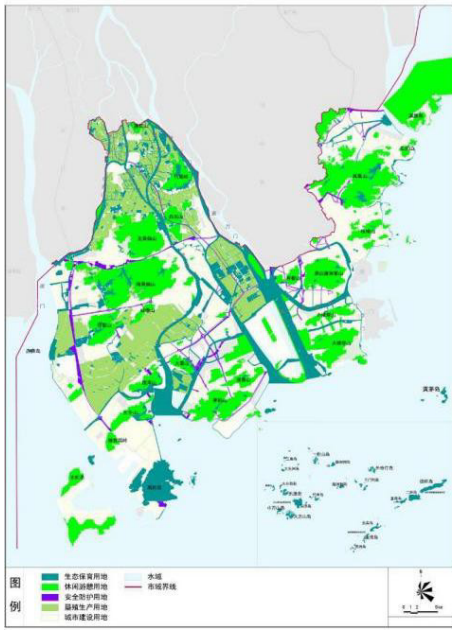


Figure5. Ecological Control Line of Zhuhai City.

To effectively protect the eco-environment and guarantee ecosystem safety, the Bureau of Housing and Urban-Rural Planning and Construction of Zhuhai City formulated the "*Ecological Line Control Plan of Zhuhai City*", which was approved by the municipal government in December 2015. The ecological control line encompasses 1,051.08 square kilometers, or about 58.44% of the land area, covering ecosystem conservation land, leisure and entertainment land, safety protection land, and reclaimed and production land (**see Figure 5**). Meanwhile, the city's ecological control line is divided into two levels— one control area at Level I and is an ecological protection space with a pivotal function, and also the core of the ecological control line, covering an area of 397.44 square kilometers, or 37.84% of the total ecological land. The control area at Level II covers an area of 653.01 square kilometers, about 62.16% of ecological land.

In July, 2016, Zhuhai released the "*Ecological Control Line Management Regulations of Zhuhai City (Exposure Draft)*", which plans to exercise graded administration over the ecological control lines, protect all kinds of resources encompassed by the ecological control lines, prohibit construction within the control lines and remove illegal buildings. It also defines the responsibilities of relevant administrative subjects, and emphasizes that administrative organs and staff in violation of any pertinent regulation will be ordered to make rectification, and those suspected of a crime will be delivered to judiciary authorities according to the law.

3.2.4 Implementing comprehensive environmental improvement of the Qianshan River Basin

Rivers and lakes are the most important ecosystem of Zhuhai. The Qianshan River originates in the southeast, at the foot of Wugui Mountain in Zhongshan City and runs through Sanxiang Town and Tanzhou Town of Zhongshan City Nanping, Qianshan,

Gongbei, Wanzai of Zhuhai City, and Shijiaoju Gate to Qingzhou Bay, and finally to the sea. The 41-kilometer river is the only freshwater river in the main urban area of Zhuhai. In the early 1980s, Qianshan River was the source of drinking water for Zhuhai. However, as agricultural and industrial pollution increased, Qianshan River was polluted, and became a major problem bothering the urban environment construction in Zhuhai.

To abate pollution in Qianshan River, Zhuhai has promulgated the "*Plan for Comprehensive Environmental Improvement Project of Qianshan River Basin (2013-2017)*", putting forward "five engineering measures", including sewage treatment facility construction, pollution interception, control and treatment, upgrading of "old towns, workshops, and village communities", improvement of embankment landscapes and clearing of livestock breeding, and "five non-engineering measures", including planning as a whole, departmental coordination, regional cooperation, shared governance and administration, and legislation and enforcement. This was done to improvethe environment of the Qianshan River Basin, and further required the goal of "clear waters, green embankments, and beautiful landscapes" be met by 2017.

Qianshan River's water eco-environment has improved substantially afteryears of constant government oversight (**see Figure 6**). By the end of 2015, water quality in the Qianshan River met the standard surface water quality requirements at Category IV, and some sections have reached the standard of surface water quality at Category III. Management responsibilities have been implemented for over190 flows and channels, and problems concerning dirty flood drainage channels and offshore water pollution have been removed, and thus, the greening rate of river way has reached 90%.

Figure6. Current Situation of Qianshan River.

In order to continue to improve Qianshan River, Zhuhai has implemented the "*Qianshan River Basin Management Regulations of Zhuhai Special Economic Zone*". This regulation has raised the requirements for water pollution prevention and control, ecological protection, sewage pipeline construction, examination and assessment mechanisms and planning and construction methods.

3.2.5 Building sponge cities

As a new-generation mode of urban rainfall and flood management, sponge cities are quite resilient when dealing with environmental changes and natural disasters incurred by rainfall, and help to realize the green concept of flood control, and co-existence with nature.

While the central government is promoting the sponge city strategy, Zhuhai has formulated the "*Specialized Plan for Sponge Cities of Zhuhai City*" and detailed plans for sponge city construction of two demonstrative districts. They have further defined the overall objective of building ecologically livable sponge cities with harmony between human, water,and coastal characteristics, so as to construct urban sponge cities that integrate mountains, waters, forests, farmland, cities, and wetlands under its administration. In April 2016, Zhuhai was included, into the second group of pilot cities for national sponge city construction.

The Hengqin New Area and West Center City, covering an area of 52 square kilometers, were selected as pilot regions for sponge city construction. Zhuhai put forward the controlled volume per unit of area, low-elevation green space rate and its subsidence depth, permeable pavement rate, green roof rate and other control indexes of each parcel in accordance with the low-impact development control goals and requirements as specified in decomposed plans of sponge cities and detailed plans and in combination with such binding indexes as building density and green space rate, defines the type of low-impact development facilities within each parcel and their scale, and takes incorporating planning results into key points of parcel planning and designing as planning and design conditions for land development and construction.

3.2.6 Carrying out construction of the "One-Zone Nine-Bay" Lovers Road Romantic Coastal Zone

Beaches are considered effective means to prevent coastal erosion. Beach restoration works primarily to protect the coast and to beatify urban landscapes, maintain ecosystem balance, provide travel and leisure functions, and improve city taste. The Lovers Road is a coastal road built during the 1990s. It was once a city's main tourism attraction. As the concept of marine protection and the demand for ecological civilization proceed, Zhuhai keeps changing its planning concept for the route along the Lovers Road. These changes have included restoring the beachs and making improvements in environmental protection to ecological restoration, which is to the advantage of coastal life and marine protection in Zhuhai.

In March 2015, the municipal government approved the "*Plan of Zhuhai City for Overall Improvement of the Lovers Road Romantic Coast*". It stipulated to improve the Lovers Road coastfrom the perspectives of traffic, land-and-water integration, public openness, cultural connotation, sea views and urban characteristics, and incorporating "romantic travel and building an international coastline" as the goal of development. This was done in order to build an overall spatial pattern of "one zone and nine bays" (**see Figure 7**), as well as a bluer, greener, and more beautiful romantic coast. The plan encompasses the entire Lovers Road—extending to the boundary between Zhuhai and Zhongshan to the north and the intersection between Zhuhai Avenue and Modao Estuary to the west. The road is 55 kilometers long and the hinterland encompasses 85.6 square kilometers.

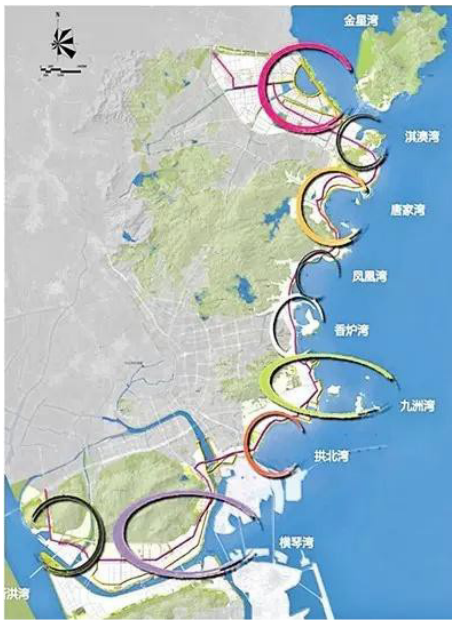


Figure7. Schematic Diagram of the "One-Zone Nine-Bay" Lovers Road Romantic Coastal Zone.

Between 2014 and 2015, Zhuhai implemented the coastal swimming pool improvement project Stage I, Xianglu Bay beach restoration project, Fenghuang Bay beach restoration project, etc. Accordingly, the restored Xianglu Bay beach has been quite popular with citizens of Zhuhai and non-local tourists, and has reaped "dividends" regarding the benefits Zhuhai's eco-environmental construction has brought to its citizens.

3.2.7 Establishing characteristic villages

As an important part of urban construction, villages attract high attention from the government of Zhuhai. The city has stuck to the strategy of common progress in urban and rural landscaping, promotion of happy village construction through development of characteristic industries, improvement of the livable environment, improvement and guarantee of people's livelihood, mobilization by cultural characteristics, social governance and construction, and consolidation of the foundations. They have further built up 209 wealthier, happier and more beautiful, and harmonious villages with the characteristics of Zhuhai (**see Figure 8**).

Figure8. Characteristic Villages in Zhuhai

In relation to livable environment improvement, Zhuhai has improved the environment for infrastructure construction in villages, and made village landscapes more beautiful through building sewage treatment facilities and enclosed garbage collection stations. In the meantime, it also attaches importance to the beautification and greening of villages. In accordance with the "*Five-Year Action Plan for Establishing Happy Villages in Guangdong Province*", Zhuhai has stuck to the principle of matching sites with trees, combining flowers and grass, and building village roads, watercourses, yards, greening around housing and public green space. For instance, Lianjiang Village of Doumen District has strengthed roads and greened houses on both sides, greened riversides and parks, dredged three kilometers of rivers, and built tour towers at the forest park. As a result, villages in Zhuhai are flourishing with green landscapes and rural residents' production and living environment has improved.

4. Implementation Achievements

Compared with other cities located in the Pearl River Delta, Zhuhai has a smaller economic aggregate and its core work is to develop the economy. But, other cities cannot efficiently advance at the expense of resources, hard work, and land. On the other hand, Zhuhai maintains great ecological strength and late-starting advantages while growing the economy.

According to statistical data, by the year 2015, Zhuhai's forest coverage rate was 35.94%, forestland area was 48,481 hectares, wetland area was 189,066.85 hectares, and per capita park green space area was 19.5 square meters.Zhuhai had built up about 896 kilometers of greenway of various kinds, and designated 1,051.08 square kilometers as encircled by the ecological control line. In the meantime, Zhuhai monitored air quality for 359 days in 2015, of which 323, or 90.0%, registering good air quality, ranking ninth in the seventy-four key cities in terms of annual air quality.

All main rivers, drinking water sources, and offshore areas attained the standard of water quality. Additionally, in 2015, its GDP was 202.498 billion RMB, and the city ranked number one in Guangdong Province in terms of GDP growth.

In multi-layer ecosystem management and practice, Zhuhai obtained great achievements in ecological civilization construction in 2015. Zhuhai also successfully established a national eco-city and a national ecological garden city, which was included in the first group of state-level marine ecological civilization demonstration areas.It was also included in the second group of pilot cities for national ecological civilization city construction and the marine economy civilization demonstration cities in Guangdong Province. They further won the golden medal in the advanced group for the first China ecological civilization award. On May 30, 2016, the Chinese Academy of Social Sciences and China Social Sciences Publishing House released the "*Annual Report on China's Urban Competitiveness*," suggesting that Zhuhai has been included into the "most livable cities in China" for the third consecutive year.

Unquestionably, Zhuhai has realized the harmonious development of environmental protection, economy, society, good eco-environmental quality, and has a competitive urban area in the growthof the city's sustainable development. At the same time, Zhuhai gains late-starting advantages for economic development and maintains blue skies by controlling ecology and industry, avoiding labor-intensive low-end manufacturing, turning down polluting industries, and developing intensive, high-end industries.

5. Inspiration and Suggestions

5.1 Practices Worth Learning

As an experimental field of ecological civilization, Zhuhai proves through its practices that a city won't be able to maintain green mountains, clear waters and local landscapes unless it remains oriented towards the people, maintains an ecological red line, sticks to simultaneous development of the economy and ecological civilization concepts, and the concepts of greening the urban life. Looking back to Zhuhai's experience in urban ecosystem management practice over 30 years, it is important to take note of the following practices:

(1) Sticking to the Ecology-First Principle With Planning in Advance

In the course of urban construction and development, Zhuhai has always maintained the strategy that "thinking runs before designing, followed by planning". The city has been highlighting the ecology-first principle since the first round of urban master planning in 1988 through tothe fifth urban master plan in 2015, or when it promulgated the prime plan—"*Conceptual Plan for Urban Spatial Development of Zhuhai*", which planned for protection and utilization of mountains and waterfronts,

ecological construction of river systems, water and soil conservation, wetland protection, green land construction, and water protection, so as to support the implementation of the overall plan and fulfill the requirements of the "*Conceptual Plan*". In addition, the city assures the implementation of prescribed objectives by formulating forward-looking, instructive, and flexible urban planning and construction systems.

(2) Promoting Ecological Construction Under Legal Safeguards

Zhuhai's success in ecological civilization construction comes along with powerful legal safeguards. Since 1996, the city has knitted a "green net of justice" with 17 local regulations and 12 government regulations making the best of the special economic zone's legislative power, and in accordance with the spirit of reform and innovation, so as to move forward the rule of law for ecological protection, break institutional obstacles, and provide reliable guarantee for urban ecological civilization.

(3) Protecting Ecosystems with Strict Policies

Zhuhai has implemented strict policies of environmental protection and development management to protect ecosystems. On the one hand, the city strengthens environmental protections and ecological civilization examination. On the other hand, it rejects high-polluting and high-energy industries by establishing industrial admittance regulations and thus, maintains clear waters and blue sky.

(4) Building Eco-Space With Advanced Concepts

The urban ecosystem management exploration of Zhuhai also witnessed China's practice of advanced ecological concepts. The city's construction of a garden city in the 1990s, the ecological garden city in the 21st century, and the current forest city, sponge city, and livable city is all based on the opinions of renowned Chinese and foreign urban planners, including Liu Thai Ker, Wu Zhiqiang, Zhang Tingwei, Li Xiaojiang, Peter Calthorpe, Danial Rijinstein, Yoshiki Toda and Ouyang Zhiyun. Urban ecosystemsare built by reference to advanced concepts at home and abroad.

(5) Jointly Building an Eco-City Via Multiple Approaches

The eco-city construction of Zhuhai remains dependent on the all-round improvement and optimization of ecosystems, such as building community parks across the city, establishing an urban greenway network, designating ecological control lines, and constructing sponge cities, building characteristic villages and carrying out construction projects targeted at the water environment of Qianshan River Basin, and sandbeach restoration of the Lovers Road. A real eco-city is built by improving, and optimizing, urban ecosystem services through specific projects.

5.2 Suggestions for Duplicating and Generalizing the Practices of Zhuhai

Why is Zhuhai the experimental standard for ecological civilization? The reason lies in the city's inborn advantages, as well as its unremitting joint efforts. Any Chinese city that wants to improve their urban ecological civilization through duplicating and generalizing Zhuhai's experience should 1) investigate its urban eco-environmental background, and define its objectives for urban ecosystem management; 2) formulate urban plans, laws, and policies matching its objectives to provide theoretical basis and policy guarantees for its urban ecological civilization construction; 3) implement urban plans and policies in projects, define stage tasks based on projects, and improve urban ecosystem service capacity step by step; and 4) persist on ecological protection, avoid anxiety for success, or all-purpose projects, or being discouraged by a setback, and strive persistently and unswervingly towards the stated objectives.

References

[1] Zhuhai Overview 2016, Zhuhai Municipal Bureau of Statistics,

http://www.stats-zh.gov.cn/zhgl/201605/P020160525405231099842.pdf, 2015-05-25.

[2] Overall Plan for Urban Greenway Network of Zhuhai City (2010-2020), Zhuhai Institute of Urban Planning & Design, April 2011.

[3] 2015 Report on Environmental Quality of Zhuhai City, Zhuhai Municipal Bureau of Environmental Protection, June 2016.

[4] Zhuhai Obtained a GDP of 202.498 Billion RMB Last Year and Was Ranked Top for GDP Growth, Zhuhai Daily,

http://zh.southcn.com/content/2016-01/24/content_141378621.htm, 2015-01-24.

[5] Conceptual Plan for Western Center City of Zhuhai, Wilcoter (Shanghai) Architectural Planning & Design Co., Ltd., January 2010.

[6] Zhuhai: Expanding Sustainable Development Space, People's Daily, October 4, 1998 (First Edition).

[7] 2015 Report on Environmental Quality of Zhuhai City (Public), Zhuhai Municipal Bureau of Environmental Protection, July 1, 2016.

OVERVIEW: Build Regenerative City, and Develop Green Urbanization

Yangliang[15], Chen Boping[16]

【**Abstract**】International explorations on sustainable urban development show that cities need to shift their focus from simply doing less damage to the environment to having a positive and beneficial impact on the local ecologyby establishing a truly symbiotic relationship with their urban and peri-urban natural areas. This meansdeveloping "*Regenerative Cities*". By covering a wide range of issues, including finance, economy, and technological innovation, and with the aimof creating a livable, healthy, participatory, and a service-based city, the concept of the regenerative city goes beyond the traditional sustainable development pattern. Developing a regenerative city also means improving the city's self-sufficiency in terms of energy and natural resources, as well as strengthening its climate resilience and adaptive capacity. Given the increasing pressure cities exert on the natural environment, transforming how cities develop appears to bemore urgent than ever. The regenerative city concept reflects a different type of development gaining widespread momentum in China, also known as the New Normal, which is a new strategy of urbanization that favors people-centered development, slower economic growth, innovation, domestic market development, and that is particularly devoted to environmental protection. Decision makers need to adopt a long-term vision and build the strong political will and leadership needed for the development of regenerative cities. Effective co-operation among a wide range of stakeholders, as well as public participation, should also be encouraged to accelerate the transformations needed.

【**Keywords**】regenerative city; recycling; green city; new-type urbanization; sponge city

1 International Background on Regenerative City Development

Today, over 50% of the population worldwide is living in cities, and by 2030 this percentage will increase to nearly 60%, which means that about 5 billion people will be living in cities. This means that urban areas, the hubs of business, culture, technology, productivity and social development,will be facing unprecedented challenges. The increasingly serious urban problems caused by rapid urbanization, such as population growth, traffic congestion, environmental pollution, resource shortages, the gap between the rich and the poor, and cultural conflicts makethe sustainable development of citiesone of the most urgent and complex tasks of the 21st century.

[15]Yang Liang:China Projects Researcher from WFC; Postdoctor from Landscape - Human Development Institute of University of Kiel, Germany;
[16]Chen Boping: Director of World Future Council China Program

The international community is therefore increasingly committed to defining a new type of sustainable development, and to assigning cities a chief role in leading this transition forward. In September 2015, the UN General Assembly ratified 17 Sustainable Development Goals (SDGs), which will replace the Millennium Development Goals (MDGs) that expired at the end of 2015. The need for a sustainable model of growth not only concerns the poorest countries worldwide, but also includes a broader target group, and set of diverse relevant issues. As one of the 17 SDGs, the 11th goal, also known as the urban SDG, specifically aims to "make cities and communities inclusive, safe, resilient and sustainable".

Parallel to the SDGs is the Habitat Conference, a UN global summit that was held in October 2016, in Quito, the capital of Ecuador. During this conference nearly 200 member-states gathered to finalize a New Urban Agenda providing agreed non-binding guidelines and strategies on how urban settlement around the world should unfold in the upcoming 20 years. This document is supposed to assist governments in addressing urbanization challenges by setting clear guidelines to support national and local development policy frameworks.

In practice, many cities in the world are consuming and wasting various resources at an unprecedented scale, and they are also suffering from huge environmental threats like intense water and air pollution. Obviously, the old developmental pattern needs to change either for the planning and management of new cities, or for the rebuilding of old districts. The transition must be guided and pushed forward by a set of effectiveand innovative policy measures. The approval of urban SDGs, and the upcoming agreement on a global New Urban Agenda can unquestionably offer a wide range of opportunities for cities around the world, and will require governments and relevant stakeholders to think outside of the box, go beyond the traditional sustainability concept, and explore a broader and radically different approach to urban development.The concept of the regenerative city, which emphasizes the need of regenerating urban eco-systemsinstead of simply maintaining damaged natural environments, appears to be the most viable pattern of development that cities need to embrace if they intend to continue thriving in the years to come, and to respond most effectively to the threats of climate change and resource scarcity.

2 The Concept of theRegenerative City and its Key Objectives

The Regenerative City can be defined as a city that regenerates the resources it consumes by maintaining an environmentally enhancing, restorative relationship with the ecosystems from which it draws resources. Specifically, it means rebuilding the circulation and interactions between city and nature. A regenerative type of urban development transforms cities from systems that only deplete resources, and damage ecosystems, to dynamic systems that restore a mutually beneficial, symbiotic relationship with the surrounding environment (Figure 1). The traditional sustainability approach focuses on causing simply less damage to the eco-environment while the regenerative concept strives for a more positive, beneficial impact on the environment, not simply a less-damaging one.

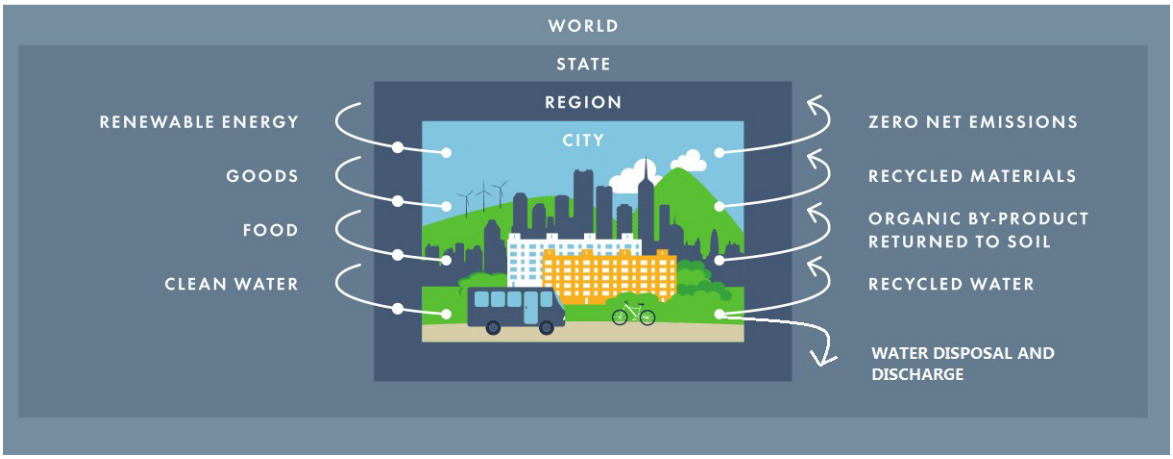


Figure 1. Conceptual Sketch Map of Regenerative City.

In the regenerative city system, the city not only consumes resources, but produces the resources it uses, and reuses the resources it consumes. For instance, the city prioritizes resources coming from the surrounding regions; the city utilizes local renewable energy resources; the waste from one department is recycled by other departments; water is discharged into natural water bodies only after treatment; the organic waste is returned to the soil as fertilizer after treatment and so on.

The development of regenerative city includes the following three basic features（Figure 2).

(1) Regeneration of Resources

Sufficiency：Reduce resource consumption, improve resource utilization efficiency, reduce consumption from the source, and save resource usage.

Circularity：Create value from waste, and raise separate garbage collection, treatment and reutilization rate.

Servitization： Advocate the concept of functionality over ownership， emphasize the practicability of resources，and exert the efficacy of allocation of the resources on proper places instead of playing the role inefficiently or idling it in the hands of owners.

(2) Regeneration of Urban Ecosystems

City as center of ecosystem regeneration：Encourage the city to be the leader and promoter of the regenerative development of resource-economic-social-environmental systems.

City as node of production：Transform the city into both resource consumer and producer.

City as leader of decision and management：Promote decentralized management and supporting policies, and encourage positive participation of primary-level organizations and individuals in the practice of cyclic development .

(3) Regeneration of Urban Spaces

Compact: Upgrade existing sites rather promoting urban sprawl, improve utilization rates of city spaces through compact and efficient planning

People-centered：Build inclusive, safe, resilient and sustainable city communities which emphasize overall convenience and comfort for residents.

Green：develop green buildings, and fully promotethe planning and construction of green areas.

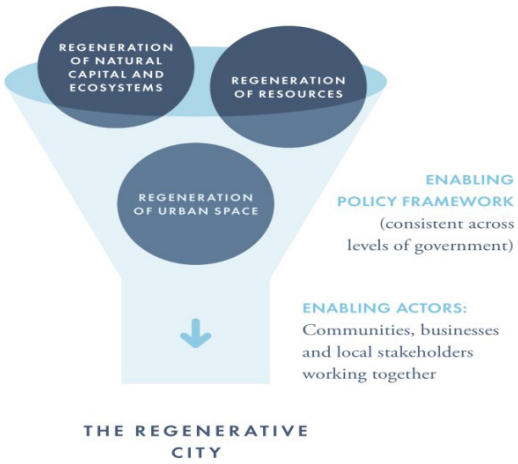


Figure 2: Basic Circulation Characteristics of Regenerative City

The core of a regenerative city‘s vision lies in establishing and enhancing a symbiotic and mutually beneficial relationship with surrounding areas. The city, as well as the ecosystem it relies on, can become healthier through utilization of waste resources, which, among others, can be achieved by implementing the following measures: returning the nutrient substance to the soil, planting trees, rotating crops, supplementing basins with water resources, increasing the urban biodiversity and developing eco-infrastructure in the city, etc. These measures arenecessary to strengthen the regenerative ability of the ecosystem both in local areas and worldwide.

The regenerative city aims at mimicking the metabolic systems of nature, and closing the circular loop of urban resources. For example, by draining the treated wastewater into the natural water system to increase water supply for farmland; by producing fertilizing materials from urban sewage and waste applied to surrounding lands; by greatly reducing dependence on petroleum products and increasing the use of renewable energy sources. Furthermore, by actively recycling waste so that the regenerative city can play a role as production center while promoting harmonious and mutually beneficial development with surrounding areas.

3 Problems to Be Solved During Construction of Chinese New-Type of Green Urbanization

While it is undeniable that China benefited immensely from rapid economic growth and urbanization, particularly in terms of poverty alleviation and increase in standard of living, it also significantly suffered, especially from environmental burdens such as air pollution, which is adversely affecting people‘s lives and endangering the long-term stability of the Chinese economy. The new type of urbanization China proposed is not denying the original path, but rather aims at improving its quality. While we affirm the effectiveness of rapid urbanization, we should keep in mind first that the urbanization of population is incomplete and goes slower than that of land; second, that unequal development opportunities exist among medium and small cities; third that the service industry is lagging behind.

3.1 Lack of social support formigrant workers; urbanization of population lagging behind that of land. For a long time, sprawling cities requisitioned large amounts of land, with farmers losing their land, but not becoming towns people.These migrant workers are drifting away from both rural and city systems. Migrants moving from rural areas to cities are not guaranteed the same public social support as urban dwellers and this has created social problems such as left-behind children and elderly, as well as empty villages. It also blocked rural development and inhibited production and consumption, hindering China‘s economic development.

3.2 Extensive urban construction thatoccupies too much land. Over the past twenty or thirty years of rapid expansion, cities sprawled extensively and urban space was inefficiently utilized. The expansion occurred very rapidly and did not allow for the formation of denser urban agglomeration, but rather a sprawled urban fabric. With the aim of protecting farmland and using land intensively and economically, several cities will face the great challenges in how to develop secondary and tertiary industries, and in meeting the requirements of high-living quality development, and shifting the mode of development from extensive to intensive.

3.3 Unreasonable urbanization system. More and more metropolises and first-tier cities are now overcrowded. Their excessive growth has caused a drop in quality of life in many urban areas, slow development of small and medium sized cities, and the unreasonable growth of urban network systems.The gigantic gap in terms of growth rate between big cities and small towns, the difficulties in establishing coordination system among cities, the weak regional economic foundations, and the serious city polarization effects have all made it difficult to coordinate balanced regional development.

3.4 Serious shortage of public service. Many cities still prefer infrastructure construction and ignore social public service, which concern people‘s living. Although, initially, many cities had good public service systems, the old districts now no longer have strong public service due to the high concentration of population. Problems like environmental pollution, difficult admission to school, shortage of medical and health facilities, public safety and so on, are present throughout the new urban areas and their hinterland. Although gradually improving, the current level of public servicesin most cities does not meet the requirements necessary for maintaining a good standard of living for all.

In terms of environmental sustainability, many cities in China are striving for new ideas to change the status quo. The development strategies of regenerative cities, which can improve gradually deteriorating ecosystems and establish a symbiotic relationship between city and environment, should be highly stressed. This new kind of urbanization needs to reflect a different type of development, also known as the New Normal, which is currently gaining widespread support throughout China. The New Normal understands the substantial changes affecting China (namely a decline in the availability of inexpensive land and cheap labor, slower economic growth and, above all, increasingly exacerbating environmental distresses) and responds by promoting a new kind of people-centered development that favors slower economic growth, people well-being, innovation, domestic market development and that is particularly devoted to environmental protection.

4 The Effect of Regenerative Cities Development on the New Green Urbanization

Considering China‘s modernization process, as well as the effects and problems existing in

Chinese urbanization, a better coordination with China‘s new industrialization, the development of service-based economy,and the modernization of agriculture should be the overall targets of our new-type urbanization in order to rectify the original ideas and doings of rapid urbanization. Unlike the previous model, the new-type of urbanization should shift from restricting rural populations from entering the city to transforming the migrant people into citizens. It should shift from extensive urban development to an intensive one, and from over emphasizing urban management to serving the public. Besides, the public service of urban government should also change from only serving the household registered population to covering all resident population. All of these transformations will considerably improve the quality of urbanization, and promote the creation of a large, medium, and small sized cities, towns, and urban agglomerations. However, in order to implement this transition,more specific strategies are needed.

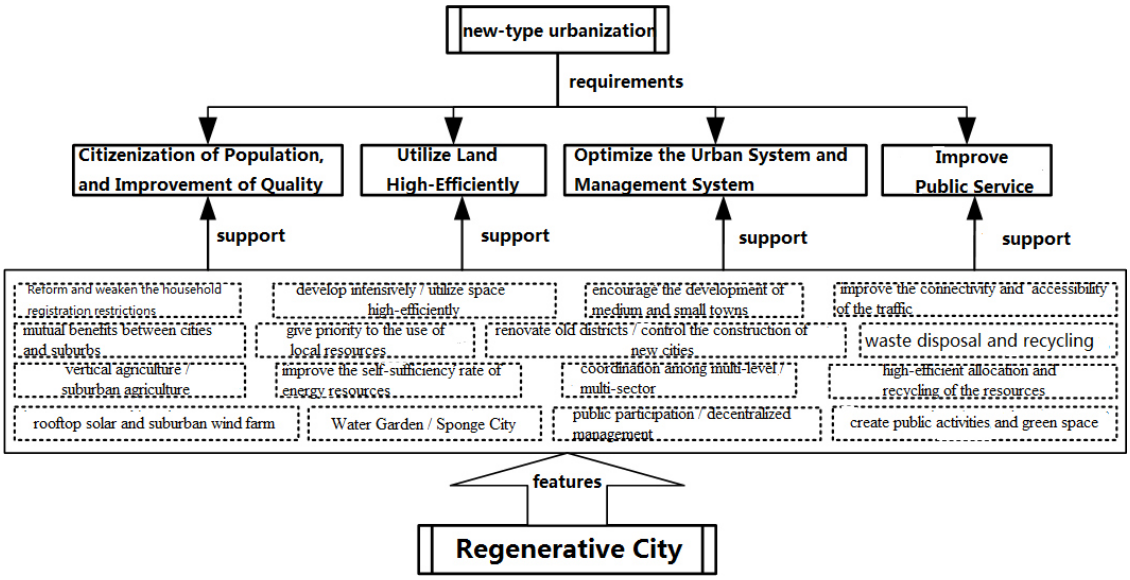


Figure 3. Regenerative City Supports the Development of New Green Urbanization in Many Aspects

Specifically, a regenerative city can meet the above requirements of the new-type urbanization in many ways and play a positive role in supporting it (Figure 3).

4.1Actively promote the full legalization of rural migrant populations and the integration of urban and rural areas. A regenerative city emphasizes that the city should establish a relationship with its suburbs, and attain resources for its development from surrounding areas, for instance, by promoting the development of suburban agriculture and urban vertical agriculture, and reducing food imports. Besides, it should also make use of local resources to strengthen local self-sufficiency, such as the development of rooftop solar energy and suburban wind power, etc. These measures will boost local development and give opportunities to create jobs for rural people, to improve supply capacity of local areas, especially in terms of energy and food, to efficiently utilize resources, minimize energy demand and improve efficiency of the supply chainby decreasing for example grain storage, packaging and transportation. By strengthening the close contact between the city and the surroundings, the interaction between urban and rural areas is more frequent, and mutual benefits can be reaped thanks to a better

integration of urban and rural economic development.The regenerative city concept encourages the development of large and small-sized cities and towns and allows them to accommodate the rural population by reducing the requirements for household registration. The development of a regenerative city is not aiming at turning villages into cities, or pursuing "synchronization" of cities and rural areas, but, according to their own rules of development and on the basis of differentiation and complementarity, promoting mutual benefits and coordination between urban and rural areas.

4.2 Improve land use regulations and promote innovative financing mechanism. The regenerative city demands intensive development of urban spaces, which is necessary to curb urban sprawl, so as to enhance resource utilization efficiency, improve transport accessibility and create effective spaces for communication and social interaction. Meanwhile, it also advocates renewable energy utilization, and innovation in the fields of intelligent technology, as well as investment and financing. The regenerative city construction can encourage innovative land development, new investments and the implementation of financing policies, which will activate the gigantic potential of the new urbanization and provide a strong driving force for sustained and healthy economic growth.

4.3 Accelerate the cultivation of medium and small-sized cities and special small-towns, and support new village construction. Regenerative city focuses on the complementary and coordinated development among large, medium and small-sized towns, for example, by developing high-tech and service industries in the central city, exploiting renewable energy sources in suburban areas, and foster new agriculture in villages, etc. The regional and differential development of the regenerative city can lead to better and more balanced distribution of population across the country, optimize urban systems management and structure more effectively and efficiently urban areasto ensure a shared prosperity of both large and medium sized cities and towns.

4.4 Fully enhance the city's multi functionality, especially the service function. A regenerative city has many functions, such as housing, production, leisure, service and so on. Developing new energy sources in the city and its hinterlands, such as rooftop solar and wind farm construction, planning of urban vertical agriculture, water park construction, and design of water permeable ground pavement of sponge city, will make the city itself become the producer of energy, food and waterrather than merely a consumer. These new facilities can also offer opportunities for leisure and entertainment by providing the public with places for rest, fitness and social interaction. Meanwhile, the system of waste dispose and recycling that a regenerative city emphasizesis also beneficial to the construction and maintenance of clean and healthy urban environments. Constructing diverse residential facilities, improving the level of the urban public service (including health care, education, sports, parks, fire prevention and so on), optimizing urban functions, improving living environment, and bettering public service are key aspects of the planning of regenerative cities.

4.5 Improve enabling mechanisms essential to promote this new-type of urbanization. The concept of a regenerative city is relevant to all the various departments and sectors of the city. Coordinating the work of different administrative levels and of different departments is key. In the past, urbanization was characterized by a lack of innovation, lack of sustainability, and a lack of cross-sectoral collaboration. Multi-level coordination and multi-stakeholder cooperation become extremely relevant for this new type of urbanization. Instead of sacrificing rural land and

damaging life-sustaining ecosystems, this new type of urbanization reconsiders the key role of farmers and their villages and promotes the integration of urban and rural development and the value of public services insupporting economic and social progress and achievinga common prosperity. The word “New” means the transformation from a system whose only driver is pursuing continuous urban expansion to one which focuses on the improvement of urban life in a broader sense, which includes environmental sustainability, culture and public service as key aspects to ensure the high-quality of life promised by cities. The regenerative city meets the requirements of this new urbanization as it is characterized by stronger and better interaction between urban and rural areas based on a mutually beneficial and environmentally sustainable development.

5 Methods to Develop Regenerative City

Case studies from around the world can help us to understand the regenerative city concept, and also demonstrate that the development of the regenerative city can bring multiple benefits. Generally, the regenerative city can help closing the urban resource cycle and promote the acquisition of resources mainly from neighboring regions. Ultimately, it creates social, economic, and environmental value for the local area.

It is a challenge to make the city the leader of regenerative growth and to fully mobilize the actors who will need to bring this vision forward. Regenerative city pilot projects can be carried out considering the following four aspects:

5.1 Strengthen the Efficient Utilization and Recycling of Resources

Regenerative urban development seeks to mimic the circular metabolic systems found in nature. This will require a switch in paradigm away from the old linear metabolism (which allows cities to operate within an isolated segment of the resource cycle) to a new circular metabolism. This will mean closing the urban resource cycle by finding value in outputs that are conventionally regarded as waste and using them as resource inputs in local and regional production systems. Concretely, it is a great task to reduce resources consumption, improveresource-use efficiency, promote waste recycling and develop renewable energy. For instance, develop green architecture to save raw materials and reduce the energy consumption from the source, and reduce waste and pollution. From the installation and operations of the construction to the end, all the material goods the city needs are not discarded into landfills but are kept in the resource loops by being recycled, upcycled, reused or by becoming a useful input in another processes such as energy production processes. Again, the waste heat generated by electric power plant can supply heat to surrounding factories, while the dust and waste residue produced by various factories can be provided to the surrounding cement plants as well as brick and tile factories as raw materials. Besides, strengthening supervision and management of garbage classification can also promote the recycling of steel, plastics, paper, glass, and organic matter.

Besides, it is necessary to promote the development and utilization of renewable energy. Transitionstowards 100% renewable energy is a prerogative of regenerative cities. For this reason, renewable energy is considered the only viable energy sources for regenerative cities, as it is continuously available and does not involve the consumption of a finite stock such as fossil fuels. The transformation towards renewable energy is also a kind of adaptable measure, because the distributed renewable energy technology will be characterized by a decentralized structure of energy production in the city and surrounding areas, which will increase resilience and reduce the

risk of overall energy supply shortages due to the closure of an energy plant (for flooding, technical failures or external damage, etc.). In addition, compared to conventional power generation, the production of most renewable energy requires less cooling water.

5.2 Promote Material Circulation within Urban and Regional Eco-systems

The regenerative city is characterized by the protection of natural assets, the improvement of the capacity of the city to generate the natural resources it needs, and the restoration of damaged ecosystems. The city therefore is not only conceived as a consuming entity, but actively contributes to the production of the resources it needs and to the cyclic development of natural ecosystems from which it depends. Concrete measures include:

Food supplies are complemented through urban agriculture, including building vertical agricultural factories, developing small-scale distributed roof-agriculture, restricting urban expansion to develop suburban agriculture, and so on. The growing urban and suburban agriculture will increase city‘s supplyof local resources and improve self-sufficiency.

Water resources can be complemented through storm water collection at the block level and by allowing urban aquifers to be replenished as water is allowed to permeate through the extensive green areas around the city. Construction of sponge city is just such typical ecological water resources development strategy.

Recycle water resources. The city needs to recycle wastewater, extract nutrient materials, which can be returned to the soil to keep it fertile and always treat wastewater before it is disposed into the rivers and oceans.

Artificial affore stations in surrounding areas and in parts of the city will produce ecological and environmental benefits and provide raw materials like timber. The increased woodland can keep the surface soil intact, improve its fertility and prevent erosion. The forests can also absorb dioxide and improve soil‘s capability of carbon sequestration so as to increase forest carbon sinks.

Extensive greener areas, like roof-gardens, and garden architecture provide benefits in terms of pollution mitigation, CO_2 sequestration, water retention, natural filtering for cleaner urban aquifer, flood resilience etc.

Regenerative city construction is required to regenerate the ecosystem services of the city and its surroundings. Besides food, water, land and green areas, it is necessary to explore new patterns to promote material circulation in other fields like industry and commerce. The regeneration of the productive capacity of the city and its ecosystems will lead to a renewed, enhanced relationship between cities and their hinterland and between urban and rural areas.

5.3 Optimize Urban Spatial Structure and Layout

With the development of the economy and system reform, the transformation of China's cities from the traditional layout of expansion to the modern functional one is urgently needed, and it has also underlined the necessity and urgency of the reorganization and optimization of urban spatial structure.With this in mind, we can construct a regenerative city starting from optimizing urban spatial structure and layout.

5.3.1 Renovate the existing urban areas toensure intensive and efficient utilization of space. Rather than sprawling and expanding on virgin land, the focus of the urbanization process should be on creating denser cities by renovating the existing urban fabric and redeveloping existing sites. Increasing density has huge benefits in terms of efficient use of energy, resources,

infrastructure, and transport. With the overall strategy of “reform and innovation, transformation and upgrading”, the central city should catch the opportunity of industrial transformation to develop local potential, integrate resources, highlight priorities, so as to promote more intensive rather than extensive development. Considering the specific conditionsof different cities, we can start from renovating the old cities, planning new districts, revitalizing the stock of land, vacating industrial land, and so on.

5.3.2 Set rigid boundaries to curb urban disordered sprawling. It is necessary for metropolis‘ to set rigid growth boundary. Large and medium-sized cities should define construction boundaries according to the specific situation to curbspreading of construction. The sites and buildings of town projects should also be regulated with boundaries by promoting intensive and highly efficient space utilization.

5.3.3 Optimize traffic design to improve accessibility, logistics, and information flow. The focus of urban regeneration projects should be on making cities more people-centered, increasingly functionality for the community, and be more accessible and inclusive. In the actual construction, we should highlight the priority of public transport and optimize the network layout and transfer convenience of public transit system.

5.3.4 Plan the City with Cluster and Corridor Layouts. Cluster layout means, according to the requirements of functional and intensive development, optimizing and reorganizing the urban functions, defining the functional orientation of each city group, advancing misplacement development, releasing the pressure of central downtown, and balancing development among different regions, to create a characteristic urban brand. Corridor layout is required to construct systems like urban ventilation corridors, green roads, "Blue Networks" and cultural belts to ensure the abundance of natural ventilation, green lands, water areas and wetlands, and cultural recreation areas. The planning of this corridor layout can link up the various parts of the city and increase the livability, sustainability, and aesthetic value of the city.

5.4 Innovative Investment and Financing Mechanisms for Sustainability

The development of the regenerative city will need new innovative financing sources. Flexible and diversified investment and financing mechanisms can stimulate the development potential of businesses, reinforce the construction of weak links, and increase the effective supply of public goods.With regard to public services, improvement of resources utilization, promotion of eco-system circulation, optimization and intensification of spatial structures, as well as the enhancement of public service level,which are all emphasized by the concept of regenerative city, we can loosen market access, innovate investment and operation mechanisms, diversify the investment bodies, and improve price formation mechanism to promote growth.

Specifically, we can encourage third parties to carry out low carbon activities, and establish systems of resource consumption assessment and waste emissions accounting with emission trading schemes. We can also support social investment to participate in pollution reduction, as well as emission trading, and carbon emissions permit trading to improve the industrialization and specialization of pollution control. This would be done through ways of commissioned management services and trusteeship services, with the polluters paying for the pollution

abatement services of professional environmental services companies.

6 Policy Recommendations on Regenerative City Development in China

Although the features of the regenerative city can be described in theory, and much of its content can be showcased in different case studies, there is not yet a city that could be recognized worldwide as a Regenerative City.Further there isnot even a clear concept for a regenerative city. Throughout the planning of circular economy by domestic cities, and the concepts it relies on, the basic principles, adopted models and methods all have existing disadvantages, certain aspects of which are even just face-lifting of eco-environment or socio-economic planning. Therefore, it still needs concerted efforts on every level to improve the concept and implementation of a regenerative city and enhance its development in China.

6.1 Set up Developmental Vision and Strengthen Leadership

It is undeniable that the growth of the regenerative city has brought many benefits, but there are still challenges in its implementation. These are mainly coming from the systemic problems of the political, economic, and social structures and whose solution needs strong leadership and courage from decision-makers. The biggest obstacle to the reform is that people cannot outline a future that is different from the current situation, and they lack confidence in realizing this future. This obstacle shows a lack of political will and shortsighted behavior in decision making.

From the few cases of sustainable cities around the world, we can see how important an inspirational vision and strong leadership is in guiding sustainable development. For example, the former mayor of San Francisco, USA, actively participates in the formulation of targets and plans of power generation through 100% renewable energy, while Frankfurt of Germany also takes 100% renewable energy as the development goal. Mayors in similar cities have imagined a completely different urban future that goes beyond the status quo and are taking a series of measures to put the vision into practice.

Imagining a future scenario that is different from the current situation is the key to getting rid of the shackles of unsustainable development, and this envisioned good living environment is also the target of urban construction, as well as the guiding principle for action. The vision shows ambition, requires a long-term plan. Take a city for instance: the first step is to set up qualitative or quantitative objectives, which can display and convey political will, political commitment, leadership and vision, and provide a force for action to promote reform, stimulate more people to participate, to give certainty and security to investors. However, setting goals is not enough to ensure the fulfillment of a programme. The Overall goal still needs to be complemented by a corresponding development roadmap, a progressive strategy, and periodical evaluation based on qualitative and quantitative indicators.

Cities in China should respond to the call of SDGs and Habitat III, embrace this greater responsibility, and try to be the first to promote the transformation and development advocated at the international level. Meanwhile, these cities should not be passively

participants compared to their International counterparts or national legislatures, but rather should play an active role in formulating international rules and show their importance in the international arena. Although governments are the key to the formulation of the overall policy framework, the city and local governments are the main body to implement specific solutions. Local leadership and political will is therefore essential.

6.2 Encourage Cities to Actively Innovate Across Fields of Industry

Most cities now still keep focusing on economic development and lack the effective mechanisms to promote innovation within the field of urban sustainability.The source of financing difficulty for the eco-environment construction is similar to other investment fields—it is not lack of capital in the market but difficultly in transferring capital to the field. These challenges can be solved only through innovative policies and incentive mechanisms for sustainable development.

6.2.1 Establish new mechanisms and criteria to evaluate government officials. These mechanisms include new ways to penalize and reward officials, by abandoning "economic growth as the only criterion in government performance assessment" and establishing a "lifelong accountability system". The establishment of a formalized system through which local officials are assessed on environmental performance in their respective jurisdictions might become a greater incentive for them to prioritize environmental performance. This would also clarify responsibilities and accountability. Further, not only result oriented indicators, but also process-oriented indicators should be established. Considering that the positive effects of environmental rehabilitation will be accumulated over longer periods of time, process-oriented indicators will allow government officials not only to evaluate their work in relation to short term results, but in relation to sound and effective processes for the achievement of sustainable long term results.

6.2.2 Invest in capacity building and system innovation. Although China has worked to improve the quality and ability of the staff of administrative organs of government, rigidity in the system has prevented dynamic change and provision of the right skills to government officials to deal with the new challenges facing urbanization in China. Investing in capacity building for public administration staff will be therefore essential to ensure that those with responsibilities are well equipped with the tools and the skills to deal with new challenges affecting Chinese cities today.

6.2.3 Create multi-stakeholder task force and coordination bodies. Much of the innovation and creative ideas come from an environment where ideas can freely move and solutions can be found jointly by working across sectors. Promotion of department-to-department partnerships (DDP) and a more integrated approach to problem solving will be essential. For this purpose the creation of formal, institutionalized platforms that can promote

and coordinate cross-departmental cooperation is highly recommended.

6.2.4 Introduce innovative and alternative financing mechanisms to mobilize financial resources at the local level. These include public private partnerships (PPP), private financing initiatives (PFI) and civic crowdfunding. Improved methods on how public money is spent are also recommended (e.g. participatory budgeting schemes). Promote the adoption of innovative and locally based taxation system pilots in some cities under appropriate conditions, such as carbon tax, waste tax, or pollution tax, and other financial or tax-based mechanisms to ensure that less polluting options are favored as opposed to carbon and resource intensive processes.

6.2.5 Establish stable, long-term national and sub-national policy frameworks supporting sustainable economic development to incentivize private investors to invest in technologies and sectors that will be supported by the government.

6.2.6 Support research in green technologies. The urban economy, which is developed through intelligent and high-tech solutions will be an important component of the regenerative city. Some important technical areas that need to develop and expand urgently include: renewable energy, energy efficiency improvement, waste management and recycling, transportation management, urban agriculture, bioremediation, sustainable green building, etc.

6.3 Strengthen the Formulation of Urban Environmental Standards and Guidelines

First, several cities can establish their own standards to guide sustainable resourceuse and green construction within the city. They should then define the specific rules, the scope, the content, the division of responsibilities, the particular evaluation standards, procedures and methods for planning and construction in order tomake it more institutionalized and standardized, and thus improve the quality of construction and its environmental sustainability.

Second, it is important to improve the existing national and sub-national legislations regarding construction and ensure it is in line with the international standards. By referring to the successful practice of developed countries, cities should formulate planning and construction regulations considering Chinese characteristics, and ensuring that they are in line with international standards. This is important in order to create codes and standards which are comprehensive and which can avoid arbitrariness, one-sidedness and limitations.

Third, establish environmental audit. Referring to documents like "*Guide for Auditing Activities from an Environmental Perspective*" from Resources and Environment Audit Committee, which belongs to the International Organization of Supreme Audit Institution, we can establish suitable resources and environment operation procedures and methods which include the basic technical standards and evaluation indicators of resource and environment

audit. Besides, environmental financial audit, compliance audit, performance audit, risk assessment etc. should also be considered. In terms of evaluation indicators, audit evaluation index systems about water pollution, air pollution, soil pollution, and solid waste pollution should be established according to different audit objects and targets.

Finally,urge and regulate corporate environmental information disclosure. In order to improve the environmental information disclosure, we must speed up the establishment of unified environmental audit systems (including audit records, measurement, valuation, cost, reports and so on) about environmental pollution. At the same time, we can develop environmental accounting, save audit cost and reduce audit riskto promote the sustainable development of China's urban environment.

6.4 Implement a strategy based on open development to attract the active participation of the whole society

On one hand, the implementation needs to be promoted by strong leaders with the support of communication strategy, and other means in order to raise awareness and educate the public. On the other hand, the local people should participate in the planning and management instead of being only the beneficiaries of the development of regenerative cities. Their participation in decision-making will ensure wide support and recognition and will ensure effective implementation of the regenerative city plan.

Attracting all the stakeholders to participate in the planning is essential to ensure that all different interests are met, which has been proved to be very important for a more equitable type of development. Besides the active publics, the governors of the regenerative city should also get in touch with those vulnerable and marginalized groups who are often neglected. For example, it is essential to consider the disabled people as stakeholders to take part in the planning, and whose special requirements and rights should also be reflected in the final solutions. Similarly, districts with a large population of immigrant groups, especially migrant workers, should take these people‘s opinions into account in the design and planning of the city. Public participation in urban renewal and development will form a positive feedback system and those who are proud of their cities will feel a greater sense of ownership. It is thanks to the emotional bond that participation fosters in citizens that will cause local residents tobe more involved in the process of improving their own living environment. A wide range of public participation can also provide greater opportunities for social interaction at the community level, help to establish local social links, and enhance the cultural value of the whole city.

6.5 Strengthen Coordination among Urban Sectors

The urban system is a network of interdependent elements and the change of one element will influence the whole network.The issues related to resource management go beyond the urban boundaries as well as many other urban related matters. It is really ineffective for a single department to consider issues only related to its department. For example, urban water

circulation system are concerned with the recycling not only of water resources, but also of the nutrients contained in the wastewater,which might be valuable for other sectors such as agriculture. The regenerative city wants to abandon a silo-approach to problem solving and comprehensively consider all the various interrelated systems and find the best way to utilize resources across different departments.This will mean better communication and coordination among government departments at every level. Good government management systems will help to replicate good practices and integrate scattered activities into one.

An effective method is to establish special institutions or offices to coordinate different departments and seek to find a comprehensive development strategy. As an example, let us consider the issues in relation to water management. If we consider the inside and outside city as a whole, we must take the entire river basin into account, which requires communication between urban authority and the management institutions of surrounding larger areas. The special institutions, which are responsible for coordinating work among local government departments, and promoting cross-department planning, implementation and synergy, play an important role in achieving unified action. Communication and coordination among local areas, regions and the central government is beneficial for promoting the introduction of national incentive policies for urban development, and to encourage more local institutions to take bold action and carry out necessary reform measures.

Effective governance in the development of regenerative cities follows the principle of subsidiarity, which means encouraging the government to delegate authority and responsibility to the level of jurisdiction closest to the issue that is capable of performing such duties effectively. Although state management plays an important role in urban development,it is also essential to properly promote decentralized management, which will give the local government more power to make decisions that are affecting its own regions, and adjust policy measures according to local conditions.

6.6 Further Strengthen International Cooperation

Excellent solutions and their implementation are often not isolated in one place, but promoted by a wide range of cooperation and open dialogue. Cities around the world are increasingly opening up and sharing their problems, challenges and solutions with other cities, and cities in China should also be actively involved in this effort. At present, there are many platforms aiming to promote cooperation and communication among cities, and local government departments should support the construction of such platforms. For example, the sister-city relationships among many Chinese cities and other cities in the world can be used to strengthen the exchange of knowledge or promote constructive competition. The platform and initiative of the United Nations mentioned above, including the Habitat Conference and the UN Habitat, can be the opportunities for Chinese cities to display image, share experience, and exchange successful methods.

The policy measures that involve effective communication and dialogue among cities are essential to accelerate the transition. The new solutions that proved successful need to bedisseminated and shared with other cities.

7 Conclusion and Prospects

Considering the serious environmental pressure Chinese cities are facing as a consequence of their extremely rapid growth, it is undesirable to continue developing following the original model of linear development. Cities must move towards a green transformation: we need to think outside the box of sustainable development and explore wider and more comprehensive patterns for urban growth. This means that focusing on maintaining the stability of the urban environment and minimization of its negative impact is no longer the only task. We must promote the active regeneration of resources and urban spaces in a way that is beneficial and regenerating for the city and its surrounding natural environment.

Although there is no perfect regenerative city at present, the exploration of this concept worldwide has already been seen in certain industries and fields. The path to a regenerative city starts from a shift in our thinking, and its final aimis to let the city continue to provide people with opportunities to improve living quality and fulfill people's potential. The reason why the cities want to realize regenerative development is that it can ensure the long-term prosperity of the ecosystems they rely on, while benefiting the cities in multiple ways. More effective utilization of local resources (e.g. reduce consumption of resources coming from far away) and supporting the development of the circular economy (starting from waste prevention) will create wide-rangingsocial, economic, and environmental benefits.

The planning concept, design of content, and research methods can well support the new urbanization strategy proposed by the central government, and help, on the basis of the integration of qualitative, quantitative and positioning, getting to know the obstacles and potential of urban growth. This can be done systematically and deeply, by correctly grasping the direction of future development, and promoting scientific decision-making and practice methods. Meanwhile, this new urbanization also reflects a different type of development, also known as "New Normal", which means favoring people-centered development, innovation, environmental coordination and sustainable development.

However, understanding the concept of the regenerative city doesn't mean getting the perfect solutions to urban development, or realizing the recycling vision easily with low cost in a short time. Many obstacles exist in our political, economic and social systems. In order to overcome the difficulties, policy makers are required to promote long-term visions and show commitment and leadership for regenerative development. It is also essential to ensure coordination among the local, regional and national management authorities, non-governmental organizations, ordinary citizens, and all relevant stakeholders. It is also important to promote public participation, adopt a more systematic approach of urban planning, ensure public acceptance, accelerate the transition process and embrace a fresh and forward-looking approach to how we think and envisage urban development.

Bibliographies:

1. Qiu Baoxing, 2012. *The Only Way to Urban Ecological Transformation---Reconstruction of Microcirculation. Urban Insight*, 2012, 6: 5-20

2. Greenstein, etc. write, Ding Chengri, etc. translate, 2007. *Regenerative City*： *Utilization and Reuse of Urban Land. The Commercial Press Ltd.*, Apr.1st, 2007

3. Urban and Small Town Reform and Development Center Research Group of National Development and Reform Commission, 2014. *The Path of Constructing New Urbanization with Chinese Characteristics: the Reform of Administrative Management,* Apr. 23rd, 2014 http://theory.people.com.cn/n/2014/0423/c207270-24933042.html

4. the Sate Council, 2016. *Several Opinions of the State Council on Promoting the Construction of New Urbanization [Announcement of State Council (2016)No.8]*. Feb.6th, 2016

5. Office of the State Council, 2015.*Guiding Opinions of the State Council Office on Promoting the Construction of Sponge City[Announcement of State Council Office (2015)NO.75]*, Oct. 11th, 2015

6. Li Bohua, He Qinghua, Liu Peilin. *The Dynamic Measurement and Empirical Study of Regenerative City Construction---Take Hengyang City for Example. Ecological Economy,* 2010, 12:24-27

7. Li Shuhua,2010. *Symbiosis and Circulation---Basic Thought of Urban Green Space Construction under Low-Carbon Economic Society. Chinese Garden,*2010,6:19-22

8. World Future Council (WFC), 2015. *Regenerative City---the Path to the Ideal City*

9. Tang Shuangcheng, Luowan, Jia Zhonghua, Yuan Huangchun,2012.*Experimental Study on Storage-Infiltration Rainwater Runoff of Rainwater Garden in Xi'an City. Journal of Water and Soil Conservation,* 2012, 6: 75-79

10. Wang Wenwen, Zhao Zhijie, Qin Huapeng, 2012. *Simulated Assessment of Hydrologic Effect of Low Impact Development Model Based on SWMM. Journal of Peking University (Natural Science Edition),* 48 (2): 303-309

11. Xingwei, Zhao Dongquan, Chen Jining, Wang Haozheng ， 2011.*Rainwater System of Sustainable City Based on Low-Impact Development(LID). China Water& Wastewater*,2011,20:13-16

12. Zhangbiao, Xie Gaodi, Xuekang, Wang Jinzeng, Xiaoyu, Zhang Canqiang 2011． *Regulatory Capacityof Urban Greenland of Beijing on Rainwater Runoff and Its Value Assessment. Ecological Journal,* 2011, 31(13): 3839-3845

13. 13. Zhang Linwei，2015.Sponge City Construction is the Booster of Transformation and Development of China‘s Urbanization. China Construction News, 2015-11-12

14. Department of Housing and Urban-Rural, 2014. Technical Guidelines for the Construction of Sponge City--- Construction of Rainwater System Based on Low Impact Development (for Trial Implementation). October, 2014

Epilogue

Over the past 5,000 years, since the birth of ancient Memphis, the earliest city in our history – we have continuously developed and sought the perfect form of human settlement, yet we have still not achieved it. As our civilization continues to evolve, so does the form of the city. This city, which used to be an unintended outcome of tribal congregation, similar to the biocoenosis, gradually turned into a complex human settlement so intimately interrelated with precise scientific planning, that any single factor involved in city design could have a lasting influence on future generations. Neglecting the concrete importance of cities would result in the failure of successful urban development in the long term, and could inevitably jeopardize the interests of future generations.

Living in a globalized era requires thinking in an inclusive way. Back in the 1950s, and earlier, London was characterized by its dangerously mysterious mist. Even tracing back to the 17thcentury, cities were surprisingly disturbed by pollution too. Foul were the crowded town streets that induced the breakout of epidemics. The air was so contaminated following the industrial revolution that it stained the used-to-be peaceful countryside, even John Evelyn in his *Fumigufium: or the Inconvenience of the Air and Smoke of London Dissipated*, gave a then-pioneering view point that it was necessary to increase green space in cities for the sake of a cleaner environment. Today, the increasingly close interrelation between cities, economics, and nature has repeatedly highlighted the urgency of sustainable development, and the integration of development factors leaves us no leeway but promoting urban development with sustainable approaches. China, whose current rapid urbanization have exceeded its western counterparts in scale and speed in history, is even facing more serious challenges for regenerative urbanization since the country has the “triple burdens” – to catch up with developed countries, keep the natural environment integrated and stand out in fierce competitions in a globalized era. The challenges China is facing today may also be faced by other developing countries tomorrow. Therefore, the shift of China’s urbanization pattern to a more sustainable and regenerative manner may have global implication and such process shall evolve together with global sharing and learning.

The Regenerative Cities concept requires a paradigm switch away from the old linear metabolism, to form a new circular metabolism to establish a new symbiotic link between urban areas and their surrounding areas, improving cities’ and their surrounding areas’ resilience, sustainability, and overall health level. In China we take the Regenerative Cities concept as a motivator in stimulating the country’s urban green and sustainable development, which lies at the heart of the vision of this report. Taking advantage of a delicate integration of Regenerative Cities concepts, with real international and domestic cases covering urban energies, eco-systems, wastes and water management, this book is also expected to draw positive influences to the public, while keeping suggestion-given as its priority. Further,we do

hope this work could do more than provide case references for our readers, which is providing reflective material and stimulate meditative contemplation regarding our urban policies. Additionally, we believe the points raised by this book are valuable outcomes necessary to improve the policy making and urban planning process.

The completion of this book owes much gratitude to our loyal partners who have always stood with the WFC, especially China Research Center for Urban Development of Beijing Jiaotong University and the case study contributors of this book. Their altruistic devotion to China's sustainable development, and steadfast determination to making this world better, deeply motivates us and expels our uncertainties, keeping us determined to succeed when setbacks strike.

Finally, our sincere thanks go to all the individuals and organizations that have been actively involved in eco-conservation, and urban sustainable development. Your kind suggestions regarding our work, as well as towards this book, are cherished by our staff at the World Future Council. Let us join hands and step towards a greener, brighter, and brisker tomorrow.

World Future Council