Planning Strategy and Practice of Low-carbon City Construction

Development in Wuhan, China

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I. Exploration on Planning of Low-carbon City Construction under the Global Context

The concept of low-carbon is proposed in the context of responding to global climate change and advocating reducing the discharge of greenhouse gases in human's production activities. While in the urban area, the low-carbon city is evolved gradually from the concept of ecological city, and these two can go hand in hand. The connotation of low-carbon city has also changed from the environment subject majoring in reducing carbon emission to a comprehensive subject including society, culture, economy and environment. Low-carbon city has become a macro-system synthesizing low-carbon technology, low-carbon production & consumption mode and mode of operation of low-carbon city. At last it will be amplified to the entire level of ecological city. The promotion of low-carbon city construction has a profound background of times and practical significance. Just as Professor Yu Li from Cardiff University of Great Britain has summed up, at least there are reasons from three aspects for the promotion of low-carbon city construction: firstly, reduce the emission of carbon through the building of ecological cities and return to a living style with the harmonious development between man and the nature; secondly, different countries hope to obtain a leading position in innovation through exploration on ecological city technology, idea and development mode and to lead the construction of sustainable city of the next generation; thirdly, to resolve the main problems in the country and local areas as well as the problem of "global warming".

From the theoretical exploration of low-carbon city construction, the effect of planning and space strategy has been more and more valued. In 1996, the organization of "urban ecology" led by Richard Register has proposed ten principles of ecological civilized city. The first is to "modify the priority of land use and exploration, develop in priority the hybrid land use community which is compact, diverse, green, safe, pleasant and attracting." In 2009,

Chris Gossop brought forward “the Statement of Seven Key Elements of Low-carbon City”, in which the fifth item is “integrated and inclusive planning of city, region and human’s settlement system, i.e., integrate land use, transportation, energy and waste planning into the space planning.”

From the perspective of practice, different urban areas with different scale have made an active exploration on the space mode. For example, in the making of planning policy of metropolitan, “City Planning Strategy for 2030” of Newyork has made a different graphical presentation of planning path on challenges faced with the city development in the future 20 years, and brought forward a special strategic content which adapts to the climate change. And Singapore, Curitiba and London have also proposed forward-looking strategies on global response, innovative development of public transportation and maintain a city space layout with local features. In the urban area development at medium scale, the booming ecological cities have become a bright spot of low-carbon planning practice, which include not only the Eco-city construction mode represented by Eco-town of Great Britain, but also the development mode of expansion of existing urban area represented by Eco-city in France, and eco-industrial park mode represented by Kalundborg in Danmark and Kitakyushu in Japan. In a microcosmic scale, the construction of low-carbon city community has obtained achievements with more operability, i.e., Sun& wind community in Beder of Danmark which was finished in 1980 and Beddington zero energy development community in southern suburb of the Great Britain which was finished in 2002, which integrate many energy-saving and emission-reducing measures into one small eco-community and effectively reduced the emission volume of carbon dioxide.

No matter what the mode and the scale are, they demonstrates long-term and structural effect that urban planning and spatial pattern exert on urban development when faced with global warming. We need to reflect and change the traditionally spatial pattern of "high carbon" city over about 300 years since Industrial Revolution. Besides, they show the integrated function of low-carbon planning as technological integration for low-carbon city construction.

The construction of ‘Low-carbon City’ in China is in the ascendant. It shows that Chinese cities have begun to make sharp response to the environment constraints in the rapid urbanization. This also indicates the rational transformation of urban development in China. According to statistics, by the end of 2008, there have been 656 cities in China, with over 600 million urban residents. Another 16 million people flock to the cities every year. The annual urbanization rate increases by 1%. It is predicted that the urban population will exceed 1

billion in 2025. Carbon dioxide emissions in cities account for 90% of the total amount of the whole country, and energy consumption accounts for 80% of the national amount. Therefore, Dr. Qiu Baoxing pointed out that, China must follow its own model in building 'Low-carbon City'—C model (Chinese model), creating efficient, harmonious, healthy and sustainable human inhabitation environment and building low-carbon eco-city with low pollution, low emission, low energy consumption but high energy efficiency, high productivity and high benefit.

In practice, various programs have been launched in China, including Environmental Protection Model Cities (from 1996 to 2006, launched by State Environmental Protection Administration), National Ecological Demonstration City (from 1995 to now, launched by NEPA), Pilot City of Recycling Economy (May 2002 and November 2007, launched by NEPA), Pilot City of National Eco-garden City (May 2002 and June 2007, the national Ministry of Construction), Demonstration City for Low-Carbon Development (launched by Ministry of Construction and WWF), etc. More than 100 cities have been involved in these initiatives, such as Shanghai, Guangzhou, Yichun, Baoding, Shenzhen, Foshan, Wuhan and Chongqing.The latest development is the various new eco-cities represented by Zhongxin New Eco-city in Tianjing, Guangming New Area in Shenzhen. The practice of the objective as well as the system shows more foresighted pursuit and more comprehensive exploration.

If we compare the outlines, standards and implementation focus of these programs, we can see that in Chinese urban development, the transition process has become deeper, the goal has become more specific and the orientation has become clearer. Seen from the index system of ecological demonstration city promoted by the State's environment protection departments, eco-city actually means some systematic requirements on the general development model of a city, which reflects the theoretical model of 'society—economy—natural compound ecological system' (Ma Shijun and Wang Rusong, 1984). Analyzed from the perspective of composition of eco-system, this index system can be divided into three aspects such as eco-landscape pattern, eco-environment governance and eco-harmony degree. Among them,Eco-landscape pattern includes three indices such as forest coverage, proportion of protected area in national surface area, average public green space area in cities and towns. This has shown the basic mode of eco-city construction, which is based on eco-pattern, centered on eco-governance and guaranteed by society-economy harmony. The demonstration city of recycling economy promoted by the State's environment protection departments is also representative, especially its examination and evaluation system which has covered 4 categories and 22 indices such as resources output and consumption, comprehensive utilization of resources and waste discharge, reflecting the development requirements of new economy based on the principle of 'reducing quantification, re-using and recycling', and can be regarded as an important supplementary standard for the eco-city construction. While 'low-carbon city' pays more attention to and focuses more on carbon emission reduction in the development of an eco-city, and it is a more operable and pointing goal. 'Low-carbon' city is actually the newest, clearest and most specific goal orientation in China's exploration on new path of city development, and is a deepening concept based on eco-city, and therefore 'low-carbon city' and eco-city have the

same spirit in theory as well as in practice.

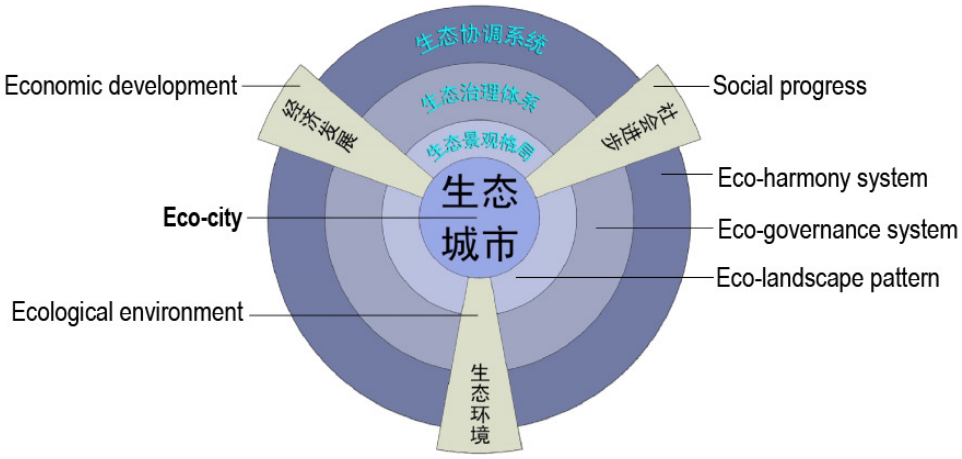

Figure 1 Basic mode of eco-city construction

II. Focusing on eco-pattern—planning strategies for 'low-carbon city' construction of Wuhan

Wuhan, the capital city of Hubei Province, is located in middle of China and at middle reach of Yangtze River. The whole city covers an area of 8,494 km^2, with a permanent population of 9.1 million and an urbanization rate of over 70%. Wuhan is l also a city that characterized by abundant natural resources and unique natural environment. The water resources are especially advantageous and the water-shed area reaches 2,200 km^2 which accounts nearly a quarter of the national territory. Yangtze River and Han River flow through the city and there are 27 lakes and 57 mountains, thus forming a spatial pattern of "a city full of water and half occupied with mountain". In a word, Wuhan has excellent conditions to build into an eco-city and a low-carbon city.

In 2008, the central government has granted Wuhan City Network the national experimental area to construct a 'resource-saving and environmentally-friendly' society. As the core city of Wuhan City Network, Wuhan will center on 'resource-saving' and 'environmentally-friendly' to build a low-carbon urban space structure according to the construction of a 'low-carbon city' laid down in *Master Plan of Wuhan City*.

1. Using 'ecological footprint' research method to determine and control the development scale of low-carbon city.

Currently, 'ecological footprint' analysis method is an appropriate method to determine the population scale from the perspective of low-carbon city construction. In the present *Master Plan of Wuhan City*,, the ecological footprint analysis method is used to calculate six categories of land including fossil energy land, arable land, pasture, forest land, construction

land and water area. In 2003, the average ecological footprint in Wuhan is 2.3980hm^2 per capita, and after the introduction of consumption adjustment coefficient, the average consumption ecological footprint in Wuhan is 0.9311hm^2 per capita, the available biocapacity is 0.3076 per capita, the ecological deficit is 0.6235 hm^2 per capita.

Based on a remission of 25% of the present ecological stress, the *Master plan of Wuhan City* has made an estimation and it suggested that the total population of Wuhan in 2020 should be controlled under 12 million. Actually the master plan has taken an estimated population of 11.8 million. This program is the strictest among the five special researches on population.

2. Determining the construction-forbidden area and construction-limited area to protect natural resources based on ecological sensitivity assessment

According to the requirements, the proportion of green space of ecological cities and towns should not be less than 40% of the total area, and at least 50% should be public green open space network with a good management and good quality. The *Master Plan of Wuhan City* has made use of GIS technology which is strong in quantitative evaluation, accuracy, timeliness and IT application in management to make an analysis on the sensibility of ecological elements of the whole city, so as to determine the construction-forbidden area and construction-limited area, to control and protect the areas separately and to achieve the goal of reducing the carbon emission as much as possible.

The master plan has divided the ecological assessment factors into 17 categories including bearing capacity of the foundation, elevation, gardens, woodlands, distribution of water resources, wetland distribution, sensibility of water body, seismogeological disaster, soil environment, sensibility of soil, soil erosion, arable land, mineral resources, gradient, distance and accessibility, and it superimposed all the ecological assessment factors according to their weight and analyzed the ecological sensibility.

According to the assessment result, the ecologically insensitive area in Wuhan accounts for 8.5%, mildly sensitive area accounts for 27.4%, moderately sensitive area accounts for 44.9% and highly sensitive area accounts for 19.2%. The biodiversity in the north of the city, eastern and western part of the central city, lake water network and beach wetland in the south of the city is very rich and these areas are highly sensitive area with strong biological function. Based on the above result, the master plan divides the urban area of Wuhan into four categories including construction-forbidden area, construction-limited area, construction-suitable area, and built area.

The total area of ecologically controlled land such as construction-forbidden area and construction-limited area account for 83%. Control on these lands has effectively protected urban ecological resources and hence played an important role in reducing carbon emission.

3. Rapid transportation corridor leading to an axial expansion and a life style of low-carbon transportation

According to statistics, in the past ten years, the emission of carbon dioxide on the earth has increased by 13% while the carbon emission of vehicles has increased by 25%. Therefore, to reduce the urban carbon emission, firstly we should reduce the carbon emission caused by vehicles, and the fundamental solution to the traffic problem is to build a scientific and reasonable urban space to reduce the transportation and commuting.

Wuhan is a metropolis in the period of an accelerating expansion. It is surrounded by lakes, mountains and green spaces. The *Master Plan of Wuhan City* of this round has changed Wuhan's traditional spatial development mode, the rings. According to TOD mode, Wuhan will form six compound transportation corridors of 'expressways, main roads and rails' made up of 18 highways/express ways, 13 skeleton arterial roads and 7 rail transit lines, leading the urban space to expand along the axis towards Yangluo, Baoxie, Zhifang, Changfu, Hanjiang and Panlong, and forming six new groups of towns with a certain balance and independence in the east, southeast, south, southwest, west and north of Wuhan.

In the compound 'expressways, main roads and rails' transportation corridor, the highways/ express ways provide long distance and spot-to-spot rapid transportation service, and the skeleton arterial roads provide middle-long distance , area-to-area transportation service. This ecological, open and intensive urban space expansion pattern of 'ring + axis' led by TOD mode not only reduces the everyday commuting of the residents and the formation of pendulum traffic but also is easy to form an aggregate public corridor between the main city and groups and between the groups. Furthermore, it can assure a convenient connection between residential groups and industrial groups by walking, cycling or public transportation, which is in favor of a low-carbon and highly efficient operation of the whole city.

4. Adopting CFD to simulate urban air flue and building a low-carbon urban space framework in favor of natural circulation

Wuhan is one of the four famous 'stoves' in China. It has big population intensity in the central urban area, and in some area the intensity has even surpassed 100 000 persons/km2, so the problem of urban heat island effect is quite prominent. In the summer of 2003, the highest temperature reached ≥35℃ for 18 consecutive days and there were 33 days when the temperature reached ≥35℃. The super long time cooling in summer also leads to a large amount of emission of living carbon. Therefore, how to use natural circulation to reduce the heat island effect will be a key issue to be considered in the construction of a 'low-carbon city'.

In the *Master Plan of Wuhan City*, computational fluid dynamics (CFD) approach is adopted to construct digital models. Based on the analysis on main wind directions in winter

and summer in Wuhan City, the temperature at Yangtze River and Han River is quite lower than that in other areas of the city, plus the stronger wind speed. Therefore, Yangtze River and Han River can serve as the natural ventilation stack to adjust the thermal conditions in the surrounding areas. On the outskirts of the city, the temperature is relative lower by virtue of lakes. Here the smooth air flow is conducive to improving air quality and effectively changing the thermal conditions in the surrounding areas. Therefore, it might be a good solution to connect Yangtze River, Han River and lakes around the city with parks, greenbelt and plaza within the city, so as to create an ecological passageway, enhancing ventilation in the big city and reducing the temperature of the city.

Based on the above analysis, in the master plan, 6 green wedges at Great East Lake, Wu Lake, Fu River, Houguan Lake, Qingling Lake and Tangxun Lake are set up, in light of such ecological elements as 6 large scenic areas, 5 national and provincial wetland nature reserves, 6 urban forest parks, 7 suburban parks and lakes, mountains and ecological farmland, along the routes of Daoguan River-East Lake, Mulan Mountain-Wu Lake, Fu River, Chang River-Houguan Lake, Lu Lake-Qingling Lake and Liangzi Lake-Tangxun Lake, in a bid to form multi-directional ecological corridor and urban ventilation stack throughout the whole city. Meanwhile, Fu River, Dao Shui, Ju Shui, She Shui, Tongshun River, Jin Shui and Sha River are utilized to form 4 connected water systems, covering Huangpi-Xinzhou, Hankou-East-West Lake, Hanyang-Caidian and Wuchang-Jiangxia regions. The water systems are also effectively connected to Yangtze River and Han River, constituting a network of water systems covering the whole city. A natural and low-carbon urban ecological framework is thereby established in the master plan.

According to the comments from SOCARP, this is an urban planning following the philosophy of low-carbon life, using advanced technologies, and probing into the microclimatology (both local and global issue of sustainable development) by connecting green infrastructure with traffic from the perspective of urban planning and design. The sustainable development strategy is also put forward, complying with the development trend of human housing modality.

III. Construction Progress of ‘Low-carbon City’ in Wuhan

Based on the guidelines of the master plan, Wuhan city has made positive achievements in building itself into a low-carbon city in recent years.The key point is to put into practice the idea of general planning in the city planning level, centering on the formation of ecological landscape pattern and the change of city development mode.

1. Defining ecological and natural resources of the whole city and building urban ecological framework

In order to build the urban ecological framework, plan for protecting ecological

framework in Wuhan, planning of non-constructive land in Wuhan, planning of green space system in Wuhan and overall planning of East Lake have been laid out, which have highlighted and utilized all the ecological elements of Wuhan City.

Green wedges have mitigated heat island effect. The summer days with extremely high temperature have apparently decreased in the urban area of Wuhan. The highest temperature in summer on average ranks six compared with other large and medium-sized cities at the same latitude. It means that Wuhan has successfully shaken off its nickname 'stove'.

2. Protecting and utilizing the waterfront resource and ensuring the openness of ecological space

In order to ensure the openness of ecological environment, reconstruction of waterfront ecological environment has been carried out in Wuhan, which has expanded the urban water and leisure space, eased the shortage of urban green space, and upgraded urban livable environment. Wuhan Riverside Park has stretched 26.2 km, covering an area of over 3 million m^2, and it becoming the largest marshland park in China.

3. Connecting rivers and lakes throughout the city and building a network of four water systems

Wuhan is rich in water resources. Freshwater resources occupancy per capita is 40 times that of the average value in China. And water covers 25% of the total area of the city. The planning has connected main lakes of the city, forming 4 connected water systems, covering Huangpi-Xinzhou, Hankou-East-West Lake, Hanyang-Caidian and Wuchang-Jiangxia regions. These water systems are also effectively connected to Yangtze River and Han River, constituting a network of water systems covering the whole city.

4. Implementing a series of waters connection project and optimizing water environment in an all-round manner

Focusing on the construction of 'Water Network' in Wuhan, optimizing the planning of water function zone, protecting the ecological environment of Wuhan City and ensuring the safety of water system, series of water environment projects have been carried out, including planning on protection of East Lake Scenic Area, 'Six-lake Connection' project in Hanyang and 'Great East Lake' ecological water network in Wuchang, etc. Pollution control, ecological restoration and water network construction have been implemented in these projects.

5. Strictly controlling the construction of main urban area, and vigorously promoting the construction of peripheral cities

Construction of main urban area is properly controlled, and the construction of peripheral

cities is vigorously promoted. Ecological environment of the new cities is improved, and new jobs in new cities are created. Convenient transportation system is established, and the flowing of population and industries from central cities to peripheral cities is guided,. Heat island effect in downtown area is mitigated, and the overall living environment in the city is improve.

6. Strengthening rail transportation system and encouraging low-carbon traffic

Five efficient inter-city railways from Wuhan to Huanggang, Huangshi, Xiantao, Xianning and Xiaogan have been built in Wuhan City Network. The total length of these railways has reached 430 km. So a regional railway network has been initiated. Public transportation system has been given priority. 3 rail transit lines have been built, and 5 rail transit lines are under construction. A transportation corridor to distribute the urban population to peripheral cities will come into being, and the pattern of low-carbon traffic is promoted.

IV. Conclusion

Seen from the practice in Wuhan, the construction of low-carbon city calls for breakthroughs in various aspects and all levels, including using low-carbon technologies, transforming urban life style, promoting clean production, developing low-carbon economy and implementing efficient city management, etc. However, from the prospective of urban planning, the fundamental principle is to create reasonable layout of urban space. Just as the saying goes: “Low-carbon planning is the most efficient way to reduce carbon emissions”. However, there is still a long way to go, and it takes time to implement the planning before we can see the effect.

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