Background Report on Low-Carbon Development Strategies and Policies in Wuhan City , China

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1. Preface

There is an urgent need for better sub-regional cooperation on low-carbon urban development to meet the challenges of global climate change and rapid urbanization. A number of North-East Asian (NEA) countries, in particular China, Japan and Korea, have introduced policies and practices on low-carbon city (LCC) development at various levels of governments and using different approaches. NEA has a wealth of experience to offer in this area and there is great scope for countries in the region to learn from each other. That is why the North-East Asian Sub-regional Programme for Environmental Cooperation (NEASPEC) launched its North-East Asia Low Carbon City Platform (NEA-LCCP) in 2015 for organizations working on LCC approaches, policies and programs to collectively support NEA countries and cities.

In March 2017, the Twenty-first Senior Officials Meeting of NEASPEC (SOM-21) approved the launch of a peer review and comparative study under the NEA-LCCP to improve knowledge and capacity and to support networking between experts, agencies and cities. At the municipal level, the peer review will provide host cities with expert advice and suggestions on better LCC planning and policies. The comparative study is focused at the national level and on reviewing national progress and government policy and providing an overview of the sub-region.

Innovative Green Development Program (iGDP), an NEA-LCCP partner, is working closely with the NEASPEC Secretariat to carry out two NEA-LCCP pilot peer reviews in China. It also leads the overall NEA-LCCP comparative study in providing national input from China. This document is the draft work plan for the peer reviews and the comparative study.

The peer review will help cities examine and evaluate their LCC development strategies. A team of organizations, experts and cities will collect data to help assemble a system of indicators that can be adjusted depending on each city's actual circumstances. The peer review process will support the exchange of ideas and best practices.

This report summarizes Wuhan's low-carbon strategies and policies; it was originally a background report to be fed into the LCCP peer review. Rather than simply

assessing the city's low-carbon performance, the background report also provides an overview of socio-economic data, urban development strategies and directions, and the performance of key low-carbon driving factors. More importantly, it includes a comprehensive examination of the strategic measures and policy instruments that local governments have implemented.

In 2010, China's National Development and Reform Commission officially launched a national low-carbon pilot program in the provinces and cities to encourage local institutional capacity on climate change mitigation and low-carbon development. China currently has six low-carbon pilot provinces and 81 low-carbon pilot cities. To better understand low-carbon development in China, NEA-LCCP chose Wuhan to be its peer-reviewed case city.

Wuhan is a mega city in central China. Its economic profile historically has been heavy industry, and it could be called a typical Chinese city in terms of the country's industrialization path. Wuhan is the provincial capital of Hubei; Hubei was in of the first batch of low-carbon pilot provinces while Wuhan was in the second batch of low-carbon pilot cities. Wuhan began working on low-carbon top-level design and institutional and policy building in 2010. Low-carbon development has been an important pathway for Wuhan in helping to restructure its economy; upgrade its industry; and improve the quality of urban infrastructure and public services. At the 2015 Sino-U.S. Climate Summit, the mayor of Wuhan formally promised that the city will peak its carbon emissions by the year 2022, and this commitment was included into Wuhan's 13th Five-Year Plan for National Economic and Social Development. With seven years of low-carbon practice under its belt, Wuhan is now moving from the exploration phase to an improvement and upgrade phase. It has made remarkable progress in establishing and innovating low-carbon strategic measures, institutional mechanisms, policies and instruments, which have proved successful and can be copied by other cities in China to pursue low-carbon development.

The effective implementation of low-carbon development strategies and policies depends on a number of factors, such as climatic conditions, natural geography, regional characteristics, culture, local resources, industrial structure, administrative levels, and the strategic positioning of urban functions and development priorities.

These factors also affect how the key driving factors of low-carbon development will change going forward. Carbon emission reduction and environmental protection in cities are public goods, and the government is the key promoter of urban low-carbon transformation. Decision-making has to be implemented at the central and provincial government levels, but local government should also introduce and implement specific measures and policies based on local characteristics to promote low-carbon transition.

This report seeks to answer the following questions: What are Wuhan's natural, social, economic and political characteristics that would impact low-carbon development practices? How did the key driving factors affecting low-carbon development change during the 12th Five-Year Plan (2011-2015)? What kinds of strategic measures and policy tools were utilized by the local government? The Wuhan background report is split into four sections and is more factual than analytical or commentary in nature.

The first section covers Wuhan city data and its future development path. China's vast territory means its cities vary widely in terms of geographical location, resource endowments, industrial profile and local culture and traditions. These characteristics, like invisible hands, impact urban development. By better understanding Wuhan's characteristics and long-term development strategies, we can get a better picture of the obstacles and challenges to low-carbon development that lie ahead.

The second section provides an overview of changes in some key drivers during the 12th Five-Year Plan (2011-2015). The key element that distinguishes low-carbon development from other development concepts is carbon reduction. Reducing carbon emissions is a systemic problem that depends on multidimensional factors such as population, economic development, energy consumption, energy mix and available low-carbon technologies. Understanding these changes and predicting future trends for factors affecting Wuhan's carbon emissions will allow us to better gauge the city's low-carbon development and the challenges it faces in the future.

The third section is the report's "core;" it presents Wuhan's low-carbon development strategies and policy practices. These span a number of sectors including urban construction, energy, industry, transportation, buildings, municipal environmental infrastructure, land use, and so on. This section covers the management

systems, strategies, and policy instruments adopted by the Wuhan government during the period of the 12th Five-Year Plan and its performance in key indicators.

The final section is a conclusion to the report that incorporates the key points raised in the three earlier sections.

2. City Profile

With a history of 3,500 years, Wuhan is now a city with more than 10 million residents and a GDP topping 1 trillion yuan. It is located in central China and along the middle reaches of the Yangtze River, and is both a modern city and one with a profound historical and cultural background. Wuhan is a city undergoing urban development with a unique geographical location, climatic and ecological environment and social, economic and cultural foundations. The relationship between these characteristics of climate, geography, culture, resources, industrial structure, and administrative structure and low-carbon development strategies and policy practices are important to understand.

As an economic center and mega city in China's central region, with its particular geographical and climatic conditions, Wuhan has long been an energy-intensive city. However, given its high dependency on energy imports and increasingly severe environmental constraints, it is inevitable that it must adopt a low-carbon development path.

Wuhan endures cold winters, hot summers, and abundant rainfall. It is located in a subtropical monsoon climate zone with average annual precipitation of 1,200 mm in its urban area. Wuhan is one of China's famous three "summer as hot as a stove" cities.

Wuhan's geographical features have led to the multi-center nature of its urban spatial development. Its administrative area is 8,569 km^2, of which 3,261 km^2 is the current urban development zone and 678 km^2 is the area of the city proper. Wuhan has been shaped by its interactions with mountains, lakes and rivers, so that the urban development area has sprung up along riverbanks and offshore. Wuhan's urban spatial development is unbalanced, making central allocation and balanced development for land use difficult.

Wuhan is located in the hinterland of China's central plains and is the country's economic and geographical center with geographical advantages extending outwards in all directions. As a central city in the central region, Wuhan acts as a gateway between the east and the west and also connects the north and the south. It has been called the "thoroughfare to nine provinces." Wuhan is China's largest inland land, sea and air transport hub, integrating railways, highways, waterways and aviation.

Wuhan has poor energy resources but is rich in non-metallic minerals and these have spurred the development of its manufacturing sector (mainly the metallurgical, building materials, chemical and fertilizer industries). But industry has a high demand for fossil fuels. Wuhan has "no coal, no oil, and no gas". It imports its energy from outside including four major hydropower stations (Gezhouba Dam, Danjiangkou, Geheyan and the Three Gorges Hydropower) and Pingdingshan Coal Mine.

Wuhan's long-term rapid economic growth has put pressure on environmental capacity, ecological restoration, and pollution reduction efforts. Between 2005 and 2015, more than 10% of its annual GDP growth was driven by energy-intensive and resource-intensive industries, such as electricity, steel, building materials and chemicals. In addition, as people's living standards improved and urban transportation developed, pollution from industry, traffic and the public have complicated and exacerbated the city's environmental problems. The pollution issue spans traditional soot, ozone, fine particles, volatile organic compounds, water pollution, and solid waste.

Wuhan has a long history and rich culture. Openness, flexibility, inclusiveness and diversity are firmly anchored in its history and culture. It also has rich science and technological innovation resources; these provide strong ideological foundations and capacity for absorbing, building and practicing low-carbon development.

Wuhan's regional culture is pluralistic and inclusive. This affects local decision-making, strategic thinking and implementation. Wuhan incorporates Jingchu culture (a culture that grew up along the river) and a Yangtze River culture. As a transport hub between east and west, and south and north, Jingchu culture is characterized by "pioneers and the pursuit of excellence;" a product of the cultural exchanges between people from the central plains and the south, the upper, middle and lower reaches of the Yangtze River.

Wuhan is a city where science, technology and intellectual resources are highly concentrated. With more than 200 specialized research institutes and more than 80 universities, Wuhan is an important science and technology education center in China. Its innovation resources are second only to Beijing and Shanghai.

As a heavy industry city that is in the process of industrial restructuring, the long-term key priorities for Wuhan in securing a low-carbon transition are industry and energy.

Traditionally, Wuhan's economy has been dominated by heavy industry but it is now in the process of transforming itself into an advanced manufacturing base. The local government has long prioritized manufacturing – as far back as 100 years ago, during the late Qing Dynasty, Wuhan led the country in iron, clothing, spinning, textile and firearms manufacturing, earning it the reputation of being China's industrial center. After the founding of New China in 1949, Wuhan became one of the country's key cities for the development of heavy industry by virtue of its industrial base, geographical location and strategic position. It built a comprehensive industrial network based on the metallurgical industry, machinery manufacturing and textiles. After Reform and Opening Up that began in 1978, Wuhan started developing a consumer goods industry – such as household appliances, plastics, and textiles. By the late 1990s, Wuhan had expanded its industrial base from textiles, metallurgy, chemicals and home appliances into more capital-intensive areas, such as automobiles, steel, optoelectronics and pharmaceuticals. With the support of a series of national and local development strategies, focusing on western China, central China, Wuhan city, and on upgrading Wuhan's industry, Wuhan's industrial structure became characterized by its four pillar industries -- steel, automobiles and machinery equipment, electronic information, and

petrochemicals, as well as some other key sectors such as environmental protection, tobacco and food, home appliances, textiles and clothing, medicine, paper and packaging and printing. During the 12th Five-Year Plan period (2011-2015), Wuhan implemented a strategy focusing on industrial development, and established itself as an advanced manufacturing center; some industries topped 100 billion yuan, including IT, automobiles, equipment manufacturing, steel, petrochemicals and food. Wuhan's traditional industries, such as steel and textiles, are on the decline and are predicted to be replaced by IT, biomedicines and smart production.

As a sub-provincial city, capital of Hubei Province, and national pilot, Wuhan has abundant administrative resources to support a low-carbon transformation.

Wuhan has a special administrative status which gives it more administrative resources. Wuhan's extensive administrative capacity can support public policy making and city governance and its interactions with the central government, the provincial government and other local governments in the region. In 1984, Wuhan was approved as a pilot city for economic reform. It implemented its own separate plans having been given the authority to make provincial-level economic and social management decisions. In 1994, Wuhan was upgraded to a sub-provincial city，which means its government was given more administrative capacity and considerable influence over local public resource allocation. As a sub-provincial city, Wuhan's fiscal budget and financial mechanisms are independent of the provincial budget. Wuhan does not turn over its revenue to the provincial government, which means that it has greater financial resources for urban construction and management. The city has built a modern transportation system, improved the environment and urban management. Furthermore, as a pilot city in a number of initiatives, it has abundant support in terms of funding, innovative institutions, policy, and capacity building. During the 12th Five-Year Plan period (2011-2015), Wuhan was not just designated a low-carbon pilot city but also a pilot city for a number of other categories -- sustainable urbanization, smart city, low-carbon industrial zone, renewables in building, alternative fuel vehicles, low-carbon integrated transportation planning, and public transit city.

Wuhan is currently undergoing shifts in its industrial and urban structures. Advancing an Industrial Manufacturing City and Strengthening and Improving Urban

Construction is one key development strategies supporting its long-term vision of making Wuhan a national central strategic city. Low-carbon City Development is also supporting Wuhan's economic transformation and upgrading and improving its urban functionality.

The strategic vision of becoming a National Central City and a key development area do not represent the real status of a city, but rather they are long-term goals that guide a city's future development, which means they do have an impact on how the key driving factors on low carbon development change over time.

Wuhan has set its long-term strategic vision and objective on becoming a National Central City, the highest in the urban hierarchy of China's urban system. Wuhan has had this goal since 2011. In 2016, the NDRC issued *Guiding Opinions on Supporting the Construction of Wuhan as a National Central City*. It proposed that the four top functions of a future Wuhan should be national economic center, top-level scientific and technological innovation center, trade and logistics center, and international exchange center. In September 2016, the State Council issued *Outline for Planning the Development of the Yangtze River Economic Belt*, which positioned Wuhan as a megacity. The strategic visions of megacities mean that in the future Wuhan will focus more on urban functionality, industrial agglomeration and acquiring human resources.

During the 12th Five-Year Plan period (2011-2015), Wuhan launched a series of plans: the *Industrial Doubling Plan*, the *Service Industry Upgrading Plan*, the *Strengthening and Improving Urban Construction Plan* and the *Improving Innovation Capacity Plan*.

Wuhan will focus on improving its capacity for innovation. In 2013, Wuhan launched the *Enhancing Innovation Capacity Plan* and proposed setting up the city as a national innovation center characterized by building up centers for high-tech innovation, emerging industries, science and technology, senior talent, and a culture of innovation. In early 2017, Wuhan launched its *Business Start-up and Employment Plan for Attracting a Million Graduates* to improve the quality of its human resources. It aims to draw in college graduates and high-tech industry professionals to start their own businesses and work in the city.

Wuhan implemented its *Industrial Doubling Plan* with the support of a local strategy on advanced industrial manufacturing. Industry is at the heart of Wuhan's development plan. The *Wuhan Action Plan on Manufacturing 2025* proposes making Wuhan into a state-level advanced manufacturing center by the year, 2025. Wuhan will quicken the pace of transforming and upgrading its traditional industries such as automobiles, equipment manufacturing, steel, petrochemicals, food, tobacco, household chemicals and other industries. Its *Emerging Industries Doubling Plan* focuses on electronic information, the life and health sector, and smart manufacturing.

Wuhan implemented its *Strengthening Urban Construction Plan* to help develop urban public infrastructure. In 2012, Wuhan issued the *Five-year Plan on Strengthening and Improving Wuhan Urban Construction (2012-2016)*, which boosted fiscal investment on urban infrastructure construction and implemented 24 projects to improve urban structure, transportation hubs, urban transport infrastructure, urban environmental quality, the urban landscape, engineering design, and construction. The *13th Five-Year Plan on Wuhan's Land Use and Spatial Planning* issued in 2017 incorporated the Yangtze River Main Section and the Yangtze River New City into Wuhan's 13th Five-Year Plan (2016-2020).

Wuhan implemented the *Service Industry Upgrading Plan* to help develop a modern service industry. In 2013, Wuhan launched the plan and introduced a series of supporting measures and policies to promote the development of the top ten service industries such as modern logistics, commerce and trade, finance, real estate and convention and exhibition tourism.

During the 13th Five-Year Plan, Wuhan's strategic deployment will include three dimensions: upgrading the economic structure (power and industry), upgrading urban public infrastructure (function and quality), and improving local livelihoods (security and governance).

3. Key Driving Factors Behind Wuhan's Carbon Dioxide Emissions

The Kaya Identity states that total carbon dioxide emissions are the product of four elements: population, GDP per capita, energy consumption per GDP (or energy

intensity), and carbon dioxide emissions per energy consumption (or carbon intensity). This section analyzes how these four key driving factors changed during Wuhan's 12th Five-Year Plan period (2011-2015).

3.1 Demography

Wuhan's population has risen steadily as has its urbanization rate. Most workers have found employment in the manufacturing and tertiary sectors. Wuhan is also an aging society.

Wuhan's population rose steadily. The population climbed to 10.6 million in 2015 from 7.1 million in 1995 (an increase of nearly 50%). In 2015, the city's population entered the "tens of millions" category. The annual growth rate of Wuhan's population was 1.4%, second only to Beijing and Tianjin. In addition, Wuhan has a floating population of almost 3 million. The continuous rise in demographic dividend has also driven urban construction and economic growth, and has been a source of strong demand in the real estate market. Wuhan's population is expected to continue to grow. According to a study on Wuhan's population growth by Peking University, the city's population is predicted to reach 15-17 million by 2030. By 2050, Wuhan is expected to have a population of between 17 and 22.5 million.

Wuhan has an obvious aging population. Wuhan's population began aging from 1993, when the over 60's numbered 710,000 (or 10% of the total registered population). By 2010, that figure was 1.13 million, accounting for 14.58% of the city's total population; clearly Wuhan suffers from an aging population. By the end of 2015, the number of people over the age of 60 in the city reached 1.63 million (or 19.74% of the total population).

Wuhan's urbanization rate has also grown steadily. In 2015, the urbanization rate was 79.41%, up 2.34% from 2010. Over those five years, 882,200 new urban residents were added to the city, that's an average annual increase of 176,400. The total number of households increased from 2,745,800 in 2010 to 2,971,000 in 2015. The average household size dropped from 2.90 people per household in 2010 to 2.66 in 2015. The urban residential construction area per capita rose to 37.25 m^2 in 2015 from 31.85 m^2 in 2010. The urban residential disposable income per capita increased from 20,806 RMB in 2011 to 36,436 RMB in 2015.

Table 1: Urbanization Rate, Wuhan (2011-2015)

	2011	2012	2013	2014	2015
Urbanization rate	78.71%	79.26%	78.26%	76.36%	79.41%

Most of the employed population is focused in the manufacturing and tertiary sectors. Between 2011 and 2015, the share of the urban employed population in Wuhan's total number of employed increased from 70.7% to 84.6%. Most workers in Wuhan are employed in manufacturing, and increasingly in the tertiary sector. Wuhan's employment structure (agriculture: secondary sector : tertiary sector) shifted from 13.2: 36.9: 49.9 in 2010 to 9.1: 38.4: 52.5 in 2015 showing an obvious decline of the primary sector share in total employment. The implementation of the *Industrial Doubling Plan* has helped boost manufacturing share of employment in the secondary sector by the end of 2015 to 20.1% of the total employed population. The top three sectors with the highest employment are manufacturing, construction, and wholesale and retail. The tertiary sector is the main area that has been absorbing rural surplus labor, college graduates and the re-employment of laid-off workers, especially wholesale and retail, transportation, warehousing and postal services, and the accommodation and catering industries.

3.2 Economic Growth and Structure

Wuhan has achieved a remarkable economic growth rate and now has largely equal secondary and tertiary sectors.

Wuhan's GDP has entered the "trillion RMB club," an unofficial classification of China's major economies with an annual GDP of more than 1 trillion RMB. There are currently 15 cities that have reached this classification, including Beijing, Shanghai, Guangzhou, Shenzhen, Chengdu, and Hangzhou. During the 12th Five-Year Plan period (2011-2015), Wuhan's GDP grew at an average annual rate of 10.4%, shifting from high-speed to medium-high speed growth; and ranking fifth among those 15 cities. GDP almost doubled from 556.593 billion RMB in 2010 to 1,090.560 billion RMB in 2015.

Table 2: GDP, annual GDP growth, GDP per capita, Wuhan (2011-2015)

	2011	2012	2013	2014	2015
GDP (100 million)	6,762.20	8,003.82	9051.27	1,0069.48	1,0905.60
GDP per capita (RMB)	68,315	79,482	89,000	98,000	104,132

Annual GDP growth (%)	12.5%	11.4%	10.0%	9.7%	8.8%
National average growth (%)	9.5%	7.7%	7.7%	7.3%	6.8%

Wuhan has the strongest economy in China's central region; it is the only central city to enter the "trillion RMB club;" its per capita GDP of 104,132 RMB in 2015 was the highest of all the central cities. Wuhan's local fiscal revenue and fixed asset investment are much higher than other cities in the central region. Wuhan is one of China's six traditional industrial cities; it has a fully functional and sound industrial structure. Its steel, automobiles and machinery manufacturing, electronic information and petrochemical industries occupy pivotal levels in the country. Wuhan's tertiary sector also leads other cities in central China.

Wuhan is in the mid- to late- industrialization stage, where the secondary and tertiary sectors have similar shares of the economy. The secondary sector is dominated by heavy manufacturing while the tertiary sector is currently undergoing rapid growth. During the 12th Five-Year Plan period, Wuhan implemented its *Industrial Doubling Plan* and *Services Upgrading Plan*. In 2015, the primary: secondary: tertiary share of GDP was 3.3%: 45.7%: 51%. During the period of the 12th-Five Year Plan (2011-2015), the tertiary sector grew the fastest. Between 1998 and 2015, except for between 2012 and 2013, when the share of the secondary sector exceeded that of the tertiary sector, Wuhan's tertiary sector was its largest sector.

Table 3: Industrial structure, Wuhan (2011-2015)

	2011	**2012**	**2013**	**2014**	**2015**
Primary sector (%)	3.0	3.8	3.7	3.5	3.3
Secondary sector (%)	38.1	48.3	48.6	47.5	45.7
Tertiary sector (%)	48.9	47.9	47.7	49.0	51

The Industrial Doubling Plan has helped Wuhan establish a modern industrial structure and supported industrial innovation and development, green low-carbon development and industrial upgrading. During the 12th Five-Year Plan period, Wuhan's industrial value-added grew an average annual 11.8%, rising from 20.982 billion RMB in 2010 to 408.1 billion RMB by 2015. The proportion of light to heavy industrial output value shifted from 1:3.24 in 2011 to 1:3.05 in 2015. High-tech industry output grew 10.7% in 2015, accounting for 52.7% of gross output value of industrial

enterprises above a designated size. Energy consumption per unit industrial value-added fell 30.67% between 2011 and 2015. There were five key industries with an output of over 100 billion RMB in 2015 (see Table 4). Wuhan is nurturing its New Economy. With the rapid development of the Internet economy, new formats, models and products are constantly emerging. The New Economy -- such as information consumption, e-commerce and logistics and express delivery – is booming.

Table 4: Five key manufacturing industries, Wuhan (2015)

Industry	Industrial Output Value (100 million RMB)	Share of gross output value of industrial enterprises above a designated size
Automobiles and components	2,614.46	21.1%
Electronic information	1,780.21	14.4%
Equipment	1,584.78	12.8%
Food and tobacco	1,528.61	12.4%
Energy & Environmental Protection	1,032.52	8.3%

3.3 Energy Consumption

Wuhan is highly dependent on imported energy resources. Its energy consumption continues to increase and coal dominates its energy mix. Even though Wuhan is working continually on optimizing its energy structure and its energy intensity is declining, it is still in the early phases of utilizing new energy resources and making clean energy popular.

Because Wuhan is oriented towards heavy industry, energy demand has been rising. During the 12th Five-Year Plan period, Wuhan's total energy consumption increased from 36.11 million tce in 2010 to 48.58 million tce in 2015. There was a marked improvement in energy efficiency, with energy intensity falling 19.4% between 2011 and 2015. Some new energy-intensive projects, such as one led by Sino-Korean (Wuhan) Petrochemical Co., Ltd, which launched in 2013, have also posed a challenge for improving energy intensity.

Table 5: Energy intensity, Wuhan (2011-2015)

	2011	2012	2013	2014	2015
Fall in energy intensity	4.3%	4.47%	3.51%	2.88%	5.95%

Wuhan is continuously improving its energy mix; while coal continues to dominate, the proportion of low-carbon and non-fossil fuels is rising. Coal consumption as a fraction of total energy consumption decreased from 53.81% in 2010 to 50.03% in 2015. Crude oil rose from 20.59% in 2010 to 23.55% in 2015; natural gas rose 2.69% in 2010 to 4.77% in 2015. Electricity consumption increased from 35.4 billion kWh in 2010 to 46.4 billion kWh in 2015, showing a decline in total energy consumption from 12.04% to 11.75% over the same period. The share of non-fossil energy in primary energy consumption increased from 8.75% to 11.50%, again over the same period.

Table 6: Energy mix, Wuhan (2010, 2015)

	2010	**2015**
Coal in total energy consumption	53.81%	50.3%
Crude oil in total energy consumption	20.59%	23.55%
Natural gas in total energy consumption	2.69%	4.77%
Electricity use in total energy consumption	12.04%	11.75%
Share of non-fossil fuels in primary energy consumption	8.75%	11.50%

The secondary sector consumes most of Wuhan's energy, but the tertiary sector's share is gradually increasing, and this is depressing energy intensity. In 2015, the ratios between primary, secondary and tertiary in terms of energy consumption in total energy consumption were 0.5% : 63.1%: 26.3%. The secondary sector's share slipped 2.2% compared with 2010, and the tertiary sector's share rose 2.5% over the same time period.

Table 7: Energy consumption share, the three sectors, Wuhan (2010, 2015)

	2010	**2015**
Primary sector	0.5%	0.5%
Secondary sector	65.3%	63.1%
Tertiary sector	23.8%	26.3%

During the 13th Five-Year Plan period (2016-2020), total energy consumption is expected to continue to increase. By 2020, Wuhan will control energy consumption at 56.43 million tce, with an average annual increase of 3.04%. The proportion of non-fossil fuels in primary energy consumption is expected to pass 15%. Total coal consumption will be kept capped at 20.63 million tce.

4.4 Carbon Dioxide Emissions

During the 12th Five-Year Plan, Wuhan's carbon dioxide emissions increased, but carbon intensity decreased which indicates that carbon dioxide emissions have effectively been decoupled from economic growth.

Wuhan's total carbon dioxide emissions in 2015 were 130 million tons, an increase of 23.7% over 2010. This increase was smaller than was seen in Beijing, Shanghai, Guangzhou and Shenzhen over the same period.

Carbon intensity decreased from 2.09 tons/ 10,000 RMB in 2010 to 1.55 tons/ 10,000 RMB in 2015; an accumulated decrease of 25.8%. This indicates that Wuhan had effectively decoupled carbon dioxide emissions from energy consumption.

In 2015, Wuhan's carbon dioxide emissions per capita was 11.9 tons with an annual growth rate of 2.68%.

4. Low-Carbon Development Strategies and Policy Practices

During the 12th Five-Year Plan period (2011-2015), Wuhan began using top-level design (planning), regulatory systems and mechanisms, strategic measures and policy instruments for low-carbon development. This was a requirement from the central and provincial governments. It also introduced strategic measures and policies tailored to local circumstances to support a green low-carbon transformation.

Low-carbon development is not only necessary for Wuhan's socio-economic development, but it is also a key part of national strategy to deal with climate change and construct an ecological civilization. The internal requirements for low-carbon development are for Wuhan to find new drivers for economic growth, create jobs, and achieve sustainable development. The external driving force comes from senior levels of government. Cities have mandatory emission reduction targets and must also implement action plans.

Wuhan has gradually improved its top-level design of low-carbon development projects and also improved guidance on green and low-carbon development. Urban

low-carbon development requires the coming together of different departments, such as those over-seeing production and consumption. Top-level design is necessary to provide the structure for implementing low-carbon development in enough detail to complete tasks and meet targets. In 2011, Wuhan incorporated the concepts of green and low-carbon development into its *12th Five-year Plan for National Economic and Social Development*. In 2011 Wuhan issued the *Comprehensive Work Program on Energy Saving, Consumption Reduction and Climate Change during the 12th Five-year Plan* and in 2013, it issued the *Action Plan on Wuhan's Low-Carbon Pilot.* These set out Wuhan's low-carbon ideas, principles, objectives, main tasks, and policy actions. Wuhan pledged to peak carbon dioxide emissions by 2022; this pledge was included in its *13th Five-Year Plan on National Economic and Social Development.*

As a provincial capital, part of the first batch of national low-carbon pilot provinces and part of the second batch of national low-carbon pilot cities, Wuhan has already established administrative management systems to support low-carbon development. Wuhan set up a Leading Group for the Municipal Low-carbon City Pilot which is headed by the mayor. Municipal agencies are responsible for making strategy and policy actions, and to ensure that key tasks are completed and targets on low-carbon development are met within the fields under their jurisdiction (see table 8).

Table 8: Key agencies and their low-carbon development responsibilities, Wuhan

Agencies	Responsibilities
Leading Group for the municipal low-carbon city pilot	Coordination, supervision and evaluation of municipal low-carbon work
Municipal Development and Reform Commission	Regulatory institutions and mechanisms Monitoring and evaluation of carbon emission reduction International cooperation
Municipal Bureau of Statistics	Carbon reduction statistics
Municipal Bureau of Energy	Low-carbon energy
Municipal Commission of Urban-Rural Development	Low-carbon buildings
Municipal Commission of Economy and Informatization	Low-carbon industries
Municipal Commission of Transport	Low-carbon transport
Municipal Bureau of Environmental Protection	Waste management systems

According to local resource endowment and its economic and social conditions, Wuhan has been exploring low-carbon development in the areas of energy, industry, buildings, transportation, the urban environment and land use, low-carbon

infrastructure and consumption patterns. Wuhan has already moved from its previous high-carbon dependence to a low-carbon pathway. In order to better understand this transition, the following section will summarize Wuhan's low-carbon development strategies and policy practices in some key areas during the period of the 12th Five-Year Plan.

4.1 Low-Carbon Management System

Develop a municipal greenhouse gas inventory and roadmap to peak carbon emissions. Wuhan started developing a greenhouse gas inventory in 2013 and released reports on greenhouse gas inventories in 2005, 2010 and 2012 to encourage the establishment of a regular system to report greenhouse gas inventories. Wuhan has also been researching how to peak its carbon emissions by studying data on its historical emissions. It has made a number of scenarios and utilized tools to analyze its medium- and long-term carbon emission trends and how to peak emissions. This can help it draw up a roadmap to reduce emissions, plan low-carbon development targets and source policy in science.

Gradually improve the city's low-carbon development and management capacity. Wuhan established a preliminary system for keeping a database on greenhouse gas emissions, assessing targets, and reporting on performance. The Wuhan Municipal Bureau of Statistics has completed a preliminary round of reports on reporting statistics on greenhouse gas emissions; it also established a system to evaluate low-carbon performance and a responsibility system for assessing greenhouse gas emissions targets, integrating low-carbon development indicators into targets for municipal and district governments and allocating the national carbon emission reduction target to key enterprises and conducting annual assessments. Wuhan has set up a system to appraise carbon emissions from fixed assets investment, adding indicators on carbon emissions and non-fossil energy consumption in energy-saving assessments into the reviews of fixed-asset investment projects. Wuhan has also set up a special fund for low-carbon development in the municipal budget, which will be used mainly for research, capacity building and publicity. Additionally, Wuhan has encouraged the establishment of a contract energy management mechanism and issued a series of incentives to provide financial support for contract energy management projects. It is establishing three

management platforms for low-carbon development, namely the Wuhan Low-Carbon Energy-Saving Smart Management System to manage energy consumption data and carbon emissions for the city, districts, key industries and key enterprises; Wuhan Fixed Asset Investment Projects Energy-Saving and Carbon-Reduction Information Management System to track the carbon emissions of new projects; and the Wuhan Low-Carbon Life and Home Platform to encourage slow-carbon green production and lifestyles.

4.2 Key Areas

Wuhan has been constantly been improving its top-level design and administrative management capacity on low-carbon development. Various departments have also put forward strategies and a timetable for green and low-carbon development targets. This section focuses on low-carbon development goals, strategic measures and policy tools in the five key areas of energy, industry, buildings, transportation, urban environment and land use. The policy tools include control directives, market-based policies, voluntary measures and information regulations. Each area includes three parts: 1) the completion of the 12th Five-Year Plan low-carbon indicators; 2) future development goals; 3) strategic measures and policy tools.

4.2.1 The Energy System

Overview

Wuhan has few natural resources; it is constrained by a “lack of coal, lack of oil and lack of gas.” It is highly dependent on energy resources from outside. Wuhan’s power sector is dominated by coal-fired power; and it has just started to incorporate new energy. All coal is imported, (making up 48%); 100% of refined oil, 100% of natural gas, and 80% of other energy resources are also imported. Uncertainties in each year’s power generation plan, the supply of hydropower, changes in temperature, the production and operation status of enterprises, etc, are all factors that impact Wuhan’s power sector. In 2015, the city generated 21.755 billion kwh, of which 21.0821 billion kwh was thermal power generation, accounting for 96.9% of the city's total generating capacity. It generated 674 million kwh from landfill gas, accounting for 3.1% of the city's total generating capacity. Hongshan Chuangyi Tiandi Natural Gas Distributed

Energy Project, now in operation, is one of the four demonstration projects assessed by the National Development and Reform Commission. A nearly 60MW photovoltaic power generation project has been completed. Currently, annual biomass power generation is 850 million kwh, accounting for 0.59% of the city's total energy consumption.

Table 9: Power Generation, Wuhan (2011-2015)

	Total Power Generation	**Growth（%）**
2011	210.58	13.4%
2012	213.01	1.2%
2013	243.24	14.2%
2014	213.32	-12.3%
2015	217.55	2.0%

Performance of Low-carbon Indicators

Energy mix optimization has four main indicators: total energy consumption per capita, energy intensity, the share of primary fossil fuels in primary energy consumption and the share of coal in total energy consumption. Wuhan's performance in these four indicators is shown in the table below:

Table 10: Low-carbon development indicators, Wuhan's energy sector (2010, 2015)

Indicators	**2010**	**2015**
Energy intensity (tce / 10,000 RMB (constant 2005)	0.81	0.66
Annual energy consumption per capita (tce / person)	2.69	4.58
Non-fossil fuel energy share of primary energy consumption (%)	8.17%	11.5%
Coal share in total energy consumption (%)	53.81%	49.79%

Strategic Measures and Policy Tools

Wuhan's energy sector is *focused on developing new energy and renewable energy (including wind power, photovoltaic power, ground source heat pumps, river water source heat pumps, biomass, etc.) and encouraging the energy conservation of existing power plants, coal efficiency of boilers, and the implementation of a cogeneration strategy as part of its low-carbon development plan.*

Table 11: Key areas, key tasks and policies and measures to reduce energy consumption and carbon emissions for energy sector during Wuhan's 12th Five-Year Plan Period

Area	Improving efficiency of carbon use	Improving energy technology
Key tasks	--Prioritize the development of non-fossil fuel energy sources --Raise the proportion of natural gas utilization --Place strict controls on coal consumption	Encourage cogeneration
Policy Instruments	Regulatory Instruments: • Average coal consumption of coal-fired generating units is less than 310 grams of standard coal / kWh • Issue industry access • Construct no high-pollution fuel zones • Eliminate small boilers • Prohibit the sale of inferior coal on the market Market Incentives • Tax breaks • Carbon trading scheme • Research and development Voluntary measures • Demonstration projects	

4.2.2 Industry

Overview

Wuhan's industrial structure is made up of a large proportion of traditional industries. Steel, petrochemicals, tobacco and automobiles account for half of the total industrial output. In 2015, industry's carbon emissions made up 59.3% (including electricity emissions) of the city's carbon emissions.

Wuhan has made progress in energy saving work including in direct energy-saving and structural energy-saving; improvement have also been seen in industrial energy efficiency. Between 2011 and 2015, energy consumption of value-added of large-scale industrial units dipped 30.67%.

Table 12： Reduction in energy consumption of value-added of large-scale industrial units, Wuhan (2011-2015)

	2011	2012	2013	2014	2015
Decline in energy intensity	5.84%	14.42%	2.06%	2.50%	9.91%

The energy consumption of major energy-intensive industrial enterprises dropped significantly. During the 12th Five-Year Plan period, comprehensive energy consumption per ton of steel produced fell 4.4%, comprehensive energy consumption per ton of cement produced fell 58.3%, comprehensive energy consumption of

processing units fell 8.6%, and the standard coal consumption of power plants fell 3.9%.

Table 13: Energy consumption for eight products, Wuhan (2010-2015)

	2010	2015
Total energy consumption per ton of mixed yarn produced (line) (kg of standard coal / ton)	871.03	613.91
Total energy consumption of machine produced paper and cardboard (kg of standard coal / ton)	600.99	279.20
Energy consumption for coking process per unit (kg of standard coal / ton)	96.06	89.41
Comprehensive energy consumption of crude oil processing	71.23	65.61
Comprehensive energy consumption per ton of cement produced (kg of standard coal / ton)	36.46	19.78
Comprehensive energy consumption per weight of box flat glass produced (kg of standard coal / ton)	14.35	13.15
Comprehensive energy consumption per ton of steel produced (kg of standard coal / ton)	637.92	609.60
Comprehensive energy consumption of coal-fired power plants (kg of standard coal / ton)	306.40	295.82

Ferrous metal smelting and rolling, raw chemicals and chemical products, and electricity production and supply were the biggest energy-intensive industries in Wuhan. Industries above a designated size -- paper and paper products, petroleum processing, coking, nuclear fuel processing, chemicals and chemical products, non-metallic minerals manufacturing, ferrous metal smelting and rolling, electricity production and supply, consumed 45.1% of the total energy consumption of the city in 2015, 1.4 percentage points lower than that of 2010 (46.5%). The energy consumption of these six energy-intensive industries slowed significantly but still accounted for 22.55% of total industrial output, 8.1 percentage points lower than that of 2010 (30.6%).

Table 14： Share of six energy-intensive industries in energy-intensive sector, Wuhan (2010, 2015)

Energy-intensive industry	2010	2015
Ferrous metal smelting and rolling	69.4%	50.5%
Chemicals and chemical products	2.1%	19.7%
Power production and supply	17.5%	20.5%
Coking, nuclear fuel processing	3.5%	4.1%
Non-metallic minerals	5.9%	5.1%
Paper and paper products	1.7%	0.7%

Performance of Low-carbon Indicators

Low-carbon development indicators in industry include the heavy industrial value share in total industrial value and energy consumption of industries above a designated

size. Wuhan's low-carbon development indicators for the industrial sector for 2015 are listed below.

Table 15： Low-carbon development indicators for the industrial sector, Wuhan (2010, 2015)

Indicator	2010	2015
Heavy industry output share of total output for industries above a designated size (%)	76.76%	73.81%
Comprehensive energy consumption of total industrial output value/ 10,000 RMB (tons of standard coal / 10,000 RMB)	0.29	0.19
Hi-tech manufacturing value-added share of total industrial value-added	45.5%	54.8%%

Strategic Measures and Policy Tools

During the 12th Five-Year Plan, Wuhan set limits on the production capacities of existing energy-intensive industries, such as electricity, steel, petrochemicals, building materials, flat glass and paper. It also phased out energy-intensive, low value-added production capacity by implementing strict industrial policies, industry access, environmental protection and safety standards. It also began monitoring energy-saving measures adopted by key energy-consuming units and set energy consumption limits on energy-intensive products. Meanwhile, it worked on upgrading coal-fired boilers and speeding up the replacement of the energy-intensive steel industry chain. Wuhan also set up a special investment fund for technological transformation. The fund provides discounts or subsidies at 8% for the purchase and renovation of advanced equipment in projects that qualify under industrial restructuring and upgrading and with an investment in fixed assets of over 50 million RMB. These measures are supporting the transformation and upgrading of traditional industries, improving technology, optimizing product structure, and improving product quality.

Strategic measures to help low-carbon development in industry are focused on four main aspects:

First, making control of carbon emissions more effective. Industrial enterprises need to use more low-carbon energy and control greenhouse gas emissions to optimize their energy structure.

Second, making raw materials production more energy efficient. Industrial enterprises need to use better quality production machinery and more energy-efficient

technologies; they need to improve their recovery and utilization of residual energy, waste heat, cogeneration, and by-product gas.

Third, improve resource productivity. They can do this through the comprehensive utilization of solid waste, extending the industrial chain of energy-intensive enterprises and increasing the resource:output ratio.

Fourth, optimize product structure. This can be achieved by improving product quality, extending service life, increasing the proportion of low-carbon products to promote energy saving and emission reduction in downstream industries.

Table 16: Key areas, key tasks and policy measures for carbon reduction in industry sector during Wuhan's 12th Five-Year Plan Period

Area	Carbon emissions	Energy efficiency of raw materials production	Resource productivity	Product quality
Key tasks	Encourage the use of more low-carbon energy and the use of clean energy in coal-fired facilities	--Improve technologies used --Improve the recycling rate of residual heat pressure	Comprehensive utilization level of resources	Transformation and upgrading of traditional industries, optimization of product structure
Policy Instruments	Regulatory instruments: • Implement strict energy saving and emission reduction standards for energy-intensive enterprises • Energy and carbon assessment system for fixed assets investment projects • Wuhan industrial directory for doubling industry • 10,000 enterprises assessment and evaluation of energy-saving targets • Special air pollution emission limits • Energy consumption limits on energy-intensive products (output value) to reach domestic advanced level • Enterprise energy management • Cleaner production audit Market-based instruments: • Implement differential pricing for energy-intensive enterprises • Special fund for industrial investment and technological transformation • Carbon trading (covering companies whose annual comprehensive energy consumption is 60,000 tons of standard coal and above) • Government procurement Voluntary • Enterprise energy efficiency benchmarking standards (international advanced level as benchmark) Information sharing • Industrial enterprises' energy consumption, other statistics and monitoring Capacity building • Fixed assets evaluation of energy conservation, contract energy management and carbon asset management trainings • New energy-saving technologies, new product financing, and best practices trainings			

4.2.3 Buildings

Overview

The buildings sector is a key contributor to Wuhan's carbon emissions. In 2015, the sector was responsible for about 30% of Wuhan's total carbon emissions. As the urbanization rate rises and living standards also improve, this sector will be a major growth area for Wuhan's future carbon emissions.

Performance of Low-Carbon Indicators

Wuhan's low-carbon development indicators for the buildings sector focus on the

proportion of newly-added green buildings in all new buildings and the implementation rate of building energy efficiency standards. The indicators are as follows:

Table 17: Low-carbon development indicators, the buildings sector, Wuhan (2010, 2015)

Indicator	2010	2015
Proportion of newly-added green buildings in all new buildings that year (%)	--	22.4%
Implementation rate of building energy efficiency standards (%)	--	100%

Strategic Measures and Policy Tools

During the 12th Five-Year Plan period, the key areas for low-carbon development in the buildings sector include energy-saving and retrofit, green building and renewable energy building applications, promotion of energy-saving appliances, and promotion of green building materials. The main policy measures include mandatory energy conservation standards, green buildings and energy-saving buildings labeling, fiscal incentives, demonstration projects, technical consultation, and education programs and trainings on energy saving. However, because the vast majority of existing buildings are not energy saving, the cost to retrofit them is high, and Wuhan still needs to improve energy efficiency standards for construction, improve research and development, energy-saving product quality and construction durability. At the same time, more emphasis should be placed on smart metering, smart communications, and peak-load management to make heating, cooling, lighting and appliances more energy efficient.

Key strategic measures supporting low-carbon development in the buildings sector are:

First, improve the efficiency of carbon emission controls, such as encouraging the integration of renewable energy into buildings (using photovoltaic energy), and the use of ground, water and air sourced heat pump systems in new residential buildings;

Second, make buildings more energy efficient with the use of better technologies. This covers green building materials technology and products (wall, roof and windows); improve equipment efficiency, use intelligent technologies and products such as electrical appliances, lighting, air conditioning, ventilation and refrigeration systems;

Third, make the whole building more energy efficient, such as constructing low-

energy buildings, using central heating/cooling, green buildings, retrofitting existing buildings, and the use of prefabricated buildings;

Fourth, reduce energy demand, including encouraging people to adopt low-carbon consumption behaviors and lifestyles and employ smart metering.

Table 18: key areas, key tasks and policy measures for carbon emissions in the building sector during Wuhan's 12th Five-Year Plan Period

Area	Carbon emissions	Energy efficiency	System efficiency (full life cycle)	Reduce energy demand
Specific tasks	--Increase the number of renewable energy buildings --Encourage the use of ground, water, and air sourced heat pump systems in new residential buildings	--Encourage the use of green building materials technologies and products --Encourage the use of HVAC, refrigeration systems, green lighting and intelligent technologies and products	--Increase proportion of green buildings in new buildings --Retrofit existing buildings Construct prefabricated buildings	Encourage the use of smart meters
Key policies	Regulatory Instruments: • Strict implementation of building energy efficiency standards: 65% of Hubei Province Low-energy residential building design standards DB / T559-2013 and Public building energy efficiency design standards GB50189-2015 Market-based Instruments • Special energy-saving funds • Government procurement • Contract energy management Information sharing • Green Building Information Platform • Energy efficiency evaluation and labeling • Green building identification system • Green building demonstration areas and top -level green building demonstrations • Energy-saving monitoring platform for buildings • Technical support, education and trainings			

4.2.4 Transportation

Overview

While carbon emissions from the transportation sector are lower than that from industry and buildings, it has been growing rapidly. In 2015, transportation was responsible for 10.7% of Wuhan's total carbon emissions. During the 12th Five-Year Plan period, the city's passenger traffic reached 2.41 billion passengers, an increase of 24% over 2010; cargo turnover was 295.2 billion tons-km, a jump of 30% over 2010. Wuhan has also experienced an explosive growth in the number of private vehicles. In 2015, the number reached 2.13 million, 50% higher than in 2010; the number rose an

average 13% per year during that period. Private trucks also rose to 1.652 million, up 29.2% from 2014. In 2015, the average number of vehicles per 1,000 people was 155.7.

Prioritizing a good public transport system and encouraging new energy vehicles are two major ways a city can steer towards a low-carbon transportation sector. Wuhan City is in the first batch of integrated transport service pilot cities, a “transit city” demonstration project, and a low-carbon transport system pilot city. In 2015, Wuhan's had 8,310 regular buses, 1,300 more than in 2010. The length of the bus network increased from 1,172 km in 2010 to 1,750 km by 2015. It has 39 bus lanes with a total length of 155 km. Wuhan has focused on building an expressway network and rail transit; it built four lines running 126 km during the 12th Five-Year Plan period. In 2015, the city's public transport share was 46.2%, of which rail transit accounted for 24%.

Wuhan is a national model city for new energy vehicles. During the 12th Five-Year Plan period, over 90% of the taxis in Wuhan were using clean energy such as natural gas; and another 700 new hybrid electric vehicles, 1,000 new electric buses and 10,539 new energy vehicles were in use.

Performance of Low-Carbon Development Indicators

Low-carbon development indicators for the transportation sector in Wuhan include public transport’s share, public transport vehicle ownership per million, the proportion of rail transit in public transport trips, and the number of new energy vehicles. Below is Wuhan’s performance based on these indicators:

Table 19: Low-carbon development indicators for the transportation sector, Wuhan (2010, 2015)

Indicator	2010	2015

Proportion of public transport in all motorized trips		58.90%[1]
Public transport share	--	46.2%
Public transport vehicles per million	15.5	13.8
Rail transit share of public transport trips	--	124%
New energy vehicles	--	10,539

Strategic Measures and Policy Tools

During the 12th Five-Year Plan period, key areas for low-carbon development in Wuhan's transportation sector were new energy vehicles and optimizing the transportation infrastructure. The main policy measures were tax subsidies, government procurement, and infrastructure investment. For Wuhan to control carbon emissions from its transport sector, it must not only better implement existing areas and policies, but it must also make policies to reduce demand for motorized travel by using measures such as establishing a slow traffic system, a compact urban form, mixed land use patterns, and introducing congestion charges. *Wuhan plans to reduce carbon emissions from the transportation sector with the following five measures:*

First, improve the carbon intensity of fuel and support the use of new energy vehicles.

Second, improve energy efficiency and encourage energy-efficient vehicles.

Third, optimize the structure of transport infrastructure, improve the public transport infrastructure and create a slow traffic system by encouraging the use of public transport, bicycles and walking.

Fourth, reduce car use both in number and duration through a more integrated, compact and mixed model use of urban space through regional restrictions, pricing policies (parking fees), advocacy and education.

Table 20: Key areas, key tasks and policy measures for carbon emissions in transportation sector during Wuhan's 12th Five-Year Plan Period

[1] using the urban population

Area	Carbon intensity of fuel	Energy efficiency	Optimize transport infrastructure	Reduce transportation demand
Key tasks	Support the use of natural gas-powered taxis, hybrids and electric buses	Encourage the use of energy-saving vehicles	Improve public transport infrastructure and encourage use of public transport over private vehicles	Functional zoning for green travel
Policy instruments	Regulatory instruments: • Implement fuel consumption limits on passenger cars, light commercial vehicles • Limiting private vehicles by car license plates • Special lane fro BRT Market-based instruments: • Transportation infrastructure investment • Government procurement, encouraging the use of new energy vehicles for public service vehicles and public transport services such as commuting, renting, sanitation, afforestation and logistics • Subsidies for new energy vehicle purchase and charging infrastructure • Subsidy policy for replacing old cars • Subsidies for phasing out (more polluting) yellow-labeled cars • Regular bus transfer discounts • Free public bicycle rental • Downtown parking fees Voluntary measures • Special day, week for public transportation and green travel			

4.2.5 Environment and Land Use

Strategic Measures

Urban form and land use patterns impact urban production and consumer behavior patterns. Wuhan's urban spatial planning will affect low-carbon development strategies and policy tools in the fields of energy, industry, transportation and buildings from top-level decision-making. They can also affect carbon emissions, for example through the use of greening policy and environmental municipal facilities.

Improving air quality has been Wuhan's focus during the 12th Five-Year Plan period.

The key areas of pollution control are connected with coal utilization, dust production, motor vehicle emissions, and volatile organic compounds and require cooperation between the departments of energy, transportation and buildings. They are focused on promoting energy-saving emission reduction measures and strategic measures on the use of coal, low-emission unit transformation, delimitation of highly-

polluting fuel combustion zones, emissions monitoring for highly-polluting industries, special law enforcement and remediation, online monitoring systems, and other types of air pollution control measures.

Performance of Low-Carbon Indicators

Table 21: Urban environment and land use low-carbon development indicators, Wuhan (2010, 2015)

Indicator	2010	2015
Park area per capita (m2)	9.24	11.12
Green coverage in built-up areas (%)	37.48%	39.65%
Forest coverage (%)	26.63%	28%
Water consumption of urban residents (L / day.person)	179.1	174
Waste production per capita (tons)	0.26	0.31
Wastewater treatment rate in central city area (%)	-	93.8%
Domestic waste harmless treatment in central city area (%)	90%	100%
Annual average concentration of PM10 （ug/m3）	-	104
Annual average concentration of PM2.5 （ug/m3）	-	70
Percentage of days with good air quality (%)	-	52.6%

5. Conclusion

Wuhan's low-carbon development is rooted in its local characteristics and will depend on its plans for the future. Wuhan's development is typical of industrial cities in China.

- As an economic center and megacity in China's central region, and because of its particular geographical and climatic conditions, Wuhan has long been an energy-intensive city. However, given its high dependency on energy imports and increasingly severe environmental constraints, it must adopt a low-carbon development path.

- Wuhan has a long history and rich culture. Openness, flexibility, inclusiveness and diversity are firmly anchored in its history and culture. It also has rich science and technological innovation resources; these provide strong ideological foundations and a capacity for absorbing, building and pursuing low-carbon development.

- Wuhan is currently undergoing transitions in both its industrialization and urbanization paths. *Advanced Industrial Manufacturing City* and *Strengthening and Improving Urban Construction* are key development strategies underpinning

Wuhan's long-term vision of becoming a national central city. Low-carbon city development will provide strong support to successfully transform and upgrade Wuhan city.

- As a city with a large heavy industry that is currently being restructured, Wuhan is focusing on industry and energy in pursuit of a low-carbon transition.
- As a sub-provincial city, the capital of Hubei Province, and a national pilot city, Wuhan has plentiful administrative resources to support a low-carbon transformation.

During the period of the 12th Five Year Plan, Wuhan further urbanized and industrialized, while focusing on improving its industrial structure and energy mix, reducing energy intensity and carbon intensity to bring down its carbon dioxide emissions.

- Wuhan's population has climbed steadily while its urbanization rate has also increased. Wuhan is an obvious aging society. The majority of the city's workers are employed in industry and the tertiary sector.
- Wuhan is transitioning from rapid urbanization to stable urbanization. Its urbanization rate is close to that of global cities in the developed world (80% - 90%).
- Wuhan's GDP in 2015 passed one trillion RMB, leading all China's sub-provincial cities. Its 2015 GDP per capita was 104,132 RMB (16,705 USD), qualifying as high-income according to the World Bank (above 12,475 USD).
- Wuhan is in the mid- to late-industrialization stage; its secondary and tertiary sectors are roughly equal in size. The city continues to improve its industrial structure, while lowering energy consumption per unit of industrial value-added (energy intensity).
- Wuhan's total energy consumption is rising, however, its energy mix is becoming more low carbon. The share of coal in total energy consumption is declining, while non-fossil fuels are increasing rapidly in primary energy consumption.
- Wuhan is in the process of decoupling economic growth and carbon dioxide

emissions; GDP output per unit carbon dioxide emissions continues to rise. Carbon dioxide emissions per capita slowly increased from 11.9 t in 2010 to 14.2 t in 2015.

Table 22: Key driving factors for carbon dioxide emissions, Wuhan (2010, 2015)

Driving factor	**2010**	**2015**
Population (million persons)	9.78	10.61
Aging rate (%)	14.58%	19.74%
Urbanization rate (%)	70.5%	79.77%
GDP (100 million RMB)	5565.9	10905
GDP per capita (RMB)	58000	104132
Primary: Secondary: Tertiary share of the economy (total GDP)	3.1:45.5:51.4	3.3:45.7:51.0
Total energy consumption (tce)	3615	4858
Share of coal consumption in total energy consumption(%)	53.81%	49.79%
Share of non-fossil fuel in primary energy consumption(%)	8.17%	11.5%
CO2 emissions per unit GDP (t/10000 RMB)(2010 constant price)	2.09	1.55
Carbon dioxide emissions per capita (t)	11.9	14.2

During the period of the 12th Five-Year Plan (2011-2015), Wuhan gained experience in exploring institutional mechanisms, strategic measures and policy tools on low-carbon development. It has now built a feasible working plan for low-carbon development:

- Wuhan has established a Leading Group for Low-Carbon Development, which is led by the mayor. Local government has used a number of scientific methods and tools to create a low-carbon development action plan that defines targets and actions for low-carbon development, has designated a year by which carbon emissions should be peaked, and allocated targets and key tasks to agencies and districts (counties). It has made low-carbon development strategic measures and policy tools in key fields such as energy, industry, buildings and transportation.

- Wuhan has established innovative management systems and mechanisms on low-carbon development. It has made mandatory targets for carbon intensity, set up accounting and responsibility systems, and evaluation mechanisms for greenhouse gas emission targets as well a system to evaluate fixed assets investment projects by carbon emissions. Wuhan has adopted a market-based approach, using carbon trading, special funds for low-carbon development, and green credit.

- Wuhan must focus on industry if it wants to reduce its carbon emissions. With

socio-economic development and rising living standards, carbon emissions from buildings and the transportation sector are constantly increasing. Wuhan has a number of strategic measures and policy tools to transform its energy mix and reduce carbon emissions in industry, transportation and buildings. These include improving energy efficiency, using new technologies, reducing carbon emissions per unit energy consumption, and reducing energy demand. It has employed policy tools, new regulations, market incentives, mandating the supply of information and introducing voluntary practices.

- Although Wuhan has established a comprehensive and systematic low-carbon development strategy and policy framework, it still faces challenges on how to effectively implement these. The city needs more laws and regulations to give legislative support for low-carbon development; it also needs to improve the monitoring and evaluation of the implementation of these policies and their effects.

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