NEASPEC NORTH-EAST ASIA LOW CARBON CITIES PLATFORM

PEER REVIEW REPORT - WUHAN

innovative Green Development Program

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I. Introduction

1. Purpose of Study and Background

This Peer Review report supports the mission of the North-East Asian Subregional Programme for Environmental Cooperation's (NEASPEC) Low Carbon Cities programme. It is designed to promote NEASPEC's goals of enhancing coordinated actions to address subregional environmental challenges, mobilizing mutual support to manage domestic environmental issues in East Asia, and contributing to the implementation of national, regional and global goals for sustainable development. Meanwhile, as the following figure shows, it can facilitate low-carbon policy knowledge sharing and peer learning among peers from government, the private sector and research institutes of different cities.

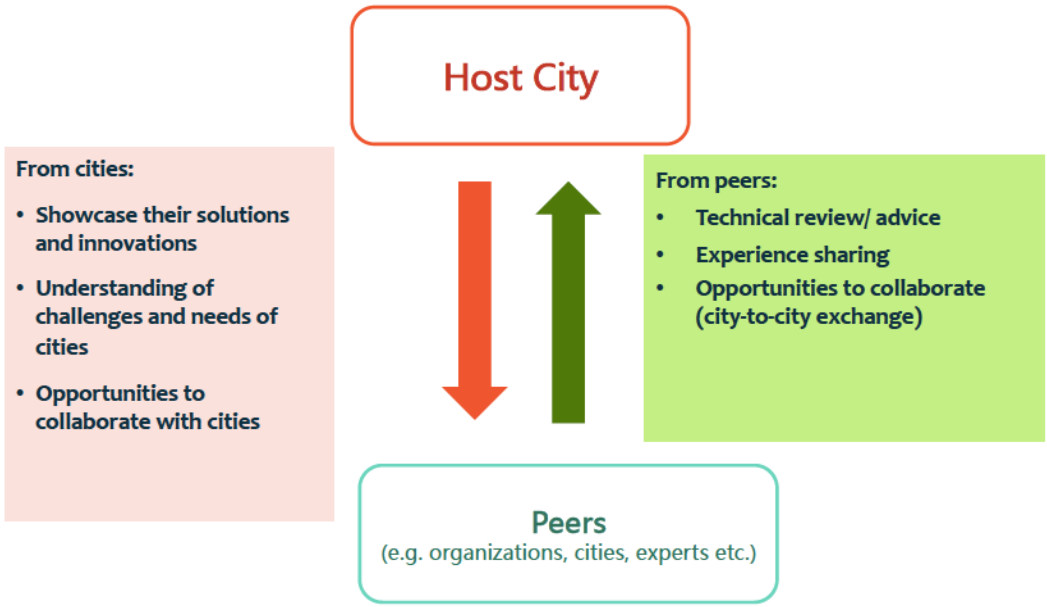

Figure 1. NEA-LCCP Peer Review

The report is a component of innovative Green Development Program's (iGDP) partnership with the NEASPEC Secretariat, under the NEASPEC North-East Asia Low Carbon Cities Platform (NEA-LCCP). In this partnership, iGDP is tasked to develop peer reviews of the characteristics and performance of policies in two Chinese cities, Wuhan and Guangzhou, that belong to China's Low Carbon Pilots program. This report is the first of these two peer review exercises, focusing on the city of Wuhan, located in central China. The second peer review exercise will focus on the southern city of Guangzhou. The partnership will culminate in a comparative study of selected cities in the Northeast Asia region. iGDP will produce the Chinese component of the comparative study and coordinate production of a draft report of the comparative study, closely working with the Institute for Global Environmental Studies (IGES) in Japan and the Korea Environment Institute (KEI) in Korea.

This peer review report builds on and draws from a peer review methodology workshop held on September 1st and 2nd, 2016 in Seoul, Korea, a methodology report associated with this workshop, a background report on low carbon policy development in Wuhan, and a peer review workshop held in Wuhan on June 11th 2018.

Throughout these activities, iGDP liaised with Wuhan public officials and technical experts to procure information, performed data collection, carried out site visits and interviews, and sought consultation on report progress.

The report includes three main sections: (1) a review of the methodology used to prepare the report, (2) a discussion of the state of low carbon development in Wuhan, as well as peer review observations about these policies and recommendations for new areas of work going forward, and (3) a concluding summary of the key findings of the peer review exercise.

2. Review Participants

The contributors to this peer review exercise gathered at a workshop on Wuhan's low carbon plans held on June 11th 2018. Titled "Green Transformation in Wuhan: International Consultation Workshop for Wuhan's Low-carbon City Roadmap", the workshop brought together more than one hundred participants. Participants included 18 government officials and experts from Wuhan government agencies, including representatives from 14 district-level governments and 4 municipal government agencies. 23 professionals from research institutions in Wuhan also attended the workshop. Also, in attendance were 23 professionals and experts from peer Chinese cities and Northeast Asian cities who shared information about low carbon policymaking and best practices in their respective locales.

The workshop also brought together 13 experts from international and domestic research institutions, including the World Resources Institute, the Rocky Mountain Institute, the Institute for Sustainable Communities, C40, the Global Environmental Institute, the Institute for Global Environmental Strategies, Natural Resources Defense Council, World Wild Fund, the National Center for Climate Change Strategy and International Cooperation, International Urban Cooperation European Union-Asia, China Sustainable Transportation Center, the Rock Environment and Energy Institute and Beijing Normal University.

II. Methodology

The production of this peer review of Wuhan low carbon policy consisted of three stages: 1) preparation, 2) consultation, and 3) assessment.

In the **preparation stage**, a background report on Wuhan's low carbon progress was developed. The report provides an overview of Wuhan's low carbon strategies and practices, drawing from multiple sources of data. First, it analyzed a wide range of primary sources (e.g. official government publications and statistical yearbooks), which detail Wuhan's low carbon policy planning process and the driving forces behind its low carbon development. Second, secondary sources were examined, including journal articles and research reports, which provided detailed analysis of Wuhan's low carbon development across multiple sectors. The background report also drew on meetings with local experts and officials during site visits, enabling the report to reflect first-hand insights on Wuhan's low carbon progress. Drawing on different types of data and information, the background report provides a full picture of Wuhan's low carbon development that helps in efforts to track and evaluate Wuhan's low carbon policy

performance.

Drawing on the peer review indicator framework developed by NEA-LCCP, as indicated below:

Table 1. Peer Review Indicator Framework under NEA-LCCP

	Indicators
Background indicators	General background (e.g. Population, GDP, Carbon intensity etc.)
Sectoral indicators	Energy consumption and CO_2 emissions
	Building Energy Use
	Land Use
	Industry (e.g. industrial structure, energy use etc.)
	Water (e.g. consumption, efficiency etc.)
	Waste (e.g. generation and treatment etc.)
	Public utilities (e.g. street lighting etc.)
	Mobility (e.g. public transportation etc.)
Policy Indicators	Governance (e.g. city strategy and targets, coordinating body, evaluation etc.)
	Supporting mechanisms (e.g. legislation, financing, incentives, education and capacity building etc.)

The background report also identified two factor categories that influence Wuhan's low carbon development policy efforts. The first group is contextual factors: local features of the city that shape and constrain a cities' low carbon development. These include a city's demographic, geographic and economic characteristics. The second group is strategy-driven factors. These are the factors that can be influenced by Wuhan policymakers to directly affect low carbon performance. They include Wuhan's economy-wide policies and sector-specific policies. This peer review assesses the strategy-driven factors shaping Wuhan's low carbon development progress.

Table 2 Key Factors in Low Carbon Development

Contextual factors	**Strategy-driven factors**

• **Geographic features**
  ○ **Climate and weather**
  ○ **Land area**
• **Demographic features**
  ○ **Population size and density**
  ○ **Urbanization rates**
• **Economic features**
  ○ **Economic growth and structure**
  ○ **Energy consumption and carbon emissions**
	• Low carbon management system
	  ○ Low-carbon governance
	  ○ Low-carbon policy planning
	• Sector-specific strategies and measures
	  ○ Energy sector
	  ○ Industry sector
	  ○ Building sector
	  ○ Transport sector
	  ○ Environment and land use

For the consultation stage, a peer review workshop was held in Wuhan on 11 June 2018. The workshop developed an agenda focused on the strategy-driven factors identified in the background report, inviting experts from domestic and international peer cities to evaluate these factors. The workshop was divided into two parts. The first part of the workshop focused on Wuhan's low carbon management system, discussing the planning and implementation of Wuhan's carbon peaking policy plan as well as the experiences of peer cities in developing and implementing their local carbon mitigation policy efforts. The second part of workshop focused on carbon peaking pathways in Wuhan's industry, transportation, building and environment sectors, assessing the extent to which sector-specific strategies and measures can contribute to Wuhan's progress toward its carbon peak target.

In the following sections, the inputs of workshop participants on Wuhan's low carbon progress are presented, divided into two sections: low carbon governance and sector-specific strategies. This constitutes the assessment phase for the peer review methodology. First, the state of low carbon development in Wuhan is briefly recapped to provide context drawing on data collection, field visits and consultations prior to the workshop.

III. The State of Low Carbon Development in Wuhan

Wuhan's low carbon development is rooted in its local characteristics. 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 geographical and climatic conditions, Wuhan has long been an energy-intensive city. It has a high dependency on energy imports and faces severe environmental constraints.

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 scientific and technological resources; it contains the largest number of universities of any major Chinese city. These features provide a strong intellectual foundation and high capacity for absorbing, developing and, implementing innovative low carbon development measures.

Wuhan's population has climbed steadily, in tandem with an increasing rate of urbanization. The majority of the city's workers are employed in the industry and the tertiary sector.

As the capital of Hubei Province, Wuhan has robust administrative resources to support its low carbon efforts. During the 12th Five Year Plan period (2011-2015), Wuhan focused on improving its industrial structure and energy mix to bring down its carbon dioxide emissions, with a focus on reducing energy and carbon intensity.

Wuhan's rate of urbanization is slowing down from rapid to stable. Its urbanization rate is close to that of major cities in the developed world (80% -90%). Wuhan's GDP in 2015 passed one trillion RMB, leading all China's sub-provincial cities. Its GDP per capita in 2015 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).

Although Wuhan's total energy consumption is rising, its energy mix is increasingly becoming 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 of 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.

During the 12th Five Year Plan period Wuhan established new institutional mechanisms, strategic measures and policy tools for low carbon development. Wuhan established a Leading Group for Low Carbon Development, led by the city mayor. The local government has used several scientific approaches and tools to create a low carbon development action plan that defines targets and actions for low-carbon development. Furthermore, it has designated a year by which carbon emissions should be peaked and has allocated targets and key tasks to agencies and districts (counties). It has also designed 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 for its low carbon development efforts. It has set mandatory targets for carbon intensity, set up systems that assign accountability, 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, and with rising living standards carbon emissions from buildings and the transportation needs attention. To transform its energy mix and reduce carbon emissions in these areas, Wuhan is giving priority to energy efficiency, adoption of new technologies, reduction of carbon emissions per unit energy consumption, and reduction of energy demand. It has employed new policy tools, regulations, and market incentives information disclosure mandate, and voluntary practices promotion.

Although Wuhan has established a comprehensive and systematic low carbon development strategy and policy framework, it still faces the challenge of implementation. Policymakers need to continue to refine their laws and regulations to provide a legislative foundation for low carbon development efforts; it also needs to improve on the monitoring process and evaluation of the implementation of these policies and their effects.

Table 3 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%	50.03%
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	1.21
Carbon dioxide emissions per capita (t)	11.9	12.4

1. Official Low Carbon Development Policies

Low carbon development is a key part of China's national strategy to deal with climate change and build an environmentally sustainable society. In the context of these national priorities, cities are required to set energy saving and emission reduction targets, and to develop action plans.

During the 12th Five Year Plan period, Wuhan began using top-level designs and plans to create 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.

Wuhan has gradually improved its top-level design of low carbon development projects and improved guidance on green and low carbon development. 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,* and *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.* 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 (2016-2020).*

Wuhan, as a provincial capital, a participant in the first batch of China's national low carbon pilot provinces and part of the second batch of national low carbon pilot cities, has established administrative management systems to support low carbon development. Under the Leading Group for Low Carbon Development, municipal agencies are responsible for developing strategy, undertaking policy actions, and ensuring that key tasks are completed and targets on low carbon development are met within the fields under their jurisdiction.

2. Wuhan's Low Carbon Management System

Wuhan has released reports on greenhouse gas inventories in 2005, 2010 and 2012. Furthermore, Wuhan has been researching on how to peak its carbon emissions by collecting and analyzing data on its historical emissions. It has used scenario planning tools to model its medium- and long-term carbon emission trends. These actions are helpful in refining the roadmap to reduce emissions and to set low carbon development targets.

The provincial capital 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 greenhouse gas emissions statistics; it has also established a system to evaluate low-carbon performance and a responsibility system for assessing greenhouse gas emissions targets assessment, along with integration of low carbon development indicators into targets for municipal and district governments and allocation of the national carbon emission reduction target to key enterprises and annual assessments conduction.

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. Along with this, 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.

Wuhan has also established three management platforms for low carbon development: first, 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; second, the Wuhan Energy Saving Evaluation and Examination Information Management System to track the carbon emissions of new projects; and third, the Wuhan Low Carbon Life and Home Platform to encourage low carbon green production and lifestyles.

IV. Peer Review

1. Governance – Key Findings in Governance Area

Wuhan is the provincial capital of Hubei, a province chosen to be in the first batch of low carbon pilots launched by China's National Development and Reform Commission. Wuhan subsequently was selected for the second batch of low carbon pilots. Wuhan's participation in this pilot scheme has provided a strong political and administrative impetus for it to develop a comprehensive low carbon development strategy that incorporates the aspects of economy, industry, buildings, transportation, waste disposal and environmental sustainability.

Low Carbon City Strategy

Wuhan has established its low carbon strategy based on solid research and extensive stakeholder consultation. The design and development of Wuhan's low carbon strategy has taken several steps. First, Wuhan developed a baseline GHG inventory to track the city's level and sources of emissions. Second, it established ambitious targets for GHG reduction, including a peaking year and emissions level, and carbon emissions intensity per unit of GDP. Third, it designed policies, measures and programs covering relevant sectors, using scenario planning, hybrid modeling tools,

and a GHG abatement cost curve. Fourth, it developed a GHG emissions monitoring, reporting and evaluation mechanism to update its targets, policies and actions on annual basis.

The policy that drives Wuhan's low carbon efforts is the *13th Five Year Plan for Social and Economic Development*, which is a legislative plan to guide Wuhan's overall social and economic development for 2015-2020. It is also important to emphasize the *Wuhan Low Carbon Pilot Action Plan* and *Wuhan Carbon Peaking Action Plan (2017-2022)*, which was issued by the municipal government in December 2017, making Wuhan one of a few major Chinese cities to publicly release an action plan for carbon emissions peaking.

Coordinating Bodies

Wuhan has established a dedicated coordinating body to lead it participation in China's national low carbon city pilot effort, the *Leading Group for the Municipal Low Carbon City Pilot*. An independent body headed by the municipal mayor, its members include the heads of key government agencies. The leading group implements and coordinates low carbon city pilot work through a system of interagency joint conferences. Furthermore, the group has a responsibility for managing and coordinating the implementation of the low carbon city pilot programme.

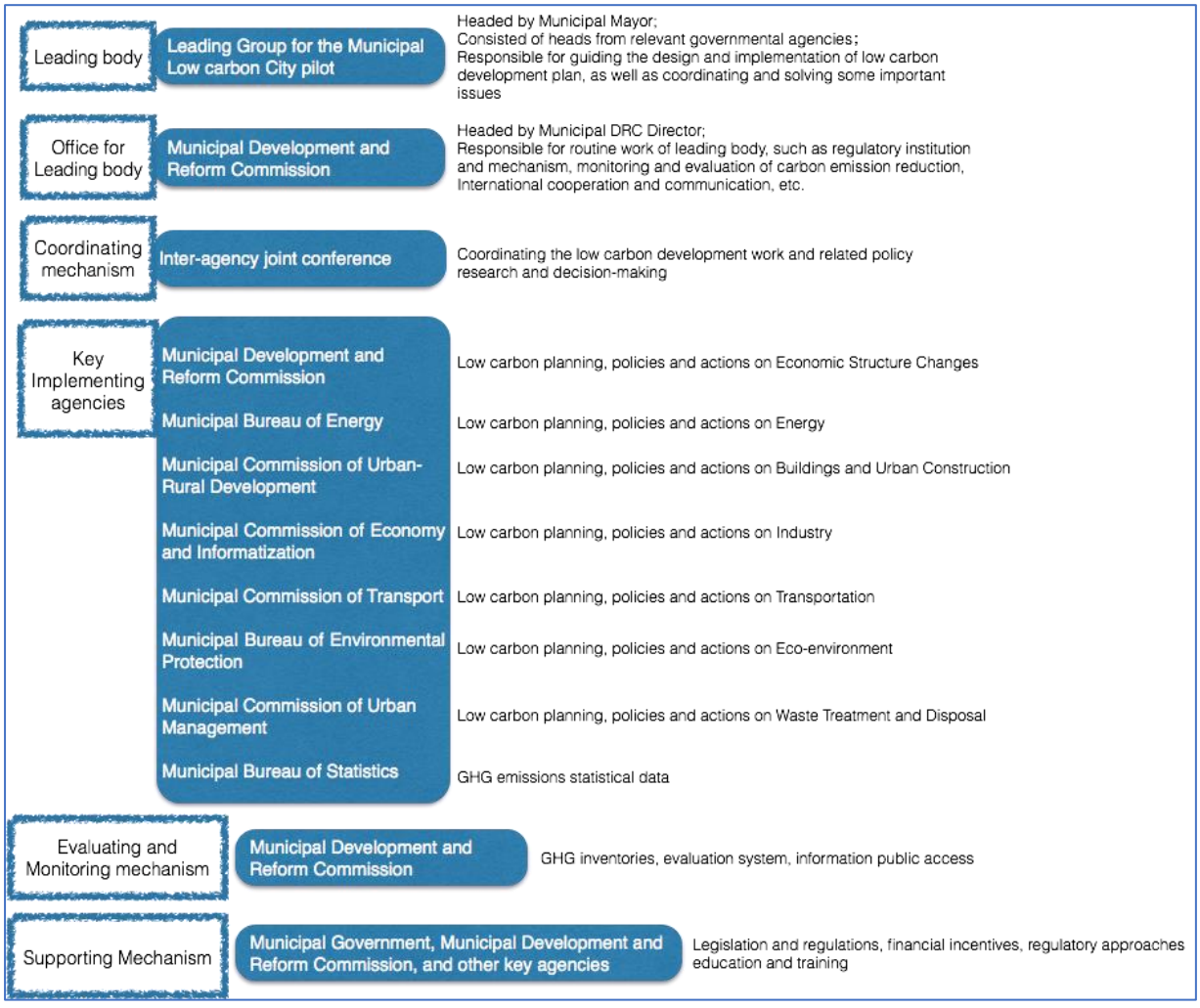

Figure 1. Coordinating structure

Implementing Body

Wuhan has formally allocated the development and implementation of policies and actions across sectors regarding low carbon strategy. Formulation and implementation of specific sectoral low carbon action plans are led by relevant government agencies and underpinned by consultations between agencies.

Overall, the Municipal Development and Reform Commission is tasked with supervising the low carbon development effort. It also designs and implements cross-cutting policies and actions, including monitoring, evaluating and reporting of carbon reductions, along with domestic and international cooperation, and so on. The key sectors under the municipal government develop and implement lower-level strategies. Relevant agencies are responsible for sectoral work in energy supply and power, industry, buildings, transport, and other city managements. These are the leading implementing agencies in the design and implementation of sector-specific low carbon targets, actions, policies and programs.

Evaluation Mechanisms

(1) GHGs Inventory

Wuhan has completed annually three citywide GHGs inventories and has set up an inventory mechanism using a nationally recognized methodology. It is currently exploring the adoption of Community-Scale Greenhouse Gas Emission Inventories, which is a widely-accepted methodology around the world. Particularly noteworthy is that Wuhan will launch its district-level GHGs inventory work by the end of 2018, making it one of the few major cities in China to do so.

(2) Monitoring and Evaluation

Wuhan has developed key indicators for tracking its low carbon development. Carbon reduction intensity and carbon emission cap targets have been incorporated into a comprehensive assessment evaluation for all districts, departments, leading bodies and leading cadres. In addition, the Municipal Development and Reform Commission has established a Carbon Emission Evaluation System on New Fixed Assess Investment projects. However, Wuhan is still lacking a systematic monitoring and evaluating system to track the performance of the city's many policies, actions and programs.

(3) Statistical System and Information Public Access

Wuhan's is exploring options to integrate a GHG statistical system into the city's overall statistical system. At present there is a lack of public channels to access local energy balances and GHGs inventories.

Supporting Mechanisms

Wuhan's official low carbon efforts are supported by three types of ancillary mechanisms: financing, incentive mechanisms, and education and capacity building.

Wuhan has developed various financial approaches to support local carbon development. These include the establishment of a special fund for low carbon development by means of grants, discount government loans, and so on. The

municipal government has actively pursued collaboration with and support from foreign governments, international organizations and other bilateral and multilateral funds to carry out scientific research, technological development, and capacity building. Energy service management contract has also been an important approach, with explicit financial incentives to deliver energy conservation and reduce carbon emissions. However, low carbon programs are still facing financial constraints, especially due to a lack of financial instruments suited for long-term investments.

As a participating province in China's national carbon markets and emissions trading schemes, Hubei province launched its carbon trading market in 2014. Therefore, it is now a priority of the Wuhan government to become a central player in the national carbon market. As of 2015, seventeen emissions-intensive manufacturing firms in Wuhan are part of the provincial carbon market.

Furthermore, Wuhan has a tradition of placing a strong emphasis on civic education. It has compiled a low carbon textbook and other reading materials, carried out low carbon promotional activities aimed at students and local communities, and recently launched a series of guides to help consumers identify low carbon products.

Best Practices and Gaps Identified in Governance

In the peer review workshop, experts raised the following critical questions about Wuhan's low carbon development:

1. Which experiences from Wuhan can be replicated and promoted in other cities?
2. Based on the local characteristics of the city, what are the core factors that influence Wuhan's design of its low carbon development plan?
3. What are potential challenges for Wuhan's low carbon development in the future?
4. How can cities promote innovation in the preparation of district-level greenhouse inventories, the decomposition and implementation of operational tasks, the development of an indicator evaluation system, and institutional mechanisms and capacity building?
5. What challenges do cities face in formulating a carbon peaking plan and what measures can they take to deal with these challenges?
6. How does a city balance the relationship between the achievement of carbon peaking goal and other important socio-economic goals such as GDP growth, population management, employment rate, income levels, industrial upgrading, etc.
7. What kind of working process and key steps should be included in the formulation of a carbon peaking plan?
8. What kind of capacities or data/information support are needed to formulate and implement a carbon peaking plan?
9. How can green finance and carbon markets support the green and low carbon transformation of cities and their industries?

Experts' comments revealed the following key findings and best practices on the design and development of Wuhan's low carbon strategy, its institutional structure

and governance processes:

- Wuhan's low carbon strategy has been accompanied by a significant reduction in carbon intensity from the level in 2010. During the 12th Five Year Plan period, Wuhan's carbon dioxide emissions increased, but carbon intensity decreased, indicating that carbon dioxide emissions have been decoupled from economic growth.

- Wuhan has very strong and sustained political will to develop low carbon policy. As one of the few leading cities to issue a carbon emission peaking action plan, Wuhan has been able to sustain its attention on low carbon and green development, regardless of the coming and going of new trends in the domestic and international environments. The fact that the *Wuhan Carbon Peaking Plan* was issued by the municipal government shows the priority of local policymakers.

- Wuhan has taken its low carbon strategy through three successive stages: pilot action plan, local five- year plan, and peaking action plan. This can be modeled by other Chinese cities.

Wuhan's low carbon strategy has had the following characteristics:

- Wuhan has developed many innovative low carbon practices in its GHG inventories, institutions, governance mechanisms, plan designs and stakeholder engagement.
- Wuhan's low carbon strategy integrates top-down and bottom-up approaches.
- Wuhan's low carbon strategy addresses emissions reduction across multiple key sectors and takes into account the city's macroeconomic development and other relevant city management plans.
- The decomposition of the city's carbon peaking target into districts and sectors is a breakthrough and unique in China. This will facilitate the monitoring and evaluation of its carbon peaking action plan's implementation.
- Wuhan has actively carried out or participated in international cooperation programs to share its experiences throughout the climate policy community.
- Wuhan's municipal government has actively pursued capacity building by assimilating new knowledge, skills and tools from national and international cooperation projects and programs.
- Wuhan has developed its low carbon strategy in a way that will facilitate future urban emission reductions.
- Wuhan has taken early steps to mainstream low carbon initiatives into its economic and social development planning (a five-year plan) to strengthen and ensure political support.

Peer review workshop experts also put forward recommendations for how to upgrade the design and implementation of Wuhan low carbon strategy and sustain its leadership among Chinese cities:

- As a pioneer in Chinese low carbon development, Wuhan should adopt higher

international standards to build and carry out its low carbon projects, such as Hanyang zero-carbon emission zone.

- Wuhan needs a clear, systematic and detailed action plan to stave off an increase in total carbon emissions as it carries out its plan of doubling local industrial output and pursues its strategic vision of becoming a "National Central City" (China's Ministry of Housing and Rural Urban Development issued a 2005 plan to designate key cities throughout China as regional leaders in terms of infrastructure, finance, public education, social welfare, sanitation, business licensing and urban planning).
- In 2015, Wuhan's carbon emissions were 1.3 billion tons. Its per capita carbon emissions exceeded 13 tons. If Wuhan cannot achieve a substantial decrease in per capita carbon emissions in the future, it will be hard to make the claim that Wuhan is a low carbon development leader going forward.
- Wuhan should have higher standards and stricter requirements for its GHGs inventory. The inventory preparation methodology should provide more specific requirements for energy classification, sub-sectors and sub-equipment. This will allow Wuhan to refine its low carbon management, policies and actions.
- Wuhan's current low carbon strategy is mainly driven by top-down regulatory approaches. In the future, Wuhan's low carbon strategy should leverage market mechanisms with the support of a systematic and sustainable institution system.
- Wuhan should develop mid-and long-term strategic plans for green finance and carbon finance that can encourage low carbon investments. Wuhan has promised to be a national center of carbon finance, but at present there is little clarity on how it intends to use financial approaches to support its low carbon development or carbon peaking.
- Wuhan's carbon peaking plan should incorporate co-benefits, such as local atmospheric pollution prevention, based on current institutional reforms and other existing measures.
- Wuhan still faces the challenge of integrating its low carbon strategy into sectoral planning and policies. Sectoral co-benefit studies have not yet received sufficient attention, most notably the link between atmospheric quality and carbon emissions, and human health and carbon emissions. Sectoral co-benefit studies can help Wuhan's low carbon development efforts win support from new stakeholders.
- Wuhan should mainstream low carbon considerations into sectoral governance and make carbon reduction a key criterion in sectoral development.
- Wuhan should make sure to create mechanisms to closely monitor the effective and efficient of implementation of low carbon plans.
- Urban spatial development has long-term "lock-in" effects for city's carbon emissions, yet Wuhan's low carbon strategy lacks targets and measures for urban form and land use. Wuhan needs to incorporate its low carbon strategy into its local urban master planning and infrastructure investment decisions.

2. Sectoral - Key Findings by Sector

This section summarizes key findings on sector-specific strategies and measures in

Wuhan's low carbon development. It identifies good practices Wuhan has adopted in each sector and the challenges Wuhan still faces.

Industry

Carbon emissions from the industrial sector made up 59% (including electricity emissions) of the city's carbon emissions in 2015. Steel, petrochemical and building materials are the three largest emitters in the industry sector. For the last eight years, Wuhan has employed a set of strategies and measures to reduce carbon emissions in this sector, such as setting limits on the production capacity of energy-intensive industries and implementing strict industry access. Reviewers examined these strategies and evaluated to what extent they can help Wuhan peak its carbon emissions and promote low carbon development.

To significantly reduce carbon emission in the industry sector, reviewers suggested four strategies Wuhan can continue to focus on, including:

- Industrial structure optimization: develop new strategic industries with a focus on advanced manufacturing.
- Improve energy efficiency: increase the application of energy-saving and emission reduction technologies and energy-saving management mechanisms.
- Energy decarbonization: promote coal-to-gas conversion and electricity-to-gas conversion.
- Upgrade production structure: support the extension of the supply chain and encourage R&D on hi-tech industrial products.

Peer review workshop participants found that Wuhan's industry sector can reduce 22.5 million tons of CO_2 with these strategies before its carbon emissions peak in 2020. Among the four strategies above, industrial structure optimization can make the largest contribution to carbon emissions reduction, followed by energy efficiency improvements. Wuhan has made a good progress in its industrial structure optimization relative to other cities (e.g. Changchun), and developed a balanced industrial structure. Furthermore, Wuhan has adopted low carbon technologies in energy-intensive industries. However, given the large emissions in the industry sector, Wuhan needs to further optimize its industrial structure with the development of advanced manufacturing industries such as computer and electronic products, and increase its energy efficiency with smart energy management systems. Also, given that Wuhan is a key area in China's manufacturing industry and the national auto industry base, it still has room to optimize its industrial structure.

The contribution of energy decarbonization to carbon emission reduction would be limited, because Wuhan has already implemented coal-to-gas switching and coal-to-electricity switching programs in the last eight years. Its progress on deep energy decarbonization may take a long time and will require complicated technological upgrades. As for product structure upgrades, reviewers' analysis indicates that this can lead to emissions increases in the short term. The process of production chain extensions could also generate more carbon emissions given the involvement of more

production in both upstream and downstream industries. However, in the long term, with strict quality control and higher energy efficiency, an upgraded product structure can contribute to emission reduction. The four main strategies not only vary in their contribution to Wuhan's general carbon emission reduction in the industry sector, but also differ in their application within different industries. For instance, the steel industry needs to prioritize energy efficiency improvement with a focus on smart energy management, but the cement industry needs to prioritize technology upgrades.

Transportation

Compared with those from the industry and building sectors, carbon emissions from transportation are relatively low, accounting for 10.7% of Wuhan's total carbon emissions in 2015. However, they have been growing rapidly in the last eight years. During the 12th Five Year Plan period, they have increased by 9% annually. Private car use has become the largest source for carbon emissions in transportation sector, followed by railway, road and civil aviation. To control carbon emissions from transportation, Wuhan has adopted low carbon strategies in the following two areas:

- Promoting the use of new energy vehicles and encouraging the use of energy-efficient vehicles.
- Developing transportation infrastructure: improving the public transport infrastructure and creating a slow traffic system.

With city expansion and population growth, it is estimated that Wuhan's transportation demand will keep increasing, deepening the challenge of emissions reductions in the sector. While current strategies can contribute to emissions reduction, Wuhan needs to develop detailed actions for each strategy to further cut carbon emissions. Currently, Wuhan has encouraged the use of energy-efficient vehicles, including natural gas-powered taxis, hybrids and electric buses, along with providing subsidies and preferential traffic rules for new energy vehicles. In addition to improving energy efficiency for passenger vehicles, reviewers suggest promoting new energy vehicles in freight transport, especially given that Wuhan will become a national freight logistic center. But whether these measures can reduce emissions largely depends on the sources of electricity. If a majority of electricity comes from coal-fired power, it could undermine effect of these measures on emissions reduction. Therefore, the promotion of new energy vehicles needs to be complemented by a policy support for clean electricity.

For transportation infrastructure, Wuhan has increased its infrastructure investment in transportation with the development of public transit networks and new vehicle charging infrastructure, which could reduce transport demand for private cars. At the same time, carbon emissions from railway and aviation, which are the second and the third largest emitters in transport, should also be given substantial attention. Reviewers suggest that Wuhan should reduce airfreight transportation and explore energy saving and emission reduction opportunities in the sector.

Buildings

The building sector is another key contributor to Wuhan's carbon emissions, accounting for 30% of the city's total carbon emissions in 2015. To contribute to its carbon peaking target and promote low carbon development, Wuhan has developed low carbon strategies in the buildings sector in two areas:

- Developing green buildings: increasing the use of renewable energies and the use of ground, water and air sourced heat pumped system in new residential buildings.
- Promoting building energy efficiency: improving building materials technology and products (wall, roof and windows) and encouraging the use of energy saving appliances.

Reviewers employed scenario modeling to analyze the effects of these strategies on Wuhan's emissions reduction in the building sector. According to the scenario analyses, Wuhan's carbon emissions in building sector will peak by 2030 with estimated 25.49 million tons of carbon emissions. The city's above-mentioned strategies can pave the way for its carbon peaking in the building sector. Specifically, high energy-efficiency technology will be applied to existing buildings, the use of renewable energy such as solar photovoltaic energy will increase in newly-built buildings, and the energy efficiency of home appliances will be improved. In addition to these strategies, reviewers have also emphasized the importance of building data and technology for shaping carbon emissions of the building sector. For example, the use of smart meters in buildings can better track and monitor energy use, which can also facilitate the city to identify sources of energy consumption and prioritized areas for energy efficiency improvement.

Reviewers also raised some issues regarding building energy efficiency, especially, regarding the use of home appliances, such as air conditioners and refrigerators, which not only consume lots of energy, but also generates other greenhouse gases emissions, such as F-gases. Further carbon emission reductions in the building sector will require proper policy and technology support, such as strengthening energy efficiency standards for the home appliances and promoting the use of low GWP (global warming potential) refrigerants.

Environment

Environmental protection can also have a large impact on a city's low-carbon development given the linkages between air pollutants and carbon emissions. Many human activities that generate carbon emissions also produce air pollutants. For instance, fossil fuel combustion process contributes greatly to carbon emissions as well as concentration of air pollutants such as particulate matter, sulfur dioxide (SO_2), and nitrogen dioxide (NO_2). Cities can take a co-benefit approach to simultaneously reduce carbon emissions and air pollutants. During the 12^{th} Five Year Plan period, Wuhan has begun to take actions to improve its air quality with the co-benefit approach. It has focused on the following key areas:

- Pollution control in fields of coal utilization, dust production, motor vehicle emissions, and volatile organic compounds.
- Promotion of energy-saving emission reduction measures on the use of coal, low-emission unit transformation and emissions monitoring for highly-polluting industries.

Reviewers evaluated these strategies based on Wuhan's performance in air pollution control. Wuhan has made progress in air quality, as its concentration of air pollutants has decreased for the last five years, and the concentration of its nitrogen oxides and particulate matter (PM2.5, PM10) remains below the national average. However, Wuhan still has further potential to improve its air quality. Reviewers examined the above-mentioned strategies from a co-benefit perspective, analyzing to what extent these strategies can simultaneously reduce carbon emissions and air pollutants. For measures dealing with carbon emission and sulfur dioxide, carbon emissions and dust production, carbon emissions and nitrogen dioxide, the strategies exerted positive effects in both carbon reduction and air pollutant reduction.

However, reviewers pointed out that cities should be cautious in their selection of co-benefit measures, as measures that facilitate air quality improvement do not always bring other environmental benefits. For example, the application of ground source heat pump can not only reduce air pollution but also increase underground environment risks. Likewise, the use of bikes can reduce air pollution but increase the demand for bike production, which can also generate high carbon emissions. Hence, the city needs to develop a holistic co-benefit approach that avoids raising emissions in other sectors.

V. Conclusion

This peer review exercise describes the drivers of Wuhan's energy consumption and carbon emission characteristics, the polices that Wuhan's policymakers have designed to reduce energy consumption and carbon emissions, and the key areas that Wuhan should focus to go forward. A summary of these forward-looking recommendations is below.

Low carbon city planning should develop an integrated and systematic framework that covers the whole design process - from setting and decomposition of emission reduction targets, the selection of optimal policies and actions, the implementation of new technologies and projects, to the evaluation of implementation effects and planning updates. The timeframe for low carbon development planning should be both medium- and long-term. It should fully reflect the expected impact of technological change and the behavioral changes that lead to the decoupling of carbon emissions from urban socioeconomic and physical infrastructure development. Low carbon planning should incorporate synergistic effect analysis and synergistic measures, and include urban form optimization, urban environmental quality control, public health, transportation, buildings and other urban infrastructure development related fields.

Below are the key recommendations for Wuhan's low carbon city:

1. Summary of Recommendations

(1) Governance

- As a pioneer in Chinese low carbon city development, Wuhan should adopt higher international standards to build and carry out its low carbon projects, for example in its Hanyang zero-carbon emission zone.
- Wuhan needs a clear, systematic and detailed action plan to stave off an increase in total carbon emissions as it carries out its plan of doubling local industrial output and pursues its strategic vision of becoming a "National Central City" (China's Ministry of Housing and Rural Urban Development issued a 2005 plan to designate key cities throughout China as regional leaders in terms of infrastructure, finance, public education, social welfare, sanitation, business licensing and urban planning).
- In 2015, Wuhan's carbon emissions were 1.3 billion tons, a high level. Its per capita carbon emissions exceeded 13 tons. If Wuhan cannot achieve a substantial decrease in per capita carbon emissions in the future, it will be hard to make the claim that Wuhan is a low carbon development leader going forward.
- Wuhan should have higher standards and stricter requirements for its GHGs inventory. The inventory preparation methodology should provide more specific requirements for energy classification, sub-sectors and sub-equipment. This will allow Wuhan to refine its low carbon management, policies and actions.
- Wuhan's current low carbon strategy is mainly driven by top-down regulatory approaches. In the future, Wuhan's low carbon strategy should leverage market mechanisms with the support of a more systematic and sustainable institution system.
- Wuhan should develop mid-and long-term strategic plans for green finance and carbon finance that are able to sustainably make low carbon investments. Wuhan has promised to be a national center of carbon finance, but at present there is little clarity on how it intends to use financial approaches to support its low carbon development or carbon peaking.
- Wuhan's carbon peaking plan should incorporate co-benefits, such as local atmospheric pollution prevention, based on current institutional reforms and other existing measures.
- Wuhan still faces the challenge of integrating its low carbon strategy into sectoral planning and policies. Sectoral co-benefit studies have not yet received sufficient attention, most notably the link between atmospheric quality and carbon emissions, and human health and carbon emissions. Sectoral co-benefit studies can help Wuhan's low carbon development strategy win support from new stakeholders.
- Wuhan should do more to mainstream low carbon considerations into sectoral governance to make carbon reduction a key criterion in sectoral development.
- Wuhan should make sure to create mechanisms to closely monitor the effective and efficient of implementation of low carbon plans.
- Urban spatial development has long-term "lock-in" effects for city's carbon

emissions, yet Wuhan's low carbon strategy lacks targets and measures for urban form and land use. Wuhan needs to incorporate its low carbon strategy into its local urban master planning and infrastructure investment decisions.

(2) Industry

- Industrial structure optimization: develop new strategic industries with a focus on advanced manufacturing industry.
- Energy efficiency improvement: increase the application of energy-saving and emission reduction technologies and energy-saving management mechanisms.
- Energy decarbonization: promote coal-to-gas conversion and electricity-to-gas conversion.
- Product structure upgrade: support the extension of energy efficiency throughout the supply chain and encourage R&D on hi-tech industrial products.

(3) Transportation

- Improve energy efficiency for passenger vehicles - promote new energy vehicles in freight transport, especially given that Wuhan will become a national freight logistic center.
- Promote new energy vehicles and complementary policy support for clean electricity.
- Pay attention to carbon emissions from railway and aviation, which are the second and third largest emitters in transport.
- Reduce airfreight transport and explore energy saving and emission reduction opportunities in the field of freight transport.

(4) Buildings

- Upgrade building data and technology to reduce carbon emissions of the building sector
- Promote smart meters in buildings to better track and monitor energy use; this will also facilitate the identification of sources of energy consumption and priority areas for energy efficiency improvement.
- Strengthen energy efficiency standards for home appliances and promote the use of low GWP (global warming potential) refrigerants.

(5) Environment

- Strengthen co-benefit pollution control in coal utilization, dust production, motor vehicle emissions, and volatile organic compounds.
- Promote energy-saving emission reduction measures on the use of coal, low-emission unit transformation and emissions monitoring for highly-polluting industries.

- Ensure that co-benefit approaches don't lead to emissions increases in other sectors.

(6) Peer Review Workshop Activities

- Impacts of the workshop: The majority of participants gave positive feedback, most of which highly acknowledged the workshop.
- Effectiveness of the workshop: Most participants were satisfied with the structure of the workshop and agreed that presentations and papers had high quality. In general, the workshop had included new knowledge and skills as well as facilitated interactions between speakers and audience.
- Overall suggestions: the workshop can be improved by giving more time after each presentation for Q&A and increasing discussions among international and local speakers and different city representatives.

2. Next Steps

With the completion of this peer review report, iGDP will begin to develop the second and complementary peer review report of the southern Chinese city of Guangzhou. This follow-up Guangzhou report will involve a literature review, desktop research and field visits for data collection, and a peer review workshop. Following the completion of the Guangzhou peer review exercise, iGDP will prepare the China component of the comparative study of selected cities in the Northeast Asia region – the capstone project of the partnership between iGDP and NEASPEC.

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Annex 1: Wuhan Background Report

LOW-CARBON DEVELOPMENT STRATEGIES AND POLICIES IN WUHAN, CHINA

BACKGROUND REPORT

This report was commissioned by United Nations Economic and Social Commission for Asia and the Pacific (ESCAP), under its North-East Asia Low Carbon City Platform (NEA-LCCP). It provides an overview of Wuhan's low-carbon strategies and policies. NEA-LCCP chose Wuhan as a case study to better understand low-carbon development in China. This report reviews Wuhan's low-carbon performance and provides an overview of socio-economic data, urban development strategies, and the key drivers of the city's low-carbon growth. It also includes a comprehensive examination of the strategic measures and policy instruments that local governments have implemented.

Innovative Green Development Program (iGDP)

2018-6

1. Introduction

In 2010, China's National Development and Reform Commission (NRDC) launched the country's national low-carbon pilot program. This program promotes climate change mitigation and low-carbon development at the city and provincial administrative levels, and currently operates in six low-carbon pilot provinces and 81 low-carbon pilot cities. The city of Wuhan is one of these low-carbon pilot pilots.

Wuhan is a large city in central China, with an economy that is dominated by heavy industry and a development experience that is in many ways typical of China's recent pattern of economic growth and urbanization. Wuhan is the provincial capital of Hubei; a province that was chosen to be in the first batch of low-carbon pilot provinces. A few years later, Wuhan itself was selected to be in the second batch of low-carbon pilot cities, though the city had been independently developing low-carbon policy since 2010. Indeed, low-carbon concepts have helped Wuhan restructure its economy, upgrade its industry, and improve the quality of its urban infrastructure and public services.

At the 2015 Sino-U.S. Climate Summit, the mayor of Wuhan announced that the city would peak its carbon emissions by 2022, and this commitment was incorporated into Wuhan's *13th Five-Year Plan for National Economic and Social Development*. In its seven years of low-carbon policy, Wuhan has developed strategic measures, institutional mechanisms, policies and other instruments that can serve as models for other cities in China pursuing low-carbon development.

Low-Carbon Policy Considerations

The effectiveness of the 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 drivers behind low-carbon development will change going forward. Carbon emission reduction and environmental protection in cities can be considered as public goods, and government is the key driver 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, according to local

condition, to encourage a low-carbon transition.

Report Structure

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

The first section concerns Wuhan's urban data and 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, just like "invisible hands", impact urban development. With a better understanding of Wuhan and its long-term development strategies, we can get a clearer picture of the obstacles and challenges to low-carbon development that lie ahead.

The second section provides an overview of the 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 the availability of low-carbon technologies. Understanding these changes and predicting future trends for those 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. It also delves into 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 offers this report's conclusion that brings together all the key points

raised in the three earlier sections.

2. City Profile

Wuhan is a city with a 3,500-year history, a present-day population of 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. It is a modern city with a rich history and culture. Wuhan, as growing city, has a unique geographical attributes, climatic and ecological environment and social, economic and cultural foundations. It is important to understand the relationship between these characteristics of climate, geography, culture, resources, industrial structure, administrative structure and low-carbon development strategies and policy practices.

Wuhan, Hubei province

As an economic center and mega city in China's central region, with its particular geography and climate, 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 will adopt a low-carbon development path.

Wuhan endures cold winters, hot summers, and abundant rainfall. It is located in a subtropical monsoon climatic zone with an 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 made up by the current urban development zone and 678 km^2 is the area of the city proper. Wuhan has been shaped by its relationship with the surrounding mountains, lakes and rivers; for example, the urban development area traces the riverside. 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 advantages of geography extending outwards in all directions. As a central city in the central region, Wuhan acts as a gateway between the east and the west; it 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, linking railways, highways, waterways and aviation.

Wuhan has few local energy resources, but it 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 driven a high demand for fossil fuels. Wuhan has "no coal, no oil, and no gas". It imports its energy from outside the city, including from four major hydropower stations (Gezhouba, Danjiangkou, Geheyan and the Three Gorges dams) and Pingdingshan Coal Mine.

Wuhan's long-term rapid economic growth has put pressure on its 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 have improved, and urban transportation has 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 a rich culture; its people are characterized by the traits of openness, flexibility, inclusiveness and diversity. It is also rich in scientific and technological innovation resources which provide strong ideological foundations and capacity for embracing and pursuing low-carbon development.

Wuhan's regional culture is pluralistic and inclusive, influencing decision-making, strategic thinking and implementation. Wuhan incorporates *Jingchu* culture (a culture that grew up along the river) and a Yangtze River culture. People from the *Jingchu* culture are characterized for their "pioneering spirit and their 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 with high concentrated scientific, technological and intellectual resources. 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 priority areas 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 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 – 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 focused on its industrial development, and established itself as an advanced manufacturing center; with some industries topping 100 billion yuan in terms of production output, including IT, automobiles, equipment manufacturing, steel, petrochemicals and food. Wuhan's traditional industries, such as steel and textiles, are on the decline and it's predicted they will be replaced by IT, biomedicines and smart production.

As a sub-provincial city, the capital of Hubei Province, and a 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 with 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 thus wielded considerable influence over local public resource allocation. Furthermore, as a pilot city in a number of initiatives, it has an extensive support base 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, a smart city, a low-carbon industrial zone, renewables for buildings, alternative fuel vehicles, low-carbon integrated transportation planning, and a 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 strategy supporting its long-term vision of making Wuhan a national central strategic city. Low-Carbon City Development is another strategy that 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 a real status, 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 China's urban hierarchy. Wuhan has had this goal since 2011. In 2016, the NDRC issued *Guiding Opinions on Supporting the Construction of Wuhan as a National Central Cit*y. 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 with plans to build 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 attract college graduates and high-tech industry professionals to come to Wuhan and 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 speed up the transformation and upgrading of its traditional industries, such as automobiles, equipment manufacturing, steel, petrochemicals, food, tobacco, household chemicals and others. Its *Emerging Industries Doubling Plan* focuses on electronic information, the life and health sector, and smart manufacturing.

Wuhan has implemented the *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 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)*.

In 2013, Wuhan implemented the *Service Industry Upgrading Plan* to help develop a modern service industry. It introduced a series of supportive 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 Emissions

Total carbon 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 it has become more urbanized. 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 passed the "ten million" 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 Beijing University, the city's population is predicted to reach 15-17 million by 2030; while by 2050, that figure should reach 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; showing the aging population issue in Wuhan. 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 has also steadily become more urbanized. In 2015, urbanization was 79.41%. Over those five years, 882,200 new urban residents were added to the city, that's an average annual increase of 176,400 people. 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, Wuhan (2011-2015)

	2011	2012	2013	2014	2015
Urbanization	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 in primary sector share in total employment. The implementation of the *Industrial Doubling Plan* helped boost manufacturing's 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's economy has grown at a remarkable rate and its secondary and tertiary sectors

are now roughly equal in size.

Wuhan's GDP has entered the "trillion RMB club," an unofficial classification in China of cities with an annual GDP of more than 1 trillion RMB. There are currently 15 cities that have entered this "club", 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 down a gear from high-speed to medium-high speed growth; and ranking fifth among those 15 cities. Its 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's economy is the strongest in China's central region; it is the only city in central China 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 make up similar-sized 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 (2011-2015), Wuhan implemented its *Industrial Doubling Plan* and *Services Upgrading Plan*. In 2015, the primary: secondary: tertiary ratio of GDP was 3.3%: 45.7%: 51%. During that the 12th Five-Year Plan period, the tertiary sector grew the fastest. Between 1998 and 2015, except for 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 207.982 billion RMB in 2010 to 408.1 billion RMB by 2015. The proportion of light to heavy industrial output value shifted from 1:3.30 in 2010 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 19.9% 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.

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.

3.4 Carbon Dioxide Emissions

During the 12th Five-Year Plan, Wuhan's carbon dioxide emissions increased, but carbon intensity decreased, indicating 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 1.32 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 13.58 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 energy saving and 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.* In 2016 and 2017, Wuhan issued *Wuhan 13th Five-year on Low Carbon Development, and Wuhan Carbon Peaking Action Plan (2017-2022) respectively.*

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. 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 Energy-Saving Evaluation and Examination 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 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 (current price)	2.09	1.21
Annual energy consumption per capita (tce/ person)	3.69	4.58
Non-fossil fuel energy share of primary energy consumption (%)	8.17%	11.5%
Coal share in total energy consumption (%)	53.81%	50.03%

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	

Case study: Controlling coal consumption

Wuhan has released a series of Plans to improve air quality, optimize the energy mix, and peak carbon emissions as soon as possible. These are: Wuhan's *13th Five-Year Plan on Energy*

Development, its *13th Five-Year Plan for Embracing Blue Skies,* and its *Action Plan on Peaking Carbon Emissions (2017-2022).* In particular, Wuhan aims to reduce total coal consumption by five million tons during the 13th Five-Year Plan (2016-2020) and has in place a series of measures to do so. These include strict controls on all new coal-fired projects, replacing small coal-fired boilers and industrial kilns with heat and power cogeneration, central heating, natural gas and electricity, and banning coal for residential use in certain areas. Between 2016 and 2017, Wuhan shuttered more than 200 small coal-fired boilers and kilns and 115 bulk coal shops.

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 59.1% (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; improvements 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 for industries above a designated size, energy consumption of total industrial output value, and the share of hi-tech manufacturing value-added in total industrial value-added. 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 cement and steel industries that fail to meet energy consumption limits requirements • 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

Case study: Improving industrial energy efficiency

Wuhan has been encouraging industry to adopt technologies to help them improve their energy conservation and efficiency. It has released several measures and programs to this end including: *Interim Measures on Special Funds Management for Industrial Energy-Saving, Supportive Measures for Improving the Energy Efficiency of Motors, Special Action Plan on Transforming Machinery in the Injection Molding Industry, Proposal on Accelerating the Implementation of Contract Energy Management, Supportive Measures for Contract Energy Management Projects, Management Measures for Preferential Income Taxes for Contract Energy Management, Projects in Energy-Saving Services,* and *Operational Guidelines on Contract Energy Management Project Loans.* They focus on offering financial support, tax incentives, preferential loans, and other kinds of assistance to support energy conservation and contract energy management projects. These measures have helped reduce Wuhan's industrial energy intensity by 19.9% between 2014 and 2017, and industrial carbon intensity by 22.5% over the same period. Wuhan is in the first batch of "Made in China 2025" pilot demonstration cities that was announced in 2016.

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 30.3% 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

Case study: Modernizing the construction industry

Wuhan's *Proposal on Accelerating the Modernization of the Construction Industry* proposed that the city use the period between 2015 and 2017 to encourage developers to design and build pilot demonstration projects as examples of modern construction. These should include affordable housing and projects with state investment. Under this scheme, the area of new construction projects should be at least 2 million m^2, of which no less than 500,000 m^2 should be started in 2015; 600,000 m^2 in 2016; and 900,000 m^2 in 2017. From 2018 onwards, Wuhan has been encouraging the modernization of the construction industry throughout the city with the aim of making sure that at least 20% of all construction projects are "modernized" in the first year, with an annual growth of 5%; and that the prefabrication and assembly rate should be at least 30%.

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	--	24%
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

[1] using the urban population

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 terms of number and duration through a more integrated, compact and mixed model use of urban space via 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

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 for areas in Wuhan Yangtze River Bridge and Jianghan Bridge • Special lane for 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

Case study: Expanding rail transit and encouraging use of new energy vehicles

By the end of 2017, Wuhan's metro system had seven line: Line 1 to 4, Line 6, Line 8 and the Yangluo Line. It has 167 stations and a total length of track of 237 km, 7th in length in mainland China. There are another 16 lines (360 km) under construction. By 2020, it is estimated that Wuhan will have 11 metro lines with a total length of 400 km to form a "main city network, new city link" rail transit network system. Public transport makes up 62.5% of all motorized transport, while rail transit makes up 53% of all public transport.

Wuhan has issued several Plans to support new energy vehicles such as: *New Energy Vehicles Promotion and Application Plan 2016, New Energy Vehicles Promotion, Application and Industrialization Implementation Plan (2017-2020) and Notice on Accelerating the Promotion and Application of New Energy Vehicles.* These suggest that Wuhan should encourage the use of new energy vehicles in the city so that there are no less than 3,000 in 2017; 4,000 in 2018; 5,000 in 2019, and 6,000 in 2020. It also called for building and putting into operation no less than 3,000 charging piles by 2017; 3,500 by 2018; 4,000 by 2019; and 4,500 by 2020. A number of measures are being used to achieve these targets such as providing financial support such as subsidies, using preferential traffic rules to give greater road access to new vehicles, preferential taxes and fees, supportive electricity pricing, building new vehicle charging infrastructure, including new energy vehicles on government procurement lists, encouraging use of new energy vehicles for officials, public transport, and public services that require transport such as sanitation and logistics.

4.2.5 Environment and Land Use

Strategic Measures

Urban form and land use patterns impact urban production and consumer behavior.

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%

Case study 1: Building a Sponge City

In April 2015, Wuhan became one of the cities in the first batch of Sponge City pilots. Accordingly, Wuhan then drew up a *Special Sponge City Plan (2016-2030)* and issued its *Sponge City Construction Pilot Project Implementation Plan*, *Management Measures on Sponge City Construction*, and *Notice on Accelerating the Construction of a Sponge City*. It

drew up seven local technical standards (see *Wuhan Sponge City Construction Technical Guidelines (trial)*), built a monitoring and evaluation platform; and employed a rainwater runoff control rate of 38.5 km^2. It also drew up standards on reducing non-point source pollution. The cumulative investment into the pilot was RMB 9.548 billion. The pilot's Dai Jia Lake Park won the China Habitat Environment Model Award. The Ministry of Housing and Urban-Rural Development incorporated the Lin Jiangwan Community Restoration Project into the first batch of case studies in the Sponge City Pilot program.

Case study 2: Huashan New Eco-City and Sino-French Eco-City

Hubei Province has released several Plans on building eco-cities focused on low emissions. These include: Hubei's *13th Five-Year Comprehensive Work Plan on Energy Saving and Emission Reduction,* Hubei's *13th Five-Year Plan Implementation Scheme on Greenhouse Gas Emissions Control,* Wuhan's *13th Five-Year Plan on Climate Change and Energy Saving,* Wuhan's *13th Five-Year Plan for National Economic and Social Development, Key Points on the Comprehensive Reform for Constructing a Resource-Saving and Environmentally-Friendly Society in Wuhan,* and Wuhan's *13th Five-Year Plan on Low-Carbon Development.* These were used to support Huashan New Eco-City and Sixin Eco-city as demonstration projects that target near-zero emission areas. The Sino-French Eco-City is envisaged as a joint country initiative to create a model for sustainable city development.

Huashan New Eco-City

When Huashan New Eco-City is finished it should cover about 66.4 km^2 of which 18 km^2 will be construction land and home to around 200,000 people. It is one of eight national low-carbon cities (towns) pilot projects listed in the NDRC's *Notice on Accelerating National Low-Carbon City (Town) Pilots*. Its aim is to create a low-carbon city and become a model for other eco-cities in China. It will build an integrated public transport system, with metro and bus rapid transit systems at its core, linked by a regular bus system, and supplemented by taxi services and slow traffic. In building a smart city, it will employ IT and communications technologies to integrate key urban data; as an example, work on the Chu Tian Yun Big Data Industrial Park project has been started. It has promoted the use of clean energy vehicles in its public transport system and put more than 30 electric buses into operation in 2016. Yida Yunshan Lakes, a residential project, was 100% served by solar photothermal systems in 2016. Schools are being targeted first to join a pilot project for separating garbage; this will be extended later to residential communities and industrial parks. An eco-demonstration Wetland Park was built around Yanxi Lake and Huashan River. There are currently 27 hectares

of estuarine wetland park.

Sino-French Eco-city

This joint project between China and France has been supported by a number of Measures, including: *Proposals on Accelerating the Sino-French Eco-City, Policies and Measures to Support French-funded Enterprises in Wuhan's Sino-French Eco-City (Trial),* and *Suggestions on Supporting the Modern Service Industry in the Sino-French Eco-City.* The *Sino-French Eco-City Master Plan（2016-2030）* was drawn up after specialist advice from both countries. Caidian District was chosen as the site for the eco-city. Its mission is to become a model of sustainable development using low-carbon concepts. The planned core area is about 39 km^2, which will later be expanded by 62 km^2 with a further 120 km^2 of peripheral area. It will use expertise, experiences and technologies from both countries in sustainable development in urban planning, design, construction and management. It will focus on renewable energy, low-carbon transport, green buildings and so on, to create a joint endeavor between China and France that showcases low-carbon living, industrial innovation and the concept of a livable city, while embracing industrialization, informatization, urbanization and agricultural modernization. So far, the project has been running smoothly and the major projects that have been built, or are in the planning stage, include the sustainable use of water resources and the Dongfeng Renault production base. One of the world's largest power producers plans to invest more than RMB 1 billion yuan in the initial period into programs involving geothermal energy and natural gas and waste heat recovery from wastewater treatment plants.

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%	50.03%
Share of non-fossil fuel in primary energy consumption(%)	8.17%	11.5%
CO_2 emissions per unit GDP (t/10000 RMB)(current price)	2.09	1.21
Carbon dioxide emissions per capita (t)	11.9	12.4

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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Annex 2

Wuhan Carbon Peaking Action Plan 2017-2022

To accelerate the city's green and low-carbon development and promote the city's carbon emission to peak by 2022, this action plan is formulated based on "Wuhan's 13th Five-Year Plan on National Economic and Social Development".

Objective

Further implement the spirit of 19th National Congress of the Community Party of China, keep promoting the eco-civilization, carry out the concept of creative, coordinative, green, open and shared development, so as to take low-carbon development as the main support for the construction of modern, international and environmental Wuhan. By 2022, the whole city's carbon emissions will peak, and carbon emissions from industry (not include energy industry), buildings, transportation, energy sectors and all 14 districts of the city will be controlled, then basically build a low-carbon-oriented industrial structure, energy system, building system and transportation system, and form a "Wuhan Model" of low-carbon production and lifestyle with a demonstration effect, put Wuhan as a top runner in China's low-carbon development.

Main Tasks

1. Implement Low-carbon Industrial Project

1) Accelerate the development of high-tech industries. Promote the construction of "Made in China 2025" pilot demonstration cities, by 2022, the output value of information technology, life and health, and intelligence manufacturing will reach to 800, 400, 400 billion RMB respectively, the output value of above-mentioned new strategic industries will account for more than 70% of high-tech industries.

2) Further develop modern service industry. Increase the following four production-based service industries: modern logistic service, finance, software and information technology, business exhibition service, consolidate the following four lifestyle-based service industries: modern business and trade, tourism, real estate, public service, further promote the following five new style service industries: technology service, creative industry, engineering design,

car service, new industry with new style. By 2022, the added-value of service sector will reach to 1200 billion RMB, accounting for more than 56% of the city's GDP.

3) Improve the de-carbonization level of agriculture. Promote models of agricultural planting and breeding style and clean agriculture. Improve the application level of "Two styles" agricultural production technologies. By 2022, the use of fertilizer and pesticide will reduce 1-2% annually, the comprehensive utilization of crop straw reach more than 95%, the comprehensive utilization of large-scale livestock manure reach more than 85%, and the rural household rate with clean energy will reach more than 80%.

4) Accelerate upgrade of traditional industries. Fully forbid new construction of heavy-polluted programs in sectors such as steel, cement, flat glass, coking and non-ferrous metals. Except for the ongoing projects, strictly prohibit new construction of heavy-polluted chemical industrial parks within 1km range of Wuhan section along the Yantze River and Han River. Strength energy-efficiency supervision on key energy-intensive entities, promote industries to reach their energy efficiency standards, strictly implement energy consumption standards on high energy-consuming products. Promote the implementation of ladder and differential electricity price in steel and cement industries. Support industries to implement energy-saving renovation of industrial boiler and kiln, energy-saving of motor system, recovery and utilization of residual heat and pressure, cogeneration, recovery and utilization of industrial by-product gas, construction of enterprise energy control center and other energy efficiency upgrading projects.

2. Implement Energy Low-carbon Project

1) Reasonably control the total energy consumption. Insist on prioritizing energy conservation, improve energy efficiency, and ensure to achieve goals of energy efficiency and carbon emissions reduction from provincial government.

2) Prioritize the development of non-fossil fuel. Develop wind and solar power programs and establish Hubei Longyuan huangpi liujiashan wind farm and state-grid huangpi wushan wind farm. Develop a series of solar power programs and make the installed capacity of solar power reach more than 250,000 kW. Promote large-scale utilization of biomass and landfill, build

10-15 new large and medium biogas projects, more than 150 small biogas projects, so the city's total volume of biogas projects will reach more than 100, 000 m^3.

3) Increase the use ratio of natural gas. By 2022, The city will build more than 700 kilometers of high-pressure pipelines, 3200 kilometers of medium pressure pipelines and more than 270 natural gas stations of all kinds. Try best to complete Baihushan large liquefied natural gas reserve base by the end of 2020. Encourage the development of urban gas heating, guide and support the production of industrial enterprises using natural gas pipeline or liquefied natural gas, promote the implementation of coal (oil)-to-gas shift in the boilers outside of the city's third-line circle, encourage the development of natural gas peak-load dispatching power stations, and vigorously develop natural gas distributed energy.

4) Increase the use ratio of electricity. Implement "Extra-high-voltage near city, Ultra-high-voltage (UHV) within city" program, promote the construction of 1000 kV UHV AC substation and±800kV UHVDC converter station projects. Improve the urban and rural 220 kV network, by 2022, build and expand 17 new 220 kV power transmission projects, the new added substation capacity will be 6.41 million kVA, the total capacity will be 20.27 million kVA. Improve the 110-kV electricity dispatching system, by 2022, build and expand 73 new 110 kV power transmission projects, the new added capacity will be 5.85 million kVA, the total capacity will reach 19.43 million kVA. Promote the transformation of urban distribution network, new urban area rural power grid transformation and upgrading project, to the integration of urban and rural power grid transition. Promote the transformation of urban distribution network, the upgrading of new rural power grid transformation in newly built urban area, moving to the integration of urban and rural power grid transition.

5) Strictly control coal consumption. Strengthen the source management, for new projects, do not approve the construction of new coal-fired boilers in principle; for a region that completely has no conditions for the use of clean energy but does need to build new coal-fired boilers because of industrial development, strictly control is required, the new (remodeling, expanded) coal-consuming projects must ensure its coal consumption or part of it will be replaced. Strict implement he city's regulations on high-pollution fuel ban zones. By 2022, the city's total coal consumption will be controlled within 19.5 million tons of standard

coal equivalent and strive to control it within 16 million tons of standard coal equivalent or less.

6) Promote cogeneration. Mainly focus on cogeneration, take natural gas distributed energy stations and industrial waste heat as supplement, also consider ground source heat pump, river water source heat pump and biomass fuel boilers, promote central heating (cold). By 2022, ensure the city's main city and the development zone have both the production and living supporting heating, meet the industrial production load 4300 tons / hour, heating area 42 million square meters, annual heating 6.5 $X10^7$ GJ.

3. Implement Life-based Low-carbon Project

1) Promote low-carbon buildings. Strictly implement energy efficiency design standards of low-energy buildings, ensure the standard implementation rate to be 100%. By 2022, newly built green buildings account for 50% of the newly completed buildings, a total of more than 45 million square meters of green building will be built, create 5 of low-carbon and eco demonstration areas, 10 green building demonstration areas and 50 high-star green building demonstration projects, and a total of 50 million square meters of building area for renewable energy construction will be built; the promotion and application rate of new wall materials reaches 100%, no waste and wastewater discharge for building materials industry. In order to promote the modernization of the construction industry, since 2018, the proportion of modern construction projects in the construction industry to the total area under construction for that year should not be less than 20%, and not less than 5% annually thereafter.

2) Promote low-carbon transportation. Optimize the development of green public transport and build “city of subway”. By 2020, basically form a rail network system that covers “three towns” and accesses “new city”, the total mileage of rail transit will reach 400 km, the rail transit will account for more than 50% of public transport passenger traffic. Construct an integrated public transportation system with the national railway hub as the node, the urban railroad as the backbone, the routine public transportation as the basis and the ferry as the supplement and the slow traffic linked up. By 2022, public transport accounted for more than 60% of motorized travel and increase bus lanes in a timely manner. Promote the construction

of shared transportation, improve the smart car dispatching system for public transport and passenger taxis, and the maritime administration information system of port and shipping. Accelerate the promotion of clean energy transport demonstration projects, implement "new energy bus replacement project", and give priority to the use of clean energy in port handling machinery and transportation equipment. By 2022, the city will promote 40,000 new energy vehicles and build more than 150 centralized charging stations and over 70,000 charging posts.

3) Promote low-carbon public institutions. Promote paperless office and online office and reduce the use of disposable office supplies. Promote a streamlined and efficient conference organization mode and continue to improve the teleconferencing system. Carry out "low carbon office week" activities. Comprehensively promote the low-carbon use of official vehicles and phase out "high-pollution and high-emission" official vehicles by the end of 2018. Government agencies and institutions strictly enforce energy saving and environmental protection policies for the government procurement, and gradually increase the proportion of low-carbon products in government procurement.

4) Promote low-carbon lifestyle. Launch “low-carboner+” action plan, construct “carbon wallet” low-carboner platform, and guide customers to choose low-carbon products. Strengthen the certification of energy-saving, environmental-friendly products. Promote the source of domestic waste classification and improve the comprehensive utilization of garbage facilities. Support and guide the sharing of economic development, innovate the sharing of economic development patterns and fields. Carry out college low-carbon promotional activities, and regularly organize college students’ participation in low-carbon practices.

4. Implement Ecological Carbon Reduction Project

1) Optimize the urban ecological pattern. Taking the mountain range and water system as backbone, Wuhan will form a green structure of "one centre, two axes and five rings, six wedges and multiple corridors, one network with multiple points", bringing a green space structure of “green mountains as natural defense, green wedges for wind, blue sky and clear water as a network and big and small pearls embedded the river city”. By 2022, the forest coverage rate is expected to reach over 14.05%, and the green coverage rate of the built-up area to reach over 41%.

2) Implement the “Green Skeleton" main project. Wuhan will build the Green Road of Bali East Lake as a model of world-class city lake. Accomplish green landscape with cross axis’ green construction and build the world-class city’s landscape belt with middle axis around the Yangtze River area; build the "vertical axis" --- 15.4 km Yangtze River beach park in Kan Jiaji, Liu Tonggan and other areas and the "horizontal axis” --- 5 km Han River beach park in Hanjiang Wan area, extending the "Two Rivers and Four Banks" green bank line to the third ring urban ecological belt. The city will carry out the "Two Rivers and Four Banks" green promotion and Guishan scenic view transformation project, building a green corridor of ChangchunGuan --- Hong shan --- Mount Luojia. Besides, it will widen the third ring urban ecological belt with over 19 hectares new green area, implement the 50 meters wide public welfare forest belt construction at each side of 146 kilometers of the fourth ring, and promote the demonstration project of green wedge into the city.

3) Implement the “Clear River City, Blooming Flower Town” project. By 2020, Wuhan will increase 120,000 *mu*[2] woodland, and ensure the city’s public forest stays around 900,000 *mu*; build 23 new parks and continue to build 7 parks, increasing 810 hectares of green parks. In addition, promote the construction of 200 central parks and implement projects of aerial gardens, flyovers, pedestrian flyovers’ special space greening, roof greening, etc.

4) Implement projects of ecological blue network greening and of wetland conservation and restoration. By 2022, complete over 20 lake parks or the construction of lake green land and build more than 20 kilometers riverside ecological oasis. Promote the ecological protection and restoration of the wetlands, such as the Chen Lake, Shangshe Lake, Zhangdu Lake, Wu Lake and Zao Lake and so on, and create 1 international key wetland and 3 provincial and above level reserves and 2 municipal reserves. Accelerate the construction of the national wetland parks, such as the Houguan Lake in Cai Dian district, Anshan in Jiangxia district, Canglong Island and Dugong Lake in Dongxi Hu district and provincial wetland parks, Suozi Changhe Lake and Tong Lake in Chadian district, Zhuyang Hai in Jiangxia district and Mulan Huaxi in Huangpi district. Boosting the restoration of wetland’s ecological function and build 5 national wetland parks and 4 provincial-level wetland parks.

[2] 1 mu equals to 0.0667 hectare or 1/6 acre

5) Implement the project of mountain restoration and mountain park construction. Promote ecological restoration of 12 damaged mountain (3980 *mu*) including Mount Lujia in Huangpi district, Mount Heng in Caidian district and Mount Jitou in Qingshan district and build the Mount Tangjia, Mount Guoding, Mount Xiannu, Mount Zhu, Mount Jiangjun and Mount Jitou and other mountain parks.

5. Implement the Low-carbon Fundamental Capacity Promotion Project

1) Conduct a greenhouse gases emission (GHGs) inventories. Wuhan will incorporate the basic statistical indicators of GHGs into the whole city's statistical index system, and establish a statistical system that covers energy activities, industrial production processes, land use change and forestry carbon sinks, waste disposal and so on, and adapts to the requirements of GHGs measurement and government's target assessment. It will achieve the normalization of municipal GHGs inventories development, so as to launch the development of district-level GHGs inventories by the end of 2018.

2) Establish a low-carbon and energy-saving smart management system. By 2022, the low carbon energy saving smart management system will basically cover the main energy-using entities, realizing immediate surveillance, analysis and early warning on these entities' energy consumption and carbon emissions.

3) Develop relevant low-carbon standards. Research and develop local standards on Wuhan key industries and products' greenhouse gas emissions and energy consumption limits. By strengthening its implementation, it will promote enterprise's carbon emission reduction and improve energy efficiency.

6. Implement Low-carbon Development Demonstration Project

1) Implement the Near Zero Carbon Emission demonstration project. Taking the China-France Huhan ecological demonstration city and Huashan ecological new city as a carrier and the low-carbon production, living, and service as the main content, Wuhan will develop a national Near Zero Carbon Emission demonstration project to promote the development of green low carbon industrial ecological chain and form a replicable model project.

2) Implement the "Five-Ten-One Hundred" low-carbon demonstration projects. The city will establish low-carbon pilot units, such as low-carbon enterprise, institution, campus, hospital, etc. and create relevant evaluation criteria, indicator system and incentive mechanism. By 2022, 5 low carbon demonstration districts (parks), 10 low carbon demonstration communities and more than 100 low carbon demonstration units will be built.

3) Develop low-carbon scientific and technological innovation demonstration. Establish a low-carbon innovative system with government-guided, enterprise-oriented, industry, education and research-connected, enhance research of key technologies in the low-carbon technology field and build a low-carbon scientific research platform. Encourage independent innovation in low-carbon technologies such as carbon capture and storage and add it to scientific and technological plans as a major scientific and technological innovation project.

7. Establish and Improve Low-carbon Institutional Mechanisms

1) Strengthen the project entry mechanism. Centered on the "double control" of energy conservation control and carbon emission control, strictly regulate the energy and carbon projects' assessment system, and strictly control the construction of high energy consumption and emissions projects. Enhance the supervision and post-supervision on energy assessment.

2) Promote the construction of low-carbon market mechanism. Wuhan will strive to have the national carbon emissions trading registration system settled in Wuhan. The provincial carbon market's allowance allocation not only include the companies that consume more than 10,000 tons of standard coal of 7 industries but will also seek to expand the scope to those enterprises of 5,000 tons standard coal and more. Develop regional energy rights trading.

Support the construction of Wuhan Mineral Exchange, Wuhan will strive to build a platform for urban mineral exchanges based on the central region and radiating the whole country.
Accelerate the promotion of contract energy management and contract water-saving management mechanism, promoting the implementation of top runner programs on energy efficiency and water efficiency.

3) Build a green financial system. Explore green financial products such as green credit, green bonds, green insurance, green finance, and green financial instruments as well as policy innovations, and a green financial service system supporting the development of green industry. Encourage green enterprises to raise funds through listing, equity transfer, bond issuance and so on. Establish fund for low-carbon industry guide, and attract social capital, especially venture capital to invest the low-carbon economy and ecological construction, and further expand a more solid trading system that includes carbon credit, carbon capital market, carbon insurance trading, gradually exploring to establish a domestic leading carbon finance market.

4) Improve fiscal and tax incentive mechanism. Wuhan will implement fiscal and tax policies, arrange related special funds, and support the construction of key projects in energy-saving and emission reduction, capacity building and public communication. Also, it will implement such policies as income tax preferential, value-added tax preferential for comprehensive use of resources, income tax preferential for contract energy management project in those enterprises that use special device in environmental protection, energy and water saving.

5) Improve the energy conservation supervision mechanism. Wuhan will strengthen the energy conservation supervision of those key energy-using units, and jointly enforcement of departments in energy conservation supervision, economy and informationization, environmental protection, urban and rural construction, commerce, industry and commerce, quality supervision and security supervision. Explore the introduction of the fourth party mechanism into the city's carbon trading market to verify the reports issued by the carbon verification agencies and supervise the compliance performance of emission entities.

The city will strengthen the construction of regional energy conservation supervision institutions, by the end of 2020, it will have a full coverage of district energy conservation supervision institutions that can carry out energy conservation supervision work according to the law.

8. Strengthen Low-carbon International Cooperation

Wuhan will deepen the climate cooperation mechanism between China-U.S and China - Europe, continue to hold the China-France Forum on cities' sustainable development, and actively participate in international conferences on climate change to promote international cooperation. Wuhan will make full use of C40 city climate leadership platform to publicize its work on low-carbon development.

9. Complementary Measures

1) Strengthen the leadership. The low-carbon pilot city's leading working group should plan and coordinate the city's carbon peaking work. Each district and related department follow its work responsibilities, and formulates carbon-control friendly policies in investment, finance, taxation, price, trade, technology and so on, try their best in their carbon control work, and ensure each work task has assignment, supervision, implementation and results.

2) Strengthen evaluation and review. The low-carbon pilot city's leading working group evaluates and reports the completion of each department's carbon emission peak operations every two years and urges the one that lag behind the targets to finish the task by a deadline. At the end of the project (the year of 2022), the group will assess the accomplishments of each department's goals and tasks, taking it as an important part of comprehensive assessment evaluation for all districts, departments, leading bodies and leading cadres.

3) Strengthen policy support. The city and district's finance departments should increase investment, co-ordinate arrangements for special funds for low-carbon development and guide all kinds of funds to invest in low-carbon and carbon emission reduction projects. Accelerate the integration of the existing special funds for finance and support such major projects as low-carbon development and demonstration projects of science and technology and industrialization by means of guidance, incentives, rewards or discount loans. Actively strive for the use of foreign governments, international organizations and other bilateral and multilateral funds to carry out low-carbon economy in the field of scientific research and technological development.

Annex 3: List of Wuhan Workshop Speakers and Discussants

Theme 1	**The Planning and Implementation of Wuhan's Carbon Peaking Policy Plan**
Nobuko Kajiura	United Nations Economic and Social Commission for Asia and the Pacific (ESCAP)
XIANG Dingxian	Wuhan Energy Conservation Supervision Center
YANG Li	innovative Green Development Program (iGDP)
Zhen Jin	Institute for Global Environmental Strategies (IGES)
Man Chi Lao	ICLEI East Asia Secretariat
LI Ting	Rocky Mountain Institute
YANG Xiu	National Center for Climate Change Strategy and International Cooperation (NCSC)
LIAO Cuiping	Guangzhou Institute of Energy of Chinese Academy of Sciences
ZHOU Yong	Institute of Science and Technology for Development of Shandong
LIU Jia	Shanghai Information Center
Theme 2	**Peer Cities Experience Sharing – Carbon Peaking Planning and Implementation**
WANG Zhigao	Energy Foundation
WANG Ke	Renmin University
SHI Xin	International Urban Cooperation (IUC) Asia
ZHANG Fan	Hunan Low-carbon Development Center
Jiyoung Cho	Incheon Climate & Environment Research Center
Jung Min YU	Seoul Energy Corporation
Theme 3	**Pathways of Carbon Peaking in Industry, Transportation and Buildings, Green Finance and Carbon Market**
XIANG Dingxian	Wuhan Energy Conservation Supervision Center
CHEN Ji	Rocky Mountain Institute
JIANG Xiaoqian	World Resources Institute (WRI)
YU Zhongyi	CITIC General Institute of Architectural Design and Research

GU Peiqin	China Sustainable Transportation Center
GE Xingan	Shenzhen Emissions Exchange Center
XU Shengnian	Global Environmental Institute
LI Ang	Innovative Green Development Program
ZOU Song	Office of Wuhan Building Energy Saving
QI Shaozhou	Wuhan University
ZHANG Gao	China Hubei Emission Exchange
Theme 4	**Discussion on Key Issues**
Mao Xianqiang	School of Environment, Beijing Normal University
Junko Akagi	Research Manager, IGES Kitakyushu Urban Center
ZHENG Jianjiao	Shenzhen Institute of Building Research
Masayuki Higuchi	Global Warming Prevention Division, City of Kitakyushu, Japan
HAN Wei	Energy Foundation
HU Min	Innovative Green Development Program