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The Role of Chinese Cities in Greenhouse Gas Emission Reduction

Stephanie Ohshita
University of San Francisco, sbohshita@usfca.edu

L Price

N Zhou

N Khanna

D Fridley

See next page for additional authors

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Authors
Stephanie Ohshita; L Price; N Zhou; N Khanna; D Fridley; X Liu; and China Energy Group, Lawrence Berkeley National Laboratory

The role of Chinese cities in greenhouse gas emission reduction

Briefing on urban energy use and greenhouse gas emissions

Prepared by Stephanie Ohshita, Lynn Price, Nan Zhou,
Nina Khanna, David Fridley, and Xu Liu
China Energy Group, Lawrence Berkeley National Laboratory

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Stockholm Environment Institute
U.S. Center – Seattle Office
1402 Third Avenue, Suite 900
Seattle, WA 98101
USA
Tel: +1 (206) 547-4000
Web: www.sei-international.org

Stephanie Ohshita
University of San Francisco
Visiting Researcher in the China Energy Group, Lawrence Berkeley National Laboratory

Lynn Price, Nan Zhou, Nina Khanna, David Fridley, and Xu Liu
China Energy Group, Lawrence Berkeley National Laboratory
Author contact: Stephanie Ohshita, sbohshita@lbl.gov

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1. CITIES AND GREENHOUSE GAS EMISSIONS: CHINA IN A GLOBAL CONTEXT

Role of cities in global greenhouse gas abatement

Currently, 3.9 billion people live in cities, representing 54% of the world's population.[1] Cities, as hubs of fossil fuel-based economic activity, emit over 70% of global energy-related greenhouse gas (GHG) emissions. The world's 50 largest cities are collectively the third largest emitter of energy-related GHGs, after China and the U.S.[2] In many North American cities, transportation accounts for the largest share of emissions, while industry and buildings are major sources in many Asian cities. The rate of urbanization is accelerating in the world's most populous countries, with associated rapid and high-volume production of energy- and carbon-intensive building materials to construct urban infrastructure.

Impacts of climate change are already being experienced in cities, from severe storms damaging infrastructure, to droughts and floods, intensified heat waves, worsening smog, and other ecological and human health impacts.[3] Nearly 80 million Chinese city dwellers live in coastal zones at risk for sea-level rise, compared to 30 million in India and 20 million in the U.S.[4] Both as drivers of climate change and sites vulnerable to climate impacts, cities are at the forefront of pursuing energy-efficient and low carbon development.

Chinese cities in international and national contexts

China has more than 100 cities with a population greater than one million, and it has six of the world's mega-cities (population >10 million).[5] The administrative boundaries of Chinese cities are broad, and classification of cities is based on total gross domestic product (GDP), share of GDP in the tertiary (service) sector, and the non-agricultural population.[6] China has three levels of cities – provincial-level municipalities, prefecture-level cities, and county-level cities – all of which typically have heavy industrial-based economies that make a significant contribution to GDP as well as energy use and associated emissions.

In 2014, China's urban population reached 742 million, accounting for 54% of China's population and 10% of total world population.[7] In 2007, China became the world's largest emitter of energy-related carbon dioxide (CO_2).[8,9] Rapid urbanization has driven unprecedented economic growth, but also resulted in significant energy consumption and CO_2 emissions. In 2010, China's urban residents on average were responsible for energy-related CO_2 emissions of about 7 tons of CO_2 emissions per capita (tCO_2/capita).[10] The growing city of Wuhan increased from 9.7 tons of CO_2 emissions per capita (tCO_2/capita) in 2005 to 15.2 tCO_2/capita in 2011, while Shanghai's emissions remained relatively stable, growing slightly from 12.4 tCO_2/capita in 2005 and 13.1 tCO_2/capita in 2011.[11] In some large cities in China, CO_2 emissions per capita are higher than in European and North American cities. In 2013, emissions were 5.7 tCO_2e per capita in London and 8.3 tCO_2e per capita in Los Angeles.[12]

Key national policies and programs on energy and climate change

For the past decade, China has undertaken significant steps to reduce the energy- and carbon-intensity of its economy. Listed below are highlights of selected national policies, from promotion of renewable energy in electricity generation to energy conservation in industry.

- **China's Climate Change Goals (2015):** China announced its international climate pledge (Intended National Determined Contribution, or INDC) in June 2015. China's national goal is to peak CO_2 emissions around 2030, making efforts to peak sooner, to increase non-fossil energy to 20% of its energy mix by that same year, and to reduce the carbon intensity of its economy (CO_2 emissions per unit of GDP) by 60 to 65% from 2005 to 2030.[13]

- **Energy Conservation Law (2007):** China's Energy Conservation Law was enacted in 1990 and amended in 2007. The law covers energy conservation in the industrial, buildings, and transportation sectors and established a target responsibility and evaluation system for energy conservation through integrating the requirement to achieve energy conservation targets into the performance evaluations of local governments and their officials.[14]
- **Renewable Energy Law (2005) and Five-Year Plans (FYPs) for Renewable Energy:** China's 2005 Renewable Energy Law set the foundation for promoting renewable energy and China's Five-Year Plans expanded those efforts, including guaranteed grid connections, Renewable Portfolio Standards, a government wind concession program, and government financial support for renewable energy projects such as the Solar Roofs Program and Golden Sun Demonstration Projects.[15] China is on track to achieve its 12th FYP target of 11.4% non-fossil energy in 2015.
- **11th Five-Year Plan (2006–2010):** To address the surge in domestic construction and industrial production and associated dramatic increase in energy use and related emissions in the early 2000s, China set a national target to reduce energy intensity (energy use per unit of GDP) by 20% during the 11th Five Year Plan period. China's national Top-1000 Energy-Consuming Enterprises program was launched in April 2006 to help achieve the energy intensity reduction goal in the 11th Five Year Plan. The program targeted the largest 1,000 energy consuming industrial enterprises in the country. The energy savings of the participating enterprises surpassed the program savings goal by 50% and total CO_2 emission reductions from 2006-2010 were almost 400 million tons.[16] Overall, China achieved a 19.1% improvement in economic energy intensity during this period.
- **12th Five Year Plan (2011 – 2015):** The 12th Five Year Plan added a goal to reduce the carbon intensity (CO_2 emissions per unit of GDP) of the economy by 17% along with a national energy intensity reduction target of 16%.[17] The 12th Five Year Plan also strengthened and expanded implementation programs, such as the Top 10,000 Enterprises Program, which now includes around 17,000 enterprises responsible for 85% of China's industrial energy use and is expected to contribute nearly 40% of the savings required to meet the 12th FYP energy-savings target.[18]
- **Program for Low-Carbon Pilot Cities and Provinces (2010):** In 2010, China's National Development Reform Commission (NDRC) initiated eight low-carbon pilot cities: Tianjin, Baoding, Hangzhou, Chongqing, Nanchang, Guiyang, Xiamen and Shenzhen and five low-carbon pilot provinces: Yunnan, Guangdong, Hubei, Shaanxi, and Liaoning.[19] This followed an earlier effort by the Ministry of Housing and Urban/Rural Development (MoHURD) to promote urban sustainability through eco-city pilot projects. In 2012, NDRC added 28 cities and Hainan province to the low-carbon pilot program: Beijing, Shanghai, Shijiazhuang, Qinhuangdao, Jincheng, Hulunbuir, Jilin, Great Khingan area, Suzhou, Huaian, Zhenjiang, Ningbo, Wenzhou, Chizhou, Nanping, Jingdezhen, Ganzhou, Qingdao, Jiyuan, Wuhan, Guangzhou, Guilin, Guangyuan, Zunyi, Kunming, Yan'an, Jinchang, Urumchi.[20] China's low-carbon pilot cities have prepared climate action plans, conducted energy and GHG inventories, and developed local standards and incentives that go beyond national requirements.[21]

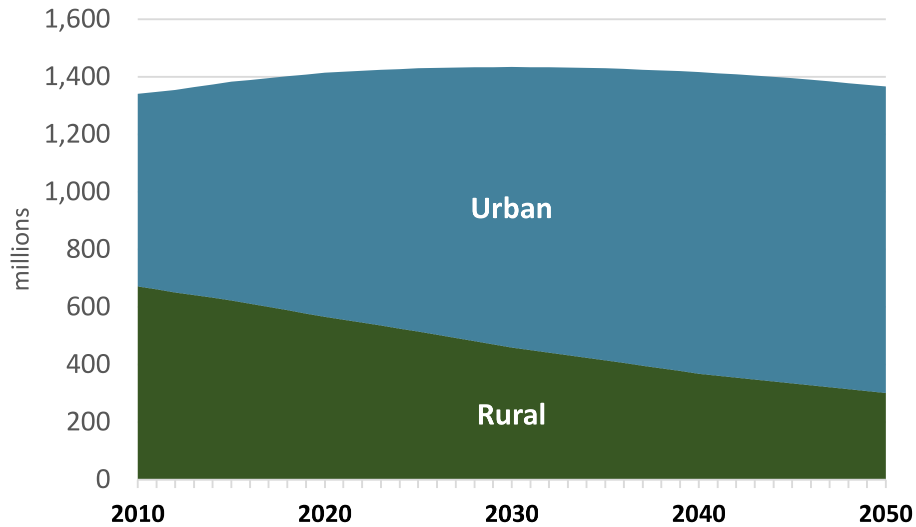
- **Program for Carbon Trading in Pilot Cities and Provinces (2011):** In 2011, NDRC identified five cities (Beijing, Chongqing, Shanghai, Shenzhen, and Tianjin) as well as two provinces (Guangdong and Hubei) to develop carbon-trading pilots.[22] In June 2013, Shenzhen started carbon trading and by June 2014 when Chongqing started its pilot, all 7 pilots had been initiated. By the end of October 2014, the 7 pilots had traded 13.75 $MtCO_2$ with a total transaction volume of over 500 million Yuan.[23] These pilots will accumulate experience and inform the design of a national carbon trading to be developed during the 13th Five Year Plan period.[24,25]

2. TRENDS IN CHINA'S URBAN ENERGY USE AND CO_2 EMISSIONS

Rapid urbanization

China is experiencing an unprecedented migration from rural areas to cities. By 2011, more than half of China's 1.3 billion population was already living in cities,[26] and China's 2014 *Urbanization Plan* targets increasing that share to 60% by 2020.[27] The urban population is expected to increase by 305 million between 2015 and 2050,[28] nearly the population of the United States, and a large share will be migrants from the countryside. Figure 1 illustrates these population trends.

Figure 1: China's Urban and Rural Population Trends (2010–2050)



Source: National Bureau of Statistics (NBS), 2012. China Statistical Yearbook.

Large-scale urban construction

Chinese cities experienced a construction boom over the past decade, driven in part by stimulus funding after the 2008 global financial crisis but also driven by the migration of rural Chinese to urban areas. To accommodate the huge influx of urban residents, an estimated 40 billion square meters of additional floor space will be built from 2005 to 2025, in five million buildings, 50,000 of which could be skyscrapers, the equivalent of ten New York Cities.[29] The magnitude of this urban construction could be reduced if construction quality improves and building lifetimes increase, and as per capita floor space declines with increasing population density.

Urban footprint

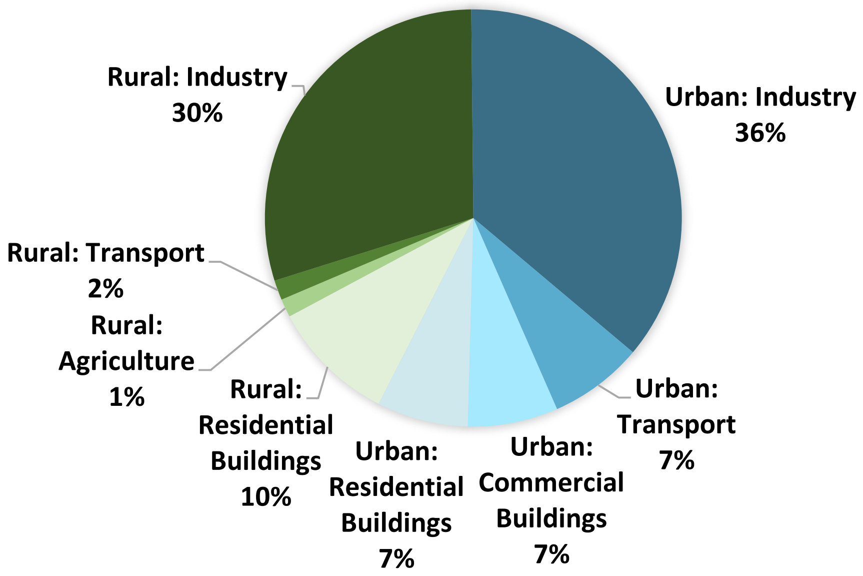
Not only is a larger share of China's population living in cities – urban residents are consuming more commercial energy per capita than their rural counterparts,[30] due to rising income levels and greater amenities. The average urban dweller emitted 1.4 times as much energy-related CO_2 as a rural resident. Focusing on just the buildings and transport sectors, urban residents emit 1.7 times as much as rural residents, on average. Figure 2 shows the relative shares of urban and rural energy-related CO_2 emissions in China, by sector. In 2010,[31] the urban and rural populations were nearly equal, but the urban share of national CO_2 emissions was higher, at 58%.

Why the higher per capita emissions in Chinese cities? Transportation and commercial buildings have greater activity in urban areas, contributing a larger share of total emissions. Rural residential buildings are responsible for more CO_2 emissions per capita than their urban counterparts, due to larger floor space per person and greater use of coal in heating, but rural transport contributes less than urban transport. The larger share of urban industry increases the footprint of Chinese cities.

Industrial cities

In both urban and rural areas, the industrial sector is by far the dominant source of CO_2 emissions (see Figure 2). Urban industry accounted for 36% of national emissions, while rural industry accounted for 30%; in total, industry had a 66% share of China's national energy-related CO_2 emissions in the year 2010. Within Chinese cities, on average, industry had a 62% share of CO_2 emissions. While national industrial policy is essential for holding industry to common performance standards, Chinese cities play an important role in furthering GHG reductions in industrial enterprises under their jurisdiction.

Figure 2: China Urban and Rural CO_2 Emissions by Sector, 2010



Source: Based on LBNL calculations using the Reinventing Fire: China model.

3. CHINA URBAN GHG EMISSIONS AND ABATEMENT POTENTIAL

Urban energy use

China's cities are heavily reliant on fossil fuels to power and heat buildings, fuel transport systems, and run urban manufacturing facilities. In 2010, coal and coke accounted for 45% of total urban energy consumption, followed by 25% oil consumption and 6% natural gas use (Figure 3). Electricity, which provided roughly 20% of urban final energy, is mostly produced by fossil fuels, with 75% produced by coal and 1% by natural gas. Non-fossil sources of urban electricity are 20% hydropower, 2% nuclear, and 2% other renewables like solar and wind.

Most of the coal and coke consumed by China's cities is used by the industry sector, which is responsible for 56% of urban primary energy. China's urban residential and commercial buildings account for 27% of urban primary energy use, which is mostly heat and electricity, both of which are predominately produced by coal. Urban transport is responsible for 17% of primary energy use, the bulk of which is oil consumption (Figure 4).

Figure 3: China's Urban Final Energy Use Mix, 2010

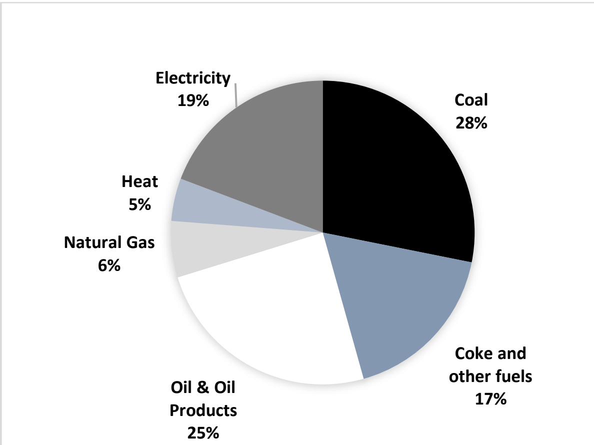
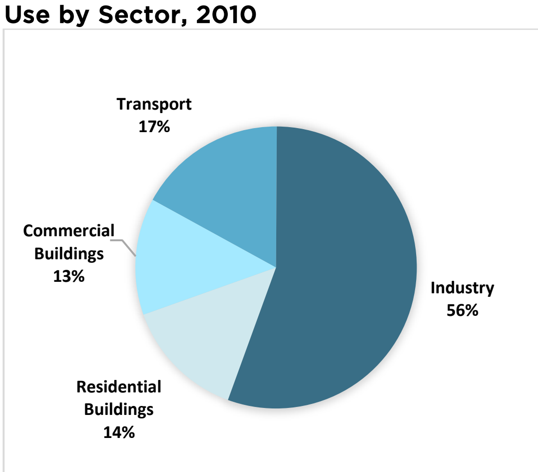


Figure 4: China's Urban Primary Energy Use by Sector, 2010



Source: Based on LBNL calculations using the Reinventing Fire: China model.
Note: Electricity is composed of 75% coal generation, 20% hydropower, 1% natural gas generation, 2% nuclear power and 2% other renewable power.

Urban GHG emissions and abatement potential

China does not have an official annual GHG emissions inventory; the country's most recent inventory is for 2005.[32] Even so, many international organizations have used China's annual energy statistics to calculate energy-related CO_2 emissions. These calculations, however, are typically at the national level and do not provide a breakdown of emissions at the city or provincial level.

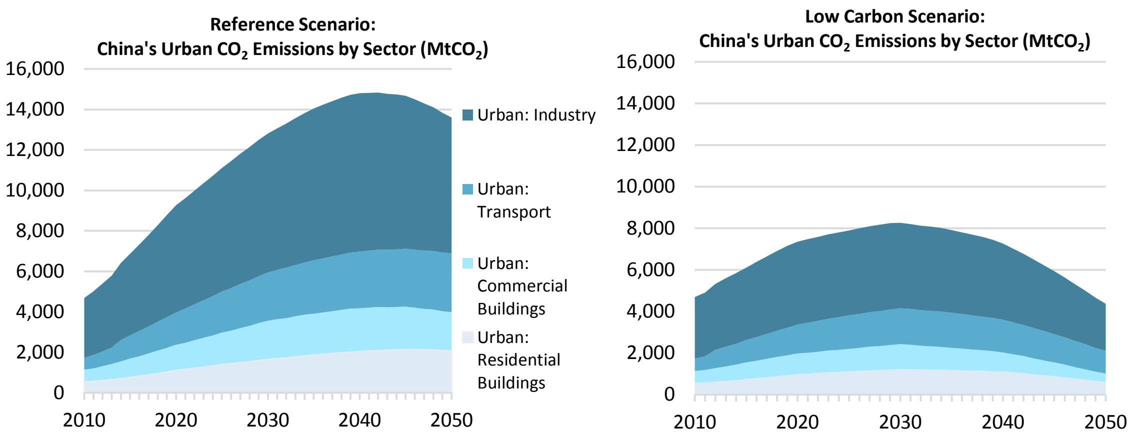
In 2011, the National Development and Reform Commissions (NDRC) Climate Change Department published guidance on provincial-level GHG emissions inventory methods, with recommendations for city-level inventories.[33] NDRC has worked with the low-carbon pilot cities, the national Energy Research Institute (ERI), the Institute for Urban and Environmental Studies of the Chinese Academy of Social Sciences (CASS), and international partners to develop city-level protocols that are consistent with Chinese provincial guidelines and international methodologies.[34]

While individual cities have conducted energy and GHG emissions inventories, there is not yet a systematic gathering or publishing of city-level GHG data in China. In addition, the rapid pace of urbanization means that emission trends across Chinese cities and across urban sectors are changing quickly. Thus the information here provides snapshots in time, illustrative examples, and future scenarios of urban GHG emissions – and the potential for cities to contribute to overall national emissions reductions.

China's urban energy-related CO_2 emissions were dominated by industrial emissions from manufacturing facilities, industrial parks, and even heavy industries such as cement and steel plants located near cities, representing 62% of urban CO_2 emissions in 2010. Buildings represent about a quarter of urban CO_2 emissions, divided relatively evenly between residential and commercial/public buildings, while about 13% of emissions were from transportation energy use.

What are the possibilities for energy and CO_2 emissions reductions in China's cities in the future? Figure 5 presents two scenarios from the year 2010 to 2050 for China's urban areas: a Reference Scenario in which only current policies are in place and autonomous energy efficiency improvement occurs and a Low Carbon Scenario in which commercially-available cost-effective technologies are employed to their fullest. The scenarios are based on bottom-up drivers of energy consumption and energy-related CO_2 emissions, such as population and urbanization, economic growth, building floor space, infrastructure, net exports, and other variables.

Figure 5: China Urban CO_2 Emissions by Sector (2010–2050): Reference Scenario and Low Carbon Scenario



Source: Based on LBNL calculations using the Reinventing Fire: China model.

If China's cities follow the Reference Scenario pathway, then urban CO_2 emissions will more than triple by 2042, when they begin to decline as population growth peaks in China and urbanization slows. Alternatively, if China's cities aggressively pursue low-carbon options – improving the energy efficiency of manufacturing facilities, commercial and residential buildings, and transportation in cities as well as pursuing options to reduce overall demand, move away from energy-intensive manufacturing, and switch to lower carbon fuels – urban CO_2 emissions could peak in 2030 at a level that is not even double the level of 2010 emissions, then decline to levels below those of 2010 CO_2 emissions by 2050.

Both scenarios are dominated by industrial energy-related CO_2 emissions, which is a unique characteristic of Chinese cities. As such, much of the mitigation potential for Chinese cities is found in the industrial sector, followed by commercial buildings, residential buildings, passenger transport, and freight transport, respectively. Urban CO_2 abatement strategies need to be designed to address the relative importance of these different sectors along with the city's ability to enact, manage, and enforce specific policies and programs.

4. SOCIO-ECONOMIC BENEFITS OF URBAN CLIMATE ACTION

Chinese cities face multiple challenges during rapid urbanization, including financing, air quality, and development of new neighborhoods and social services for urban migrants. Low-carbon development can be carried out in ways that support these urban priorities, as well as reduce GHG emissions.

Urban finance and land management

One of the most significant challenges to urban planning and climate action in China is limited urban finance. Chinese cities have traditionally relied on revenue from sales of public land, since much of the tax revenue goes to the central government.[35]

- *Establishment of property taxes and re-distribution of other taxes[36] would allow municipalities to better plan, invest, and maintain services and infrastructure.*

Urban migration, housing and social services

For many years China has lifted millions of people out of poverty, with the *hukou* system of tracking population origin and land rights, and the *danwei* system of job assignments and housing. With rapid urban migration and a more mobile workforce, social services are lagging behind housing for urban migrants.[37]

- *Better provision of social services can also address a key feature of resilient, low-carbon cities: proximity of daily amenities (food, healthcare, education, jobs, social activities), reducing the need for energy-intensive transport. Construction of energy efficient buildings and maximizing the use of renewable energy, is also crucial for controlling growth of urban energy demand and related emissions.*

Air, health, and quality of urban life

Severe air pollution in Chinese cities, in the form of smog and haze, is of great concern as 1.6 million premature deaths per year are attributed to air pollution.[38] Air pollution, especially from fine particulate matter ($PM_{2.5}$) has become the fourth largest risk factor for non-communicable disease in China.[39] In 2012, the 12th FYP for Air Pollution Prevention and Control announced tougher controls on air pollution. In 2013, the State Council announced implementation details in a new *Air Pollution Prevention Plan* and established a network of 500 $PM_{2.5}$ monitors across 70 Chinese cities. The five-year (2013–2017) Plan calls for at least a 10% reduction of PM_{10} in cities across the country, placing the strictest standards on three industrial-metropolitan areas, calling for reduction of $PM_{2.5}$ levels of 25% in the Beijing/Tianjin/Hebei (BTH) area, 20% in the Shanghai/Yangtze River Delta (YRD), and 15% in the Guangzhou/Pearl River Delta (PRD) area.[40]

- *Centering urban design around mixed-use (but non-industrial) neighborhoods, with amenities and public transit within biking and walking distance, will help clear the air and enhance the quality of urban life. This approach is especially needed as rising temperatures and shifting rainfall patterns due to climate change exacerbate the formation of smog and particulate air pollution.*

Resilient, low-carbon socio-economic development

China's central government is encouraging domestic consumption, to shift away from an industrial export economy, toward a service-oriented economy.[41] At the same time, urbanization is shifting social demographics and consumption patterns.

- *More attention to low-carbon socio-economic development can enable China's cities to better manage climate change impacts, as well as save energy and reduce energy-related emissions.*

5. NEXT STEPS IN URBAN LOW-CARBON ACTION

Early analysis on the performance of China's low-carbon pilot cities finds they are making progress in decreasing the carbon intensity of their economies, as CO_2/GDP declined from 2010 to 2015. However, the estimates show that total and per capita CO_2 emissions are still increasing.[42] Though it is common for per capita energy consumption to rise in developing countries as prosperity increases, Chinese cities will need to reverse this trend to achieve low-carbon status.

Several strategies for GHG abatement are being explored through low-carbon city pilots and other initiatives in China. While the pilot efforts are showing progress, further climate action is needed at the local – and national – levels to enable Chinese cities to achieve desired savings of CO_2 and other GHGs.[43] Enhanced urban planning and financing, and development of institutions and data gathering systems, are needed along with implementation of technologies and policies.

Integrate low-carbon action in urban planning and development

There are a number of key steps to ensure successful low-carbon action in urban planning and development at the city level (Figure 6). Many cities in China have shown leadership by participating in low-carbon or eco-city efforts. International experience shows that commitment by city mayors and other leaders is crucial, because low-carbon development involves nearly all city operations. City low-carbon development and sustainability efforts must be integrated with regular city planning efforts to be effective. In addition, a strong administrative team is needed, including managers ("change agents"), dedicated staff, community support groups (with active public participation), and knowledge partners (universities and research institutes).[44]

Figure 6: Key Steps for Low-Carbon Urban Planning and Development

Chinese cities have been analyzing their energy use and GHG emissions and reporting their inventories, energy intensity, and carbon intensity. With knowledge of their emissions, cities are identifying potential energy savings and emissions reductions in order to set specific targets. City-level GHG target-setting in China has focused on carbon intensity (CO_2/GDP), in line with the national target in the 12th FYP. Carbon intensity targets range from 15% to 50% reduction from 2005 levels by 2020. Fewer Chinese cities have set absolute reduction targets for CO_2 emissions.[45] In contrast, U.S. cities with climate action plans have set GHG emission reduction targets. Example targets include Chicago's commitment to reduce GHG emissions 25% from 1990 levels by 2020; New York City's pledge of 30% reduction from 1990 by 2030; and the Austin, Texas, goal of net zero emissions by 2050.[46]

The remaining sections of this brief highlight key strategies and policies for Chinese cities, including examples of efforts already underway. The final step in low-carbon development is to monitor and evaluate progress, providing feedback to the leadership so that strategies can be modified and strengthened as needed. A systematic reporting and publishing of urban GHG data and indicators in China would enable benchmarking within and across cities, to track progress toward a low-carbon urban future.

Enhance industrial energy planning, target-setting, management, audits and incentives

Industrial energy use is a significant contributor to urban CO_2 emissions in China, and city efforts are critical to reducing industrial energy use and related emissions. Chinese cities are tasked with implementing national and provincial industrial requirements, such as 12th FYP industrial targets for reducing energy intensity and carbon intensity.[47] Cities may establish stricter standards or additional programs for industrial enterprises under their jurisdiction to achieve these targets. For urban industrial GHG savings, Chinese cities can: develop an industrial energy plan and set targets for industrial energy efficiency improvement, require enterprises to adopt energy management standards and train energy managers, provide technical assistance for energy audits of industrial facilities, and establish financial mechanisms to assist enterprises in implementing energy efficiency and emissions reductions measures.

Industrial energy plans: Local governments and industrial enterprises can use an energy plan to set an overall industrial energy-saving target in the region or industrial sub-sector – such as targets for iron and steel enterprises in the cities of Laiwu and Jinan, Shandong province – and providing guidance for implementation. Chinese cities also support implementation of national industrial energy plans, such as the 12th FYP target for Waste Heat Recovery on 65% of clinker capacity in the cement sector.[48]

Energy management systems: Energy management is a key means for industrial enterprises to improve an organization's energy performance, control energy costs and, ensure compliance with energy efficiency legislation. China first published its national energy management standard in 2009, then revised it to the Management System for Energy – Requirements and User Guidance in 2012, in order to be compatible with the International Standard Organization ISO 50001 Energy Management Standard issued in 2011. China has been developing guidance and training to enable provincial and local government agencies to better implement energy management plans and meet 12th FYP targets in the Top 10,000 Enterprises program. The NDRC and the Certification and Accreditation Administration (CNCA) are developing requirements and guidance for local energy conservation authorities and local certification regulatory departments to implement and monitor performance of energy management systems in the Top 10,000 enterprises.[49]

Circular Economy and By-Product Synergy

The circular economy approach to resource-use efficiency integrates cleaner production and industrial ecology in a broader system encompassing industrial firms, networks or chains of firms, eco-industrial parks, and regional infrastructure to support resource optimization. Inspired by Japanese and German Recycling Economy Laws, China formalized aspects of the circular economy concept in the Circular Economy Promotion Law. According to the law, the term "circular economy" is a generic term for the reducing, reusing, and recycling (3Rs) activities conducted in the process of production, circulation, and consumption. By-product synergy activities between industrial enterprises are important components to achieve a circular economy. By-product synergy (BPS) projects utilize wastes from certain industrial facilities as inputs to other facilities, leading to operational savings, improved energy efficiency and environmental performance, and reductions in CO_2 emissions. In 2012, the Bohia By-Product Synergy Project was initiated in Qinhuangdao in Hebei Province, China as one of the U.S.-China EcoPartnership projects.[50]

Energy audits and assessments: Conducting an energy audit or assessment of an industrial enterprise involves collecting data on the major energy-consuming processes and equipment in a plant as well as documenting specific technologies used in the production process and identifying opportunities for energy efficiency improvement. To enhance implementation of Chinese industrial energy audits in the Top 10,000 Enterprises program during the 12th FYP, NDRC issued the Technical Principle of Energy Audits in Enterprises (GD/T17166).[51] For Chinese industry, there are a variety of experts that can provide energy auditing services including private consulting firms, energy service companies, provincial energy conservation centers, and the China Energy Conservation Association (CECA). The technical expertise and abilities of these organizations varies widely, with some highly skilled in energy auditing and others in need of significant training. The energy conservation centers in Sichuan, Jiangsu, and Henan provinces are known for their strengths in energy auditing, while Shanghai and Shandong energy conservation centers are well qualified in energy conservation work.[52]

Suzhou's Energy Efficiency Star Program

The Suzhou Energy Efficiency Star Program ranks participating manufacturing enterprises on a scale of 1 (low) to 5 (high) stars to indicate their energy efficiency level.[53] The ranking is based on compliance with legal requirements, energy performance criteria (including energy consumption per unit product, energy savings projects, etc.), implementation of energy management systems, reporting on energy consumption, and efficiency level of energy-consuming technologies and processes in the facilities. The Energy Efficiency Star rating is valid for 3 years with a mid-term assessment conducted by the Suzhou Energy Conservation Center. In addition, the Center provides technical assistance to the participating enterprises through workshops and trainings related to energy audits, energy efficiency, and industry-specific energy-efficiency technologies. In 2013, the City of Suzhou was awarded an Energy Efficiency Visionary Award by the Alliance to Save Energy for its outstanding contribution to modernizing the city through the promotion and implementation of energy efficiency and demand side management programs. Suzhou's Energy Efficiency Star Program and its energy audit and retrofit program were highlighted, noting that these combined efforts are estimated to save 7.32 million tons coal equivalent (Mtce) annually.[54]

Financial incentives: To incentivize use of energy audits or assessments as well as adoption of recommended energy efficiency technologies and measures, fiscal incentives, such as fiscal rewards, energy efficiency loans and funds, or tax relief can be provided. Other policies, such as a national or sub-national energy or CO_2 taxes or differential electricity pricing could also incentivize industrial plants to achieve higher savings through conducting energy audits and implementing the recommended energy-saving measures. Subsidies and rewards can also be used to conduct energy benchmarking, implement recommended measures from energy audits/assessments, meet stretch targets, and invest in energy-efficiency projects in low-carbon industrial parks.

Localize and de-carbonize energy supply

Electricity supplies just under 20% of China's urban energy mix (in terms of final energy, see Figure 3), with 58% of electricity used by urban industry, 41% in urban buildings, and 1% in urban transportation.[55] Considering that 75% of that electricity is coal-fired, the effect of electricity on urban primary energy use and CO_2 emissions is much higher. Improving efficiency of electricity use in urban industry and buildings, and de-carbonizing electricity supply, are therefore important strategies. Yet cities have limited control over their electricity; China's power sector is dominated by five regional electricity grids under the State Grid Company and the China Southern Grid Company. National reform of the electric power sector could enable distributed power generation and enable cities to choose renewable electricity.[56] Specific policies to de-carbonize electricity supply include: prioritizing renewable energy in electricity dispatch; pricing signals that encourage renewables; direct contracting or Renewable Energy Credits (RECs) for low-carbon urban electricity supply; and renewable energy targets such as Renewable Portfolio Standards (RPS).[57] To de-carbonize the electricity supply, China has set 2015 and 2020 goals to increase renewable energy installed capacity, including targets for 100 GW (2015) and 200 GW (2020) of wind, 35 GW (2015) and 100 GW (2020) of solar, and 350 GW (2020) of hydropower. As of 2014, China's installed capacity of on-grid wind power is 95.81 GW, of solar is 28.05 GW, and of hydro is 300 GW.[58]

Direct use of coal, oil, and other fuels accounts for an even larger share of urban energy and CO_2 emissions than electricity in Chinese cities, with coal at 28% of final energy, oil and oil products at 25%, and coke and other fuels at 17% (see Figure 3). Since urban industry dominates coal use (70%) and use of coke and other fuels (nearly all), improved efficiency, fuel switching, and increased use of renewable energy are all needed for the industrial sector. Within the buildings sector, 34% of final energy use comes from coal, highlighting opportunities for electrification with renewable energy, solar thermal water heating, improvement of thermal efficiencies, the use of combined heat and power (CHP), and the upgrade and maintenance of district heating networks.

Differential electricity pricing and power contracting

Differential electricity pricing is being explored as a strategy for encouraging energy conservation, as are options for carbon fees. Pilot programs in power contracting directly between provinces and electricity generators are being tested, along with a city-level pilot program in Shenzhen on opening up the grid to new generating companies.[59] In Guangdong, Shanghai and Fujian, differential electricity prices were introduced on June 1st, 2010 to eight heavy industries in response to the central government's call to promote energy efficiency.[60] The three local governments also used a punitive pricing policy on those energy-intensive enterprises, which exceed the national and local standards on minimum energy performance for industrial products.[61]

Trend toward green, low-energy buildings

With the rapid growth in urban commercial and residential buildings in China, cities can pursue numerous policies and programs to hasten progress toward green, low-energy energy buildings.[62] At the national level, China has made progress with building energy efficiency codes for large urban residential construction, with requirements tailored to three climate zones.[63] Cities can implement more stringent local building energy codes that specify requirements for thermal resistance in the building shell and windows, minimum air leakage, and minimum heating and cooling equipment efficiency. Experience has shown that building efficiency can be improved with modest or no increases in up-front project costs. For large cities that have numerous municipal buildings, establishing a municipal building energy-efficiency task force and standards has accelerated implementation of energy-efficiency improvements in government buildings.

Buildings designed to maximize the use of passive energy and integrative design have substantially lower energy consumption than conventional buildings due to increased use of envelope insulation, high-performance windows, infiltration control, natural ventilation, and daylighting. Improving construction quality and extending the lifetime of buildings reduces overall demand for energy-intensive construction materials. Building energy rating or performance labels can be used to compare a building's energy performance to that of other similar buildings, to provide information for endorsement labels such as the U.S. ENERGY STAR label for new homes and commercial buildings, and can provide information to potential buyers or tenants prior to a sale or rental. City-specific green building guidelines or certification programs can encourage construction of green buildings and use of green building technologies. Local governments can prioritize green buildings at low or no cost by making simple modifications to the building project review process to expedite permitting of green projects. Local and city governments can promote installation of distributed generation in new or existing buildings by providing financial incentives such as preferential loans, rebates, subsidies, or grants to building developers or owners.

Leadership in building energy efficiency in Chinese cities

Tianjin's leading local building energy code. Tianjin adopted one of China's first mandatory local residential energy codes in 1997, followed by a 30% more stringent revised code in 2004 with international assistance.[64] Compared to the baseline of inefficient 1980s buildings, Tianjin's 2004 building energy code required 65% reduction in heating intensity. The 2004 building energy code was further strengthened in 2007 with the addition of provisions for efficiency improvements such as cooling and ventilation, sun shading and structural integrity. Tianjin has also adopted a third-party compliance approach to oversee implementation and enforcement of the building codes, with close to 100% reported compliance rates by 2008.

The Building Energy Conservation Codes of Tianjin, effective July 1st, 2012, stipulate that renewables such as solar and ground source heat pump should be the prioritized energy sources for heating, cooling, water heating and lighting for new buildings; meanwhile, the use of renewables should be integrated into building design, construction and inspection all the way. Annual savings from Tianjin's more stringent building energy code is estimated to have save 870 GWh and 400,000 metric tons of CO_2 emissions per year. The more stringent local building code has also proven to be cost-effective, with low incremental costs and estimated short payback period of 5 to 7 years.

High-performance office building in Shenzhen[65,66] The office building of the Shenzhen Institute of Building Research (IBR) is a high-performance green commercial building that maximizes whole building system energy efficiency through the use of passive, low-cost, and soft energy efficiency technologies, such as pre-fabricated building materials, shading, and passive airflow. By employing both simple design tactics and complex technological systems, the building reduces about 1,622 tons of CO_2 emissions per year. IBR's performance has enabled a 58% reduction in CO_2 emissions compared to conventional buildings and has the potential for an 80% reduction if the building is able to produce excess energy that can be fed into the power grid. The Shenzhen IBR building uses one third less energy per square foot than the average energy use of 22 green federal buildings in the U.S.[67] Additionally, the construction cost of IBR Building is lower than that of a typical office building. It is certified as a 3 Star Green Building, the highest level in the Chinese certification system.[68]

Low-carbon urban form and transportation

Low-carbon strategies for the transport sector go beyond efficiency and electrification of vehicles. The foundation for low-carbon transport is an urban form that promotes walking and biking, provides easy access to public transit, and reduces vehicle trip length and total vehicle kilometers traveled (VKT). Trip lengths and VKT are reduced with mixed-use zoning and appropriately-sized block development, by requiring transit-oriented development and inclusion of services near housing developments. Analysis of Chinese urban form in the city of Jinan found that superblock developments lead to much higher VKT, using three to four times the amount of automobile energy than in traditional urban village form or mixed-use enclave urban form.[69] Clustered (articulated) densities, also known as hub and spoke pattern of development, can reduce VKT and promote public transit,[70] as well as enable district-level energy services with renewable energy. Clustered densities also protect agricultural land. On land that is used for commercial development, cities can encourage a low-carbon economy by prioritizing land leases to less energy-intensive enterprises in the service sector.[71] Freight transport of goods both to cities and within cities – which is a major cause of both congestion and local air pollution - can be optimized through better logistics, improving load factors, and switching to hybrid or electric urban delivery vehicles.

Low-carbon transport initiatives in Chinese cities

Integrated transit in Guangzhou: Integration of public transit with walking and biking is the key to low-carbon transportation. After years of coordinated planning, in February 2010, Guangzhou opened 22.5-kilometers of Bus Rapid Transit (BRT), the first BRT in Asia connected with the metro rail system.[72] The Guangzhou BRT system also includes bicycle parking in its station design and a greenway parallel to the corridor, integrating the city's bike share program of nearly 5,000 bicycles and 50 bike stations.[73] Within 18 months of opening the BRT, Guangzhou achieved the world's highest rate of BRT passengers—805,000 daily boardings—carrying more passengers per hour than any mainland Chinese metro outside of Beijing, and tripling the capacity reached by other BRT in Asia. The efficiency improvements from BRT have reduced travel time for bus riders and motorists along the route by 29% and 20%, respectively. The fuel savings will in turn save 86,000 tCO_{2e} annually. [74]

Beijing boosts bicycles: Beijing nearly doubled its number of bicycles for rent, to 25,000 in 2013, with plans to add more, in an attempt to cut air pollution and traffic congestion in the city. The bikes are free to rent for the first hour, then are charged at 1 yuan (16 cents) for each additional hour. The maximum expense for a full day is no more than 10 yuan ($1.6 USD), and people can only rent a bike for a maximum of three days each time. People with an ID card or passport can register at designated places and deposit 200 yuan ($32 USD) to allow them to use their regular transport card to access the service.[75]

Limiting automobile licenses to ease congestion – and reduce emissions: Shanghai's practice of auctioning license plates has controlled the number of automobiles near 2 million and kept traffic flowing, although only the wealthy can afford the auction. In contrast, Beijing's past policy of allowing access to certain license numbers on certain days did not sufficiently control traffic, and roads jammed with more than 5 million cars.[76] Guangzhou has learned from these experiences, and is implementing a combination of auction and lottery for automobile licenses.[77] This approach will reduce traffic, save CO_2, and enable more equitable access to licenses. Several Chinese cities are now exploring the use of license restrictions as well.

Conclusion

Globally, cities are at the forefront of action on climate change and low-carbon economic development. Chinese cities have an especially large role to play during rapid urbanization, to quickly choose and implement low-carbon urban design and infrastructure options that will have long-lasting effects on the country's GHG emissions. The largest potential for GHG savings is in urban industry, with efforts to improve energy efficiency and ease demand. Tougher building efficiency standards, leveraging of passive design strategies, and incorporation of distributed renewables can achieve further savings. A shift in urban development patterns – away from superblocks and toward mixed-use clusters with walking, biking, and public transit – can avoid an upswing in transport sector CO_2 emissions and harmful air pollution. An accelerated transition to renewable electricity, solar water heating, and combined heat and power will contribute to savings in all city sectors. National reform in the power sector is needed to support city efforts. Finally, the strengthening of reporting, benchmarking, public engagement, and management structures will enable China to achieve both local and national low-carbon urban development goals.

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