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Nan Zhou, Stephanie Ohshita, Lynn Price, Nina Zheng
China Energy Group
Environmental Energy Technologies Division
Lawrence Berkeley National Laboratory

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A Low Carbon Development Guide for Local Government Actions in China

Nan Zhou[a1], Stephanie Ohshita[a2], Lynn Price[a3], and Nina Zheng[a4]

a. Energy Analysis Department, Environmental Energy Technologies Division, Lawrence Berkeley National Laboratory, Berkeley, California 94720, USA
1. Scientist, China Energy Group; Tel.: +1 510 486 5534; Fax: +1 510 486 6996; E-mail: nzhou@lbl.gov
2. Visiting Faculty, China Energy Group and Associate Professor, Department of Environmental Science, University of San Francisco; Tel.: +1 510 486 5062; Fax: +1 510 486 6996; E-mail: sbohshita@lbl.gov
3. Staff Scientist, China Energy Group; Tel.: +1 510 486 6519; Fax: +1 510 486 6996; E-mail: lkprice@lbl.gov
4. Senior Research Associate, China Energy Group; Tel.: +1 510 486 4537; Fax: +1 510 486 6996; E-mail: xzheng@lbl.gov

Abstract

Local level actions are crucial for achieving energy saving and greenhouse gas emission reduction targets. Yet it can be challenging to implement new policies and actions due to a lack of information, funding, and capacity at the local level—especially in developing countries such as China. Even though the Chinese government has set national energy and carbon intensity reduction targets, most local governments do not have sufficient knowledge regarding actions to achieve the targets, effectiveness and cost of policies, or how to design and implement a low carbon development plan.

This article presents information for local governments on how to create an action plan to tackle climate change and increase energy efficiency. The research examines indicators that can be used to define low carbon development and to evaluate the effectiveness of actions taken. The guidance provides a step-by-step description of how action plans can be established and essential elements to be included—from preparing a GHG emission inventory to implementation of the plan. It also provides a menu of policies and best practices found internationally and in China to encourage low carbon development in industry, buildings, transportation, power, agriculture and forestry.

Executive Summary
Chinese Cities and Low Carbon Development China's new national carbon intensity target directs local governments to make energy-related greenhouse gas reductions in tandem with economic development, i.e., low carbon development. As this is China's first mandatory policy on carbon, all levels of government are searching for guidance and strategies to define and undertake low carbon development.
Low Carbon Indicators Indicators help to define, compare, and track progress toward low carbon development. Aggregated indicators include: CO2 per unit GDP, CO2 per capita, energy structure, etc. Sectoral indicators include: industrial carbon intensity, residential energy per m^2 floor space, CO2 per kWh of electric power, share of renewable sources in electric power supply, transport CO2 per person-km traveled, waste and recycling per capita, etc. Social and economic indicators include: population density, income distribution, share of green jobs
Steps for Low Carbon Development Planning Leadership Commitment Energy and Carbon Inventory Set Targets Choose Policies to Meet Targets and Develop a Low Carbon Development Plan Implement Policies and Actions Monitor, Report, and Verify Progress
Policy Measures for Low-Carbon Development Examples of policy measures are provided for the industry and buildings sectors

Key Terms

Low-Carbon City: A city that is actively and significantly lowering carbon emissions, even as its economy is maturing.
Low-Carbon Indicators: Metrics used to define a low carbon city, to help cities explore their potential for carbon saving, to evaluate progress in implementing low-carbon development actions, and to compare or benchmark across cities.
Carbon Intensity: CO2 per unit GDP

Introduction

Local level action and leadership are crucial for saving energy and reducing greenhouse gas (GHG) emissions. In regions with national energy-saving and GHG emission targets, local action helps to achieve those targets, such as efforts by European Energy Cities, Climate Alliance and Covenant of Mayors. In the absence of national targets, local action such as the U.S. Conference of Mayors Climate Protection Agreement can be even more essential. Other groups coordinating local action span the globe, including the International Council for Local Environmental Initiatives (ICLEI) Cities for Climate Protection (CCP) campaign and the C40 Cities Climate Leadership Group of the world's largest cities [101]. New methodologies and strategies are emerging daily, as cities search for local responses to the global problems of excessive energy consumption and climate disruption [1-3].

In China and elsewhere, innovative policies or practices can be relatively easily implemented at the local level because of the reduced scale and the possibility of exemption from national legislative bureaucracy. Local level actions can assist in proving the effectiveness of new policies or initiatives by demonstrating them at a smaller scale. Following success at the local level, the pilot policies or practices can be replicated to other localities or expanded to a national program. For example, China's Top-1000 Enterprise Program for energy saving drew upon the successful experience from a demonstration program implemented in two steel mills in Shandong province that was modeled after the voluntary agreements program in The Netherlands [4, 14].

In the US, many states, cities, and counties have forged ahead with dedicated funding and strategic policies to promote energy efficiency and renewable energy. Specifically, eleven states in the US have rebate programs for energy efficiency initiatives with a total of over one thousand state, local and utility rebate programs [102]. Additionally, all but three states have at least one tax incentive program for renewable energy development, including personal, corporate, sales and/or property tax incentives [102]. Beginning in 1974, California established energy efficiency standards for buildings and appliances, de-coupled electricity and natural gas utility profits from sales to promote demand-side management, and set ambitious energy efficiency and, eventually, GHG emission reduction targets [103-104]. As a result of these strong and innovative policies and programs, California's per capita electricity consumption has remained constant from the early 1970s to the present, and is currently about 40% less than the average per capita electricity use in the U.S. [105]. California's experiences have often been replicated or echoed in other states, and some of the policies eventually became national regulations. Many federal appliance standards today are the direct result of such state leadership [106]. In addition, the experience also demonstrates that the adoption of comprehensive energy and climate actions can stimulate the local economy and create green jobs [107].

Despite the importance of local action, local government agencies may find it challenging to initiate and implement new policies and actions due to a lack of information, funding, and capacity. This is particularly the case in China. Even though the Chinese government has committed to reducing carbon dioxide (CO2) emissions by 40% to 45% from 2005 levels by 2020 [108] and has set national energy intensity and carbon intensity targets as part of the 12^{th} Five-Year Plan (12^{th} FYP) [109] most local governments do not have sufficient knowledge regarding actions to achieve the targets, the cost effectiveness of policies, the possible impact of policies, or how to design and implement a low-carbon development plan.

Recognizing the importance of low-carbon development for achieving national goals, the Chinese government announced a policy for establishment of low-carbon cities and selected five provinces and eight cities as pilots in August 2010 [123]. The five provinces are Guangdong, Liaoning, Hubei, Shaanxi and Yunnan; and the eight cities are Chongqing, Shenzhen, Xiamen, Hangzhou, Nanchang, Guiyang, and Baoding. The policy outlines the following activities:

- Develop a low-carbon development plan
- Establish supporting policies to support low-carbon development
- Establish low-emission industries
- Establish GHG data collection and management systems
- Promote low-carbon/green lifestyle and consumption model.

The national policy recommends these activities, but does not give detailed guidance on how the pilot cities should undertake them. Thus it is unclear what measures will be adopted.

As more attention is being paid to low-carbon cities in China in response to the national-level emissions reduction goals, many cities and counties are following the trend toward low carbon development. However, there is no consistent definition of low carbon and specific indicators have not been developed to help define such cities. Some supposedly low-carbon cities built wide roads; although lined with beautiful trees, the roads encourage *more* vehicle use [110]. Some cities exclude imported electricity from their carbon accounting, giving a false impression of their energy use and carbon emissions [111]. Thus, it is important to clearly define indicators, standardize the development process, and identify policies, programs, technologies, and measures that can be undertaken to realize carbon emission reductions (or carbon intensity reductions) in participating cities.

This article presents information for local governments in China on how to create an action plan to tackle climate change and increase energy efficiency based on a guidebook developed by Lawrence Berkeley National Laboratory (LBNL) and China's Energy Research Institute (ERI) [5]. It provides a simple step-by-step description of how action plans could be established and essential elements to be included—from preparing a GHG emission inventory to implementation of the plan. The guidance also provides a list of pertinent policies and best practices internationally and in China to encourage low carbon development in industry, buildings, transportation, power, agriculture and forestry. Where available, the GHG emission reduction potential and cost-effectiveness of policies are also provided. This guidance does not intend to provide independent evaluation or analysis of the GHG emission reduction or cost-effectiveness of each policy, but rather to provide information for the development of a climate action plan and related policies based on existing literature, documents and reports.

Definition and Measurement: Low-Carbon City Indicators

Indicators can be used to define a low-carbon city, to help cities explore their potential for carbon savings, to evaluate progress in implementing low-carbon development actions, and to compare or benchmark across cities. The LBNL/ERI effort to develop low-carbon indicators for Chinese cities began with identifying indicators that are commonly used in benchmarking programs, energy and GHG inventories, and ranking systems around the world. The next step was to assess the availability of data needed to determine metric development priorities. Finally, the adaptability of existing indicators to China was examined, as well as the relative importance of indicator categories.

China has committed to energy and carbon intensity targets for the 12th Five Year Plan and a carbon intensity target for 2020. These targets are being disaggregated to provinces, cities and counties. However, the targets need to be further disaggregated by sector at the local level to evaluate the energy and carbon savings potential and to develop specific action plans. Indicators need to be identified to measure and track trends in GHG emissions or energy consumption.

Indicators can track information at the macro-level (aggregated indicators) as well as at the disaggregated level. A macro-level indicator can give an overall sense of a city's energy efficiency, or to what extent a city is low carbon. While aggregated indicators are fairly simple and allow for broad comparison, they do not isolate physical, structural and behavioral influences. In contrast, disaggregated sector-level indicators can provide far more information and can serve as the foundation for future planning and actions. However, the indicators chosen also need to be based on data availability. In developing countries such as China, data availability is particularly an issue due to the lack of survey mechanisms and the lack of transparency.

Indicators which are designed to measure improvements in CO_2 intensity or energy efficiency independent of economic growth or growth in production, use either an economic or a physical value for the denominator. For example, the energy intensity of cement production can be measured as energy use per unit of value added by the cement industry (economic metric) or energy use per ton of cement produced (physical metric). Economic metrics are typically used when aggregating across heterogeneous entities that do not produce comparable products (e.g. the entire manufacturing sector). Physical metrics are typically used to compare entities that have similar production outputs (e.g., firms producing cement). Analyses have shown that there is great variability in economic metrics—such as structural and activity effects—and that metrics based on physical values more accurately trace actual trends in emissions or energy intensity, even though the heterogeneity of the industrial sector can make development of such indicators difficult for some industries [6-7]. As a result, there have been a number of efforts to develop suitable physical indicators [8-12].

In examining numerous indicators of city-level low carbon development, the following categories of key indicators were identified:

- Aggregated: energy or CO_2 per unit GDP, energy or CO_2 per capita or per land area
- Structural: share of GDP and energy by end-use sector
- Residential and Commercial Buildings: energy or CO_2 per floor area or per person; percent compliance with building efficiency codes
- Industry: physical efficiency (energy or carbon per ton of product) and economic energy or carbon intensity (energy per unit value-added)
- Power: CO_2 per kWh, share of renewable energy sources in electricity supply

- Transportation: energy or CO_2 per person-kilometer traveled, urban density, public transit use, and kilometers of public transit per 100,000 population
- Land Use and Waste Management: area share of mixed–use zoning (residential and commercial), area share of green space and agricultural land, waste generated per capita, and recycling rate of waste
- Economic and Social: share of green jobs, income distribution, income per capita, and housing affordability

Aggregated and structural indicators are commonly used to define whether a city is "low-carbon" or "energy-efficient" and to track actions taken to reduce energy use and emissions. There are, however, some issues to consider when using these indicators, which are discussed below.

Energy Intensity and Carbon Intensity (Energy/GDP and CO2/GDP)

The ratio of energy consumption to gross domestic product (GDP) is used to measure the energy intensity of an economy. Similarly, economic carbon intensity is the amount of carbon emissions per unit of GDP. These are key indicators used in China's 12th Five-Year Plan and announced internationally. An intensity indicator is appealing at the aggregate level, as it offers flexibility and utilizes sets of data already tracked: energy, carbon, and GDP. However, this is a mixed indicator, accounting for both physical energy efficiency and economic structure that influences energy consumption. As economic development proceeds, the economic energy intensity typically declines yet absolute energy use and carbon emissions still increase. Thus, there are significant limitations to the use of this indicator for tracking low-carbon development. Indicators distinctly focused on physical energy and carbon intensity, and on aspects of economic structure that affect energy consumption and carbon emissions, are encouraged to supplement or replace an economic energy or carbon intensity indicator.

Energy/capita and CO_2/capita

Because energy consumption and carbon emissions can be strongly influenced by the size of the population, per capita indicators provide a better and more equitable basis for comparison across cities, provinces, and countries. This indicator is widely used in China and internationally. Highly aggregated per capita indicators, such as total energy or CO_2 per person, should still be used with caution, however. A city with heavy industry and small population, which supplies other cities with cement and steel, would have high energy per capita. Yet the people of the city might use relatively little energy in their residences. Thus it is important to consider *residential* sector energy per capita, and the *energy structure* of a city, as well as total energy or CO2 per capita.

Energy/land area and CO_2/land area

Another measure of the energy or carbon intensity of a city can be a spatial measure, such as density per land area. This indicator is less common, but is being examined as cities consider how density of development influences energy consumption and carbon emissions.

Economic Structure: Sectoral shares of GDP (primary, secondary, tertiary)

Because different sectors of the economy have notably different energy and carbon intensity, economic structure is an important indicator of structural influences on consumption and emissions. Of many definitions of economic structure, the simplest and most often used in China is the share of primary, secondary, and tertiary sectors of the economy. The secondary sector represents industry and construction – the most energy intensive—while the tertiary sector represents commerce and service-focused businesses such as Information Technology (IT), communication services, health care, and energy saving services. Even this fairly aggregated indicator can help cities identify areas for low-carbon development.

Energy Structure: Sectoral shares of energy consumption

Similar to an economic structure indicator, energy structure helps to identify areas needing extra attention for low-carbon development. Typical definitions of energy sectors include: industrial, residential, transport, agriculture and forestry, commercial, construction, etc. Data are most easily obtained for the first 3 sectors; often the remaining energy sectors are grouped into "other energy." The industrial energy sector coincides with the secondary economic sector, while the other energy sectors have overlap to different extents with other economic sectors.

The LBNL/ERI low-carbon city development guidebook presents additional information on indicators for each energy and carbon sector, including the industry, buildings, power, transportation, and waste sectors [5]. In addition, LBNL has developed a more robust indicator system to weigh and combine multiple indicators into a composite low carbon indicator for ranking and comparing Chinese cities [13].

Steps for Low-Carbon Development Planning

The essential steps recommended for creation of low carbon development plans by local governments in China are commonly used in local climate action plans in cities throughout the world (for example, [112]). For China, these steps will involve coordination among local economic and energy offices, with leadership from those under China's National Development and Reform Commission (NDRC) and the Ministry of Industry and Information Technology (MITT), as well as environmental offices involved in carbon policy.

The key steps are to gain leadership commitment, conduct an energy and carbon emissions inventory, set targets, choose policies and actions to meet the targets, create a low-carbon development plan, implement the policies and actions, and monitor, report, and verify progress on the actions. Each of these steps is discussed further below for local government offices unfamiliar with the planning process.

Leadership Commitment

The first essential step is to solidify the commitment of the city's leadership. With the city's attention turned to low-carbon development, and sufficient staff and resources committed to the effort, the city can successfully develop and implement its low-carbon plan.

Conduct Energy and Carbon Emissions Inventory

Since China's commitments are focused on carbon emissions, the inventory should cover the two main carbon-based GHGs: CO_2 and methane (CH_4). CO_2 is emitted primarily from burning fossil fuels but is also emitted from non-energy industrial processes (like cement production) and forest loss. Methane emissions arises from agriculture (especially rice production), animal husbandry, other land use, industry (e.g., coal-bed methane), and waste decomposition.

An emissions inventory is a best estimate of emissions from activities in the city or province – not a precise measurement. The emissions inventory should cover sources of CO_2 and CH_4 from the electric power, industrial, residential buildings, commercial buildings, transportation, land management (agriculture and other land use, rural and urban), and waste sectors. Key considerations for development of an emissions inventory are explained below.

Since some emission-generating activities may cross city boundaries, it is important to clearly define the scope of the emissions inventory, to know what emissions get counted by the city. Internationally-recognized inventory protocols have defined three emission scopes: (1) direct, (2) indirect, and (3) associated emissions [112, 113]. Table 1 explains what emissions are included under each scope.

Table 1. GHG Emissions Inventory Scope

Emissions Scope	Scope Acitivities
Scope 1: Direct Emissions: Generated Within City Boundaries	Direct Energy Consumption within the City (fuel for Industry, Heating, Cooling, Electricity generation, Infrastructure, etc.) Transportation within the City Land Use and Waste Management within the City
Scope 2: Indirect Emissions: Due to Activities Within City Boundaries, Generated Outside City Boundaries	Import of Electricity and Heating used in the City
Scope 3: Associated Emissions: Due to City Activities, Occuring Across or Outside City Boundaries	Intra-regional Transportation City Waste in Landfills outside the City

Source: Based on Clean Air-Cool Planet, 2010; ICLEI 2009.

City staff preparing the carbon emissions inventory must work with the local and provincial statistical bureau, with utilities supplying electricity to the city, with transportation and waste agencies, as well as enterprises. The basic emission sources and data needed are summarized in

Table 2. The energy and other data on emission sources and activities, combined with emission factors, yield a GHG emissions inventory.

Table 2. Data Needs for GHG Emissions Inventory

Sector	Data on emission sources
Electric Power	Energy mix and amount of generation: kWh from coal, natural gas, oil, hydro, wind, solar, nuclear, etc.
Industrial	Electricity and fuel (natural gas, coal, heat, others) consumption Production levels, energy use, and economic output of major industrial products
Residential	Electricity and fuel (natural gas, coal, heat, others) consumption Building floor space and type
Commercial	Electricity and fuel (natural gas, coal, heat, others) consumption Building floor space and type
Transportation	Electricity and fuel (gasoline, diesel, others) consumption Mix of Transport Modes (feet, bicycle, motorbike, bus, light rail, train, auto, truck) Vehicle Efficiencies (Fuel Economy) for each mode Vehicle Miles Traveled (VMT) on local roads, for each mode VMT on highways (related to the jurisdiction)
Land Use	Hectares of food production, by type (rice, wheat, etc.) Numbers of cattle, pigs, horses Hectares of Forest cover (existing, removed, added)
Waste	Total landfill waste (tonnes) Typical composition of waste (organic matter, plastics and other non-degradable material, land-cover materials)

Figure 1 illustrates the different mix of fuels and sector emission shares in a U.S. city (Portland, Oregon) and a typical Chinese city. While Portland may not be typical in terms of its fuel mix for a U.S. city, it emissions inventory does show a higher reliance on electricity, natural gas, and gasoline than most Chinese cities. In contrast, GHG emissions from many Chinese cities are dominated by direct coal use, as well as coal-fired electricity. Portland's GHG inventory shows a commonly high share of transportation emissions (38%), followed by the commercial (25%) and residential (21%) sectors, then industry (15%). In contrast, GHG emissions of Chinese cities are dominated by industry (69%), with smaller shares of emissions from other sectors. The high share of industry is due in part to the jurisdictional boundaries of Chinese cities (more akin to a county in the U.S.), and even more so to the strong presence of heavy industry in many local economies in China.

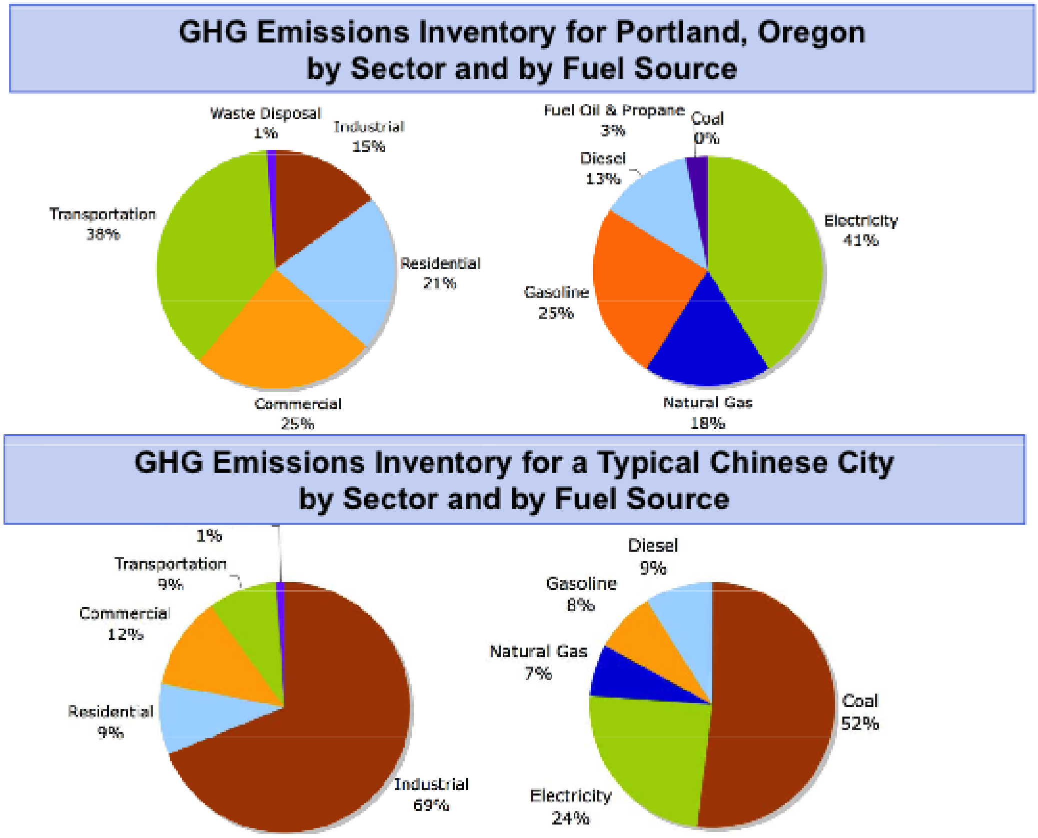

Figure 1. Comparison of U.S. and Chinese City-level Carbon Inventories

Source: Based on Portland's Climate Action Plan, and author analysis of Chinese city-level energy end-use statistics.

Set Targets

Target setting involves choosing the type of target and the target value. Targets need to be measurable and reportable, so that progress toward goals can be tracked. A physical target is preferable—such as total CO2 emissions, or energy use, or amount of wind energy—because it can be measured and has a direct influence on the health of the city and province. Economic targets are also important. The target value is set by projecting energy and carbon in scenario analysis (Business-As-Usual Scenario, and Savings Scenario), and evaluating the impact of potential policies.

Choose Policies and Actions to Meet Targets and: Create a Low Carbon Development Plan

The savings potential from the policies will depend on the local situation (e.g., baseline inventory, mix of efficiencies in building stock, etc.). The cost will also depend on the local situation (e.g., energy pricing, renewable energy resources), as well as a typical unit cost. To choose which policies to implement, a city should first conduct a rough review of potential policies and actions, qualitatively considering estimates of savings and costs, followed by a more detailed, quantitative analysis of a shorter list of actions. The actions should be closely connected to the emissions inventory and scenarios, addressing each sector of the economy. Cities should also consider soliciting input from research institutes, the community, businesses, and government officials.

Implement Policies and Actions

In order to implement the identified policies and actions, it is important that specific organizations or other entities are identified and allocated responsibility for each policy and action in the low-carbon action plan. Funding for implementation must also be identified and allocated. Implementation work plans and timetables should also be established to set expectations and provide a means to measure progress. Finally, support for the implementation of the policies and measures, such as incentives (and/or penalties), training, and public outreach, should be established.

Monitor, Report and Verify Progress

Progress must be tracked with monitoring, including reporting and verification. Reporting on intensity must include data on energy use, carbon emissions, and data on economic activity, to verify the resulting intensity number. Public reporting of data, along with progress toward goals, focuses attention and effort from government, enterprises, and the public, and helps to achieve the targets. City government websites are an effective means for publicly tracking progress on energy, carbon, and low-carbon economic development.

Policy Measures for Low Carbon Development

Because the heart of a low-carbon development plan is its actions, the guidance developed for Chinese cities also provides a menu of pertinent policy options and performance indicators. To assist local governments in prioritizing actions, the guidebook includes an estimate of each policy’s potential for energy and carbon savings (the policy impact) and the relative implementation cost. Because energy and economic structures vary from city to city, the impact of the policies and associated costs also vary; each city needs to evaluate its particular circumstances in order to determine priorities and select most cost effective policies. Nevertheless, to assist local governments, each policy in the full guidance document is categorized into “High, “Medium” and “Low” in terms of potential energy and carbon savings, and in terms of implementation costs.

The guidebook includes policies and actions for low-carbon development in the following sectors: industry, buildings, transportation, power, agriculture and forestry, as well as cross-cutting policies (not focused on a specific end-use sector). For each policy or action identified in each sector, the following information is included, where available:

- Description
- Performance metric
- GHG emission reduction potential
- Cost-effectiveness

The policies draw on international examples, including both national and state or provincial level measures. Chinese approaches are also included if they are considered to be successful or innovative. Examples of policies for the industrial and building sectors are provided below to illustrate the format and content of the policies included in the guidebook.

Examples of policy categories and their significance in the building sector are shown in Table 3 and Figure 2. A sampling of policy options for the industrial sector, along with their categorization of savings and costs, are show in Table 4 and Figure 3. These tables and figures represent only a selection of the policy options examined in the guidebook. A quantified cost-benefit analysis of policies would further facilitate policy prioritization and implementation by local governments, but such an analysis was beyond the scope of the current effort.

Table 3. Policies and Programs for Building Sector

Policy Option	Performance Metric	GHG Reduction by 2020			Cost		
		High	Med	Low	High	Med	Low
Targets							
Targets for new buildings [114]	Inspection and evaluation on compliance level both at design phase and construction phase	X					X
Targets for existing building retrofit [14]	m2 retrofitted	X				X	
Voluntary and negotiated agreements [15]	Target achievement		X			X	
Standards							
Building Standards [115]		X					
National	Level of the building codes; level of compliance	X					X
Leading	Level of the building codes; level of compliance	X				X	
Appliance Standards[15, 16]							
National	Level of the standard; level of compliance	X				X	
Leading	Level of the standard; level of compliance	X			X		
Certification, Labels, and voluntary programs							
Buildings [17,116]				X	X		
Categorical labels	Coverage; compliance			X			X
Endorsement label	Coverage; compliance		X		X		
Appliance Labels [18,19]							
Categorical labels/information label	Level of compliance; product grade market shift	X			X		
Voluntary endorsement label [a]	Level of compliance; product grade market shift		X		X		
Energy management							
Energy reduction in existing buildings and quotas [117]	Coverage; compliance	X			X		
EE Technology/Measure Promotion [15]							
Subsidies for purchase of the technology [b]	Increase of the investment of the EE equipment	X					X
Subsidies for new building design and construction beyond codes		X				X	

Subsidies for building ee retrofit	Retrofitted area	X				X	
Tax credit and other Tax incentives for EE technologies [c]	Increased sales in EE technologies	X			X		X
Setting technology dissemination goals	MW installed						
Co-operative procurement	Coverage; compliance rate	X				X	
Zoning [118]							
Zoning	Area coverage of zoning regulation; stringency of requirements	X					
Public Sector Leadership [14, 15]							
Government leadership in demonstrate new technologies or practices	Coverage; compliance	X			X		X
Government procurement	Whether the information is clear and accessible, compliance level (US 20%)	X				X	
Public Benefit Charges [119]							
	Total energy savings; ratios of programs/ projects funded by public benefits charge		X		X		
Building Commissioning/Auditing [14]							
Mandatory audits [d]	Number of audits conducted	X				X	
Information Dissemination/Data Sharing							
Survey and database [120]	Website, brochures for energy consumption of the product or buildings		X			X	
Benchmarking	Database establishment; accessibility of the tool or database		X				X
Awareness raising, education, information campaign [e]				X	X		
Recognition and Awarding Policies							
	Increased motivation in EE through survey		X			X	
Support for ESCOs [121]							
	Publicizing, media	X				X	
Reporting [14]							
Detailed billing or energy consumption data and disclosure programs [f]	Data availability		X				n.a

Carbon or Energy Tax [14]							
	Tax level and coverage; variations b/w sectors		X		X		
CO2 Cap or Quota [14]							
	Stringency of cap; coverage	X			X		

Notes: [a] effective with financial incentives, voluntary agreements and regulations. [b] Positive for low-income households, risk of free-riders, may induce pioneering investments. [c] Low cost for tax credit. [d] Audits most effective if combined with other measures such as financial incentives. [e] More applicable for residential sector than commercial. [f] Success conditions: combination with other measures and periodic evaluation.

Table 4. Policies and Programs for Industry Sector

Policy Option	Performance Metric	GHGs Reduction by 2020			Cost		
		High	Med	Low	High	Med	Low
Targets							
Voluntary Commitments - Enterprises	Average savings per participating enterprise # of enterprises with targets # of enterprises that meet or surpassed targets		X			X	
Voluntary Commitments - Energy-Saving and GHG Emission Reduction Sector Targets	Achieved savings/emissions reductions		X			X	
Negotiated Agreements - Enterprise or Sector Level	Average savings per participating enterprise # of enterprises with targets # of enterprises that meet or surpassed targets	X				X	
Mandatory Targets - Enterprises	Average savings per participating enterprise # of enterprises with targets # of enterprises that meet or surpassed targets	X				X	
Standards							
Product Standards	Energy saved and/or CO2 emissions reduced annually		X				X
System Assessment Standards	Energy saved and/or CO2 emissions reduced annually		X				X
Process or Performance-Based Standards: Equipment Energy Efficiency Performance Standards	Cement sector reaches "advanced minimum"; Steel sector reaches "advanced minimum"	X				X	
Process or Performance-Based Standards: Small Plant Closures	Final/primary energy saved per t cement; Final/primary energy saved per t iron; final/primary Energy saved per t steel; electricity saved per kWh; Final/primary energy saved per t paper; Final/primary energy saved per t aluminum		X		X		
Energy Management Standards	Information on standards disseminated to industry; standards adopted		X				X
Fiscal/Financial Instruments							
Energy or CO2 Taxes	Benefit net of costs per ton CO2 saved	X					X
Grants and Subsidies	Energy saved and/or CO2 emissions reduced per unit of		X			X	

	funding provided						
Energy Efficiency Loans and Innovative Funding Mechanisms	Energy saved and/or CO2 emissions reduced per unit of funding provided		X			X	
Tax Relief	Energy saved and/or CO2 emissions reduced		X			X	
Electricity Price Variation			X				X
Incentives/Rewards	Energy saved and/or CO2 emissions reduced	X				X	
Energy Auditing							
Large-Scale Enterprises	# energy audits conducted; typical savings identified/audit		X			X	
Small and Medium Enterprises	# energy audits conducted; typical savings identified/audit			X			X
Benchmarking							
Enterprise Level	# enterprises undertaking benchmarking; Energy saved and/or CO2 emissions reduced as a result of benchmarking		X				X
Information Dissemination				X			X

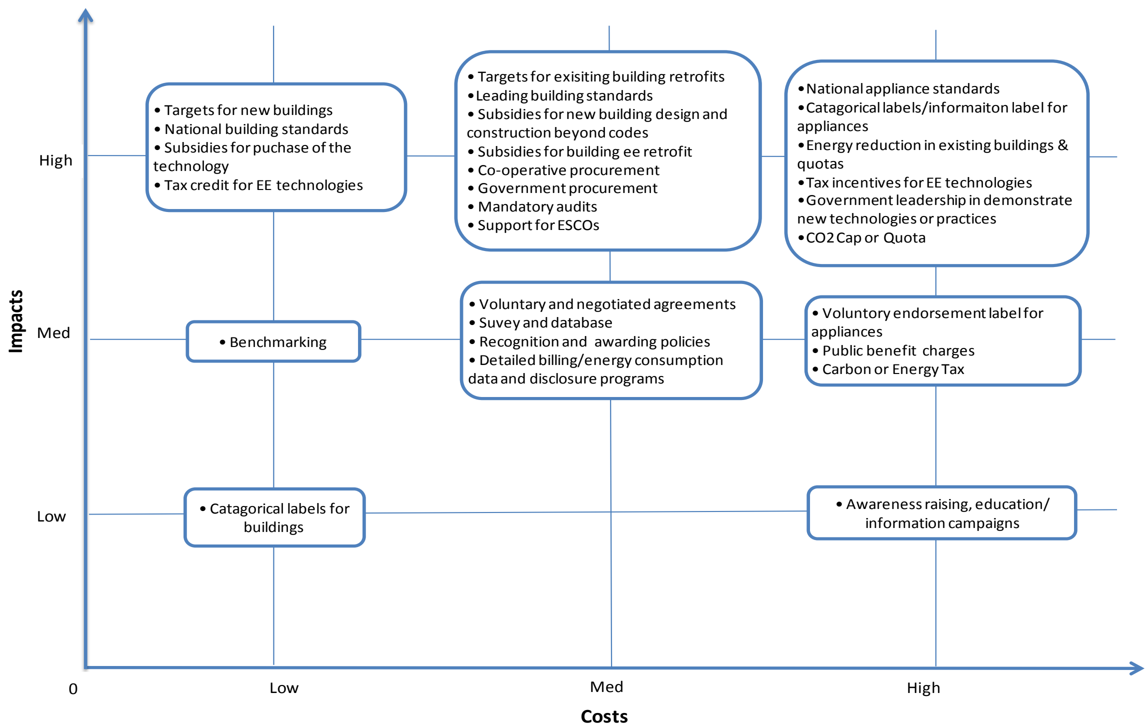

Figure 2. Costs and Savings of Energy Efficiency Policies for Buildings and Appliances

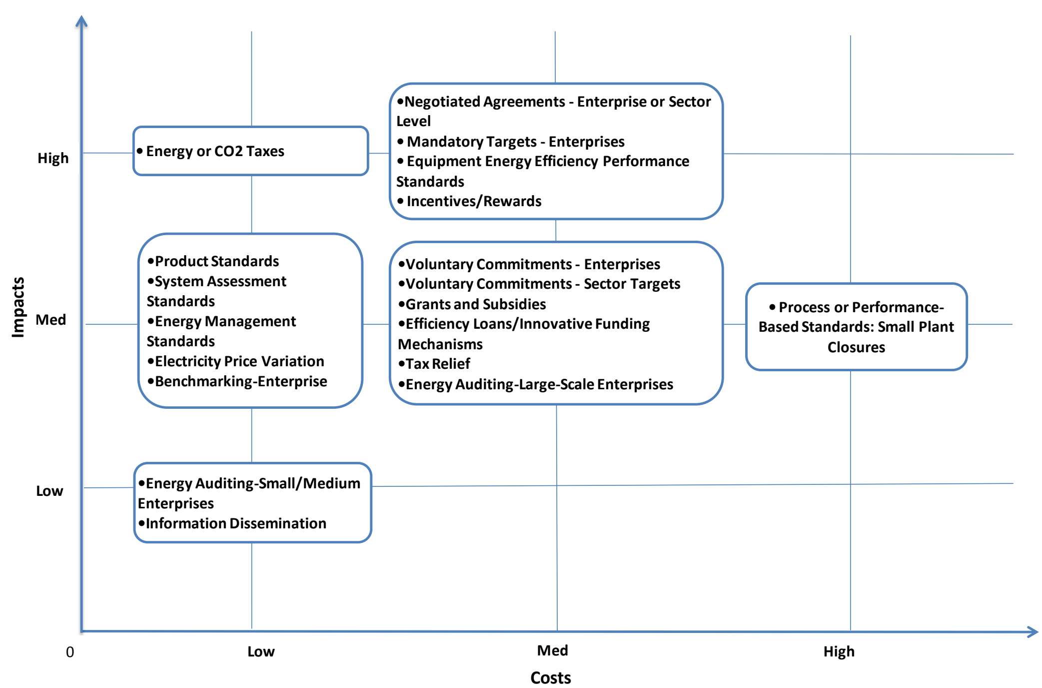

Figure 3. Costs and Savings of Energy Efficiency Policies in Industry Sector

Two excerpts are presented below to illustrate the policy information provided in the low carbon development guidebook. The first is an example of industrial sector policy experience for energy and carbon saving: energy management standards. The second is an example for the building sector: public sector leadership. Both of these policy examples are particularly pertinent for local government in China, where energy management standards are under development and action in government buildings and facilities has not yet been tapped.

Industrial Sector Policy Example: Energy Management Standards

Policy Description. Energy management standards are used to institutionalize continuous improvement in energy efficiency within industrial facilities. These standards are typically based on the "plan-do-check-act" approach with the goal of providing guidance to industrial facility managers related to how to structure their operations in a manner that continually identifies, adopts, and documents energy-efficiency opportunities. Energy management standards have been adopted in China, Denmark, Ireland, Japan, South Korea, the Netherlands, Sweden, Thailand, and the United States. While most of these standards include key elements such as establishing a management-appointed energy coordinator and developing an energy management plan, they are not uniform in their adoption of elements such as external validation or certification of claimed energy savings or the intervals for re-evaluating performance targets [20]. To provide more standardized guidance for energy management systems, the International Standardization Organization (ISO) recently published "ISO 50001: Energy management systems – Requirements with guidance for use" [21]. This standard will:

- Assist organizations in making better use of their existing energy-consuming assets
- Offer guidance on benchmarking, measuring, documenting, and reporting energy intensity improvements and their projected impact on reductions in GHG emissions
- Create transparency and facilitate communication on the management of energy resources
- Promote energy management best practices and reinforce good energy management behaviors
- Assist facilities in evaluating and prioritizing the implementation of new energy-efficient technologies
- Provide a framework for promoting energy efficiency throughout the supply chain
- Facilitate energy management improvements in the context of GHG emission reduction projects
- Allow integration with other organization management systems (environment, health and safety).

Performance Indicator. The performance indicator for energy management standards is their level of adoption, as well as estimated efficiency improvement.

GHG Emission Reduction Potential. Participants in the Energy Agreement Programme (EAP) in Ireland are required to obtain the certificate of the new Irish Energy Management System IS393 and to implement the standard to maximize energy-efficiency gains. As of 2008, 28 companies were certified with IS393 implemented onsite (1 in 2006, 9 in 2007 and 18 in 2008). EAP member companies reported energy efficiency gains of 8% in 2007 and 6% in 2008 [122].

Cost-Effectiveness. Experience with implementation of energy management standards at two facilities in the US indicated cost-effective savings of 5% and 14%, respectively. It is estimated that use of energy management standards will result in approximately 10% cost-effective annual energy savings over 15 years [22].

Building Sector Policy Example: Public Sector Leadership

Policy Description. The public, or government, sector can play an important role in demonstrating new energy-efficient technologies or practices by setting more ambitious goals or targets for its buildings. This approach is used by local governments in the US to demonstrate the feasibility and benefits of energy efficiency and renewable energy standards. States that have had difficulty implementing more stringent codes often adopt the standards for public buildings as a manageable first step. Experiences gained and lessons learned can then be shared with other building owners to promote the adoption of the codes statewide. New York City is implementing strategies to improve the energy performance of its own buildings and fleets by 30% over the next decades [106]. California's Green Building Executive Order S-20-04 also sets an ambitious 2015 goal of reducing energy use in public buildings by 20% of 2003 levels. New Mexico' Executive Order 2007-053 set a goal for all state agencies to reduce their buildings' operational energy intensity (per square foot) by 20% below the 2005 level by 2015. The U.S. also passed a law requiring new federal buildings to be designed with 30% greater efficiency than building code requirements. China's policy on *Energy Management of Government Office Buildings and Large-Scale Public Buildings* also calls for energy intensity reductions of 20% between 2006 and 2010 [15].

Funding sources. Funding for these type of activities comes from the government budget, grants, private foundations, utility programs and energy performance contracts.

Performance Metric. The performance metric for public sector leadership is meeting the program's stated goal or target, such as a given % reduction in energy intensity or CO_2 emissions.

GHG Emission Reduction Potential. Public sector leadership can result in high GHG emission reductions. For example, Germany achieved a 25% reduction in CO_2 emissions in the public sector over 15 years [14].

Cost Effectiveness. Public sector leadership can be highly cost-effective. In the U.S., it has been estimated that $4 savings are realized per $1 of public investment [14]. The New York Municipal Building Code estimates that $2.3 billion over 9 years will be required to achieve its 1.68 million ton of emission reduction target. The cost for the upgrade of public buildings averages 1.5% of construction cost, and the energy upgrades pay for themselves on average in seven years [106].

Discussion & Conclusions

Much work lies ahead to appropriately define and implement low-carbon development at the city level in China. Although China has announced a goal to achieve lower carbon intensity and to develop low-carbon demonstration cities, there is still a strong need for methodologies, policies, programs, measures, indicators, and tools to achieve these goals. This paper, and the guidebook upon which it is based, provides an information resource for these efforts. The planning steps outlined in the paper can help cities shape a comprehensive effort and aim for climate-friendly city development. The policy options and categorization illustrated in this paper provide guidance for cities to take action.

Although beyond the scope in this paper, low-carbon indicators are also being examined and a new low-carbon indicator system with a ranking scheme has been developed in order to provide clear metrics for tracking energy and carbon savings over time, as well as comparing progress among cities.

To date, the findings from the research have been presented in multiple workshops organized by China's central government as part of their low-carbon cities pilot project, as well as in training workshops for approximately 40 city mayors and practitioners in China. The participants were especially interested in the steps for development of a low-carbon plan and the policy matrix. Since the low carbon development plan was only introduced to Chinese policymakers over the last year and we are still working on training and building capacity of Chinese local policymakers, our guidance is still being considered and evaluated and has not yet been directly implemented. As the next step, we will be implementing the guidebook in the cities very soon and would also like to refine the guidebook if there is any feedback. The indicators work was recently started and has not yet been thoroughly introduced to and reviewed by local government yet, thus it is still too early to say which indicators are the most useful and relevant to local governments.

Chinese local government's interests in low carbon development are very recent (due to introduction of national policy in August 2010) and without specific policies and initiatives in place, we cannot measure how much the guidance has led to a reduction in GHG emissions. Without local GHG emission inventories, it will also be very difficult to measure reductions against a baseline. This is the purpose of our work and we hope to be able to help Chinese policymakers quantify GHG reductions not only from low carbon development, but from various other policies as well.

In conclusion, the impact of our guidebook to the policy making in China is till yet to be seen, as the low carbon city efforts in China are very new and policies and initiatives are still being developed and shaped. However, the policymakers' enthusiasm and willingness to participate in the trainings and workshop suggest that this guidance will be incorporated into their policy development.

Future Perspective

As more attention is being paid to low-carbon cities and in response to China's national-level energy and carbon intensity reduction goals, many other cities or counties are also following the trend toward low-carbon development that is being initiated through the recently announced policy for establishment of low-carbon cities in China.

With the increasing interest from localities wanting to adopt the methodologies presented, the next step is the implementation of the steps outlined in the guidebook to selected cities. Based on the feedback and experience, the guidebook can be further improved and tailored to the Chinese situation and be used by as many cities as possible in order to assist both the achievement of the carbon intensity goal and to ensure the successful implementation of the low-carbon city program.

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