Promoting energy efficiency as the first fuel through enabling local government action in China

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Abstract
Low-carbon urban development is one of the key approaches promoted by the Chinese government to achieve its international commitments of reducing carbon intensity (carbon dioxide emissions per unit of gross domestic product) by 40 % to 45 % below 2005 levels by 2020 and to achieve the recently-announced goal of peaking of CO_2 emissions around 2030 or earlier. Analysis of progress in low-carbon development among Chinese cities has shown that local climate change government agencies lack knowledge of analytical tools to evaluate specific policies and programs, especially those related to energy efficiency, for achieving their goals. In addition, most Chinese urban low carbon plans lack explicit targets, metrics, and implementation mechanisms to effectively capture their energy efficiency potential. A dynamic decision-making tool called the Benchmarking and Energy-Saving Tool for Low-Carbon Cities (BEST-Cities) has been developed and tested by researchers in Lawrence Berkeley National Laboratory's China Energy Group along with colleagues from China's Energy Research Institute and the Shandong Academy of Sciences. The goal of BEST-Cities is to provide local governments in China with strategies they can follow to reduce city-wide carbon emissions. The tool assesses local energy use and energy-related emissions in nine key urban areas (i.e., industry, public and commercial buildings, residential buildings, transportation, power and heat, street lighting, water and wastewater, solid waste, and urban green space), benchmarks city energy and emissions performance to other cities inside and outside China, and identifies those sectors with the greatest energy saving and emissions reduction potential. A key feature of BEST-Cities is its ability to help Chinese city authorities evaluate the appropriateness of more than 70 energy-efficiency strategies, helping local government officials develop an effective and realistic low carbon city action plan. This paper provides an introduction to BEST-Cities as well as findings from the implementation of the tool in Jinan, the capital city of Shandong Province, which emits the most CO_2 of all of China's provinces. The Jinan case study benchmarks Jinan to other Chinese and international cities for selected key performance indicators, documents those policies and programs recommended through the use of the BEST-Cities tool, and provides information on how the recommendations were used by the local city government.

Introduction
China has recently made three important commitments related to reduction of greenhouse gas emissions: 1) Copenhagen Accord commitment of a carbon intensity (carbon dioxide emissions per unit of gross domestic product) reduction of 40 % to 45 % below 2005 levels by 2020 (UNFCCC, 2009), 2) goal to cap annual primary energy consumption at 4.8 billion tonnes of standard coal equivalent until 2020 (NEA, 2014), and 3) China's recently-announced pledge to achieve peaking of CO_2 emissions around 2030 or earlier (White House, 2014). All of these commitments will require continued, significant actions to be taken to ensure that China's rapid urban development follows a low-carbon pathway. Between 2010 and 2030, China will add nearly 300 million new urban residents (UN, 2011), all of whom need housing and associated commercial and public buildings and urban infrastructure.

In China, low-carbon development is a key element of the national 12th Five Year Plan, which covers the period 2011–2015 and will undoubtedly continue to play an important role in the 13th Five Year Plan which is currently under development. China's National Development and Reform Commission (NDRC) has a low carbon development pilot program with 6 provinces and 36 cities; other low carbon eco-city programs that go beyond carbon to cover a broader scope of sustainability issues are overseen by China's Ministry of Environmental Protection (MEP) and the Ministry of Housing and Urban-Rural Development (MoHURD). A variety of indicator systems have been developed to provide definitions and to assess the progress of these low carbon eco-cities. Participating cities typically complete an energy and carbon inventory, identify potential energy and carbon savings opportunities, and set energy or carbon emissions reduction goals or targets. This is followed by choosing strategies and policies to achieve the targets. Recent analyses of progress in low-carbon development among Chinese cities found that there has been an overemphasis on technologies and economic development, governments lack suitable performance assessment mechanisms, there is a lack of appropriate consideration of the costs associated with eco-city development, and there has been limited community engagement (Yu, 2014). In addition, review of the current situation found that cities need guidance and tools to assist them in choosing and implementing appropriate policies for realizing low carbon development within specific city sectors as well as for the city overall (Khanna et al., 2014).

This paper describes a dynamic decision-making tool called the Benchmarking and Energy-Saving Tool for Low-Carbon Cities (BEST-Cities) that has been developed and tested by researchers in Lawrence Berkeley National Laboratory (LBNL)'s China Energy Group along with colleagues from China's Energy Research Institute and the Shandong Academy of Sciences to provide local governments in China with policies and measures they can implement in support of low-carbon urban development. The free tool, which is still being finalized and beta-tested, assesses local energy use and energy-related emissions in nine key urban areas: industry, public and commercial buildings, residential buildings, transportation, power and heat, street lighting, water and wastewater, solid waste, and urban green space. BEST-Cities then benchmarks city energy and emissions performance to other cities inside and outside China, identifies those sectors with the greatest energy saving and emissions reduction potential, and assists Chinese city authorities in evaluating the applicability of more than 70 different strategies to reduce their city's energy use and carbon emissions.

BEST-Cities Methodology

BEST-Cities is comprised of three main components: (1) Inventory and Benchmarking, (2) Sector Prioritization, and (3) Policy Analysis, combining these components to assist local policymakers in development of low carbon action plans. BEST-Cities focuses on actions that reduce both energy demand and carbon emissions and prioritizes the low-carbon policies contained in its extensive database to match the low-carbon development needs of the city with the capabilities of the local government. BEST-Cities has been designed to consider data availability in China; much of the required data is available to local governments in statistical yearbooks or through other sources. For a more detailed description of the BEST-Cities tool, see Price et al. (2014).

The *Inventory and Benchmarking* component of BEST-Cities requires the user to gather and input city-wide information on population, total primary energy consumption, total greenhouse gas (GHG) emissions, gross domestic product (GDP), the city's climate zone, the city's Human Development Index (HDI), and the share of industry and service sector GDP. Most of this information is available in the city's annual Energy Balance documentation, although users may have to conduct some data-gathering with city departments to gather all of the required information. The tool requires annual energy consumption data by fuel for each of nine end-use sectors: industry, public & commercial buildings, residential buildings, transportation, power & heat, public lighting, water & wastewater, solid waste, and urban green space. Once the data are entered, the tool generates the city's energy & carbon inventory, providing final energy use and CO_2 emissions for each of the nine end-use sectors. Since the user enters fuel consumption in physical units (e.g. metric tons of coal consumed), conversions are made using fuel energy conversion factors from China's National Bureau of Statistics (NBS, 2011) and CO_2 emissions factors from the Intergovernmental Panel on Climate Change (IPCC, 1996; IPCC 2006). China-specific carbon sequestration conversion coefficients (EC, 2012) and energy unit conversion factors for power and heat by Province are used (NBS, 2011). Once the city's inventory is completed, BEST-Cities compares citywide and sector-specific Key Performance Indicators (KPIs) to those of other cities in China. BEST-Cities provides benchmarks for a total of 33 KPIs, reported as ratios so that they can be easily compared across cities (see Price et al, 2014 for the full list of KPIs). BEST-Cities allows for filtering of comparable cities by population, climate zone, Human Development Index (HDI), and industrial share of GDP.

The *Sector Prioritization* component of BEST-Cities assists local governments in identifying those sectors with the highest potential for energy saving and carbon emissions reductions. Based on the benchmarking results, BEST-Cities estimates the sector improvement potential for one "representative" KPI for each sector. For example, for residential buildings, the representative KPI is residential buildings energy use per capita and for the power and heat sector the representative KPI is the share of renewable energy in the local electricity supply. The BEST-Cities sector improvement potential value is calculated as:

$$\text{Sector Improvement Potential [\%]} = \frac{|\ \mathrm{KPI_{City}} - \mathrm{KPI_{average\ better}}|}{\mathrm{KPI_{City}}} \qquad \text{(eq. 1)}$$

where the $\mathrm{KPI_{average\ better}}$ is the mean of the values of all chosen peer cities with better performance. The improvement potential is an estimate for the purpose of selecting policy strategies to pursue for energy and carbon savings. Users can override the calculated potentials based on their knowledge of the actual savings potentials in each sector. It is also important to understand the level of authority the city (or other relevant jurisdiction) has to enact and implement policies and programs. BEST-Cities asks the user to indicate the level of control city authorities have (between 0 % and 100 %) for each of the nine sectors covered by BEST-Cities. Level of control ranges from the low level of a national or provincial stakeholder to the high level of control of a regulator or enforcer. With this information, BEST-Cities automatically calculates the sector prioritization results, ranking each sector based on the calculated sector improvement potential, the magnitude of CO_{2e} emissions, and the sector city authority assessment. The sector prioritization results assist the local governments in deciding which sectors to focus on given the potential for savings, the level of energy use or emissions, and the degree to which the user has the authority and associated financial, policy-making, regulatory, and enforcement capability.

The *Policy Analysis* component of BEST-Cities assists local governments in identifying policies and programs for energy saving and carbon emissions reduction across the nine sectors in their city. BEST-Cities contains a database of more than 70 policies and programs drawn from international and Chinese policy experience that can be adopted at the city level in China (for the full list of policies and programs, see Price et al., 2014). The information provided for each policy or program includes a description, implementation strategies and challenges, monitoring metrics, case studies, and attributes including the carbon savings potential, first cost to the government, the speed of implementation, and any related co-benefits such as reduction of pollutant emissions, reduced water use and waste, improved air quality, enhanced public health, increased productivity, and energy and cost savings for enterprises. The Policy Analysis component includes a section to understand the capability of the city in terms of project finance, human resources, and policy, regulation, and enforcement for each of the nine sectors. The Policy Appraisal section ranks policies based on the results of the assessment of the capabilities of the city, comparing each policy's minimum requirements against the observed levels of capabilities and opportunity in the city. The initial appraisal is undertaken by the user of the BEST-Cities tool to give guidance to the city; it is not prescriptive and it is the responsibility of the local authorities to determine which policies will be taken further. The Policy Review section displays all policies selected through the Policy Appraisal, including information on speed of implementation, carbon savings potential, and the initial capital costs to the local government. The estimated range of values for these policy attributes are from the BEST-Cities database, based on the size of the city, or any override values the user entered. The Policy Matrix shows all recommendations from the prioritized sectors sorted by first cost and CO_2 emissions reduction potential. The user can alter the output based on their preferences for speed of implementation. Finally, the Priority Policies section of the tool shows the city's prioritized list of low-carbon policies, based on data and analysis by the BEST-Cities tool.

BEST-Cities Recommendations for Jinan

Jinan is the capital city of Shandong province, which is the province with the largest CO_2 emissions in China. Jinan is a typical second-tier city with a population of 6 million and gross domestic product (GDP) of 481 billion RMB in 2012 (Government of Jinan, 2013). In late 2013 and early 2014, BEST-Cities was beta-tested in Jinan using 2008 data; the results are presented in He et al. (2014) and summarized below.

Jinan's energy and carbon inventory found that the industrial sector was the largest energy consuming and carbon-emitting sector in Jinan in 2008, using 15.2 million tons of coal equivalent (Mtce) in final energy and emitting 42 million tons of CO_2 emissions (see Figure 1). The next largest energy users were public and commercial buildings, residential buildings, and transportation. Public lighting, water and wastewater, and solid waste were small emitters of CO_2. In addition, urban green space sequestered 365,800 tons of CO_2 that year.

Once the energy and carbon inventory was completed, Jinan was compared to other cities using the BEST-Cities benchmarking feature. Figure 2 shows the benchmarking results for a city-wide indicator – GHG emissions per capita (tCO_2e/person) – for Jinan compared to other cities of a similar population size, from a database of 288 Chinese cities (the data for Jinan are shown in yellow). Due to the heavy industrial base of Jinan's local economy and its high consumption of coal, the city ranks very high in per capita GHG emissions. Citywide, Jinan ranks 277 when compared to all cities, 83 when compared to the 85 cities with similar population size, and 75 when compared with the 78 cities in the same climate zone in China.

Following the benchmarking step, BEST-Cities was used to prioritize sectors where local government action would have the greatest impact in Jinan. As described above, sector improvement potential value is calculated as the mean of the values of all the chosen peer cities with better performance than Jinan. In the residential building sector of Jinan, for example, if ten peer cities used less energy per capita in residential buildings than Jinan (i.e., the ten peer cities performed "better" than Jinan), the improvement potential is the difference between the average value of those ten peer cities' residential energy per capita, and that of Jinan, divided by the residential energy per capita in Jinan. The authority of Jinan city officials to take action in each sector and the capabilities of the local Jinan government in terms of project finance, human resources, and policy, regulation, and enforcement, were all entered into BEST-Cities based on the results of our interviews with local officials and an assessment of local capacity.

Table 1 shows the resulting priority ranking of each sector in Jinan, based on the sector improvement potential, the magnitude of CO_{2_e} emissions of each sector, and the assessment of the local government authority in Jinan. The industrial sector, which has a large sector improvement potential when compared to other industry in other Chinese cities, also has the largest CO_{2e} emissions among the end-use sectors. In addition, local government officials in Jinan have a high level of authority over this sector, so the overall score results in industry being the highest priority sector for action for Jinan. The power and heat sector, by contrast, has large CO_{2e} emissions, but local government authorities have little authority over this sector, which is controlled by the national government and the power generation and distribution companies. As such, the overall score for this sector is low despite the relatively large sector improvement potential.

The policy analysis section of the BEST-Cities tool is based on a pool of 72 policies in eight sectors that cities can implement to achieve energy saving and carbon mitigation. BEST-Cities provides a full description of each policy, including a description, implementation strategies and challenges, monitoring metrics, case studies, and attributes including the carbon

City-wide Inventory - Reported	2008	
	Primary Energy (10^4 tce)	Carbon (10^4 tCO_2 e)
City-wide	3,127.71	7,033.33
Note: Energy and carbon based on primary energy.		
Sector Summary - Calculated	**2008**	
End-Use Sector	Final Energy (10^4 tce)	Carbon (10^4 tCO_2 e)
Industry	1,523.23	4,200.61
Public & Commercial Buildings	392.25	1,013.97
Residential Buildings	260.83	659.09
Transportation	299.61	642.48
Public Lighting	6.01	16.66
Water & Wastewater	8.67	9.62
Solid Waste		2.43
Urban Green Space		-36.58

Figure 1. Summary of Jinan's citywide energy and carbon inventory with the BEST Cities tool. Note: Sector energy and carbon include use of electricity and heat.

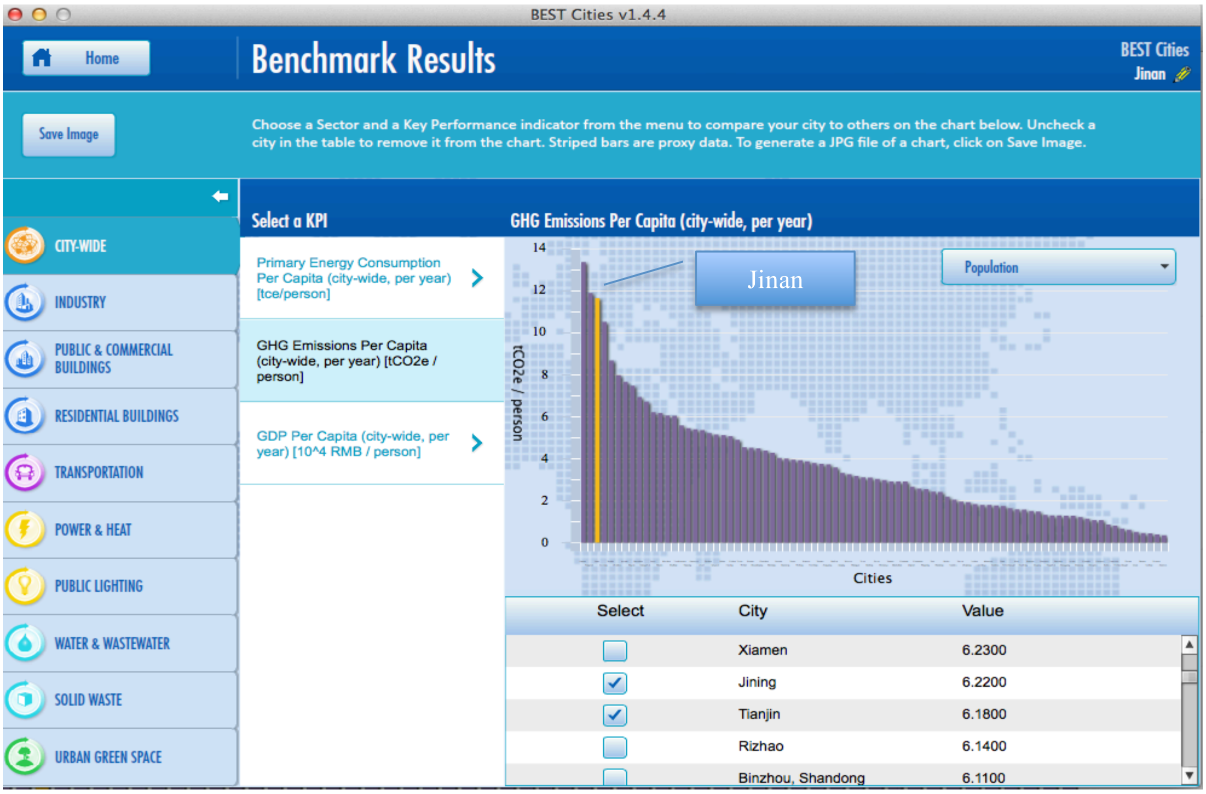

Figure 2. BEST-Cities GHG Emissions Per Capita (tCO_2e/person) Benchmarking for Jinan.

savings potential, first cost to the government, the speed of implementation, and any related co-benefits such as reduction of pollutant emissions, reduced water use and waste, improved air quality, enhanced public health, increased productivity, and energy and cost savings for enterprises. The majority of the policies in the BEST-Cities policy database are energy-efficiency policies, including more stringent local building codes, green building guidelines for new buildings, building energy labeling, energy use audits for buildings and industrial facilities, vehicle fuel economy standards, reach standards for efficient appliances and equipment, etc.

BEST-Cities was first used to investigate Jinan's ability to implement each policy, based on the results of our assessment of the city's capabilities in terms of project finance, human resources, and policy, regulation, and enforcement in each prioritized sector; comparing each policy's minimum requirements against the observed levels of capabilities and opportunity in the city.

Table 1. BEST-Cities sector prioritization results for Jinan.

Rank	Sector	Sector Improvement Potential (%)	CO_2e Emissions (tCO_2e)	City Authority (%)	Overall Score
1	Industry	62	42,006,100	75	1,966.92
2	Urban Green Space	433	(365,800)	91	144.24
3	Public & Commercial Buildings	26	10,139,700	50	132.82
4	Transportation	21	6,424,800	30	41.46
5	Power & Heat	37	23,188,400	4	34.78
6	Residential Buildings	23	6,590,900	20	31.37
7	Public Lighting	85	166,600	91	12.90
8	Solid Waste	4	24,300	53	0.05
9	Water & Wastewater	0	96,200	53	0.00

Notes: CO_{2e} stands for carbon dioxide equivalent. The overall sector score is determined by the following calculation: Sector Improvement Potential (%) × Sector CO_2 Emissions (10^4 tCO_2e) × City Authority.

All policies selected through policy appraisal were considered, along with their attributes: speed of implementation, CO_{2e} emissions reduction potential, and first cost to the local government. The estimated range of values for these policy attributes are from the BEST-Cities database, based on the size of the city and an understanding of Jinan's features, based on interviews conducted by LBNL and staff of the Shandong Academy of Sciences. BEST-Cities then puts all of the recommendations from the prioritized sectors sorted by first cost and CO_{2e} emissions reduction potential into a matrix, to make it clear for policy makers in choosing policies based on their concerns about time frame, cost and carbon mitigation potential. Finally, Jinan's prioritized list of low-carbon policies, based on the data and policy analysis was created using the BEST Cities tool.

Table 2 summarizes the policies that were labeled as very high priority policies for Jinan. Those policies focus on the industry, public and commercial building, residential building, transportation, power, and heat sectors. Information on the speed of implementation, CO_{2e} emissions reduction potential, and first cost to government are also listed for policy makers to reference.

In the example of Jinan, the policies with rapid implementation, high CO_{2e} emissions reduction potential, low cost to the government are an energy or CO_2 tax for industry, "reach" standards for efficient appliances and equipment for the residential buildings sector, and vehicle CO_2 emissions standards. It was determined earlier that the local Jinan government has a relatively high level of authority over the industrial and public and commercial buildings sectors, so they are able to implement such policies at the local level.

Researchers at LBNL have been working along with collaborators at the Shandong Academy of Sciences to collect data, implement BEST-Cities, and provide policy recommendations to advise Jinan's local government on options for low carbon development. BEST-Cities has also been used by researchers at the Shandong University of Finance and Economics, Jinan University Soft Power Research Center, the Green Economic Society of Jinan University, and the Shandong University of Technology to assist in Jinan's low carbon development strategy including recommendations for Jinan's 13th Five Year Plan. In addition, BEST-Cities has also been used by the Climate Center of Guangdong Province, the Climate Center of Shaanxi Province, and the Shanghai Carbon Asset Consulting Inc. to conduct research on low carbon development strategies.

Next Steps

BEST-Cities is now being used to support the low-carbon cities program of China's National Development and Reform Commission (NDRC) and will be used for Chinese cities participating in a new California-China Urban Climate Collaborative and U.S.-China Collaborations on Low Carbon Cities following the U.S.-China Joint Announcement on Climate Change. Researchers at LBNL have delivered several training programs to researchers from Shandong, Guangdong, Yunnan, Beijing, Shanghai, Shenzhen, Tianjin, and other provinces and municipalities. The participating institutions are all providing technical assistance to the central government or to their local governments in various areas of policy development such as the 13th Five Year Plan, Low Carbon Eco City Pilot Programs, Emission Trading Programs, CO_2 emission peaking and emission reduction pathways, and development of strategies for combating climate change. LBNL will extend the "training the trainers" strategy to ensure further deployment of BEST-Cities to facilitate local policy making in low carbon cities. Future plans – based on feedback from Chinese users – includes adding a module for calculating key associated air pollutants as well as the co-benefits of pollutant mitigation to make BEST-Cities more applicable to the current policy demands in China.

Table 2. Very high priority policies recommended by the BEST Cities tool.

Sector	Policy	Speed of Implementation	First Cost to Government (million RMB)
Industry	Energy or CO_2 Tax	1–3 Years	<5
Public & Commercial Buildings	More Stringent Local Building Codes	> 3 Years	5–50
Residential Buildings	More Stringent Local Building Codes	> 3 Years	5–50
Residential Buildings	Reach Standards for Efficient Appliance and Equipment	1–3 Years	<5
Transportation	Vehicle CO_2 Emission Standards	1–3 Years	<5
Transportation	Vehicle Fuel Economy Standards	1–3 Years	5–50
Transportation	Public Transit Infrastructure: Light Rail, BRT, and Buses	> 3 Years	5–50
Power & Heat	Minimum Performance Standards for Thermal Power Plants	1–3 Years	5–50
Power & Heat	Renewable Energy and Non-fossil Energy Targets or Quotas	> 3 Years	<5

Notes: Very high priority policies each have a carbon savings >2.5 $MtCO_{2e}$. Other priority policies are not listed, due to space constraints. $MtCO_{2e}$ = million tonnes of carbon dioxide equivalent. RMB = renminbi. BRT = bus rapid transit.

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