Is Your City Really Sustainable? A Tale of Jinan City Using Quantitative Low-Carbon Eco-city Tools

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ABSTRACT

Low-carbon eco-city development is one of the key approaches taken by the Chinese government to achieve its international commitment of reducing carbon intensity by 40% to 45% by 2020, as well as other national targets. Cities have planned and implemented various measures to fulfill these goals; however, most of the plans lacked explicit targets, metrics, and implementation mechanisms, and strategies undertaken are often too vague and piecemeal, therefore hindering their effectiveness. To fill these gaps and significantly accelerate the speed of developing low-carbon and eco-city plans, and to facilitate selection and implementation of sound policy apparatus at a large scale, Lawrence Berkeley National Laboratory has developed multiple tools based on both international and Chinese best practices. This paper introduces the application of two of the tools in Jinan, China. The Benchmarking and Energy Saving Tool for Low Carbon Cities (BEST Cities) focuses on energy savings and carbon emissions reduction potential and strategies. The Eco and Low-carbon Indicator Tool for Evaluating Cities (ELITE Cities) has a broader scope that includes air, water, and land use. These tools help cities benchmark and evaluate performance, track progress, and provide practical and scientific prescriptions. This paper sheds light on understanding where a city falls on the path to sustainability, quantifies the city's sectoral energy- and carbon-saving potentials, and reveals challenges and barriers a city may have in implementing the tools and policies. The prioritized policy recommendations made are based on the carbon savings impact, the city's capacity to act, and the government's program costs.

Introduction

Low-carbon eco-city development is one of the key approaches taken by the Chinese government to achieve its international commitment of reducing carbon intensity by 40% to 45% by 2020, as well as other national targets. Cities have planned and implemented various measures to fulfill these goals. Government entities at both the central and local level have moved aggressively on building low-carbon eco-cities. According to statistics reported by the Chinese Society for Urban Studies, by February 2011 China expected to have 230 cities at the prefecture-and-above level establish themselves as "eco-cities," accounting for 80.1% of 287 such cities nationally. Of those 230 cities, 133, or 46.3%, had established targets to develop specifically as "low-carbon cities" (Chinese Society for Urban Studies 2011). However, most of the plans lacked explicit targets, metrics, and implementation mechanisms, and strategies undertaken were often too vague and piecemeal, therefore hindering effectiveness (Zhou, He, and Williams 2012; Williams et al. 2012; Price et al. 2013). Given the proposed scale of the effort, China's potential success or failure in demonstrating and implementing low-carbon eco-cities could greatly affect how China, and the world, addresses both the climate change impacts of urbanization and the sustainable development of cities.

To fill these gaps and significantly accelerate the speed of developing low-carbon and eco-city plans, and to facilitate selection and implementation of sound policy apparatus at a large scale, Lawrence Berkeley National Laboratory (LBNL) has developed multiple tools based on both international and Chinese best practices. This paper introduces the application of two of the tools in Jinan, China. The Benchmarking and Energy Saving Tool for Low Carbon Cities (BEST Cities) focuses on energy savings and carbon emissions reduction potential and strategies; whereas the Eco and Low-carbon Indicator Tool for Evaluating Cities (ELITE Cities) has a broader scope that includes air, water, and land use. These tools help cities benchmark and evaluate performance, track progress, and provide practical and scientific prescriptions.

Jinan is the capital city of Shandong province, and will be possibly joining the pilot cities in U.S.–China Low Carbon Eco-city Program.[1] Jinan has a population of 6.09 million, and its reported gross domestic product (GDP) in 2012 was 481.27 billion RMB,[2] which makes it a very typical second-tier city in China. Jinan has been working with the China Green Foundation to develop a five-year action plan to achieve eco-Jinan by 2017. The action plan has identified 13 key projects, including an eco-zone, greenways, parks, recreation green land, and wetland,[3] in order to achieve "clean water, blue sky, green land, and fresh air" in Jinan.

Jinan also participated in the Ministry of Environmental Protection's Model City Initiative. The working plan proposed to have 50% of its electricity sourced from outside of the city and 50% of its energy from clean energy by 2015.[4] There is no comprehensive indicator system that can be used to evaluate Jinan and compare the status quo with the best practice status. Those initiatives have been mostly focused on the ecosystems and environment, but they have put little emphasis on energy, and especially carbon emissions and climate change. China has 287 cities of prefecture level and above that face similar needs to Jinan's. Jinan is an ideal case study to demonstrate how local low-carbon development could be assisted by applying the LBNL's tools given its pioneer efforts in making the city ecological and sustainable, with comparatively better availability of data.

By applying the BEST Cities and ELITE Cities tools to Jinan, this paper sheds light on understanding the position of the city on the path towards sustainability, quantifying the city's sectoral energy- and carbon-saving potentials, and revealing challenges and barriers a city may have in implementing the tools and policies. The prioritized policy recommendations made are based on the carbon savings impact, the city's capacity to act, and the government's program costs.

This paper is organized as follows. We first introduce the methods and data used for the Jinan case, and then present the key results from the demonstration. Finally, we discuss how the experiences from Jinan's case could be applied to other cities in China and around the world.

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[1] The first round of six cities in this program are Langfang in Hebei Province, Weifang and Rizhao in Shandong Province, Hebi and Jiyuan in Henan Province, and Hefei in Anhui Province. Source: http://www.mohurd.gov.cn/zxydt/201307/t20130724_214466.html (In Chinese), accessed February 20, 2014.

[2] Key statistics are from Jinan Statistical Communique for 2012. http://www.jinan.gov.cn/art/2013/4/11/art_15063_433804.html (In Chinese), accessed February 21, 2014.

[3] More information of Jinan Eco-city Action Plan can be found at: http://stjn.e23.cn/ (In Chinese), accessed February 21, 2014.

[4] Jinan Environmental Protection Bureau, Jinan Working Plan to Create National Environmental Protection Model City. http://www.jnepb.gov.cn/moudle%5Cdown.aspx?id=1559, accessed February 21, 2014.

Methods and Data

Two tools developed by LBNL, the BEST Cities tool[5] and the ELITE Cities[6] tool, were used to examine Jinan's low-carbon development status.

The BEST Cities tool is designed to provide city authorities with strategies they can follow to reduce citywide carbon dioxide (CO_2) and methane (CH_4) emissions. BEST Cities tool is inspired by the TRACE Tool,[7] developed by World Bank, but it extends the functionality and adaptability to Chinese cities. The tool quickly assesses local energy use and energy-related CO_2 emissions across nine sectors (i.e., industry, public and commercial buildings, residential buildings, transportation, power and heat, street lighting, water and wastewater, solid waste, and urban green space), giving officials a comprehensive perspective on their local carbon performance. Cities can also use the tool to benchmark their energy and emissions performance against other cities inside and outside China, and identify those sectors with the greatest energy saving and emissions reduction potential. Another important feature of BEST Cities is its ability to help city authorities evaluate the appropriateness of more than 70 different strategies that can reduce their city's energy use and emissions and prioritize them, based on the reduction potential, cost, and level of control a city may have. By identifying those strategies most relevant to local circumstances, the tool helps local government officials develop a low-carbon city action plan that consists of a package of policies and measures that can be implemented in phases over a multi-year timeframe.[8]

The ELITE Cities tool was developed to evaluate a city's performance by comparing it against benchmarked performance goals and using the results of that evaluation to rank it against other cities in China. ELITE Cities measures progress on 33 key indicators selected to represent priority issues within eight primary categories. An Excel-based tool was developed to package the key indicators, indicator benchmarks, explanation of indicators, point calculation functions, and transparency-oriented data recording instructions. ELITE Cities could be a useful and effective tool for local city governments to define the broad outlines of a low-carbon eco-city and assess the progress of a city's efforts towards this goal. ELITE Cities can also be used by higher-level governments to assess city performance and discern best practices (He et al. 2013).

As discussed in the introduction, a current problem in the low-carbon eco-city development is there is no clear matrix and consistent indicators for evaluating cities. Cities are just claiming that they are eco-city, but their actual performances are unknown. The ELITE Cities tool includes a Star System that enables policy makers at the national level to compare and rank participating cities on their performances. The Star System is categorized using the performance score calculated by the tool. It can be used to rate a city across different areas, with features to compare peer cities in the same climate zone, with similar economic structures, or similar resource endowments. It can also be used for government to launch a certification system that can consistently and fairly evaluate a city's status in the low-carbon eco-city development.

[5] The BEST Cities tool can be found at http://china.lbl.gov/tools-guidebooks/best-cities

[6] The ELITE Cities tool can be found at from http://china.lbl.gov/tools-guidebooks/elite-cities

[7] The Tool for Rapid Assessment of City Energy (TRACE) is a decision-support tool designed to help cities quickly identify under-performing sectors, evaluate improvement and cost-saving potential, and prioritize sectors and actions for energy efficiency intervention. More information about TRACE can be found at: https://www.esmap.org/TRACE.

[8] More information about the BEST Cities tool can be found at: http://china.lbl.gov/tools-guidebooks/best-cities.

Both tools evaluate and benchmark some key performance indicators (KPIs) for a city, but BEST Cities places more emphasis on energy and climate aspects (including detailed components of energy consumption by sectors and by fuel type), while ELITE Cities incorporates ecosystems and socio-economic aspects of the city. In addition, the BEST Cities tool includes a rich, built-in database, so a city can compare its performance with all cities in the database or those filtered by population, climate zone, human development index (HDI), industry share of gross domestic product (GDP), and service share of GDP to create a peer city grouping. A policy analysis module is also integrated in BEST Cities tool to make policy recommendations based on a city's capabilities—including policy, regulation and enforcement, human resources, and finance capabilities—and provide a prioritized list of policies. The ELITE Cities tool can be used as a diagnosis tool; whereas, the BEST Cities tool can provide prescription by prioritizing policy instruments. Therefore, BEST Cities and ELITE Cities can be used by cities for different purposes and focuses. Table *1* presents a comparison of the tools' major features.

Table 1. The different applications of BEST Cities tool and ELITE Cities tool

Feature	BEST Low Carbon Cities	ELITE Cities
Sector Covered	8 sectors (industry, buildings, transportation, power and heat, street lighting, municipal solid waste, water and wastewater, urban green space)	8 categories (energy and climate, water, air, waste, mobility, economic health, land use, and social health)
Principal Components	3 modules (energy and carbon benchmarking; sector prioritization; carbon reduction recommendations)	2 modules (benchmarking and evaluation)
Benchmarking KPIs	35 KPIs spread across 8 sectors and the city	33 KPIs spread in 8 categories
Applications	Sector prioritization, policy recommendation, decision-making attributes	Benchmarking, evaluation, comparison, ranking

The BEST Cities tool requires citywide data and sectoral data on industry, public and commercial buildings, residential buildings, transportation, power and heat, public lighting, water and wastewater, and urban green space, by fuel type and product where appropriate. The ELITE Cities tool requires data in eight major categories, including energy and climate, water, air, waste, mobility, economic, health, land use, and social health. The data for ELITE Cities tool are most collected from various years of the *Jinan Statistical Yearbook,* the latest of which reports data from 2012 (Jinan Statistical Bureau 2013). The BEST Cities tool requires more detailed data by sector, therefore it involves more coordination and effort. The industrial energy consumption was collected with the assistance of the Jinan Office of Energy Savings and the Policy Research Office of the Jinan Municipal Government. The best available year of data for the BEST Cities tool is 2008. The Institute of Science and Technology for Development of Shandong helped coordinate local data collection across multiple government branches.

Results and Analysis

The data collected through coordinated efforts were applied to the BEST Cities tool and the ELITE Cities tool. The main results are shown below.

The first function for the BEST Cities tool is to develop the energy and carbon inventory. The results showed that industry was Jinan's biggest energy consumer and carbon emitter in 2008, using 15.2 million tons of coal equivalent and emitting 42 million tons of CO_2 emissions (Figur). Industry is followed by public and commercial buildings, residential buildings, transportation, public lighting, water and wastewater, and solid waste. Urban green space sequestered 365,800 tons of CO_2 that year, and therefore contributed to a negative carbon emission. The highest-ranked sector for energy use and carbon emission in Jinan is industry, which illustrates the heavy domination of industry in Chinese cities as compared to U.S. cities.

Benchmarking is the first function of the BEST Cities tool. The benchmark results show Jinan's performance in the key performance indicators. Citywide, for the KPI on greenhouse gas emissions per capita, for example, Jinan ranks 153 if no filter is applied among the 287 prefectural and above level cities, 58 in the 85 cities filtered by population, and 41 in 78 cities filtered by climate zone. Figure shows an example of the filter results by climate zone. Jinan is highlighted in yellow in the bar chart, and other filtered graphs can be generated interactively. The charts show the gap and the potential performance improvement that Jinan could achieve, comparing it to similar cities at comparable climate and city size.

Sector prioritization is the second key function of the BEST Cities tool. Sector improvement potential value is calculated as the mean of the values of all the chosen peer cities with better performance. We first indicated the authority of city officials to take action in each sector, and then filled the capabilities of Jinan in terms of project finance, human resources, and policy, regulation, and enforcement, based on our interviews with local officials and our understanding of local capacity. The priority ranking of each sector is based on the overall score.

Table **2** shows the priority ranking of each sector, based on the sector improvement potential, the magnitude of CO_2e emissions, and the sector city authority assessment.

Policy analysis is the third function of the BEST Cities tool. The tool provides a pool of 70 policies in eight sectors that cities can implement to achieve energy saving and carbon mitigation. We first investigated Jinan's capabilities in regard to each policy, based on the results of the 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. **Error! Reference source not found.** shows Jinan's capabilities in some of the key policies.

All policies selected through policy appraisal were considered, along with their attributes: speed of implementation, carbon savings potential, and first cost to the government. The estimated range of values for these policy attributes are from the BEST Cities database, based on the size of the city and our understanding of Jinan's feature, based on our interview. We put all recommendations from prioritized sectors sorted by first cost and CO_2 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. We then created Jinan's prioritized list of low-carbon policies, based on the data and policy analysis using the BEST Cities tool (Table **3**).

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.

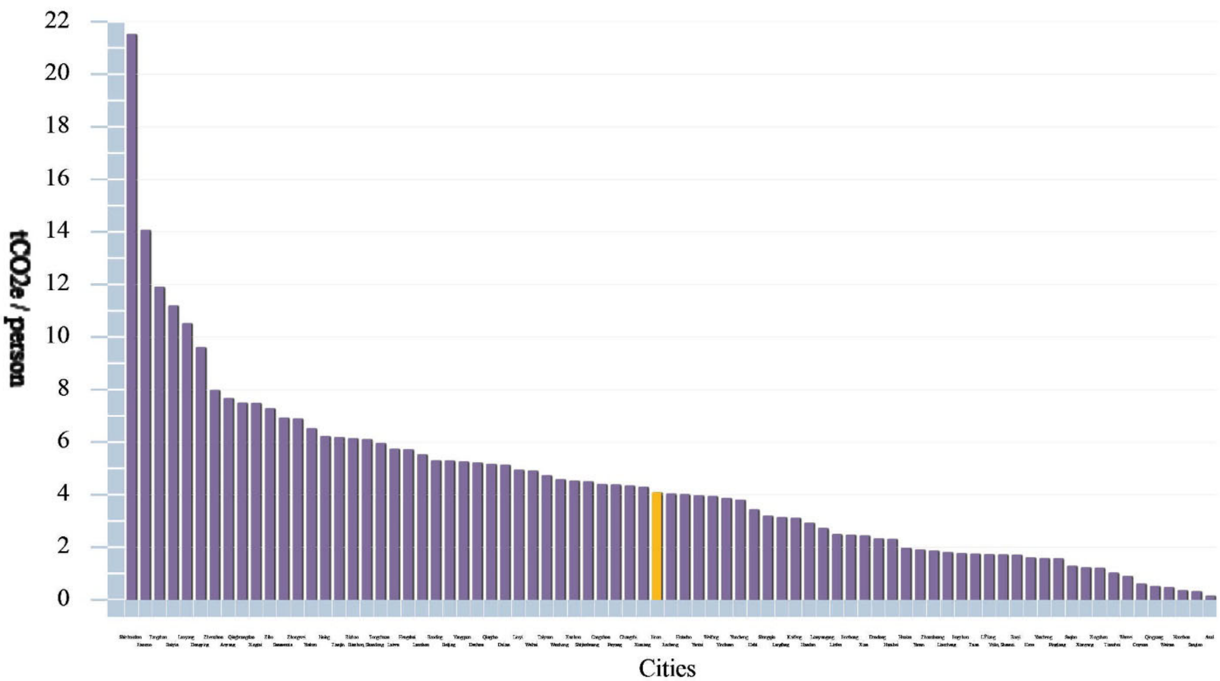
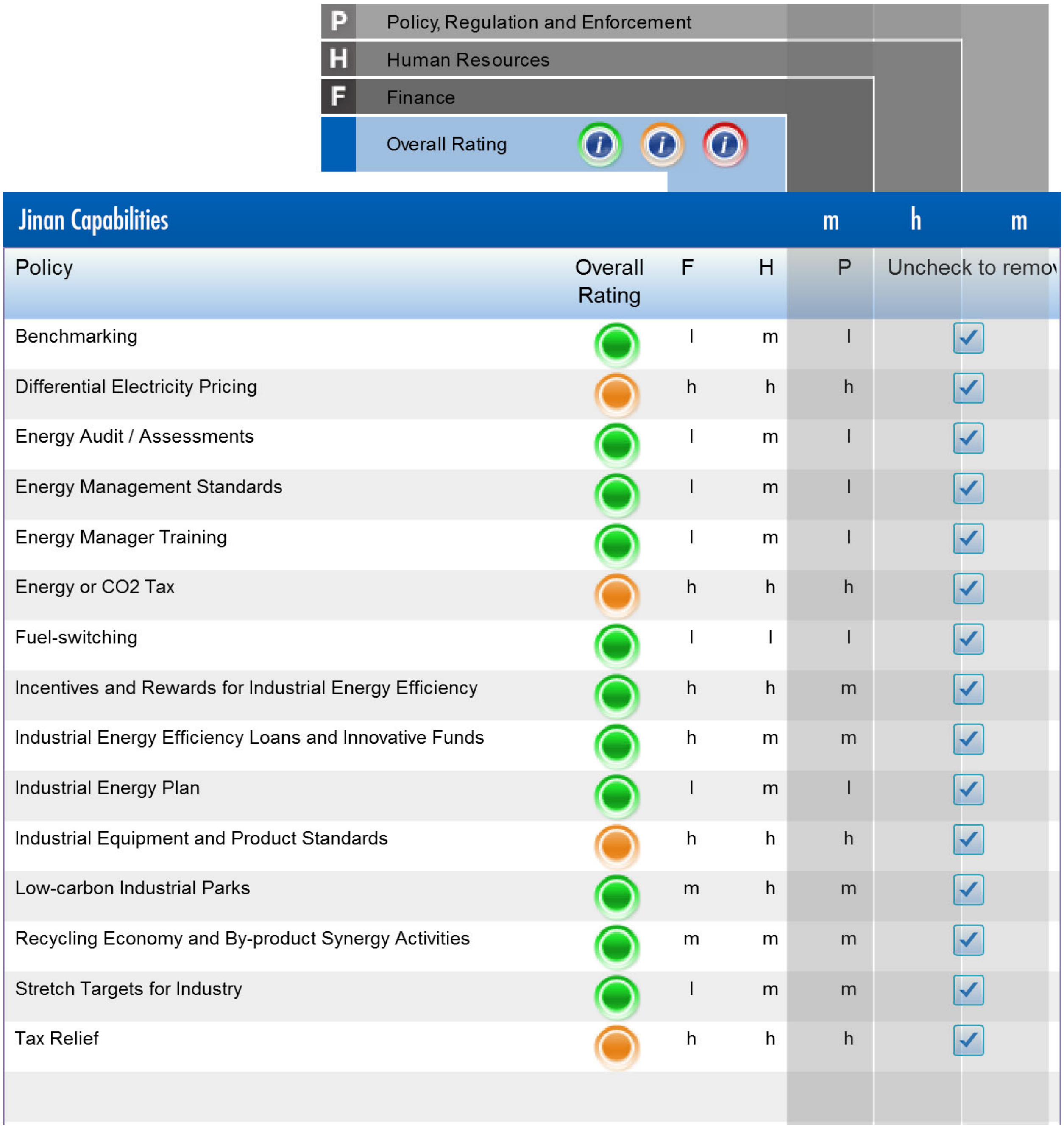


Figure 2. Benchmark results of Jinan as compared to cities in similar climate zones with the BEST Cities tool. Note: Jinan ranks in the middle of per capita carbon emissions compared with other cities in similar climate zones.



Policy	Overall Rating	F	H	P	Uncheck to remov
Benchmarking		l	m	l	✓
Differential Electricity Pricing		h	h	h	✓
Energy Audit / Assessments		l	m	l	✓
Energy Management Standards		l	m	l	✓
Energy Manager Training		l	m	l	✓
Energy or CO2 Tax		h	h	h	✓
Fuel-switching		l	l	l	✓
Incentives and Rewards for Industrial Energy Efficiency		h	h	m	✓
Industrial Energy Efficiency Loans and Innovative Funds		h	m	m	✓
Industrial Energy Plan		l	m	l	✓
Industrial Equipment and Product Standards		h	h	h	✓
Low-carbon Industrial Parks		m	h	m	✓
Recycling Economy and By-product Synergy Activities		m	m	m	✓
Stretch Targets for Industry		l	m	m	✓
Tax Relief		h	h	h	✓

Figure 3. Summary of Jinan's capabilities in the BEST Cities tool. Note: l, m, and h refer to low capability, medium capability, and high capability, respectively.

Table 2. Sector prioritization results by the BEST Cities tool

Rank	Sector	Sector Improvement Potential (%)	CO_2e emission (10^4 tCO_2e)	City Authority (%)	Score
1	Industry	62	4,200.61	75	1966.92
2	Public & Commercial Buildings	26	1,013.97	50	132.82
3	Transportation	21	642.48	30	41.46
4	Power & Heat	37	2,318.84	4	34.78
5	Residential Buildings	23	659.09	20	31.37
6	Public Lighting	85	16.66	91	12.90
7	Solid Waste	4	2.43	53	0.05
8	Water & Wastewater	0	9.62	53	0.00
9	Urban Green Space	433	-36.58	91	-144.24

Notes: CO_2e stands for carbon dioxide equivalent. Other priority policies are not listed, due to space constrains. The overall sector score is determined by the following calculation: Sector Improvement Potential (%) × Sector CO_2 Emissions (10^4 tCO_2e) × City Authority.

Table 3. Very high priority policies recommended by the BEST Cities tool

Sector	Policy	Speed of Implemen-tation	Carbon Savings Potential (tCO_2e)	First Cost to Government (RMB)
Industry	Energy or CO_2 Tax	1–3 Years	>2.5 million	<5 million
Public & Commercial Buildings	More Stringent Local Building Codes	> 3 Years	>2.5 million	5 million – 50 million
Residential Buildings	More Stringent Local Building Codes	> 3 Years	>2.5 million	5 million – 50 million
Residential Buildings	Reach Standards for Efficient Appliance and Equipment	1–3 Years	>2.5 million	<5 million
Transportation	Vehicle CO_2 Emission Standards	1–3 Years	>2.5 million	<5 million
Transportation	Vehicle Fuel Economy Standards	1–3 Years	>2.5 million	5 million – 50 million
Transportation	Public Transit Infrastructure: Light Rail, BRT, and Buses	> 3 Years	>2.5 million	5 million – 50 million
Power & Heat	Minimum Performance Standards for Thermal Power Plants	1–3 Years	>2.5 million	5 million – 50 million
Power & Heat	Renewable Energy and Non-fossil Energy Targets or Quotas	> 3 Years	>2.5 million	<5 million

Notes: Other priority policies are not listed, due to space constraints. tCO_2e stands for *tonnes of carbon dioxide equivalent.* RMB stands for *renminbi.* BRT stands for *bus rapid transit.*

Table **3** summarized all 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. All policies are saved in html and can be printed separately. The speed of implementation, carbon savings potential, and first cost to government are also listed for policy makers to reference.

While the BEST Cities tool provides an evaluation of carbon-reduction and energy-saving potential, we further applied the ELITE Cities tool to check other indicators beyond energy and climate to achieve a more comprehensive assessment of Jinan's status quo. Figure **1** shows the results of Jinan's performance in a low-carbon eco-city indicators compared to best practices. In the eight major categories of the ELITE Cities tool, Jinan received low scores in energy and climate, air, economic health, and social health; each with a score that is less than or equal to 60. Jinan has very good performance in the water and waste categories. The total score of 534 out of 800 gives Jinan a three-star rating in its low-carbon eco-city evaluation using the ELITE Tool. The tool also provided a detailed evaluation of each indicator compared with the embedded indicator best practices database.

City Name	Jinan

Categories	Score
ENERGY/CLIMATE	57
WATER	88
AIR	44
WASTE	96
MOBILITY	66
ECONOMIC HEALTH	52
LAND USE	70
SOCIAL HEALTH	60
Total Score	534
% of Potential Total	67%

Star Rating

★★★

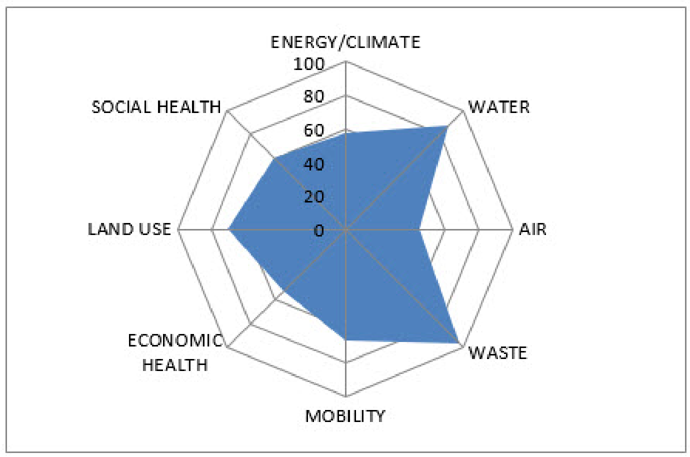


Figure 1. Screen shot of the summary of Jinan in the ELITE Cities tool.

Conclusion and Discussion

Using the BEST Cities tool and the ELITE Cities tool, we concluded that Jinan is in the middle position, compared to peer cities in China. The ELITE Cities tool demonstrated that Jinan has low scores in energy and climate, air, economic health, and social health; each with a score less than or equal to 60. Jinan has very good performance in the water and waste categories. The total score of 534 out of 800 gives Jinan a three-star rating in its low-carbon eco-city evaluation. This shows that Jinan has a lot of potential to improve its overall performances in low-carbon eco-city development.

To focus on energy- and climate-related sectors, the BEST Cities tool provides many insights for the policy makes of Jinan to identify areas of potential, policy instruments, and priorities. The results show that industry is the biggest energy consumer and carbon emitter in Jinan, using 15.2 million tons of coal equivalent and producing 42 million tons of CO_2 emissions in 2008. The industrial sector was followed by public and commercial buildings, residential buildings, transportation, public lighting, water and wastewater, and solid waste. The benchmark results show that Jinan is among the middle ground of major indicators compared to peer cities with a similar population or in the same climate zone. Sector prioritization shows that Jinan should pay the most attention to its top three sectors: industry, public and commercial buildings, and transportation. Jinan should give very high priority to nice policies in the prioritized sectors, such as an energy or CO_2 tax, more stringent local building codes, standards for efficient appliances and equipment, vehicle CO_2 emission standards, and vehicle fuel economy standards.

The use of the ELITE Cities tool and the BEST Cities tools not only facilitated the evaluation of Jinan's low-carbon eco-city development, but also shed insights on its potential improvement, and the policy instruments and priorities for the city to achieve that potentials. In a future study, we will add guidelines and create an embedded database on the best available technologies and integrate them into the BEST Cities tool, so cities can specify the policy instruments and technologies they can use to achieve its identified potentials or improve its performance in prioritized KPIs. The Jinan case provides other cities with useful experiences that they can emulate to expand the application of those tools. Lawrence Berkeley National Laboratory is working with Chinese partners to demonstrate these tools to more cities to expand the dataset of city performance.

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