



Environmental Energy Technologies Division Lawrence Berkeley National Laboratory

Energy-Efficiency and Greenhouse Gas Mitigation Policy Options: Assisting Chinese Cities in Prioritizing and Choosing Strategies to Implement to Become a Sustainable Community

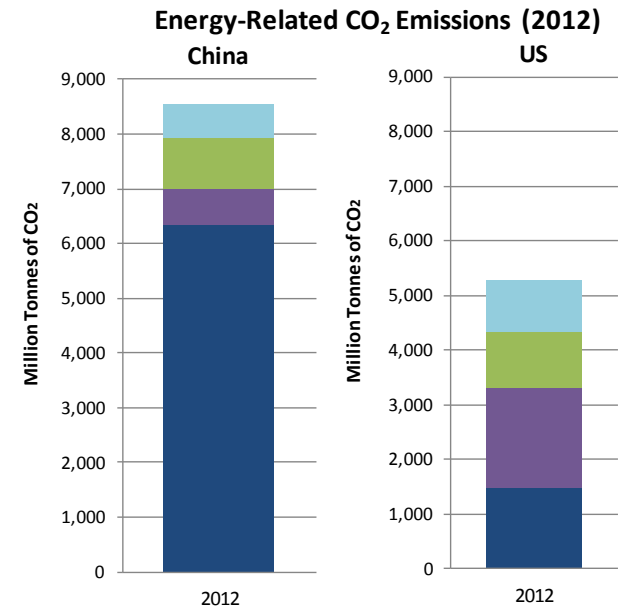
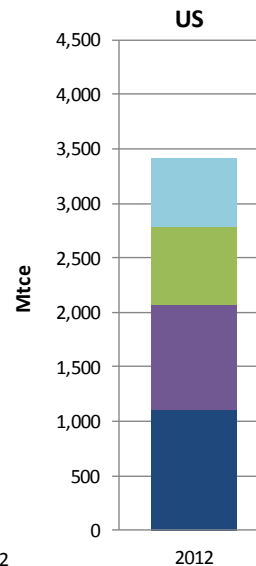
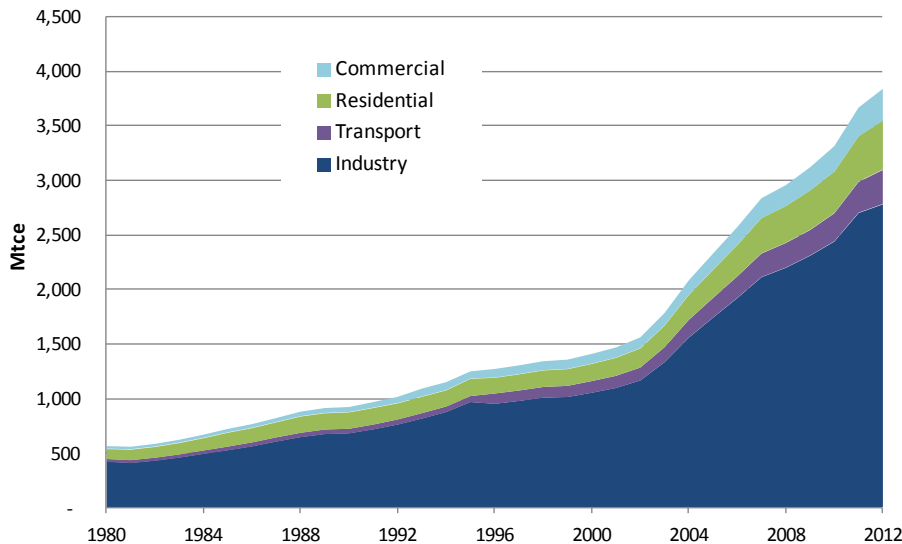
Lynn Price
China Energy Group
Lawrence Berkeley National Laboratory

ACEEE Summer Study on Energy Efficiency in Buildings
August 18 , 2014

China's Energy Use and CO₂ Emissions

- 2009/10: China became the world's largest energy consumer
 - ~70% of China's primary energy use is coal
 - ~70% of China's electricity is coal-based
- 2006/07: China became the world's largest emitter of energy-related CO₂

Primary Energy Use by Sector in China (1980-2012)

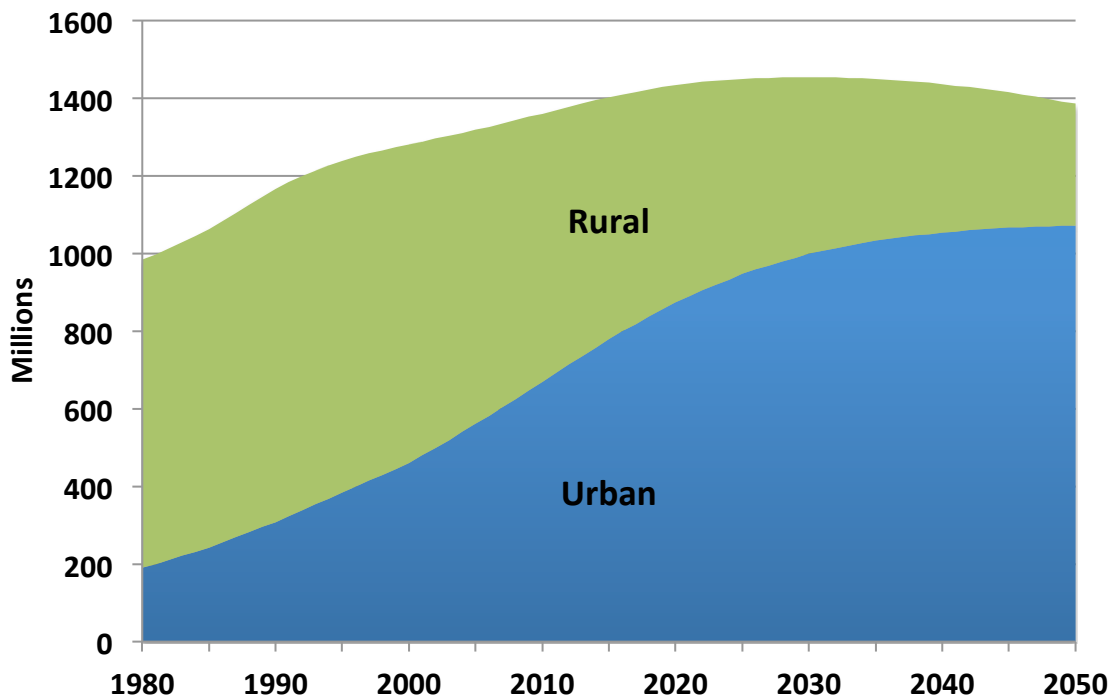


Source: NBS, 2013. China Statistical Yearbook.

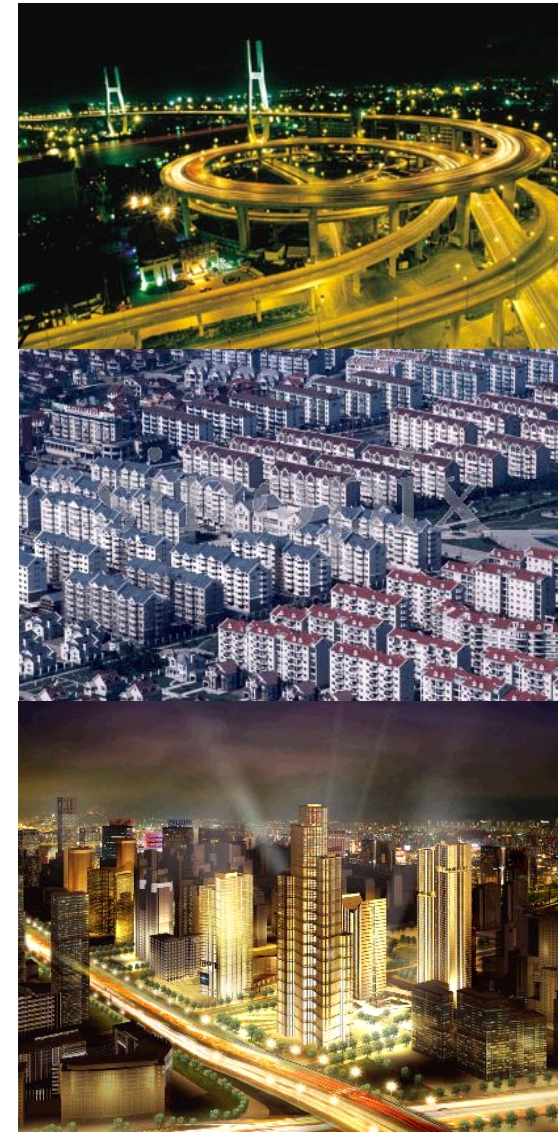
Note: Mtce >> EJ = 0.0293; EJ >> Quads = 0.9478

China's Urbanization Trends

- China's urban population growth:
 - About 20% of the total population in 1980
 - About 50% in 2010
 - Expected to be about 80% in 2050



Source: United Nations, Department of Economic and Social Affairs, Population Division (2013).
World Population Prospects: The 2012 Revision.



China's Energy and Carbon Targets

- China's energy and carbon commitments
 - 11th Five Year Plan energy intensity target
 - Domestic announcement and Copenhagen Accord
 - 12th Five Year Plan energy and carbon intensity targets
- China's low carbon development pilots
 - 2010:
 - 5 provinces: Guangdong, Liaoning, Hubei, Shaanxi, Yunnan
 - 8 cities: Chongqing, Tianjin, Shenzhen, Xiamen, Hangzhou, Nanchang, Guiyang, Baoding
 - 2012:
 - Increased to a total of 6 provinces and 36 cities



- Seeking a tool for energy/carbon inventory, benchmarking, energy/carbon policy options, energy/carbon savings, and policy prioritization
- Six existing low carbon urban planning tools were reviewed
- World Bank's Tool for the Rapid Assessment of City Energy (TRACE) developed by World Bank's Energy Sector Management Assistant Program (ESMAP)
 - Includes energy inventory, benchmarking, energy savings potential, prioritization, actions in 6 end-use sectors
 - Doesn't include carbon, industrial sector (which is predominant in Chinese cities), indicators and actions not necessarily applicable to Chinese situation
 - Requires on-the-ground consultants to implement = slow speed of dissemination/adoption

Benchmarking and Energy Saving Tool for Low Carbon Cities (BEST-Cities)

- Development funded by Energy Foundation China; training and dissemination funded by EF China and U.S. Department of Energy
- Developed in collaboration with World Bank experts, drawing from methodology and experience with TRACE, and China's Energy Research Institute
- Considers Chinese data availability
- Chinese energy units
- Available in English and Mandarin
- Citywide data plus 9 sectors:
 - Industry
 - Public & Commercial Buildings
 - Residential Buildings
 - Transportation
 - Power & Heat
 - Public Lighting
 - Water & Wastewater
 - Solid Waste
 - Urban Green Space



Benchmarking and Energy Saving Tool for Low Carbon Cities (BEST-Cities)

BEST CITIES
BENCHMARKING & ENERGY SAVING TOOL FOR LOW CARBON CITIES

BEST Cities
CITY B

Inventory and Benchmarking

Input city data, see inventory results, compare performance with other cities.

- City & Sector Data
- Energy & Carbon Inventory
- Benchmark Results

Sector Prioritization

Identify the sectors with highest potential for carbon saving.

- Sector Improvement Potential
- City Authority
- Sector Prioritization Results

Policy Analysis

Find policies and programs for carbon saving across city sectors

- City Capability
- Policy Appraisal
- Policy Review
- Policy Matrix
- Priority Policies



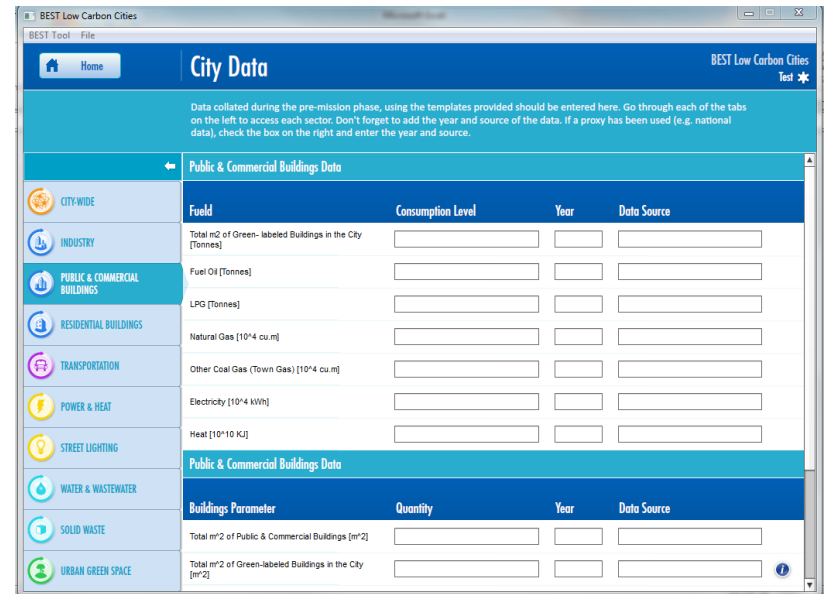
Documents

City Data

- Population
- GDP
- Climate zone
- Primary energy consumption
- GHG emissions
- Human Development Index
- Share of industry and service sector GDP

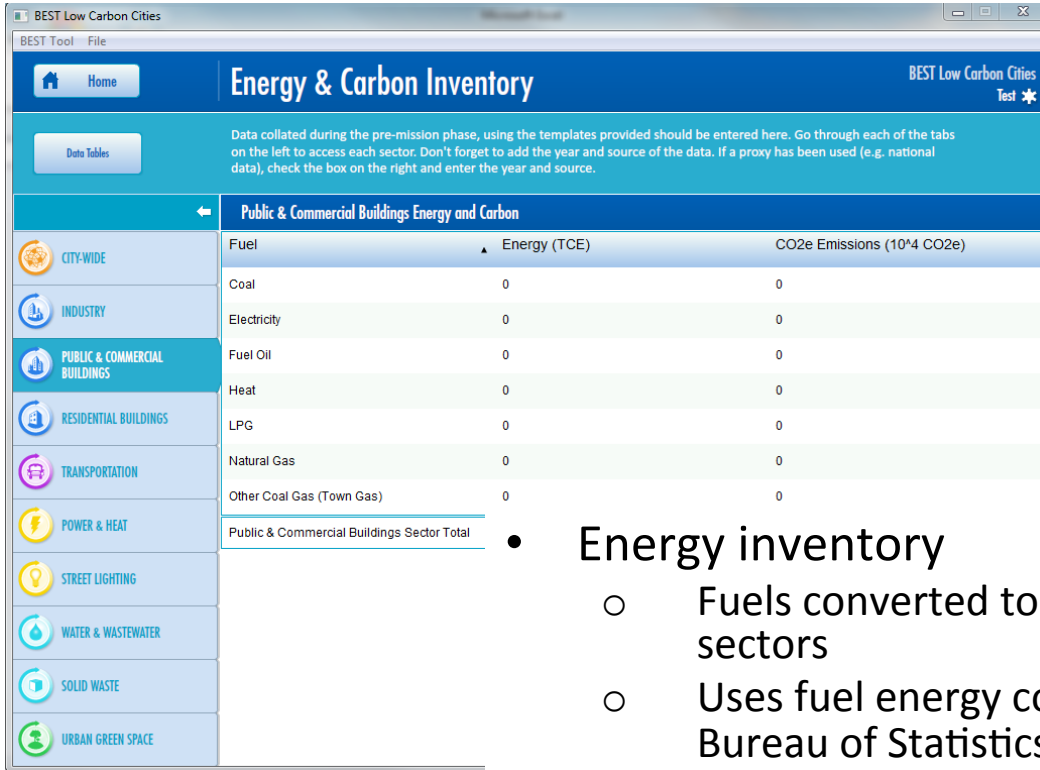
Sector Data

- Annual energy consumption by fuel for 9 sectors in physical units (e.g. metric tons of coal consumed)



The screenshot shows the 'BEST Low Carbon Cities' software interface. The main window is titled 'City Data' and contains a sidebar with navigation icons for various sectors: CITY-WIDE, INDUSTRY, PUBLIC & COMMERCIAL BUILDINGS (selected), RESIDENTIAL BUILDINGS, TRANSPORTATION, POWER & HEAT, STREET LIGHTING, WATER & WASTEWATER, SOLID WASTE, and URBAN GREEN SPACE. The main content area is titled 'Public & Commercial Buildings Data' and contains a table with columns for 'Fuel', 'Consumption Level', 'Year', and 'Data Source'. The table lists several fuel types with corresponding input fields: Total m² of Green-labeled Buildings in the City [Tonnes], Fuel Oil [Tonnes], LPG [Tonnes], Natural Gas [10⁴ cu m], Other Coal Gas (Town Gas) [10⁴ cu m], Electricity [10⁴ kWh], and Heat [10¹⁰ KJ]. Below this table is another section titled 'Public & Commercial Buildings Data' with a sub-table for 'Buildings Parameter', 'Quantity', 'Year', and 'Data Source'. This sub-table lists: Total m² of Public & Commercial Buildings [m²] and Total m² of Green-labeled Buildings in the City [m²].

Energy & Carbon Inventory



The screenshot shows the 'BEST Low Carbon Cities' web application. The main heading is 'Energy & Carbon Inventory'. Below the heading is a 'Data Tables' button and a paragraph of instructions: 'Data collated during the pre-mission phase, using the templates provided should be entered here. Go through each of the tabs on the left to access each sector. Don't forget to add the year and source of the data. If a proxy has been used (e.g. national data), check the box on the right and enter the year and source.' A sidebar on the left lists various sectors: CITY-WIDE, INDUSTRY, PUBLIC & COMMERCIAL BUILDINGS (selected), RESIDENTIAL BUILDINGS, TRANSPORTATION, POWER & HEAT, STREET LIGHTING, WATER & WASTEWATER, SOLID WASTE, and URBAN GREEN SPACE. The main content area displays a table for 'Public & Commercial Buildings Energy and Carbon'.

Fuel	Energy (TCE)	CO2e Emissions (10 ⁴ CO2e)
Coal	0	0
Electricity	0	0
Fuel Oil	0	0
Heat	0	0
LPG	0	0
Natural Gas	0	0
Other Coal Gas (Town Gas)	0	0
Public & Commercial Buildings Sector Total		

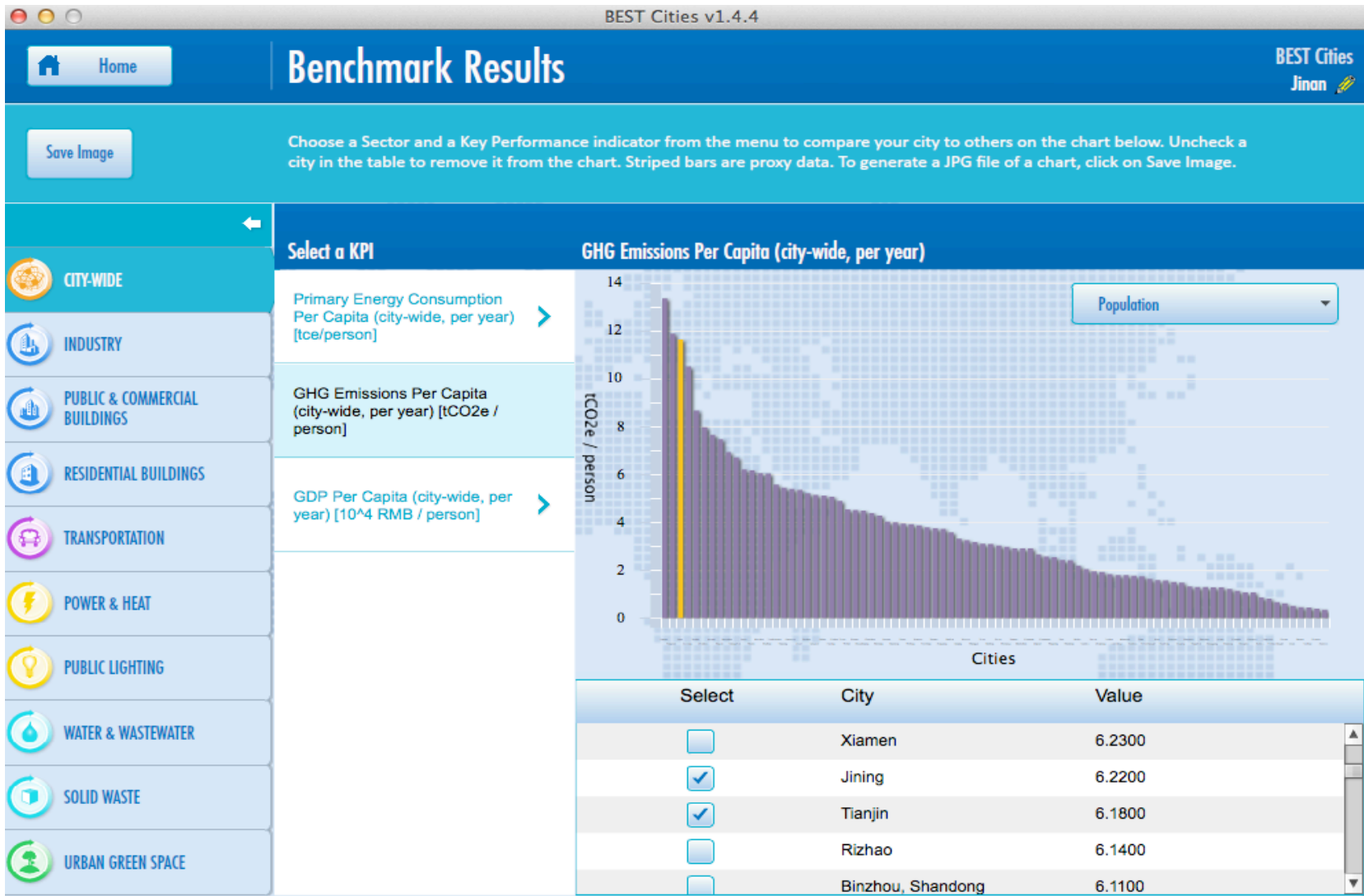
- Energy inventory
 - Fuels converted to final energy use for city and 9 end use sectors
 - Uses fuel energy conversion factors from China's National Bureau of Statistics
 - Reports in Chinese energy units
- Carbon inventory
 - Fuels converted to CO₂ emissions for city and 9 end use sectors
 - Uses CO₂ emissions factors from the IPCC
 - Reports in metric tons of CO₂

Benchmarking: 35 KPIs Citywide and in 8 Sectors

Sector	KPI Name
Citywide	Total citywide primary energy consumption per capita (per year) (tce/person)
Citywide	Total city wide GHG emissions per capita per year (tCO ₂ /capita/yr)
Citywide	Total citywide GDP per capita per year (10 ⁴ /capita/yr)
Industry	Final energy consumption per unit industrial value added (tce/10⁴ RMB)
Industry	Total GHG emissions per unit of industrial value added (tCO ₂ /10 ⁴ RMB)
Industry	Share of fossil fuel in total industrial energy consumption (not including heat and power) (%)
Industry	Share of electricity in total industrial energy use (%)
Industry	Final energy consumption per tonne of steel production (tce/tonne)
Industry	Final energy consumption per unit of building materials value-added (tce/RMB)
Industry	Final energy consumption per tonne of cement production (tce/tonne)
Industry	Final energy consumption per tonne of flat glass production (tce/tonne)
Industry	Final energy consumption per tonne of synthetic ammonia production (tce/tonne)
Industry	Final energy consumption per unit of textile sector value-added (tce/RMB)
Industry	Final energy consumption per tonne of ethylene production (tce/tonne)
Industry	Final energy consumption per unit of food sector value-added (tce/RMB)

Benchmarking: 35 KPIs Citywide and in 8 Sectors

Sector	KPI Name
Public & Commercial Buildings	Public buildings electricity intensity (kWh/m²)
Public & Commercial Buildings	% of citywide floor space in "green" buildings or other labeled buildings (%)
Public & Commercial Buildings	Total installed capacity of integrated renewable or CHP in public buildings (kW)
Public & Commercial Buildings	District heating supplied by cogeneration facilities (%)
Residential Buildings	Residential buildings energy intensity (tce/capita)
Transportation	Transportation energy use per capita (per year) (tce/capita)
Transportation	Public transit network (km/km ²)
Transportation	Mode share of non-motorized transport (%)
Power & Heat	Share of renewable energy in local electricity supply (%)
Street lighting	Grid-connected electricity consumed per km of lit roads per year (kWh/km/yr)
Water & Wastewater	Annual water consumption per capita (L/capita/yr)
Water & Wastewater	Electricity density per unit of potable water supply (kWh/m³)
Water & Wastewater	Electricity density per unit of waste water treatment (kWh/m ³)
Solid waste	Municipal solid waste disposed per capita per year (kg/capita/yr)
Urban green space	Urban green space per capita (m²/capita)



BEST-Cities Benchmarking: GHG Emissions Per Capita (tCO₂e/person)

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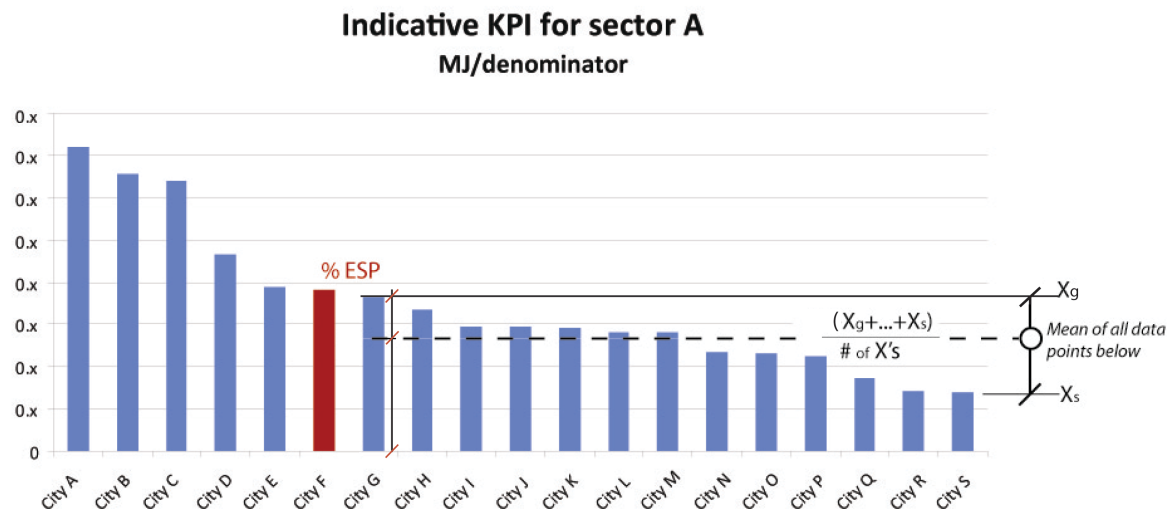
- City Capability
- Policy Appraisal
- Policy Review
- Policy Matrix
- Priority Policies

Documents



Sector Prioritization: Sector Improvement Potential

- Sector Prioritization Formula: [**Sector Improvement Potential**] x [Carbon Emissions] x [City Authority]
- **Sector Improvement Potential** calculation is based on a single “indicative” KPI thought to best represent the sector.



Equation for each sector KPI:

$$\text{Sector Improvement Potential [\%]} = \frac{\text{KPI}_{\text{City}} - \text{KPI}_{\text{average better}}}{\text{KPI}_{\text{City}}}$$

$$\text{Where } \text{KPI}_{\text{average better}} = \frac{\sum \text{KPI}_{\text{equal to or better than the city being benchmarked}}}{\# \text{ of cities equal or better}}$$

Sector Prioritization: City Authority

- Sector Prioritization Formula: [Sector Improvement Potential] x [Carbon Emissions] x **[City Authority]**
- **City Authority**: a weighting factor designed to reflect the level of policy control that local authorities can exert over a given sector



Sector Prioritization: Overall Score

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Sector Prioritization Results

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9 of 9
selected

The list below shows the priority ranking of each sector, based on the Sector Improvement Potential, the magnitude of CO₂e emissions, and the sector City Authority assessment. The overall sector Score is determined by the following calculation:
Sector Improvement Potential (%) x Sector CO₂ Emissions (10⁴ tCO₂e) x City Authority

Rank	Sector	Sector Improvement Potential %	CO ₂ e Emissions (10 ⁴ tCO ₂ e)	City Authority %	Score	Check priority sectors
1	Industry	15%	6,859.63	35%	360.13	<input checked="" type="checkbox"/>
2	Public & Commercial Buildings	20%	3,345.18	50%	334.51	<input checked="" type="checkbox"/>
3	Power & Heat	37%	3,548.39	20%	266.12	<input checked="" type="checkbox"/>
4	Residential Buildings	10%	2,194.77	75%	164.60	<input checked="" type="checkbox"/>
5	Solid Waste	87%	110.34	65%	62.66	<input checked="" type="checkbox"/>
6	Transportation	10%	196.22	35%	6.86	<input checked="" type="checkbox"/>
7	Urban Green Space	50%	-10.00	90%	4.50	<input checked="" type="checkbox"/>
8	Water & Wastewater	10%	5.03	20%	0.10	<input checked="" type="checkbox"/>
9	Public Lighting	9%	0.04	75%	0.00	<input checked="" type="checkbox"/>

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Documents

- Identifies energy-saving and emissions-reduction policies and programs
- Database of more than 70 policies and programs that can be adopted at the city level
 - Policy/program description
 - Implementation strategies and challenges
 - Monitoring metrics
 - Case studies
 - Attributes: carbon saving potential, first cost to government, speed of implementation, co-benefits

Using your knowledge of the capabilities of the city in terms of project finance, human resources, and policy, regulation, and enforcement, select the description that most accurately describes the situation in your city for each of the prioritized sectors (tabs on the left).

← Residential Buildings ▲

INDUSTRY

PUBLIC & COMMERCIAL BUILDINGS

RESIDENTIAL BUILDINGS

TRANSPORTATION

POWER & HEAT

PUBLIC LIGHTING

WATER & WASTEWATER

SOLID WASTE

URBAN GREEN SPACE

Finance

City Capability

Low Funding is available from municipal budget streams only. Municipal government has no experience of other financial or partnering mechanisms.

Medium Municipal government has some experience with grants, soft loans, and commercial financing instruments.

High Municipal government has relevant experience in innovative financing mechanisms, such as performance contracting, ESCO partnerships, and carbon financing, in addition to grants, soft loans, and commercial financing instruments.

Human Resource

City Capability

Low Municipal government has few technically skilled staff and/or a small available workforce. Staff must be trained/or workforce expanded to deliver any new low carbon projects.

Medium Municipal government has access to a highly trained/skilled person to lead the initiative and/or a medium sized workforce available. Additional staff and/or training may be necessary to deliver any new low carbon projects.

High Municipal government has access to a sufficient number of trained/technically proficient staff resources, including skilled planners/modelers.

Policy, Regulation and Enforcement

Buildings Policies



Residential Buildings	Public and Commercial Buildings
Reach Standards for Efficient Appliance and Equipment	More Stringent Local Building Codes
Building Workforce Training	Green Building Guidelines for New Buildings
Green Building Guidelines for New Buildings	Expedited Permitting for Green Buildings
More Stringent Local Building Codes	Targets for Efficient and Renewables in Buildings
City Energy and Heat Maps	Building Energy Labeling and Information Disclosure
Building Energy Labeling and Information Disclosure	Mandatory Building Energy-Efficiency Audit
Targets for Efficient and Renewables in Buildings	Public Education Campaigns on Building Energy Efficiency and Conservation
Expedited Permitting for Green Buildings	Municipal Building Energy Efficiency Task Force
Retrofit Subsidies and Tax Credits for Existing Buildings	Energy Performance Contracting and Energy Service Companies
Subsidies for New Buildings that Exceed Building Code	Retrofit Subsidies and Tax Credits for Existing Buildings
Energy-Efficient Equipment and Renewable Energy Technology Purchase Subsidies	Subsidies for New Buildings that Exceed Building Code
Public Education Campaigns on Building Energy Efficiency and Conservation	City Energy and Heat Maps
	Cooperative Procurement of Green Products
	Financial Incentives for Distributed Generation in Buildings

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Policy Review

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Export as a Report

All policies selected through Policy Appraisal are displayed below, along with their attributes: Speed of Implementation, Carbon Savings Potential, and First Cost to 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.



For a city of 5 million - 9,999,999 population:

Sector	Policy	Speed of Implementation	Carbon Savings Potential (tCO ₂ e)	First Cost to Government (RMB)	Override
Residential Buildings	Green Building Guidelines for New Buildings	< 1 Year	500,000 - 2.5 million	< 5 million	Override
Residential Buildings	City Energy and Heat Maps	< 1 Year	< 500,000	< 5 million	Override
Residential Buildings	Building Energy Labeling and Information Disclosure	1-3 Years	500,000 - 2.5 million	< 5 million	Override
Residential Buildings	Building Workforce Training	< 1 Year	< 500,000	< 5 million	Override
Residential Buildings	More Stringent Local Building Codes	> 3 Years	> 2.5 million	5 million - 50 million	Override
Residential Buildings	Reach Standards for Efficient Appliance and Equipment	1-3 Years	> 2.5 million	< 5 million	Override
Residential Buildings	Targets for Efficient and Renewables in Buildings	1-3 Years	500,000 - 2.5 million	< 5 million	Override
Residential Buildings	Expedited Permitting for Green Buildings	< 1 Year	< 500,000	< 5 million	Override
Residential Buildings	Retrofit Subsidies and Tax Credits for Existing Buildings	1-3 Years	500,000 - 2.5 million	> 50 million	Override
Residential Buildings	Subsidies for New Buildings that Exceed Building Code	1-3 Years	500,000 - 2.5 million	5 million - 50 million	Override
Residential Buildings	Energy-Efficient Equipment and Renewable Energy Technol	1-3 Years	> 2.5 million	> 50 million	Override
Residential Buildings	Public Education Campaigns on Building Energy Efficiency	< 1 Year	< 500,000	< 5 million	Override

 Home

Priority Policies

BEST Cities
CITY B 

Export as a
Report

This is your city's prioritized list of low-carbon policies, based on your data and analysis by the BEST Cities tool. Click on a policy name to see details (Description, Implementation Strategies, Metrics, Case Studies, and Attributes). All Policies are saved in html and can be printed separately. Use the Export function in the File Menu to save a list of your Priority Policies.

Very High Priority Low-Carbon Policies

Recommendation	Sector
More Stringent Local Building Codes	Public & Commercial Buildings
More Stringent Local Building Codes	Residential Buildings
Reach Standards for Efficient Appliance and Equipment	Residential Buildings
Public Transit Infrastructure: Light Rail, BRT, and Buses	Transportation
Minimum Performance Standards for Thermal Power Plants	Power & Heat
Renewable Energy and Non-fossil Energy Targets or Quotas	Power & Heat

High Priority Low-Carbon Policies

Recommendation	Sector
Benchmarking	Industry
Energy Audit / Assessments	Industry
Industrial Energy Plan	Industry
Stretch Targets for Industry	Industry
Energy Management Standards	Industry
Energy Manager Training	Industry
Recycling Economy and By-product Synergy Activities	Industry
Low-carbon Industrial Parks	Industry
Fuel-switching	Industry
Subsidies for New Buildings that Exceed Building Code	Public & Commercial Buildings
Cooperative Procurement of Green Products	Public & Commercial Buildings

- Testing
 - Beta-testing of tool – Jinan, capital city of Shandong Province
- Training
 - Technology Development Strategy Institute of Shandong Academy of Science
- Dissemination
 - National Development and Reform Commission, Macroeconomic Institute, Energy Research Institute, National Center for Climate Change Strategy and International Cooperation, Energy Foundation China
 - U.S.-China EcoPartnerships: LBNL's China Energy Group and Shandong Academy of Science



Website

<http://china.lbl.gov/>



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Home

Policy Appraisal [?]

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Save Image

The policies listed below are ranked based on the results of the assessment of the capabilities of the city 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.

P Policy, Regulation and Enforcement

H Human Resources

F Finance

Overall Rating i i i

CITY B Capabilities		l	h	m	
Policy	Overall Rating	F	H	P	Uncheck to remove
Building Energy Labeling and Information Disclosure	●	l	m	m	<input checked="" type="checkbox"/>
Building Workforce Training	●	l	m	l	<input checked="" type="checkbox"/>
City Energy and Heat Maps	●	l	m	l	<input checked="" type="checkbox"/>
Energy-Efficient Equipment and Renewable Energy Technology Purchase	●	h	m	h	<input checked="" type="checkbox"/>
Expedited Permitting for Green Buildings	●	l	l	l	<input checked="" type="checkbox"/>
Green Building Guidelines for New Buildings	●	l	m	m	<input checked="" type="checkbox"/>
More Stringent Local Building Codes	●	l	m	h	<input checked="" type="checkbox"/>
Public Education Campaigns on Building Energy Efficiency and Conservation	●	l	m	l	<input checked="" type="checkbox"/>
Reach Standards for Efficient Appliance and Equipment	●	l	l	m	<input checked="" type="checkbox"/>
Retrofit Subsidies and Tax Credits for Existing Buildings	●	h	m	h	<input checked="" type="checkbox"/>
Subsidies for New Buildings that Exceed Building Code	●	h	m	h	<input checked="" type="checkbox"/>
Targets for Efficient and Renewables in Buildings	●	l	l	m	<input checked="" type="checkbox"/>

Definition of Attribute Tags

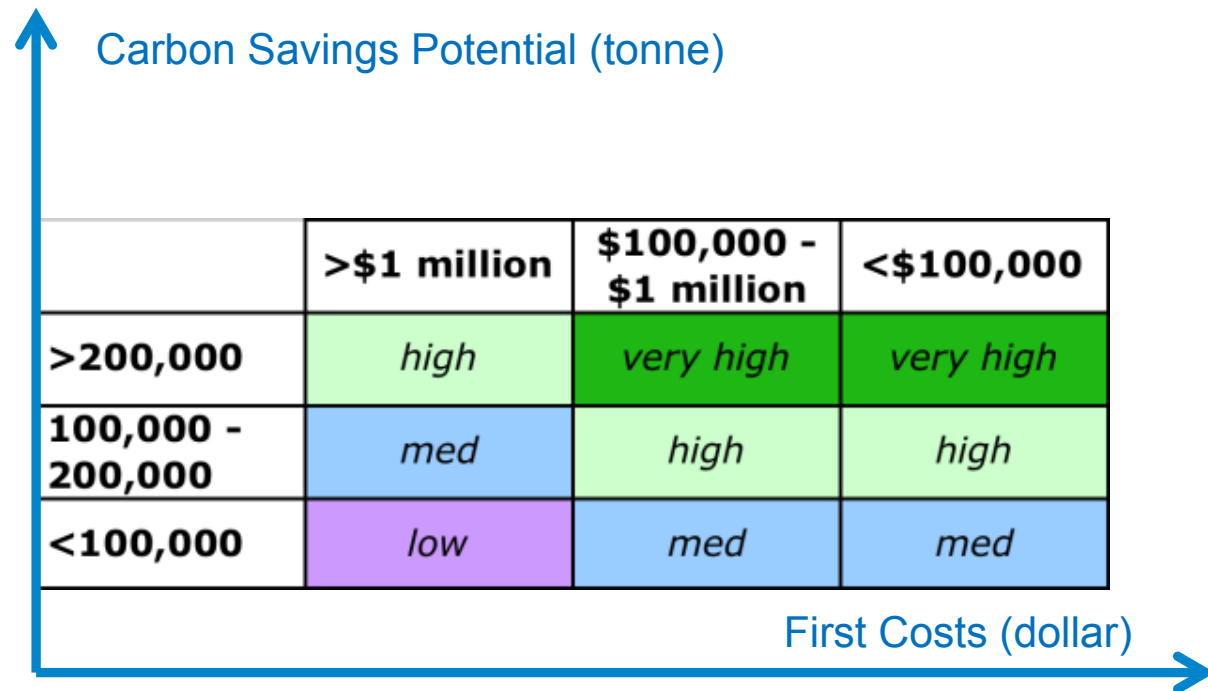
- **Speed of Implementation: low (<1 year), medium (1-3 years), high (>3 years)**
- **Carbon Savings Potential: low, medium, high**

Speed of Implementation	Carbon Savings Potential (unit: tCO ₂ e)					
	Varies by city size (unit: population)					
	<500K	500K – 1 m	1 -5 m	5 – 10 m	>10 m	
Low	< 1 year	< 50 K tCO ₂ e	<125 K tCO ₂ e	< 250K tCO ₂ e	< 500K CO ₂ e	<1 Mt CO ₂ e
Med	1 – 3 years	50K -250 K tCO ₂ e	1.25 -12.5 m tCO ₂ e	2.5 -25 m tCO ₂ e	500K – 2.5 m	1- 5 m tCO ₂ e
High	>3 years	>250K tCO ₂ e	> 625K tCO ₂ e	>1.25 M tCO ₂ e	>2.5 M tCO ₂ e	>5 mtCO ₂ e

- **First Costs: low, medium, high**

	First Cost (unit: RMB)					
	City Size (unit: population)					
	<500K	500K – 1 m	1 -5 m	5 – 10 m	>10 m	
Low	500k RMB	<1.25 m RMB	<2.5 m RMB	<5 m RMB	<10m RMB	
Med	500K - 5 m RMB	1.25 -12.5 m RMB	2.5 -25 m RMB	5 – 50 m RMB	10 – 100m RMB	
High	>5 m RMB	>12.5 m RMB	>25 m RMB	>50 m RMB	>100 m RMB	

- Recommended policies in four “priority” categories:
 - Very high priority
 - High priority
 - Medium priority
 - Low priority




Recommendation Matrix

BEST Low Carbon Cities

BEST Tool File

Home

Recommendation Matrix [?]

BEST Low Carbon Cities
TEST 

Back to Review

The matrix below shows all recommendations from prioritized sectors sorted by First Cost and CO2 Emissions Reduction Potential. The check boxes allow the user to alter the display based on Speed of Implementation.

Final Priority List

Filter by speed of implementation

< 1 Year 1-3 Years > 3 Years

Carbon Impact Potential	First Cost		
	< 500,000	500,000 - 5 million	> 5 million
> 250,000	<ul style="list-style-type: none"> Energy or CO2 Tax Cooperative procurement Targets Mandatory Building Codes for New Build... Targets Mandatory Building Codes for New Build... 	<ul style="list-style-type: none"> Stretch Targets Fuel-switching Vehicle Emission Standards – CO2 Vehicle Emission Standards – Fuel Eco... 	<ul style="list-style-type: none"> Mandatory Audit and Retrofit Purchase subsidies Minimum efficiency or emission standar... Targets or Quotas (RE and Non-fossil T... Power Investment subsidies and tax inc...
50,000 - 249,999	<ul style="list-style-type: none"> Industrial Energy Plan Enforcement of Product Standards Differential Electricity Pricing Energy Manager Training Circular Economy Activities Urban Form Land-Use Planning 	<ul style="list-style-type: none"> Energy Audit Energy Management Standards Low-carbon Industrial Parks Subsidies for exceeding building code Energy Performance Contracting (EPC) ... Green Building Guidelines for New Build... 	<ul style="list-style-type: none"> Incentives and Rewards for Industrial En... Energy Efficiency Loans and Innovative F... Tax Relief Retrofit subsidies and tax credits Retrofit subsidies and tax credits Public Transit Infrastructure: Light rail an...
< 50,000	<ul style="list-style-type: none"> Benchmarking Municipal Building Energy Efficiency Tas... Expedited permitting City energy and heat map Expedited permitting City energy and heat map 	<ul style="list-style-type: none"> Public education on building energy effi... Public education on building energy effi... Landfill Methane Recovery 	<ul style="list-style-type: none"> Worker training