

City Energy Efficiency Assessments

Energy Efficient Cities

MAYORAL GUIDANCE NOTE #5





For more information related to energy efficiency in cities, please visit ESMAP's website at: www.esmap.org/Energy_Efficient_Cities.

ADDITIONAL RESOURCES

TRACE learning course: background information (including an e-learning course about how to use TRACE): <http://esmap.org/esmap/TRACE>

BEST Cities, Lawrence Berkeley National Laboratory:
<http://china.lbl.gov/tools-guidebooks/best-cities>

Applying Abatement Cost Curve Methodology for Low Carbon Strategy in Changning District, Shanghai, World Bank: [http://imagebank.worldbank.org/servlet/WDSContentServer/IW3P/IB/2014/01/20/000442464_20140120121910/Rendered/PDF/840680ESW0whit00City0Summary0Report.pdf](http://imagebank.worldbank.org/servlet/WDSContentServer?IW3P/IB/2014/01/20/000442464_20140120121910/Rendered/PDF/840680ESW0whit00City0Summary0Report.pdf)

Sustainable Urban Energy and Emissions Planning Guidebook, World Bank: <http://documents.worldbank.org/curated/en/2012/01/17193899/sustainable-urban-energy-emissions-planning-guidebook-guide-cities-east-asia-pacific>

Sustainable Urban Energy Planning: A Handbook for Cities and Towns in Developing Countries, ICLEI/UN Habitat/UNEP: http://www.unep.org/urban_environment/PDFs/Sustainable_Energy_Handbook.pdf

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EXECUTIVE SUMMARY

For cities that want to take concrete actions on improving energy efficiency, it is essential to understand what, where, and how big the potential energy-saving **opportunities** are, what **measures** are needed to capture the savings and at what **costs**, what the implementation **constraints** are, and how **priorities** should be set given local capacity and resources. An energy efficiency assessment can provide the necessary clarity on these issues.

Energy efficiency assessments can be done at different depths and with varying scopes, depending on the city's needs, capacity, and resources. For a city that is just beginning to contemplate introducing energy efficiency programs but has limited knowledge of its energy efficiency opportunities, a **multi-sector rapid assessment** can help quickly identify underperforming sectors, major energy efficiency opportunities, and key constraints, and recommend a course of action for a city to build and expand its energy efficiency efforts. For a large city (e.g., one to two million people), a limited-scope multi-sector rapid assessment can be done at moderate cost by a small team—led by an energy efficiency expert—in as little as three months, but this requires the close cooperation of city authorities for data, information, and consultation.

If a city already has a basic knowledge of its energy efficiency landscape and wants to develop an energy efficiency program for a selected sector or subsector (e.g., public buildings), a **single-sector in-depth assessment** can help identify specific energy efficiency issues and intervention options, quantitatively evaluate energy savings potential, investment costs and benefits, thoroughly assess implementation constraints, and recommend concrete solutions and actions. This could also be a follow-up activity after a sector is identified as a priority by a multi-sector rapid assessment. In order to do this, a small team led by a sector energy efficiency specialist is needed. The duration and cost of the assessment depends on the quality of existing data and the size and complexity of the sector. For a large city, an assessment of the public buildings sector may take six months or more, if the basic building inventory and energy use data does not exist, since energy use surveys and simple energy audits will have to be conducted. Assessment of residential buildings tends to be more difficult and takes greater effort.

If a city wants to develop a concrete action plan to achieve low carbon growth, such as New York City's PlaNYC 2030, a **multi-sector comprehensive assessment** can provide more rigorous analyses and greater clarity for prioritizing policy interventions and investments across urban sectors than a rapid assessment. But it also requires significantly more effort and resources, as it is not a simple collection of multiple single-sector in-depth assessments. To enable cross-sectoral prioritization, a common set of metrics must be used, for example, using a standard methodology to evaluate the net benefits of energy efficiency interventions in all sectors. A team of sector specialists, economists, and institutional experts is needed. Such an exercise for a large city is likely to be relatively expensive and can take 12 months or more, depending on data availability.

This guidance note provides an introduction to the objectives, scope, and outputs, as well as the basic steps and approaches of conducting the three types of energy efficiency assessments. It may be used as a general reference for choosing and defining the type of energy efficiency assessment that a city might pursue.

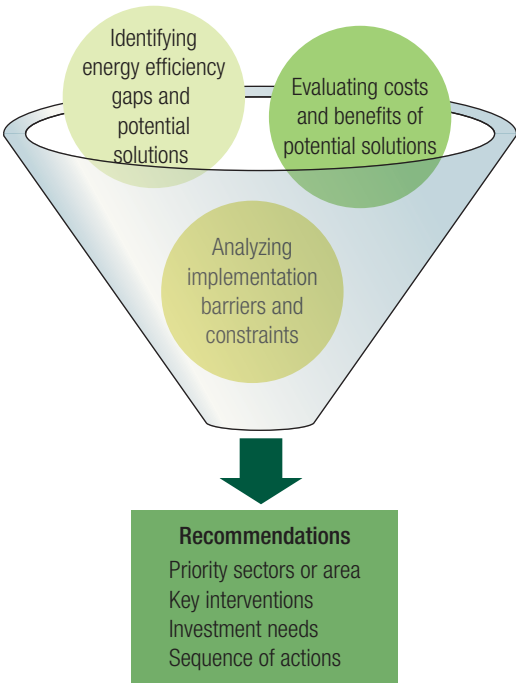


WHY DO CITIES NEED ENERGY EFFICIENCY ASSESSMENTS?

Cities account for about two-thirds of the world's final energy consumption. This share is projected to be almost three-quarters by 2030 due to continued urbanization in developing countries (IEA 2008). Using energy more efficiently increases cities' competitiveness and livability, and is one of the most important actions to mitigate climate change. Improving energy efficiency also keeps money in city government coffers, money that can be spent on other critical services. For example, the Municipality of Emfuleni in South Africa initiated an energy and water efficiency project that cost US\$ 1.8 million and achieved annual monetary savings of over US\$ 4 million, which enabled the municipality to pay back the initial investment in less than six months and generate a net cash-saving stream that will last for years (ESMAP 2009). The benefits of investing in energy efficiency in cities go beyond immediate financial savings. For example, the City of Los Angeles spent US\$ 56.9 million to replace 140,000 of the city's street lights with LED technology. The investment will not only provide an estimated US\$ 10 million in annual energy and maintenance cost savings; it will also enhance lighting quality, improve street safety, reduce light pollution, and cut local CO₂ emissions by more than 40,000 tons each year (ESMAP 2011).

For cities that want to take concrete actions on improving energy efficiency, it is essential to understand what, where, and how big their energy-savings *opportunities* are, what *measures* are needed to capture the savings and at what *costs*, what the implementation *constraints* are, and how *priorities* should be set given local capacity and resources (Figure 1). An energy efficiency assessment can provide the necessary clarity on those issues.

Figure 1 | Elements of Energy Efficiency Assessment



WHAT DOES AN ENERGY EFFICIENCY ASSESSMENT DO?

An energy efficiency assessment is an investigative process that yields practical recommendations for improving energy efficiency in one or multiple sectors. It generally includes the following four steps: (i) identifying energy efficiency gaps and potential solutions; (ii) evaluating the cost and benefits of potential solutions; (iii) analyzing the barriers and constraints to implementing the potential solutions; and (iv) recommending a course of actions based on energy efficiency goals, local capabilities, and available resources.

The scope and depth of an energy efficiency assessment may vary depending on the specific need or interest of a city. In general, an assessment falls into one of the following three categories, the main characteristics of which are summarized in Table 1:

- **A multi-sector rapid assessment** can help a city quickly identify underperforming sectors, major energy efficiency gaps, and key constraints; and recommend a course of action the city government can undertake to build and expand its energy efficiency efforts. This approach is suitable for cities that have little or limited knowledge of their energy efficiency opportunities.
- **A single-sector in-depth assessment** can help a city clearly identify the energy efficiency issues and solutions for a specific sector; quantitatively evaluate energy savings potential, investment costs, and benefits; thoroughly assess implementation constraints; and recommend concrete actions and solutions. This approach is suitable for cities that already have a basic knowledge of their energy efficiency landscape and want to develop an energy efficiency program for a selected sector or subsector (e.g., public buildings). This could also be a follow-up activity after a sector has been identified as a priority by a multi-sector rapid assessment.
- **A multi-sector comprehensive assessment** can provide a more rigorous analysis and greater clarity with which to prioritize policy interventions and investments across urban sectors than a rapid assessment. However, this approach is not a simple collection of multiple single-sector in-depth assessments. To enable cross-sectoral prioritization, a common set of metrics needs to be used, for example, using a standard methodology to evaluate the net benefits of energy efficiency interventions across all sectors. A multi-sector comprehensive assessment is useful for cities that want to develop a concrete action plan on low carbon growth, such as the PlaNYC of New York City.

None of the three approaches outlined above should be confused with an energy audit, which is a narrowly focused technical diagnosis of the energy efficiency of a building, a system (e.g., water supply), a manufacturing process, or a factory. An in-depth sector energy efficiency assessment will likely include simple energy audits to ensure the technical robustness of energy-savings estimates.

WHICH ENERGY-CONSUMING SECTORS IN CITIES SHOULD BE ASSESSED?

At the initial phase of introducing energy efficiency measures, a city government may focus on sectors in which it can significantly influence energy efficiency investment decisions and results. While levels of influence vary among countries, most city governments tend to have strong influence on urban transport, public buildings, and municipal services (Table 2). In cities where industries account for a large share of local energy consumption, such as in China, a city government may have a strong interest in supporting energy efficiency efforts in industries as well. A compelling reason for a city government to include

Table 1 | Selecting an Appropriate Energy Efficiency Assessment

	Main Objective	Scope of Work	Duration and Cost*
Multi-sector Rapid Assessment	Initiate city-level energy efficiency efforts	Identify underperforming sectors and main energy efficiency gaps Prioritize sectors and actions based on potential benefits and implementation constraints Recommend a course of actions to establish and/or expand the city's energy efficiency program based on the city's needs and available resources	About 3 months by a small team led by an energy efficiency specialist *US\$50,000 or more
Single-sector In-depth Assessment	Design a sector-specific energy efficiency program	Diagnose sector-specific energy efficiency gaps and issues Analyze the costs and benefits and implementation constraints of the potential solutions Recommend practical solutions and implementation approaches to address major sector energy efficiency issues based on local capacity and resources	Vary significantly, depending on the size and complexity of the sector Public lighting assessment can be relatively short and low cost; assessing the entire building sector can be costly and require many months *US\$50,000–100,000 or more
Multi-sector Comprehensive Assessment	Develop a concrete citywide energy efficiency action plan	Conduct in-depth energy efficiency analysis for selected sectors Prioritize energy efficiency interventions across sectors using a common set of metrics Recommend a course of actions based on the city's integrated multi-sector energy efficiency goals and resources	About 12 months by a relatively large team involving sector specialists, economists and institutional experts *US\$200,000 or more

*Rough estimates for a large city of 1–2 million people in developing countries based on anecdotal evidence; using international consultants tends to increase cost.

Source | Authors.

Table 2 | Energy Consumption in Cities: Main Sectors/Clusters

Sector Category	Subcategory	City Government Influence
Industry	Manufacturing	Indirect, weak*
	Construction	Indirect, weak*
Transport	Private/commercial motor vehicles	Indirect, weak
	Transport demand management	Direct, strong
	Government motor vehicles	Direct, strong
	Public transit systems	Direct, strong
Buildings	Public buildings	Direct, strong
	Commercial buildings (non-public)	Indirect, strong in new constructions
	Residential buildings	Indirect, strong in new constructions
Municipal Services	Water supply and sanitation	Direct, strong
	Solid waste management	Direct, strong
	Public lighting	Direct, strong

*Cities in China are probably an exception, but are gradually converging to the global norm.

Source | Authors.

industries in a citywide energy efficiency program may be to control industrial air pollution or develop a low carbon growth strategy to tackle industrial CO₂ emissions.

This guidance note does not specifically cover energy efficiency assessments for industries, but rather focuses on typical urban sectors, such as transport, buildings, and municipal services, where a city government’s leadership and intervention in energy efficiency is often sorely needed.



MULTI-SECTOR RAPID ENERGY EFFICIENCY ASSESSMENT

City officials may recognize the benefits of promoting energy efficiency, but often have little experience with this topic and little idea as to where to begin. Such situations are typically best addressed by limiting the scope of intervention to municipal government operations and other areas in which local officials can exert significant policy or managerial influence. As such, a low-cost, multi-sector rapid assessment is often a good starting point.

Attempting a timely and low-cost, multi-sector assessment requires significant simplification and standardization of energy efficiency assessment procedures to reduce data acquisition needs and processing time. A diagnostic tool covering all the basic elements of energy efficiency assessment serves such purposes well. The Tool for Rapid Assessment of City Energy (TRACE) developed by the Energy Sector Management Assistance Program of the World Bank is specifically designed for this application and has been successfully deployed in 27 cities around the world.¹ By using key energy performance indicators, TRACE allows cities to compare the energy efficiency performance of six municipal sectors—buildings, transport, public lighting, water and wastewater, power and heat, and solid waste—to their peers and to select appropriate interventions with which to address underperforming areas based on local capacity, resources, and priorities. The deployment of TRACE is an open diagnostic process that lets city decision makers assess and adjust their choices based on readily available and relevant international experiences. It accomplishes this rapid assessment through a three-step process: (i) energy performance

benchmarking, (ii) sector prioritization, and (iii) the selection of appropriate energy efficiency interventions (Figure 2). A TRACE diagnostic deployment usually takes about 12 weeks.

Step 1 | Identifying energy efficiency opportunities through benchmarking.

TRACE allows users to compare their energy performance against a range of peer cities based on 28 different performance indicators. The tool currently has data from 93 cities from across Africa, Asia, Europe, Latin America, and the Middle East. The diversity in various city characteristics enables users to compare cities with similar population, climate, and human development index ranking. The benchmarking tool highlights how a city is faring in relation to others in terms of energy use, and where improvements may be possible.

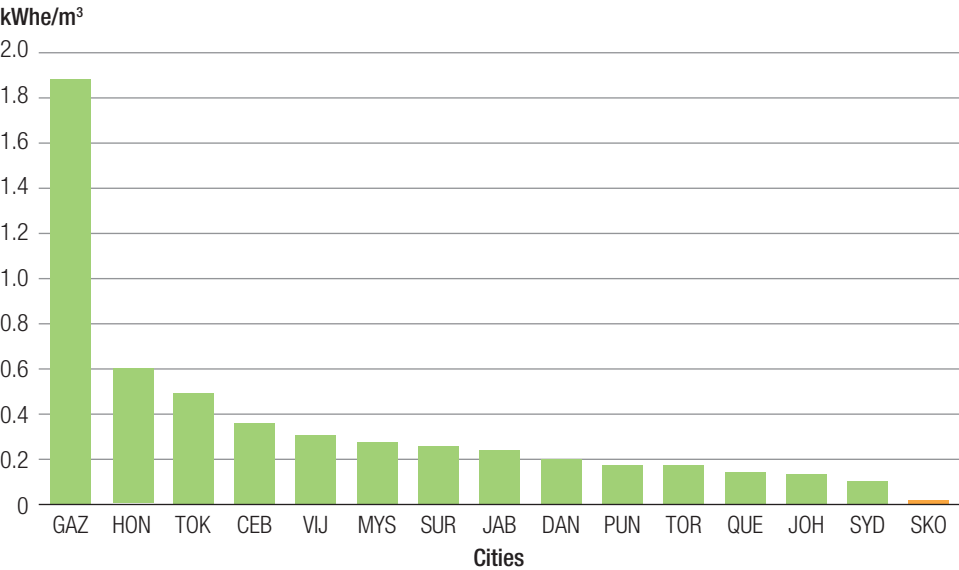
Results of the benchmarking exercise in the TRACE deployment in Skopje, Macedonia, are provided in Figure 3 and Figure 4 as an illustration of how it works. Figure 3 shows the efficiency of Skopje’s potable water production system compared to water supply systems in other comparable cities chosen from the database (Skopje is the city on the far right). Skopje’s low score in terms of energy density of potable water production reflects the energy benefits of its historic decision to locate its water reservoir high above the city, letting gravity do much of the work distributing water around the city. Figure 4 compares the efficiency of Skopje’s street lighting system (orange bar) with systems in other cities. Skopje generally performs well, but the fact that so many other cities use less energy per light pole suggests this is an area where further analysis may be worth pursuing.

Step 2 | Evaluating potential cost savings and implementation constraints for sector prioritization. Knowing how a city’s energy use compares against peer cities is

Figure 2 | TRACE Home Interface



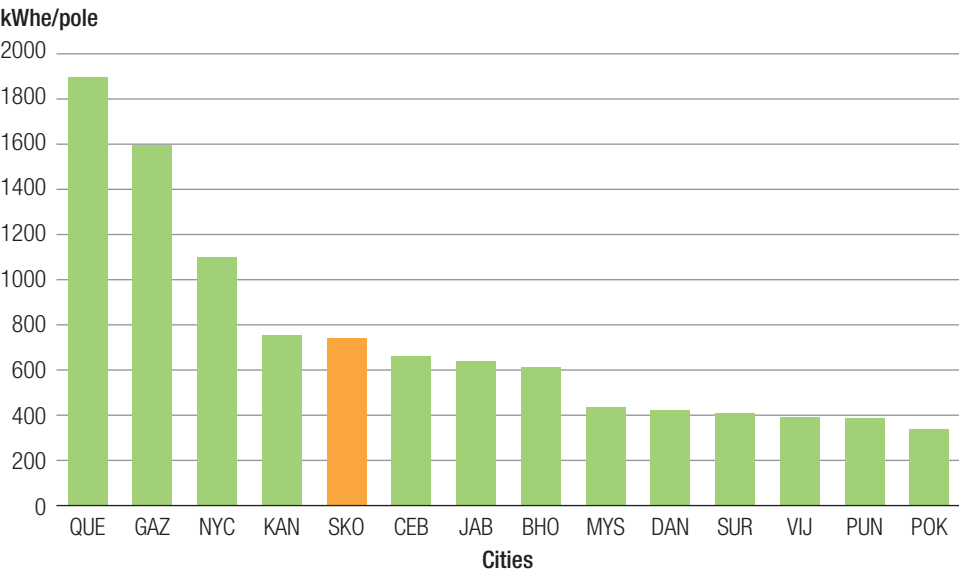
Figure 3 | Benchmark Data on Energy Density of Potable Water Production in Skopje, Macedonia



Source | World Bank (2011) ECA Sustainable Cities: Improving Energy Efficiency in Skopje, Macedonia.

helpful, but it is only one factor in determining where local authorities should target their interventions. TRACE helps local authorities prioritize among key energy-using sectors by taking other relevant factors into account. The benchmark results are converted into rough ‘energy-savings potential’² estimates, multiplied by relevant energy-spending data, and then adjusted to account for a local authority’s level of influence over the specific sectors to yield a priority score.

Figure 4 | Benchmarking Data on Electricity Consumed for Public Street Lighting



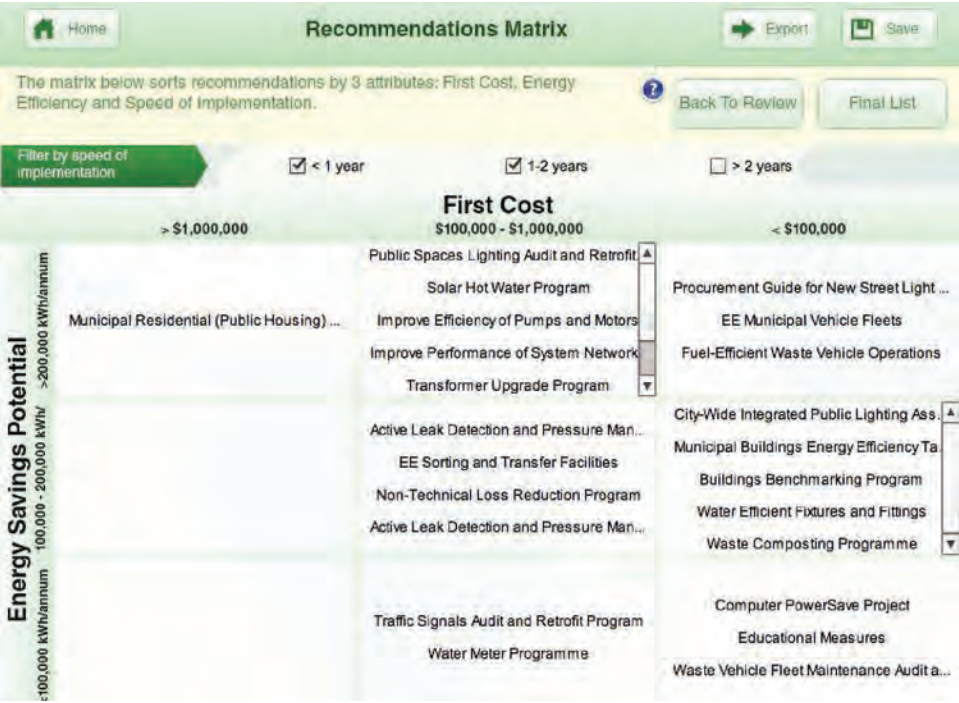
Source | World Bank (2011) ECA Sustainable Cities: Improving Energy Efficiency in Skopje, Macedonia.

Step 3 | Screening and recommending suitable energy efficiency interventions to fit a city's objectives and resources. The final phase of the TRACE process explores potential energy efficiency interventions in each targeted sector. A total of 59 tried and effective energy efficiency interventions are currently programmed into the TRACE database, and this number will likely grow over time. Interventions specifically applicable to a city are chosen through discussions with sector leaders and by matching capabilities of a city with the capabilities required to implement the interventions (based on global experiences). Detailed information about each intervention is provided: its energy savings, first cost, and speed of implementation. In many cases, worksheets are provided that help users better assess the energy- and cost-savings potential of a particular intervention, using local energy use data, energy prices, and labor and installation costs. Additionally, links to case studies, reports, other research that flesh out implementation challenges, and alternative policy approaches (e.g., mandates vs. incentives) that can be used to deliver each strategy are provided.

The final list of recommended interventions for prioritized sectors is presented in a 3 × 3 matrix which is easy to share with senior officials and other stakeholders. The matrix offers crude estimates of how much individual recommended interventions would cost, how quickly they can be implemented, and how much energy can be saved (Figure 5).

The main lessons learned in applications of TRACE so far are: (i) city ownership of the assessment and participation in the process are critical and help ensure that access to data and information is maximized, the participation of relevant city departments is strong, the recommendations are realistic and reach the mayor's office, and that follow-up actions are implemented; (ii) relevant data, such as building and equipment inventories and energy consumption, are often incomplete and field assessments are

Figure 5 | TRACE Recommendation Matrix



crucial to compensate for the lack of documented information; and (iii) expert judgments, based on international experiences and local context, are important to interpret benchmark results, conduct fruitful consultations, and develop appropriate recommendations.

For cities wanting to expand the rapid assessment process to include industries and non-public buildings, a broader assessment tool called Benchmarking Energy Savings Tool for Low Carbon Cities (BEST Cities) has been developed by the China Energy Group of the Lawrence Berkeley National Laboratory using TRACE's architecture and platform. The BEST Cities tool, currently geared for application in Chinese cities, is designed to provide city authorities with strategies to reduce citywide CO₂ emissions by assessing local energy use and energy-related CO₂ emissions across nine sectors—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.³



SINGLE-SECTOR IN-DEPTH ENERGY EFFICIENCY ASSESSMENT

For cities that are interested in developing a energy efficiency program in a specific sector, such as residential, public, or commercial buildings, or in public lighting, or water supply and sanitation services, an in-depth sector assessment will help properly design the program. There are different ways to conduct an in-depth sector energy efficiency assessment, with particular tasks varying by sector. But the general approach usually includes the following basic steps:

Step 1 | Diagnose sector energy efficiency gaps and issues. The main purpose of this first step is to attain a good understanding of the current situation and clearly define the baseline against which improvements need to be made and measured. This would generally cover the following activities:

- Taking stock of the inventory of equipment, systems, and buildings, and their energy consumption characteristics (e.g., age, type, quantity, cost). This could involve surveys and simple audits, if existing data are insufficient.
- Identifying main energy efficiency gaps and potential technical measures for improvements. This is usually done through benchmarking and/or expert judgment based on similar experiences elsewhere.
- Taking stock of national and local policies and regulations that influence sector energy use and energy efficiency investment decisions (e.g., energy prices and billing practices), as well as current and past experiences of relevant energy efficiency interventions and summarization of lessons learned. This may include relevant experiences of other cities in the country or around the world.
- Identifying stakeholders and their respective roles and potential influences on sector energy efficiency improvement, for example, relevant local and national government entities, energy utilities, local banks, and energy service companies.

Step 2 | Evaluate the costs and benefits of energy efficiency measures. Realistic cost-benefit analyses of potential energy efficiency measures are crucial for making energy efficiency investment decisions and for prioritizing and packaging interventions (e.g., financial incentives may be needed for measures that have large savings benefits but which require relatively long payback times). A cost-benefit analysis would generally involve:

- Calculating the economic and financial costs and benefits of potential energy efficiency measures based on actual and empirical data to the extent possible to reflect local reality. The economic analysis looks at energy efficiency from a broad social investment standpoint and would include social and environment benefits, if data permit. The financial analysis looks at energy efficiency from a financial investment point of view and only accounts for the direct financial returns of energy efficiency measures.
- Ranking energy efficiency measures by a selected metric by type of energy (electricity or fuel) and estimating overall sector energy savings potential and investment cost. The commonly used metrics are generally financial, for example, simple payback time, net present value, or levelized cost of saved energy (Box 1), which is often compared with the price of energy (electricity or fuel).

Step 3 | Assess key barriers or constraints to implementation. The successful implementation of financially attractive energy efficiency measures requires addressing

Box 1 | Definition and Calculation of Cost of Saved Energy

Cost of saved energy (CSE) is used to compare energy savings with conventional energy supply options such as electricity and fuels. This helps decision makers understand the cost of investing in energy efficiency as an alternative to new supply or buying energy. The cost may be given in different units, such as \$/kWh for electricity or \$/MJ for fuel. The following equation depicts the calculation of the cost of electricity saved:

$$\text{CSE (\$/kWh)} = (C * 10^6) * (\text{capital recovery factor}) / (E * 10^3)$$

$$\text{Capital recovery factor} = [r * (1+r)^n] / [(1+r)^n - 1]$$

Where:

C = total cost of energy efficiency measure in millions of US\$

E = total MWh saved per year by the energy efficiency measure

r = discount rate

n = measure life in years

Source | Authors

major implementation constraints, such as a lack of financing and local technical capacity, or a lack of key stakeholders' motivation due to energy pricing and billing issues. Analyzing the causes and relevant impact of these issues and determining the means or limits for a city government to resolve issues or mitigate their impact will enable a city to design a practical energy efficiency intervention program for the sector. This would generally cover the following activities:

- Evaluating the awareness and motivation of key stakeholders, the conduciveness of relevant policies and regulations, the capability of concerned local institutions, access to financing, and capacity of local trades and energy service providers. This may be carried out through interviews and surveys.
- Conducting consultation workshops with stakeholders to review key issues and discuss potential solutions and sensible approaches.

Step 4 | Design a practical energy efficiency intervention program. By combining the results of Steps 2 and 3, the assessment team should be able to put together a sector energy efficiency intervention program that includes the following elements:

- Sector energy efficiency improvement priorities and targets;
- Investment needs and potential financing arrangements;
- Implementation arrangements, including program monitoring and evaluation; and
- Actions needed to address main implementation barriers or constraints.

Box 2 provides an actual example of a sector analysis performed for Quezon City, Philippines, for the purpose of strengthening the city's efforts in advancing its building energy efficiency agenda. The assessment was undertaken by a team of international and local consultants and took about 6 months to complete with about 30 total staff-weeks.

Box 2 | Quezon City Building Sector Energy Efficiency Assessment

The objective of the energy assessment was to assist Quezon City in developing a specific energy efficient building program for existing buildings and new constructions and to develop guidance for institutionalizing these measures in future building ordinances.

The scope of work included:

- 1 | Reviewing current building construction and market to determine a baseline** from which potential energy efficiency measures can be assessed. This included a review of existing building codes and standards, typical construction practices by building type, typical design weakness related to energy efficiency, and representative energy audits of target sector buildings (e.g., public, private, office, school, hospital/clinic). The review also sought to identify key technical parameters, relevant to both new and existing buildings, which were not adequately covered by existing codes and standards.
- 2 | Analyzing various energy efficiency options**, including building envelope measures, efficient building equipment, green/reflective roofs, etc., to assess their relative costs and energy/energy cost savings to identify cost-effective and practical measures.
- 3 | Conducting an upfront workshop with stakeholders and city officials** to present global experiences with energy efficient/green building codes and programs, market mechanisms, and summary of main program models, typical costs/benefits, incentive mechanisms, enforcement options, results, lessons learned, etc.
- 4 | Conducting selected interviews, focus groups, stakeholder workshops to discuss proposed energy efficient building program options** (regulatory, incentive, and information), identifying key barriers or constraints, and discussing practical solutions or mitigating measures.
- 5 | Based on Tasks 2, 3, and 4, work closely with the city counterpart staff to develop various program components and an action plan** for the program, to identify funding requirements and sources, institutional arrangements, scheduling, training needs, outreach, etc., as well as a set of recommendations for actions to be taken to revise current regulations concerning building construction to include energy efficiency measures and the systems, capabilities, institutional, and other resources necessary to fully implement and enforce the regulations.
- 6 | Organizing a final workshop to present the action plan** to city officials, stakeholders, neighboring cities, national government officials, donors, and other interested parties and reach consensus on the way forward.
- 7 | Preparing a final report**, summarizing the key market baseline conditions, global experiences, key barriers and opportunities, cost/benefit analyses, and the action plan to be submitted to the city.

One of the implementation issues identified by the assessment was a lack of solid benchmark data on how much energy is used in different types of buildings around the city. It, therefore, was agreed that a protocol should be developed to guide the collection and analysis of building energy use data. A 17-step process was ultimately crafted that focused both on the data gathering itself, and how this information could be used to force or encourage building owners to take actions.

The project also established a 'Green Schools' program and a project pursuing retrofits in other local government buildings and health care facilities. It is estimated that simple lighting retrofits, the installation of timers on air conditioning units, and other strategies to reduce heat gain in the schools could reduce energy use there by 30 percent, at a savings of 127 million Philippine pesos (\$2.8 million) per year. Energy efficiency upgrades in other public buildings are expected to cut energy use by 20 percent, saving the Quezon City municipal government an additional 95 million Philippine pesos (\$2.1 million) per year.

Source | Authors



MULTI-SECTOR COMPREHENSIVE ENERGY EFFICIENCY ASSESSMENT

A multi-sector comprehensive energy efficiency assessment may follow similar steps as those described for a single-sector assessment. However, a multi-sector assessment is not a simple compilation of sector-specific energy efficiency assessments. It generally requires the use of a common methodology across sectors to ensure consistency in analysis and results, especially with regard to economic and financial analyses. A multi-sector comprehensive energy efficiency assessment is often needed for cities that want to develop a concrete long-term low carbon growth action plan. This assessment typically involves the construction of a citywide greenhouse gas abatement cost curve, which enables cities to rank mitigation measures across sectors and different options. The abatement cost curve would include energy efficiency measures, transportation interventions, renewable energy options, and other mitigation actions a city may want to include. Such an undertaking is complex and time consuming, and usually requires substantial resources and external expertise. A multi-sector comprehensive energy efficiency assessment conducted for Changning District of Shanghai is used for illustrating the basic steps undertaken in such an assessment (Box 3).⁴

Step 1 | Conducting a comprehensive baseline survey and identifying CO₂ abatement measures, with a major effort to diagnose current energy use patterns in buildings. The survey covered current energy consumption in, or the potential for CO₂ emissions reduction from: (1) existing commercial buildings; (2) new buildings; (3) existing residential buildings; (4) distributed renewable electricity generation; (5) street lighting;

Box 3 | An example of Comprehensive Energy Efficiency Assessment for Developing Low Carbon Interventions, in Changning District, Shanghai Municipality, China

Context: China introduced carbon intensity reduction targets during its 12th Five-Year Plan period (2011–15). This binding obligation was implemented through provinces and municipalities. The Shanghai Municipality and Changning District (one of the districts of Shanghai) sought assistance from the World Bank to help design a low carbon intervention program to achieve its carbon intensity-reduction targets. In particular, the Changning District government articulated a vision aimed at transforming Changning into a leading low carbon district—both in Shanghai and nationwide.

An established district with mostly commercial buildings and few industrial activities, Changning has a permanent population of about 690,000 and a land area of about 37.2 km². The district government decided to use the Hongqiao area as a focal point for a study, especially in assessing low carbon interventions. Centrally located in Changning, Hongqiao contributes 28.5 percent of gross domestic product in Changning District with about 10 percent of its land and population. The selection of a representative area helped limit the scope of data collection and analysis while enabling greater depth of assessment with the available financial resources for the study.

The **objectives** of the low carbon growth options study were (i) to help establish a target for carbon reduction; and (ii) to assist in defining priority investment programs to achieve their low carbon targets, including those financed by the World Bank.

Source | Authors.

(6) carbon sequestration in green areas; (7) local transportation; and (8) behavioral changes through strengthening people's awareness of energy use. A total of 58 different energy-saving and low carbon measures were identified.

Step 2 | Analyzing potential cost of abatement measures. The 58 measures were categorized into 5 main groups: (1) retrofitting existing buildings; (2) low-emission new buildings; (3) low carbon energy supply; (4) green mobility; and (5) behavior changes. The incremental investment and operational costs of each energy-saving measure were estimated together with the potential of each to save energy and reduce carbon emissions by 2015. Finally, in order to compare the measures across sectors, the net CO₂ emission abatement cost of each measure was calculated—specifically, the present value of a measure's incremental capital, operating, and maintenance costs per ton of CO₂ abated per year. The results were summarized in the marginal abatement cost curve, which ranks the measures by their marginal abatement cost (vertical axis) from low (a figure that can be negative) to high, with each measure's abatement potential indicated by the width of the representative bar (Figure 6).⁵

Step 3 | Prioritizing mitigation measures based on abatement potential, cost, and ease of implementation. The assessment of the ease of implementation focused on three sets of constraints associated with each measure:

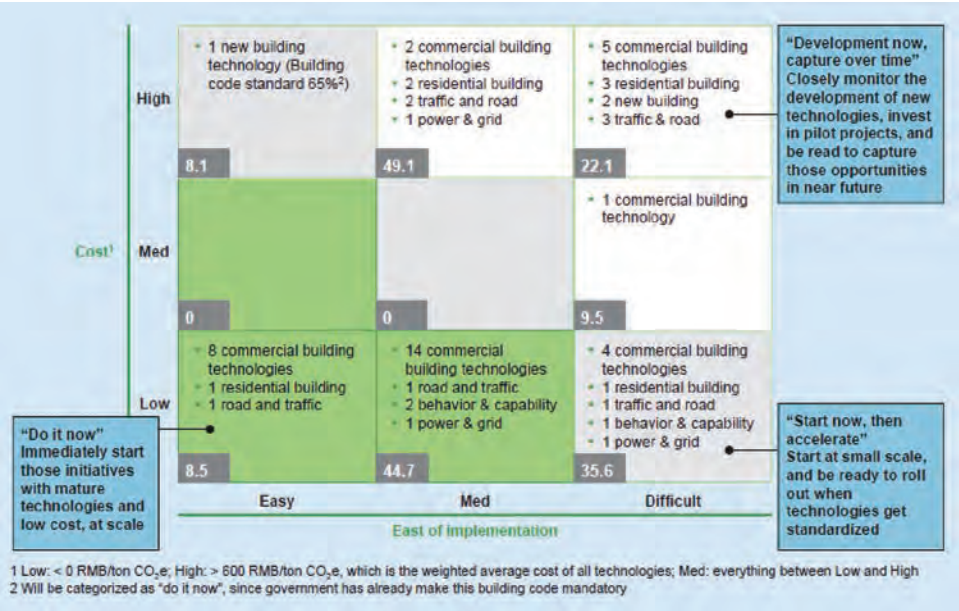
- **Economic feasibility.** Investors are primarily interested in mitigation measures that bring high rates of return (or short payback periods). However, investments such as these will not be sufficient to achieve a government's deep emissions-reduction targets. Government financial incentives, therefore, are essential for making financially unattractive opportunities viable for private sector investors.
- **Technology readiness.** Tried and proven measures will be more easily accepted and rolled out. Also, less complex measures are easier to handle and, thus, more likely to be accepted. Furthermore, measures with a wider range of applications are more frequently chosen.
- **Market circumstances.** Even though many green technologies have a positive net present value, the management of enterprises often do not recognize or accept these positive effects because the technologies are too new to be well understood.

Based on these analyses, the measures were mapped into an overview prioritization matrix that depicts the relative cost and ease of implementation (Figure 7). For decision-making purpose, they are grouped into three categories: those which can be implemented immediately—"Do it now," those which are more challenging—"Start now, then accelerate," and those which are costly and most difficult to implement—"Develop now and capture overtime."

Step 4 | Developing long-term scenarios for low carbon growth, including one that met the national government's carbon intensity-reduction target (baseline scenario) and one that exceeded the national government's target (stretch scenario). This scenario exercise was useful as it allowed the Changning District to see how the three categories of measures needed to be "dispatched" (when to start pilot, small scale replication, and roll out to reach the needed level of penetration of measures in a particular category) in order to achieve the national target and go above and beyond (Figure 8), as well as the relevant investment needs (Figure 9).

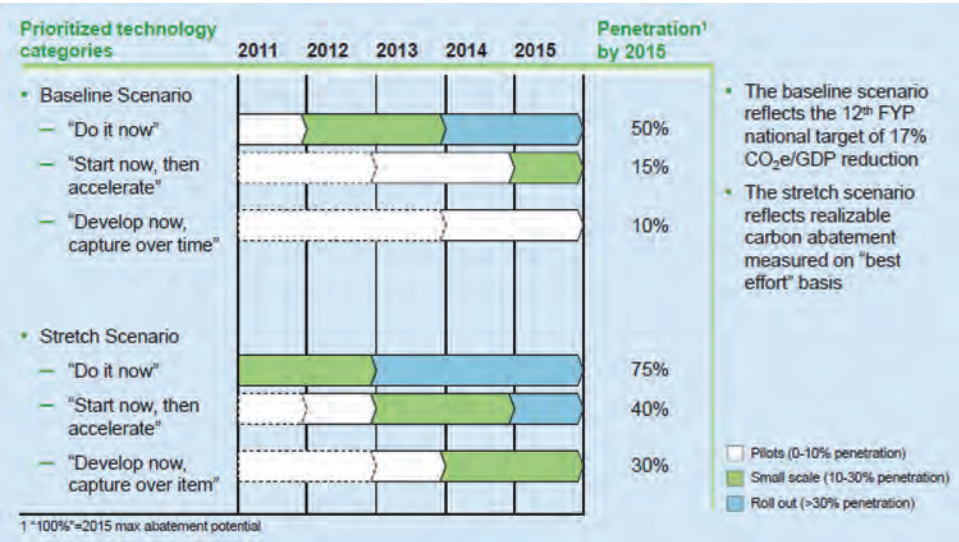
Step 5 | Applying analytical results of a representative area to the whole jurisdiction. For Hongqiao, scenarios from the 2011–15 (Figure 9) were extrapolated to project

Figure 7 | Prioritization of Low Carbon Measures in Hongqiao Area of Changning District



Source | World Bank 2013.

Figure 8 | Technology Penetration Rate for Different Low Carbon Scenarios

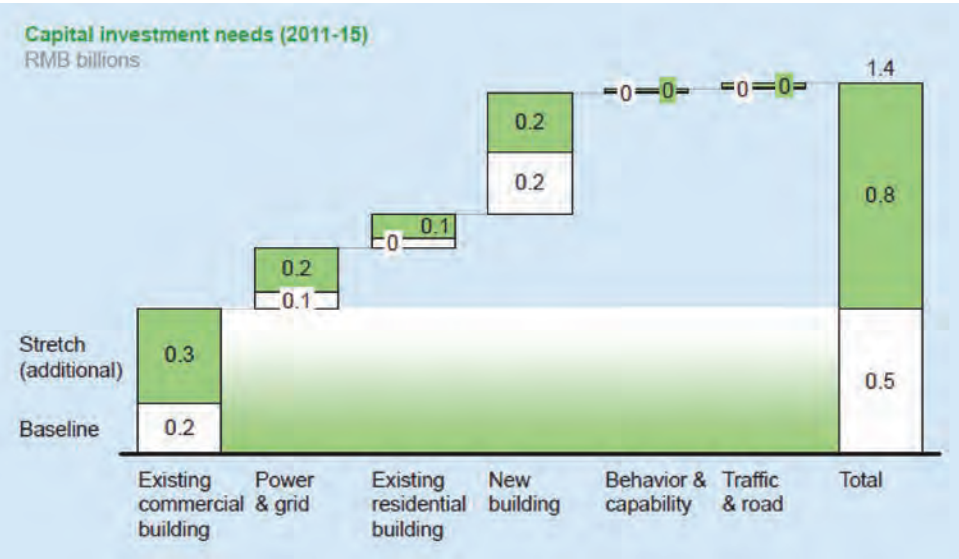


Source | World Bank 2013.

Changning District carbon-reduction potential and accumulative investment cost for the period of 2011–20 (Figure 10), under the assumption that Hongqiao is adequately representative of the entire district.

Observations of the Changning study: The methodology adopted in this study are useful analytical tools for determining a low carbon target and defining a cost-effective,

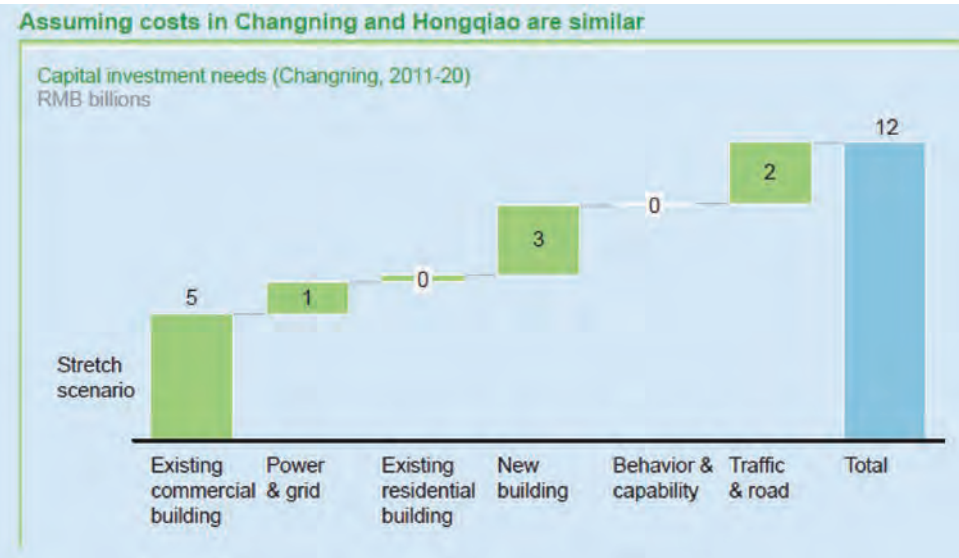
Figure 9 | Cumulative Investments Needed to Achieve Baseline Scenario and Stretch Scenario for Hongqiao Area of Changning District



Source | World Bank 2013.

low carbon investment program to achieve city-level carbon emission targets. Even with a limited geographical focus for the assessment, the data acquisition and analysis were quite demanding. It took the combined efforts of a dedicated local team, technical support from a professional consulting firm, and overall guidance by a World Bank team. Because Changning District is an established commercial district with few industrial activities—where buildings account for more than 90 percent of total energy consumption—the assessment indicated that building retrofit measures provided the

Figure 10 | A Low Carbon Scenario for Changning District, 2011–20



Source | World Bank 2013.

greatest potential for reduction of emissions. The methodology is flexible and can be used in any city to define low carbon cities. If the same methodology were to be applied in another city with different characteristics, the conclusion could be different.

CONCLUSIONS

This guidance note, through descriptions and examples, provides a structural framework for conducting energy efficiency assessments. However, the actual approach may vary for each specific type of assessment. To that end, this guidance note provides an introduction to the objectives, scope, and outputs, as well as the basic steps and approaches of conducting the three types of energy efficiency assessments. It may be used as a general reference for choosing and defining the energy efficiency assessment that the city would like to pursue.

ENDNOTES

- ¹ An e-learning course and the TRACE software can be downloaded at <http://esmap.org/TRACE>.

² Technically, the energy savings potential is the quotient of the average energy usage of cities performing better than the target city by the city's energy use, and the city's energy use. For example, if cities performing better than the target consume 50 units of energy on average, while the city consumes 100 units, then its energy-savings potential is 50 percent.

³ <http://china.lbi.gov/tools-guidebooks/best-cities>

⁴ Based on *Applying Abatement Cost Curve Methodology for Low Carbon Strategy in Changning District, Shanghai* (World Bank 2013).

⁵ The marginal abatement cost curve, or MAC curve, has been widely used to illustrate the estimated
- net cost of different greenhouse gas mitigation measures based on technical/engineering analysis. The MAC curve is calculated from an opportunity cost to the society as a whole (i.e., excluding taxes, subsidies, and application of social discount rate). The width of each column represents the greenhouse gas reduction potential (quantity) of a specific mitigation measure in a specific year (2015) compared to a defined baseline (the counterfactual situation of what if without the mitigation actions). The height of each column represents the average cost of abating 1 ton of CO₂ equivalent by 2015. The graph is ordered from left to right from measures with negative net cost (meaning the measure has net benefit) to the ones with positive net cost.

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ACRONYMS AND ABBREVIATIONS

BEST Cities	Benchmarking Energy Savings Tool for Low Carbon Cities	TRACE	Tool for Rapid Assessment of City Energy
CO ₂	Carbon dioxide	US/USA	United States of America
CSE	Cost of saved energy	US\$	United States dollar (currency)
LED	Light emitting diode		



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