Eco2 Cities: Environmentally and Economically Sustainable Urban Development

ESMAP's Draft Working Paper

Prepared by: Feng Liu and Jas Singh. March 11, 2009

Draft Energy Sector Brief

for

Eco2 Cities: Environmentally and Economically Sustainable Urban Development

Overview

Cities, or urban areas, currently account for about two-thirds of the world's annual energy consumption. In the coming decades urbanization and income growth in developing countries are expected to push this share even higher.[1] As the main consumption centers of energy and at the frontline of implementing national and regional sustainable energy policies and programs, cities have a crucial role in shaping our energy and environment futures by making smart choices in urban development, energy demand management, and energy supply options. In return, cities will become more livable, affordable, and sustainable.

Traditionally city/urban energy planning and management have been driven by improving access, security, reliability, and affordability, typified by the development of network-based energy systems (which cities have become dependent on), such as electricity grids, district heating networks, and natural gas pipelines. These objectives still are essential to cities because without them modern cities simply cannot function. The environmental dimension of energy use in cities was brought to the fore in the wake of the London Smog disaster of 1952, which killed about 12,000 people. The serious urban air pollution in many developing countries is a sober reminder that many up-and-coming cities still cannot cope with the clear and present harms resulted from consumption of fossil fuels. The importance of energy efficiency, conservation, and renewable energy sources began to enter people's consciousness after the first oil crisis in 1973. Thirty-five years on, achieving broad-based progress in energy efficiency and renewable energy use in cities remains a tough challenge to developed and developing countries alike. The emergence of climate change as an overriding global development constraint, much of it relates to the prevailing energy consumption habits and supply options in cities, sets motion for fundamental changes in the ways which countries and cities approach urban development, manage energy demand, and secure energy supply.

<u>What can cities do to deal with the multi-dimensional energy challenges</u>, which affect their current performances and long-term development prospects? The evolution of the energy agenda of cities – from its historical core of access, security, reliability, and affordability to the inclusion of environmental quality and public health concerns, and more recently, climate change mitigation and adaptation – has challenged cities and their national and regional governments to break away from supply-centric practices and harden the environmental constraints in urban energy planning and management. The largely successful control of local and regional air pollutions in developed-country cities is an encouraging story about the possibilities of meeting similar energy challenges in developing countries. That success has primarily relied on stringent

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[1] World Energy Outlook 2008, International Energy Agency (IEA). This paper adopts IEA's definition of cities as a general and interchangeable reference for urban areas, which may be large metropolitan city-regions, such as New York City, or small urban settlements that only have a few thousand people. The exact definition of urban areas varies by country.

national or regional emissions regulations on industries and motor vehicles, relocation of factories, and switching to cleaner fuels. As a result, many cities have become more attractive and competitive. Controlling the carbon footprint of urban energy use represents the greatest energy challenge to cities and their national and regional governments. Cities can turn this challenge into opportunities for strengthening energy security and enhancing energy access, affordability and reliability. To be successful, cities need to actively manage energy demand by promoting energy efficiency across all urban sectors, support the uptake of renewable and more-energy-efficient energy supplies, and particularly important for developing-country cities, incorporate sustainable energy solutions – energy efficiency and renewable energy considerations – in urban land-use planning and land development. This spells an involved and active role for cities in urban energy planning and management, as well as farsightedness and deliberateness in city development/redevelopment planning.

Visionary cities are moving toward this new paradigm of integrated urban energy planning and management. Recent examples include the PLANYC 2030 of New York City and Plan Climat de Paris.[2] However, the real test of turning the visions into realities still lies ahead. This is not surprising since city governments are often faced with many urgent tasks and competing interests and have to prioritize their actions against constraints in human and financial resources. There are also specific barriers to pursing integrated urban energy planning and management. There is not a single department in a city administration which can muster the authority required to spearhead such a cross-cutting agenda, with the exception of the mayor's office, which by itself is the Achilles' heel of sustaining the effort because of the limits of mayoral terms. In addition, urban energy planning and management is not entirely within the jurisdiction of city governments. In fact, the prevailing urban energy supply infrastructures, with the exception of district heating systems, are often not under the direct purview of local governments.[3] For proactive cities to succeed, they also need strong support from their national and regional governments.

Why should a city government care about getting assertive and involved in making sustainable energy decisions and making them happen? The short answer is that it pays. Most energy efficiency and conservation measures are not high-tech, or expensive and pay back quickly. The municipality of Emfuleni (South Africa), for example, initiated an energy and water efficiency project and achieved savings of some 7 billion liters of water and 14 million kWh per year. At a cost of only US$1.8 million, the project saved over US$4 million each year, giving the project a payback period under 6 months. Since the contract was financed and implemented by an energy service company or ESCO, the municipality not only saved large sum of money because of reduced water losses and pumping costs but also did not have to pay for the investment upfront. The ESCO, on the other hand, recouped its investment quickly by sharing part of the cost savings.[4] Another example, the Växjö Municipality (Sweden) began replacing all their street lighting in 1994 with high efficiency lamps, reducing energy use by 50%. At an investment cost of about US$3.6 million, the city saved US$0.75 million/year, or a payback period of under 5 years.[5] For cities looking for ways to meet budget shortfalls or mine the

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[2] www.nyc.gov/planyc and http://www.paris.fr/portail/Environnement/Portal.lut?page_id=8412
[3] For example, grid-based electricity supply and prices are generally regulated by regional or national governments.
[4] USAID Energy Update, Issue 2, April/May 2005.
[5] C40 Cities, Lighting Best Practices (http://www.c40cities.org/bestpractices/lighting/vaxjo_streetlight.jsp).

municipal expenditures for worthy pursuits, such as extending tap water services or street lighting coverage, there is no better place to look for new funds than energy cost savings in the government's own facilities and operations.

In developing-country cities facing serious air pollution problems, promoting energy efficiency and cleaner energy also pays in reduced medical bills and improved productivity, aspects which affect cities' livability and competitiveness. A recent joint study of the Chinese Government and the World Bank estimated that the cost of ambient air pollution in China's urban areas – in air pollution-caused premature deaths and illnesses – amounted to about US$63 billion in 2003, equivalent of 3.8% of China's GDP in 2003.[6] In fact, much of China's efforts in the past two decades or so in modernizing urban energy infrastructure and improving energy efficiency in cities have been driven by the desire to reduce health damages of air pollution. This is evident in the fast penetration of gaseous fuels in all cities for cooking, as well as the rapid expansion of district heating systems in northern Chinese cities, which also are at the forefront of implementing national building energy efficiency standards.

For the fast growing cities of developing countries, making the shift toward the new paradigm of urban energy planning and management is as much about contributing to global welfare as enhancing their abilities to serve their own growing energy needs at lower costs and with greater security. Good environmental stewardship practiced in the energy planning and management of individual cities is essential to mitigate regional and global environmental impacts, which in one way or another (for examples, acid rains and climate change-induced storms and rising seal levels) affect the long-term wellbeing of cities. Making cities more energy-efficient and more accessible to renewable energy supplies also help cities hedge their risks of higher energy costs if a global agreement is reached to drastically reduce anthropogenic CO_2 emissions. This does not mean that developing cities should take on a broad sustainable energy agenda all at once. Taking sustainable energy actions, however cost-effective they may be, requires public and private investments, demands additional efforts from city governments and citizens, and needs strong support of regional and national governments. Cities should tailor their efforts with available resources and pursue sustainable energy actions which will generate significant and immediate local benefits first.

Where should a city start? In general, there are three areas where city level actions and interventions are critical and city governments are in the driver's seat:

- *Investing in sustainable energy retrofits and supplies in city government facilities and operations*. Cities could start with a range of energy efficiency and conservation measures in government-owned buildings and municipal services, such as water supply and wastewater treatment facilities, public lighting, transport, and solid waste management. Large government complexes are often good candidates for distributed energy supply options such as co-generation of heat and power using natural gas. Local government can also support the expansion of renewable energy supplies through purchase of "green" electricity and accommodation of renewable energy technologies in its own buildings and facilities, such as photovoltaic systems and solar water heating;

[6] Cost of Pollution in China, 2007, the World Bank.

- *Promoting energy efficiency and application of renewable energy technologies in the urban built environment*. Beyond the public sector city governments can promote energy efficiency and renewable energy options in non-municipal owned or operated sectors through their dominant role in shaping the urban built environment. One of the most critical and effective interventions is enforcing national or regional energy efficiency standards in new building constructions and building renovations.[7] A more ambitious green building agenda can also include additional requirements in water efficiency and conservation, adoption of renewable energy technologies, incentive programs for industry and residential users, as well as other measures to reduce the environmental impact of buildings;[8] and

- *Promoting energy efficiency and renewable energy through land use planning and land development policies*. On the broadest scale and within their control, city governments can shape or reshape land use and development patterns in ways that minimize the carbon footprint of urban growth while ensuring lower overall operating costs. This is where energy planning meets and integrates with transportation and other urban infrastructure planning to best serve a city's growth ambitions and environmental aspirations.

In approaching the above mentioned three areas of actions cities of developing countries are faced with much tougher challenges than their counterparts in developed countries. Knowledge and technical capacity are often lacking. Competition for resources is fierce. Under the pressure of growth and with capital constraints, compromise is often made to serve more instead of serving more and better.[9] While cities must become assertive and involved in promoting sustainable energy solutions for urban development, they will need more support and cooperation of their regional and national governments to become more successful. Substantial donor support in knowhow and finance also is needed to engage and encourage developing-country cities pursuing sustainable energy actions in the three areas outlined above.

This sector brief provides a general review of the urban energy landscape in terms of basic energy-consuming activities, energy services and supply options, factors affecting urban energy planning and management, as well as the good practices, lessons, and challenges in urban energy planning and management in the context of developing-country cities. Figure 1 below is a schematic depiction of the domain of sustainable urban energy planning and practice which this note will elaborate.

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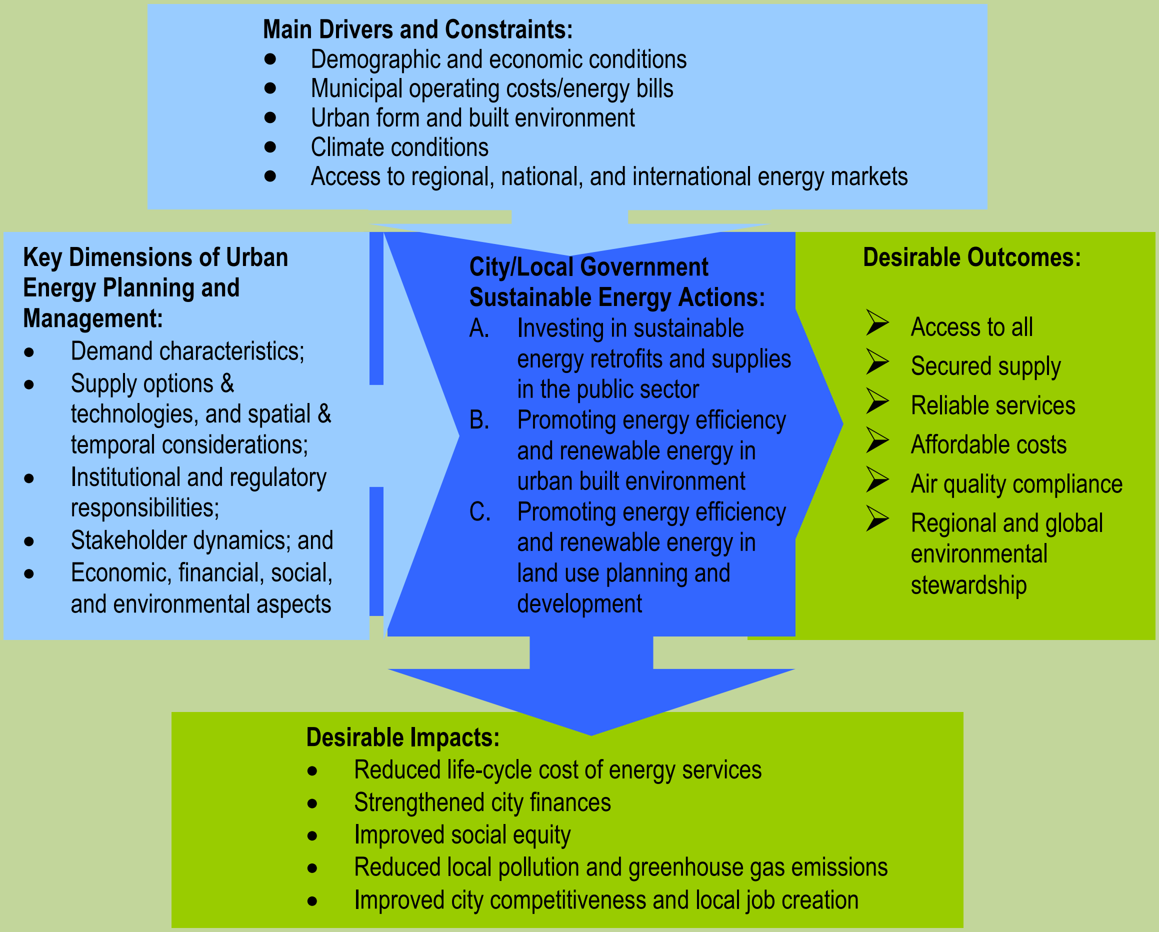
[7] Building energy codes in general are regulated at regional level (province or state) or national level depending on country. But the compliance is completed dependent on local/city-level enforcement.
[8] Refer to California Green Building Standards Code, State of California, USA, 2008
[9] Energy efficiency-enhanced alternatives are often more expensive upfront, requiring higher capital investment. But the lifecycle costs of more energy-efficient alternatives are generally lower than those of business-as-usual practices because of lowered recurring cost such as energy bills.

Figure 1: A Stylized Framework for Approaching Urban Energy Planning and Management



Urban Energy Planning and Management: Key Dimensions

Understanding Energy Use in Cities

A city's energy profile – amount of use, mix of energy types, and patterns of use by sector or end-use activity – is determined by a number of factors, including its population size, economic structure, income level, energy prices, end-use efficiencies, climate conditions, its urban form, built environment, as well as access to regional and national energy markets. Understanding the dynamics induced or constraints imposed by these factors on a city's energy demand is the starting point of sustainable urban energy planning. It is important to note that the amount of energy use is not a good indicator for the actual level of energy service (lighting, cooling, heating, or refrigeration, for examples) rendered or needed. The critical factor is ***energy efficiency***, which refers to the adoption of improved technologies and/or practices in order to reduce the energy required to provide the same output or level of service. In the urban context, it is important to assess how much useful energy can be extracted from the primary source, delivered to the end-users, and turned into actual energy services.[10] In the case of buildings, energy efficiency also means reducing the level of energy services needed through building design and use of materials.[11]

In IEA's recent account of urban energy use all energy-consuming activities which take place within the jurisdiction boundary of a city are included (IEA, 2008). Following this accounting concept one can lump energy use in cities into four broad categories: industry, transport, municipal services, and buildings. A finer breakdown of these categories is presented in Table 1, below.

Table 1: Energy Consumption in Cities: Main Sectors/Clusters

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

Buildings, which do not conform to the sector theme of the first three categories, include a broad spectrum of buildings (and the entities which they host or belong to), from single-family houses and apartment buildings, to schools and hospitals, as well as offices and shopping malls. But factory buildings are excluded. For statistical purpose, buildings are usually divided into residential and commercial buildings. Residential buildings, which accounts for most of urban building stock, are well defined – owner- or renter- occupied houses or apartments. But commercial buildings are diverse and usually cover office buildings, shopping malls, supermarkets, hotels, and any other buildings which host commercial or public entities. Government-owned and operated buildings, as well as schools and hospitals are lumped into commercial buildings. Government buildings are separately identified in Table 1 to highlight the special opportunity for sustainable energy interventions by the city government.

Typically, buildings and transport dominate urban energy use in large service-oriented cities often found in developed countries, where they usually account for two thirds or more of urban energy consumption. In rapidly industrializing developing countries, such as China,

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[10] Electric lighting is a good example. On average, about 70 percent of the energy content in coal is already lost (in conversion, transmission and distribution) when electricity reaches a light bulb. Then, a compact fluorescent lamp can deliver the same amount of lighting service (brightness per square meter) using about 20 percent of the amount of electricity needed by an incandescent lamp.

[11] Passive houses using ultra low energy for space cooling and heating are already demonstrated in Europe and the United States. http://www.nytimes.com/2008/12/27/world/europe/27house.html?ref=world&pagewanted=all

industrial energy use often takes the lion's share in large cities. Even in Beijing, one of the most modern and high-income cities in China, manufacturing still accounted for about 50% of total final energy consumption in 2006 (IEA, 2008). In general, buildings and transport are the fastest growing energy sectors in developing-country cities. They are also the sectors where sustainable energy actions of city governments can have the largest impact. Countries with growing middle classes typically show explosive electricity load growth in residential air conditioning and other larger appliances. Although cities generally do not have control in appliances efficiency, and equipment standards are under the purview of national governments, cities can adopt incentive programs to encourage the adoption of more efficient appliances.

While industries are often part of the urban landscape, including them in urban energy accounting leads to skewed view of the energy consumption and performance of cities, depending on what industries a city may have and how significant they are in the city's economy. For consistency in cross-city energy comparisons, it may be necessary to exclude (or separate) industrial energy consumption from the typical urban energy-consumption sectors indicated in Table 1.

For urban energy planners it is also necessary to break urban energy demand/consumption into key end-use activities, often within each of the four main sector categories outlined above. Characterizing end-use activities is more or less similar across cities, although the actual energy type used for a specific end-use can vary even within a city (Table 2).

Table 2: Energy Consumption in Cities: Key End-use Activities and Energy Types

Main Energy End-use Activities in Cities	**Common Energy Types Used in Cities**						
	Electricity	Natural Gas*	LPG**	Kerosene	Gasoline Diesel	Coal	Firewood Charcoal
Lighting	■			■			
Cooking	■	■	■	■		■	■
Water heating (domestic hot water)	■	■	■			■	■
Appliances (refrigerator, etc.)	■						
Home & office electronics	■						
Air conditioning	■						
Space heating (cold climate)	■	■				■	■
Motorized transportation	■	■	■		■		
Motive power (stationary)	■						
Processing heat or steam	■	■				■	

* Some cities still have town gas supply provided by coal-gasification or coking facilities. But in general town gas is no longer an attractive energy supply option for cities.
** LPG = liquified petroleum gas.

Excluding industrial consumption, end-use energy patterns in developing-country cities, especially those in low-income countries, tend to skew toward the most basic energy services such as lighting and cooking, and space heating in cold climate regions. The direct use of solid fuels, such as coal and firewood, is common in developing-country cities and often is the main cause of indoor and ambient air pollutions. This is particularly true in poor urban areas and slums, where access to cleaner cooking fuels is limited.

Electricity is the most extensively used form of energy in cities. The share of electricity in total energy use and the amount of electricity per capita often indicate the modernity and wealth of a city. Satisfying the fast growing electricity needs often dominates the energy agenda of developing-country cities. On the other extreme, gasoline is exclusively used for transport.

Energy costs are a critical aspect of understanding energy use in cities and are often a primary energy-related concern of city government. Sustainable energy decisions must be economic and financial decisions. Beyond prices for key energy types, actual aggregate energy costs in major urban sectors are often lacking. Energy cost information of individual end-use activities, or even simple energy indicator data (for examples, kWh/m^3 of water delivered, ton of oil equivalent/person per mode of transport, W/m^2 for lighting in buildings), is as rare as the studies that analyze them.

Few cities in developing countries track their energy consumption patterns and costs systematically. Without adequate energy consumption data and cost information cities will not be able to plan their sustainable energy actions effectively. Recent efforts in establishing an international protocol and associated tools for greenhouse gas emissions inventory in cities are helping build a platform which can support more specific tasks needed for cities to make informed decisions on sustainable energy actions.[12] Beyond the basic accounting, a critical element of understanding a city's energy use patterns is to inform urban energy planners of the specific opportunities for energy demand management through energy efficiency investments and conservation programs, as well as for introducing alternative supply options. Simple benchmark data can help city managers identify sectors that exceed typical norms so they can then investigate ways to address them, whether they be high energy use for lighting in buildings to high space heating consumption per square meter. Options for additional supply, such as cogeneration from wastewater treatment plants or methane capture from landfills, can also be assessed in terms of costs and benefits. Evaluation of such options would require the use of evaluation tools which can help cities examine and compare their energy performances with good/best practices, as well as understand the cost and benefit implications. Development of practical decision support tools and methods for sustainable urban energy planning and management will help cities quickly identify and prioritize sustainable energy actions grounded on local capacities and realities.

Energy Supply Options, Technologies, and Spatial and Temporal Considerations

Modern cities are highly dependent on network-based electricity and, to less extent, natural gas supplies which are connected to regional and/or national networks. There are power plants located within a city's boundary. But they often are owned and operated by regional or national electric utilities, or independent power producers.[13] Having secure and reliable access to regionally-integrated and network-based energy supplies still is what developing cities aspire to.

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[12] International Local Government GHG Emissions Analysis Protocol, http://www.iclei.org

[13] There are also distributed energy resources (DER) in urban areas. They are parallel and stand-alone electric generation units located within the electric distribution system at or near the end user, for example a micro gas turbine system, a wind turbine system, a fuel cell, or a rooftop photovoltaic system. Distributed generation can be beneficial to both electricity consumers and, if the properly integrated, the electric utility.

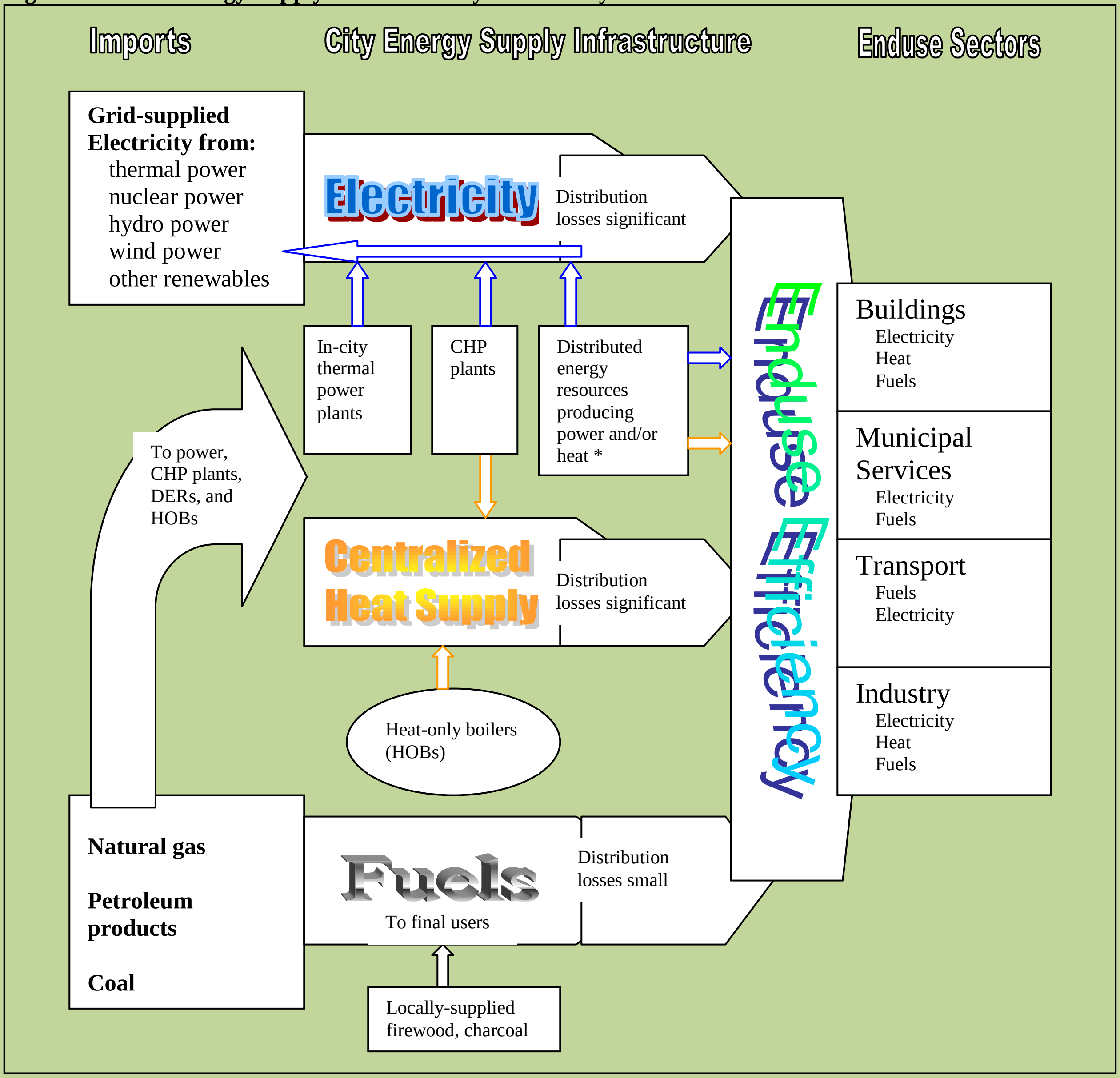
District heating systems are another network-based energy service common in cold climate cities, especially in Europe and China. But they are limited to areas of a city with sufficiently high building density. Supplies of solid and liquid fuels, such as coal and petroleum products, are usually decentralized (different users may buy fuels from different producers or local distributors). The supply of transport fuels is usually vertically controlled by oil companies. Firewood and charcoal are often important cooking and, in cold climate, heating fuels in low-income-country cities where peri-urban and slum population is significant. Firewood is locally supplied and often is self-collected by individual households; charcoal usually is supplied by informal service providers. As a city grows in wealth and modernizes there is a progression toward higher dependence on network-based energy supplies and decreasing use of solid fuels (coal and firewood) in households and other dispersed service points. In general cities/urban areas are almost entirely dependent on external energy supplies (even for power plants located in cities, they still need to import fuels).

One may think a city's energy supply options and technologies along three main energy delivery channels as depicted in Figure 3. In mildly cold and warm climates centralized heat supply is generally not an economically viable option and is not considered. Electricity and centralized heat are often subject of urban energy optimization in cold climate cities since they can be produced together through combined heat and power plants. Cooling can also be provided by using the heat energy to drive the cooling system using absorption chiller technology. So district heating systems can also provide cooling service in the summer if it is economically justified. Very often distributed energy resources (DERs) produce electricity while also provide heating and cooling services. The introduction of natural gas not only provides a cleaner alternative to oil and coal but also brings more flexibility to a city's energy services through distributed generation facilities. For a large city, fitting all the pieces together so as to optimize sustainable energy outcomes is not an easy undertaking. This is especially challenging to developing-country cities where energy supplies are less organized or streamlined compared with their developed counterparts, where energy supplies are primarily network-based.

The advance of centralized and distributed renewable energy supply technologies, such as wind, solar water heaters, biomass, and photovoltaic systems, enable cities to source a small but increasing amount of renewable energy. Heat pumps and shallow geothermal energy also provide cities additional ways to reduce reliance on purchased energy. That saved energy from energy efficiency and conservation measures is a valid source of energy supply is a compelling way to think about energy demand-side management and integrate it into cities energy supply planning.

As pointed out earlier, consumption of solid fuels in households and other dispersed end-use points (such as restaurants) will decrease overtime as gaseous fuels, either LPG or natural gas, become available, or electricity become more abundant. Such transition can take decades and often require construction of regional and national energy infrastructures. For China, dispersed use of solid fuels in urban areas has decreased dramatically in the last twenty years or so. They are largely eliminated from cooking use and are now mainly used in a minority and decreasing portion of cold-climate urban households who have no access to centralized heating or natural gas. This has been achieved with strong national government support to increase LPG supply and expand natural gas transmission networks.

Figure 3: Urban Energy Supply Sources and Systems: A Stylized Sketch



* Many micro gas-fired generation facilities produce electricity and provide heating as well as cooling (using absorption chillers) services.

Both spatial and temporal considerations are important to the development of network-based urban energy infrastructure. The spatial planning aspect contemplates the layout of the network within the existing and planned built-up areas to achieve the most efficient routing and generation/distribution-facility locations according to demand/load distribution. The temporal planning aspect relates to the sizing of the systems based on current and anticipated demand/load, and is most critical for sizing the trunk lines or mains which are difficult to rehabilitate after they are built. The latter point is especially important for fast growing cities and has significant financial implications. Right sizing is part science and part luck (because of the uncertainty in future demand). But the science part can be greatly enhanced and expanded if the planner is well informed of the energy demand patterns and trends of the city, as well as knowledge of the experiences of other cities in dealing with similar situations.

City planners also need to consider the aspect of overlapping services of different network-based energy supplies, for example, covering the same area with both natural gas network and district heating network, which has its case in a number of Chinese cities, as well as in some eastern European cities. In the Chinese case, it is largely due to the scarcity of natural gas, which is piped into households just for cooking and water heating purposes, relatively expensive investment and operation for gas companies but could be served by electricity. As such space heating has to be provided separately by district heating systems. In the case of eastern European cities, gas supply was introduced more recently and is competing with the established district heating systems and taking away customers. While competition in general is good, in this case, it is not necessarily beneficial because it renders part of the capital investment in the district heating systems wasted. In Germany, many cities do not allow their utilities to provide district heating and natural gas services in the same area since both energy carriers provide to a large extent the same service, i.e., space heating (Box 1).

Box 1: Energy Planning in the City of Mannheim (Germany)

For energy planning purpose, Mannheim was divided into zones referring to the type of network energy supplied. A municipal owned utility supplied natural gas, electricity, and district heating. Electricity is universally supplied. For space heating, natural gas, district heating, or electricity is offered. For areas with high heat load district heating is the least-cost option and is supplied, for medium level heat load densities natural gas is used for decentralized heating, and for areas with low heat demand electricity heating using off-peak electric heat storage devices is offered. For large customers such as department stores, hotels, and office buildings cooling is also supplied by the district heating system using absorption chillers.

By avoiding laying in parallel gas and district heating pipes, the least-cost mix of energy carriers is achieved. In zones served by district heating, gas is no longer offered. Electricity and district heat is produced by a CHP plant located in the city. Public transport and fresh water supply are also operated by the same utility. In this way, it is possible to optimize the energy production and demand for the most important needs of a city.

An important result of the plan was the conversion to cleaner energies. In 1983 37% of all residential buildings were heated by coal or oil-fired heating units. In 1995 this figure has been reduced to less than 10%. SO_2 emissions were reduced by about 85%, NO_x by 40, and CO_2 by about 30%.

Source: Kalkum, 2008.

The future of energy supply in cities still lies in network-based systems, which actually facilitate the adoption of distributed energy generation and decentralized renewable power systems, if the institutional barriers associated with the traditional electric utility operations are resolved. Thus, the development of modern power grids and natural gas networks (if long-term gas supply is secure) should be the focus of urban energy infrastructure investment. In densely populated cold climate cities where natural gas supply is scarce or unavailable, development of district heating systems is key to reducing air pollution and improving space heating service quality. The planning and engineering of specific network-based systems (electric, gas, or heat) have become very sophisticated and technologies are still advancing. For urban planners, the real challenge and essential task will be to foster the integration and adaptation of the network-based energy infrastructure so as to enhance the overall supply-side efficiency and facilitate the uptake of distributed energy resources, as well as other local low-carbon energy sources (for example, methane from landfills and wastewater treatment plants).

Policies, legislations, and regulations

In general, national and regional legislators and governments are responsible for energy sector policies and regulations. Individual cities have rather limited influence in this political and legislative process, except for localized energy services that require some government interventions, such as district heating systems. The degree of regulation and government oversight in the energy sector vary by country. In many large economies the energy sector is subjected to multiplicity of policies and regulations and influenced by a mixture of government institutions for reasons ranging from energy security to market competition to social and environmental concerns. Network-based energy services are usually regulated for their service charges due to their natural monopolistic nature (especially in transmission and distribution) and often for social reasons (access for the poor). The prices of solid and liquid fuels also are often subjected to government interventions through taxes and subsidies. Energy sector policies and regulations used to be supply-centric but have changed a great deal since the first oil crisis in 1973. Many countries now have regulations and standards requiring minimum energy efficiency levels for energy-consuming equipment, appliances and building components. They are commonly called minimum energy performance standards. Governments may also initiate special policies and programs to incentivize adoption of renewable energy and more energy-efficient equipment. Table 3 summarizes the general elements of energy policies and regulations and how cities are affected or involved.

Table 3: Energy Policies and Regulations and Linkages to Cities

Policies and Regulations	Examples	City Government Role
General Legislation	• The Energy Policy Act of USA • Energy Conservation Law of China	Local enforcement
Supply Side		
Sector specific	• Power sector regulations • Oil and gas sector regulations • Coal sector regulations	Interactions only in local distributions or retails
District heating	• Pricing and billing regulation	Strong involvement or even autonomy
Renewable energy	• Renewable Energy Law of China • Mandatory market share policies • Feed-in tariffs	Local implementation Beneficiary
Demand Side		
Minimum energy performance standards	• Appliances energy efficiency standards • Industrial motors energy efficiency standards	Local programs to replace existing and inefficient equipment
Automobile fuel economy standards	• Corporate Average Fuel Economy – CAFÉ (USA)	Beneficiary
Building construction and renovation	• Building energy efficiency standards	Local enforcement
Utility demand side management	• Electricity rate decoupling	Beneficiary
National and regional financial/fiscal incentives	• Subsidies for hybrid cars • Tax credit for photovoltaic systems	Beneficiary
Environmental protection	• Air pollutant emissions standards	Local enforcement Beneficiary

Institutions

The multi-tiered and multi-facet nature of energy sector management and regulation lends itself to equally complicated institutional interactions. Box 2 provides an illustration of perhaps one of the more elaborate institutional and regulatory settings of urban energy planning and management.

Box 2: Public Agencies with Significant Influence on Electricity Production, Distribution, and Use in California

Federal

Federal Energy Regulatory Commission (FERC) – Wholesale rates; interstate and international transmissions; and hydropower licensing.

U.S. Environmental Protection Agency – Setting national standards for Clean Air Act and Clean Water Act compliance; overseeing enforcement/regulatory actions delegated to the states.

U.S. Department of Energy – Technology research, development, and promotion; energy efficiency programs; setting national appliances and end-use standards.

State

California Energy Commission – Licensing thermal generators 50 MW or greater; setting end-use efficiency standards; system analysis, planning, and forecasting; planning intrastate electricity transmission infrastructure; public interest energy research and development and demonstration.

California Public Utilities Commission – Rate setting for investor-owned utility retail customers; system analysis, planning, and forecasting; monitoring the electricity market; public and private sector efficiency and education programs; representing the state at FERC; and transmission delivery infrastructure.

California Independent System Operator – Monitoring/planning system reliability; system analysis, planning, and forecasting; planning electricity transmission infrastructure.

California Air Resources Board – Setting emission standards for distributed generation resources and diesel backup generators.

Regional

Regional Water Quality Control Boards – Issuance and enforcement of Clean Water Act permits and California regulations for discharges into and usage of regulated water bodies by power generators.

Regional Air Quality Management Districts – Issuance and enforcement of Clean Air Act permits and California regulations for air emissions from power generators.

Local

Cities and counties – Long-term land use planning; enforcement of building energy efficiency standards; approval of site plans and urban design in private development; permitting and sitting of all power plants under 50 MW.

Source: Lantsberg, 2005

The roles of the national and regional government are critical because national and regional energy policies, legislations and regulations provide the necessary transparency, consistency, and predictability for the development and operation of the modern energy supply systems shared by individual cities, as well as to address the common social and environmental issues associated with modern energy supply. The national and regional governments are also important in setting the general provisions which incentivize cities to adopt sustainable energy planning and practice. For examples, renewable energy feed-in tariffs which mandate electric utilities to purchase wind- or solar- generated electricity at a set price, or energy performance standards which set minimum energy efficiency levels for new appliances and new buildings. On the other hand existing national and regional regulations may also hinder the sustainable energy actions at city level. For example, in most countries the prevailing regulations on electric utilities in general discourage utility demand side management and installation of distributed generation facilities, including renewable technologies.

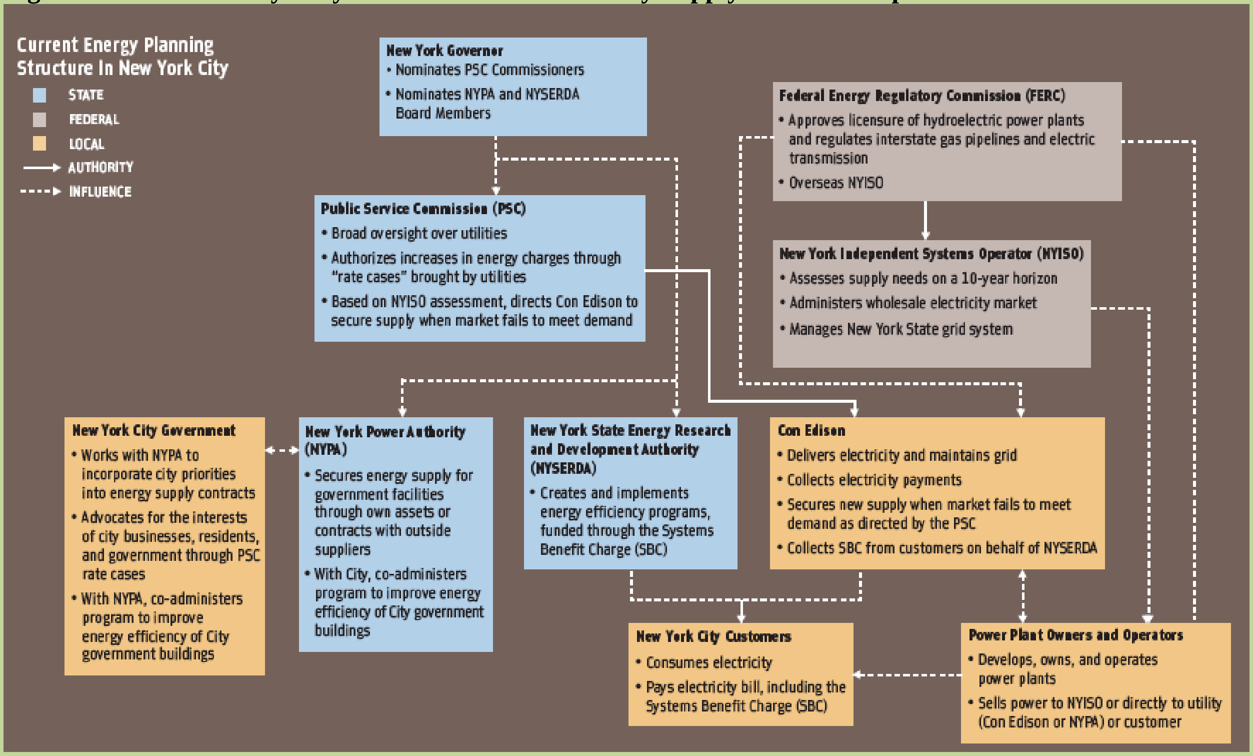
The role of city government in setting broad energy sector policies and regulations is limited and is likely to remain this way because of the nature of modern energy systems. But that does not prevent cities to plan and decide what, where, and how urban energy infrastructure should be built. Cities can also take measures to influence national policies while seeking to influence local behaviors through voluntary programs and initiatives. Since city governments are intimately involved with every aspect of urban development and management and wield real power to influence urban energy demand, they are in a *unique position of being able to tie urban energy supply and demand in one piece*. That makes them most effective in pursuing sustainable energy actions. Nevertheless, most cities are not yet organized in ways which they can act effectively in sustainable energy planning and management. In the traditional supply-driven and network-oriented urban energy landscape, cities' role is indeed rather limited. Even for a sophisticated city like New York, it realizes that it needs to establish a New York City Energy Planning Board to be able to consider supply and demand together as part of an integrated energy strategy (PLANYC 2030).

Stakeholder Dynamics

The main stakeholders of urban energy planning and management include local/city, regional/state, and national/federal governments (as represented by their relevant agencies or authorities), public or private energy utilities/companies/vendors and their investors, customers of various sectors, and public interest entities. Secondary stakeholders can include financiers, equipment and service providers (e.g., ESCOs), city service users, other local governments, etc. The broad relationships among these stakeholders are relatively straightforward: governments regulate urban energy services so as to ensure fairness (to customers and investors), quality, safety, and environmental controls; energy service providers produce, transmit/transport, and distribute/retail energy to customers at a cost; and customers pay for energy so as to sustain services and reward investors. The public interest entities or organizations often advocate on behalf of the disadvantaged social groups, such as low-income households for greater energy access and improved affordability. They are also active in informing/educating other stakeholders about sustainable energy solutions and pressing them to act. Climate change has motivated and mobilized an increasing amount of activities by the public interest entities internationally and in many countries.

Traditionally, city governments are most concerned about the needs and interests of their main constituents – the energy consumers of their jurisdictions and are primarily focused on safeguarding reliable and affordable energy services, especially electricity service, and in the case of cold climate cities heating service as well. But their means of intervention are limited as the example of New York City indicates (Figure 4). In this case the city government is only marginally involved in the planning and management of electricity supply and demand, a situation New York City is seeking to improve through its PLANYC 2030 actions.

Figure 4. New York City: Key Stakeholders of Electricity Supply and Consumption



Source: PLANYC 2030

City governments are uniquely positioned to influence the stakeholder dynamics in favor of sustainable energy planning and practice because they are a significant energy consumer themselves, able to directly influence the decision and behavior of their constituents – the rest of the energy consumers in the city, and can determine how cities are built, including its energy supply infrastructure. An often challenging dynamic is the intra-city consultations. Since energy use cuts across many agencies, getting the agencies to work together can be a big challenge, particularly where the costs and benefits are borne unevenly amongst them. Functional areas, such as technical staff, environmental officers, budget teams, procurement personnel, etc. also have various expertise, disincentives, constraints, biases, etc. to realizing energy efficiency improvements. Some of these issues can be dealt with through policies and programs, but strong leadership from the mayor's office can often help compel the aligning of interests.

Economic, Financial, Social, and Environmental Aspects

Sustainable urban energy planning and practice should be economically justifiable, financially viable, socially equitable, and environmentally sensible. These considerations form the basis for cities to properly select and better design sustainable energy actions.

Economic justification requires cities to make clear and consistent account and evaluation of the costs and benefits of alternative urban energy solutions so they can be compared with each other without ambiguity. This is sometimes hard to do because the valuation difficulties for environmental externalities, such as health impact. A critical aspect of the economic analysis is to calculate the *lifecycle cost* of alternative energy solutions. Many sustainable energy actions, especially energy efficiency measures, despite their higher initial costs, have lower lifecycle costs than their business-as-usual alternatives. The Melbourne Council House 2 (Australia), for example, has reduced electricity use by 82%, gas by 87%, water by 72% and corresponding CO_2 emissions by 87%, with a financial payback period of about 10 years.[14] While commercial practice usually considers projects viable if they have payback periods less than five years, city governments often have longer investment horizons, since their built environment often lasts for decades (lifecycle). Other sustainable energy options may have longer payback periods but may yield harder-to-quality benefits, such as higher local investment, job creation, improved competitiveness and enhanced quality of life (e.g., reduced commuting times, improved air quality and health, more green and community space).

Financial viability requires city actors to be able to obtain sufficient funds to implement sustainable energy solutions, sustain the outcomes, and maintain a positive return on investment under prevailing and projected financial cash flows. To acquire and sustain modern energy services (electricity, natural gas, or district heating), cost-recovery prices need to be charged to users. To sell energy efficiency as an energy supply option the cost of saved energy has to be cheaper than and as reliable as conventional supply options. In other words, a viable sustainable energy solution has to be a viable business proposition. Due to market failure (to account for environmental externalities), some renewable energy solutions, such as wind electricity and solar photovoltaic systems, still need government subsidies or regulations (feed-in tariffs) to be viable businesses. The recent expansion of carbon financing markets can further improve the financial attractiveness of sustainable energy investments by providing a new and sometimes more secure revenue stream for such projects. But, due to various market barriers,[15] many financially viable energy efficiency opportunities remain unimplemented, a point which will be revisited later.

As shown in Table 4, below, the package of investments most likely to be undertaken will in part be driven by the economics. Therefore, strong analytical work can help identify many short- to medium- term payback measures that a city may wish to undertake. Developing the best overall package of investments, within an acceptable payback or other investment

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[14] C40 Cities, Buildings Best Practices (http://www.c40cities.org/bestpractices/buildings/melbourne_eco.jsp).

[15] Market barriers to energy efficiency investments refer to factors, usually social and institutional, which prevent the realization of the full potential (as predicted by economics) of energy efficiency opportunities. They are offered to explain the difference between observed actual energy efficiency choices/decisions and those predicted by economic theory. Some common market barriers include misplaced incentives, lack of access to financing, high transaction cost, regulatory distortion on pricing, lack of information or misinformation, and etc.

thresholds then becomes a key challenge. Access to special funding, such as concessional donor funds or carbon finance revenues, can further enhance the overall returns to the city while bringing in the maximum number of measures into the investment package.

Table 4. Indicative Economics of Sustainable Energy Options

Sector	Short-Term Payback (under 5 years)	Medium-Term Payback (5-10 years)	Long-Term Payback (10+ years)
Public Buildings	• Equipment retrofits • Labeling building performance • ESCO contracting • Solar water heating	• Building envelope measures • Green roofs • Training in good practices in building O&M	• Building codes • Certification of building materials • Building integrated PV • Equipment standards
Public Lighting	• Lighting retrofits using high pressure sodium vapor and/or metal halide • Redesign of lighting systems • Control systems and sensors	• Retrofits using LEDs	• Street and traffic lighting standards
Transport	• Optimization of traffic signals • Fuel efficiency vehicle standards • Congestion taxes/tolls	• Alternative fuels for public buses, taxis • Bus rapid transit systems	• Modal shifts • Vehicle inspection and maintenance programs • Changes in land use patterns to promote densification
Water/Wastewater	• Pumping retrofits • Right-sizing of pumps • Leak reduction • Load management • ESCO contracting	• System redesign and optimization • Methane recovery for power generation from wastewater • Water DSM (low-flow outlets, drip irrigation)	
Solid Waste		• Methane recovery for power generation from landfills • Recycling programs	
Electricity/Heating	• Supply-side loss reduction • Power factor correction measures • Improved metering and pricing • Renewable energy portfolio standards • Retrofits of boiler and piping systems	• Combined heat and power • Load management • Energy storage systems • Promotion of distributed generation with feed-in tariffs	
Cross-Cutting	• Bulk purchase of efficient products • Awareness raising on energy issues to public sector staff • Agency awards and contests for energy efficiency	• Procurement standards for product procurement	• Improved city design and planning systems

Social equity requires cities to address the basic service access and affordability issues for the poor. The right way to approach this is not through artificially suppressed prices for energy services or universal subsidies, two approaches often used, but by targeting subsidies to the needy groups only. Everyone should pay for the full cost-recovery prices of energy services, but for those who cannot afford to pay in full, the city government can help through targeted subsidy schemes. Social equity also means that cities should link their sustainable energy actions with energy equity objectives. A good example of such actions is the promotion of compact fluorescent lamps in low-income or slum areas.

Environmental sensibility requires cities to be mindful of local, regional, and global environmental implications when they review their energy practices and plan their energy future and purposefully seek ways to mitigate those impacts in their pursuit of sustainable energy solutions. As demonstrated by the City of Rizhao in Shandong Province of China, environmental sensibility can make business sense for adopting sustainable urban energy solutions while also help address social equity issues (Box 3).

Box 3 An Extensive Solar Water Heating Program in Rizhao, China

Rizhao, a city of about 350,000 urban population in northern China, is using solar energy to provide water heating and lighting. Starting in the early 1990s with a municipal government retrofit program, the city later made it mandatory for all buildings to install solar water heaters. After fifteen years of efforts 99 percent of households in the central district obtained solar water heaters. Solar water heating is now common sense. In total, the city has over a half-million square meters of solar water heating panels, the equivalent of about 0.5 megawatts of electric water heaters. Most traffic signals and street and park lights are powered by solar cells, reducing the city's carbon emissions and local pollution. Using a solar water heater for 15 years costs about $1,934 USD (15,000 Yuan) less than running a conventional electric heater, which equates to saving $120 USD per year per household in an area where per capita incomes are lower than the national average.

This achievement is the result of a convergence of three key factors, a regional government policy that promotes and financially supports the research, development and deployment of solar water heating technologies, a new industry that takes the opportunity in strides, and a city leadership that not only has a vision but also leads in action and brings along other stakeholders.

How does it work?

- Municipal government, the community and local solar panel industries had a strong political will to adopt this practice.
- Shandong provincial government provided subsidies and funded the research and development of the solar water heater industry.
- The cost of a solar water heater was brought down to the same level as an electric one: about $190, which is about 4-5% of the annual income of an average household in Rizhao city and about 8-10% of a rural household's income.
- Panels are simply attached to the exterior of a building. City assists in the installation of such panels on households.
- City raises awareness through community campaigns and education: Rizhao held open seminars and ran public advertising on television.
- City mandated that all new buildings incorporate solar panels and oversaw the construction process to ensure proper installations.

Source: *State of the World 2007: Our Urban Future*, World Watch Institute

Indicators and Benchmarks

Sustainable urban energy planning and practice will be an elusive concept without a set of realistic metrics to quantify performances (using indicators) and measure progress (using benchmarks). For developing-country cities, the value of the indicators and benchmarks is not just about revealing gaps but also about inspiring actions to achieve greater energy services without reducing affordability or compromising the environment, as exemplified by the Rizhao City solar program. Developing such metrics is a worthy but difficult task because cities are different in so many ways and their energy use and the levels of energy services are affected by so many factors. It is thus important to focus on a small set of key indicators for which cross-city comparison is meaningful. For that purpose industrial energy consumption and related indicators should not be included and need to be dealt with separately. It is also important to keep in mind that many developing-country cities are underserved in energy (no access or cannot afford), compared with their developed counterparts. Thus, the indicators that are sensitive to such distortion (for example, per capita denominated indicators) should be carefully treated. In general there should be two levels of sustainable energy metrics for cities: one reflects the long-term strategic goals of sustainable urban energy planning and practice and the other highlights the performances/efficiency of energy consuming sectors in cities. Table 5 covers a preliminary list of sustainable energy metrics or categories of metrics proposed for cities.

Table 5: Sustainable Urban Energy * Indicators and Benchmarks – Preliminary Proposal

	Indictors **	**Benchmarks *****
Long-term and Strategic	• Share of renewable energy supply in final energy consumption • Carbon content of final energy consumption (kg CO_2/MJ) • Urban density indicator • Energy cost/affordability indicator	Benchmarks should draw on a group of comparable cities in terms of climate conditions and indicate the medium level and best practice, respectively.
Municipal Services	• Electric distribution losses • Energy used for delivering and treating one cubic meter of water • Technical and non-technical water losses • Public lighting energy efficiency • Methane recovery from landfills and wastewater treatment plants	
Buildings	• Residential buildings: cooling, heating, and lighting efficiency • Office buildings: cooling, heating, and lighting efficiency • Government buildings: cooling, heating, and lighting efficiency • Energy efficiency of key appliances	
Transport	• Carbon emissions of passenger traffic (kg CO2/person-km)	

* Urban energy in this case does not include industrial energy consumption.

** Indicators represent the current performance of a city.

*** Benchmarks are the same set of metrics as the indicators but represent the medium and best practices, respectively, of a set of comparable cities in terms of climate conditions.

Barriers to Investing in Sustainable Energy in the Public Sector

As noted previously, many sustainable energy actions can be justified based on their cost-effectiveness alone. However, for a variety of reasons, many of these investments go unrealized due to a number of policy and market barriers. Key issues include: (i) government agencies are not typically responsive to price signals since they lack a commercial orientation; (ii) public procedures for equipment and service procurement are generally not flexible to new approaches; and (iii) constrained annual budgets make funding for capital upgrades difficult while restrictions on public financing and typical one-year budget appropriations made amortizing costs difficult. A list of typical barriers by stakeholder is summarized in Figure 5, below.

Figure 5: Typical Barreis to Public Sector Sustainable Energy Investments

Policy / Regulatory	Public End Users	Equipment/Service Providers	Financiers
➢ Low energy pricing and/or collections	➢ No incentive to change or take risk	➢ Higher transaction costs for public sector projects	➢ High perceived public credit risk
➢ Procurement policies (lowest cost, defined project, unbundled services)	➢ No discretionary budget for upgrades or special projects	➢ Concerns over late/ non-payment	➢ New technologies
➢ Annual budget cycles may not allow multi-year contracting	➢ Unclear about ownership of cost/ energy savings	➢ High project development costs	➢ New contractual mechanisms
➢ Ad hoc planning	➢ Weak technical ability to assess options	➢ Limited technical, business and risk management skills	➢ Small sizes/high transaction costs
	➢ Behavioral biases	➢ Low track record in market for new contractual models	➢ High perceived risks
			➢ Behavioral biases

City Government Sustainable Energy Actions

The development of modern interconnected energy systems in the past century or so has gradually taken away the necessity and, along with it, capacity of cities to understand and plan for their energy needs. Cities have become quite passive participants in the urban energy agenda, leaving most responsibilities to the regional and national governments and to the private sector as well. To pursue a sustainable urban energy agenda, cities will need to become more assertive and involved in decisions that affect their energy demand and supply options. City governments need to become a strong partner of regional and national governments. They need to guide and mobilize private sector participation. Most importantly, they need to act within their own authority to implement sustainable energy solutions. They can be effective in three areas of actions discussed below.

Energy Efficiency and Renewable Energy Solutions in the Public Sector

Energy costs often constitute a significant portion of the operational budget of city governments. In the State of California, energy is the second largest expenditure item of city government operations, after employee salaries and benefits (Lantsberg, 2005). When looking at electricity and heating use only, the share of public sector consumption is quite high. Nine percent of Brazil's electricity is for the public sector; 20% of Eastern Europe's electricity and heating loads are attributed to public agencies; and about 10% of the European Union's electricity and heating demand is from the public sector.[16] Starting from within is obviously beneficial and easier to mobilize and should be the first step of city government sustainable energy actions. The areas of activities normally include: government owned buildings and facilities, water supply and wastewater treatment, public lighting/traffic lights, and other municipal services, such as solid waste management, public transport, and in cold climate regions, district heating.[17]

GOVERNMENT OWNED BUILDINGS AND FACILITIES. Buildings consume about one third of global energy and have significant potential for energy savings. Government buildings, particularly in developing countries, tend to be older and use more inefficient equipment, so the potential for energy efficiency gains in public buildings is significant. Improvements can be made in terms of building envelop measures (e.g., windows, insulation), electrical appliances (lighting, heating/cooling, pumping) and office equipment (computers, copiers, printers). Despite these opportunities, public facilities often have rigid procurement practices that focus on first costs and often lack discretionary budgets from which to make meaningful improvements. There is also a principal-agent or split-incentive issue, where a parent budgeting agency may determine the capital budget needs or even specify equipment while the subordinate agency is responsible for paying the monthly energy bills.

Energy efficiency programs in this area often start with relative low cost and modulated measures, such as lighting retrofit, or replacement of old equipment, such as a HVAC (heating, ventilation, and air-conditioning) system. For public building complexes, such as city halls, schools, and hospitals, it is often necessary to take a whole-building approach to achieve the most cost-effective control of the energy budget (annual energy consumption) of a building, since buildings are a complex energy system and many tradeoffs can be made to optimize among various energy-efficiency measures. For example, an often made tradeoff is between the efficiency of a HVAC system and the thermal integrity of building envelope since either one will reduce the effectiveness of the other. For new government buildings, adopting best practice in sustainable design and construction not only reduces the life-cycle costs of buildings for the government but also serve as examples for the private sector. A comprehensive analysis of the financial costs and benefits of LEED[18] certified office and school buildings in the US finds that a minimal upfront investment of about 2 percent of construction costs typically yields (20-year) lifecycle savings of over ten times the initial investment (Kats, 2003).

Recently, some governments in developing countries have been experimenting with bundling of several municipal facilities together for retrofits, given the common ownership.

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[16] Sources: Ringel 2007, Bharvirkar et al. 2008, BEG 2006, McGrory et al. 2006, Borg et al. 2003, Harris et al. 2005, Meyer and Johnson 2008, PROST 2003.

[17] District heating systems are the only modern urban energy infrastructure which is entirely city-bound. The ownership structure has undergone significant changes. But city governments still have large influence on the development and management of district heating systems.

[18] LEED – Leadership in Energy and Environmental Design – is a green building rating system, developed by the U.S. Green Building Council. It provides a suite of criteria for environmentally sustainable construction. The main financial benefits of meeting LEED criteria include lower costs of energy, water, and waste disposal.

While this can be more complex, if done right it can substantially reduce transaction costs and allow for scaled-up investments. In Hungary, for example, the Ministry of Education issued a tender in 2006 for a single consortia to be selected to finance and retrofit all the schools in the country under an ESCO-type contract. The International Finance Corporation provided a portfolio credit guarantee to the winning bidder for up to US$250 million. To date, about US$22 million has been invested in some 200 projects.

WATER SUPPLY AND WASTEWATER TREATMENT. The operation of water and wastewater systems is often the largest outlay of municipal energy budget. For example, California cities on average spend over 50% of their energy budget in water and wastewater pumping (Lantsberg, 2005). It is estimated that 2-3 percent of the world's energy consumption is devoted to pumping and treating water, with potential for energy savings of more than 25 percent. In many cities of the world both energy and water are scarce resources. Thus, there is natural synergy to save energy and water and attempt to address efficiency issues of both simultaneously. Many systems in developing countries often have outdated equipment, poor system design, leaks and other non-metered water loss stemming from a lack of investment capital and know-how to make many of these improvements. Many also operate with limited commercial incentives to be efficient. This situation has spawn a program launched by the Alliance to Save Energy called "Watergy" which has demonstrated significant benefits for developing-country cities in increasing clean water access through reducing energy costs and water losses.[19] In Fortaleza (northeast Brazil), the Alliance worked with the local utility, the Companhia de Água e Esgoto do Ceara or CAGECE, to develop and implement measures to improve the distribution of water and the access to sanitation services, while reducing operational costs and environmental impacts. CAGECE invested about R$3 million (about US$1.1 million), including the installation of an automatic control system, and has saved US$2.5 million over four years, saving 88 GWh. More importantly, the utility was able to connect an additional 88,000 new connections while still decreasing its overall energy costs.

Efficiency improvements should take a holistic approach of both supply- and demand-side measures. For example, as water leakage and waste is reduced (leak loss reduction, water-efficient and low-flow end uses, theft reduction), it allows for further efficiency gains by down-sizing (and right-sizing) pumping stations and further system optimization. Other improvements in system redesign, pressure management, pump impeller reduction, low-friction pipes, efficient pumps with variable speed drives, load management, power factor improvements, improved maintenance procedures, improved metering and water recycling can also significantly contribute to energy and water efficiency gains. Wastewater treatment plants also provide opportunities for efficiency through waste heat recovery, methane capture for power generation, improved pumping systems and other such types of measures.

For developing country-cities, the need for expansion of water supply and wastewater treatment capacities are great. Reclamation of runoff water and onsite treatment of domestic wastewater for non-drinking water purposes have been increasingly practiced in new real estate development projects. Such practices if properly configured within a city's overall

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[19] See the Alliance to Save Energy's 2007 Watergy Handbook for more discussion on barriers and opportunities for tapping water and energy efficiency in water utilities at: http://www.watergy.net/resources/publications/watergy.pdf.

water/wastewater networks can enhance the overall energy efficiency of the water/wastewater systems while relieve pressure on scarce freshwater resources.

PUBLIC LIGHTING. Public lighting is often seen as an essential public service, both in terms of economic activity and improvement in quality of life (e.g., reduction in crime, vehicular accidents). Provision of street lights can be done more effectively, extensively, and cheaply with the help of energy-efficient lighting. There are now multiple options for improving street lighting energy efficiency and the costs of energy-efficient alternatives have been decreasing. Table 6 reflects the cost-effectiveness of alternative street lighting systems in the State of New York in 2002. However, procurement of lamps is often based on least initial cost and do not consider recurring energy costs as a factor. Municipal governments also have limited capital budgets to replace their lamps, lack credible information on alternatives and may not even regularly pay their electricity bills for street lighting systems.

Table 6: Economic Analysis Comparing Several Street Lighting Systems

	Mercury Cobrahead (Conventional)	**Metal Halide Cobrahead** (Energy-efficient)	**High Pressure Sodium Cutoff** (Energy-efficient)
Lamp type	400W MV	250W MH	250W HPS
Number of luminaries	12	12	11 ***
Installed cost	$36,672	$36,240	$35,618
Annual energy cost	$2,391	$1,551	$1,419
Annual operating cost *	$2,536	$1,677	$1,601
Total annualized cost **	$6,271	$5,368	$5,229

* Includes energy and maintenance costs.
** Includes initial capital investment, energy and maintenance costs annualized over 20 years.
*** Assume 10% reduction in the number of poles needed because of higher luminous efficacy of high pressure sodium.
Source: NYSERDA, 2002

Street lamp retrofits can save 30-40 percent of the energy costs and, depending on energy costs and lamp availability, have payback periods of less than three years. In addition to switching out the lamps, the addition of time clocks, automatic control systems, and the redesigning of the street lighting system (to eliminate over-lit and under-lit areas) can help achieve further energy savings. In India, for example, the State of Tamil Nadu issued a tender for seven municipalities to be retrofitted to reduce energy use in public lighting and water pumping. Through an urban infrastructure development fund (TNUDF), ESCO bids were solicited requiring a minimum of 30% in energy savings. Several competitive bids were received an award made; the project has been operational since 2008.[20]

OTHER MUNICIPAL SERVICES. There are opportunities in other municipal services as well, such as solid waste (e.g., waste recycling, landfill methane recovery for power generation), transport (e.g., alternative fuel public vehicles, maintenance of public transit bus fleet, bus rapid transit systems, congestion tolls). An especially important area of interest of cities in cold climate regions is to improve the energy efficiency of their district heating systems (Box 4).

[20] ESMAP (forthcoming). "Public Procurement of Energy Efficiency Services." 2009

Box 4 Improving energy efficiency, reducing energy costs, and releasing municipal budgets

With partial support from a World Bank loan over 1991-1999, the Polish cities of Warsaw, Krakow, Gdansk and Gdynia undertook renovations of their heat supply systems, disseminated building-level heat meters, and reformed heat pricing from a square-meter based tariff to a two-part tariff charged at the building level.

Results in four cities

	1991/92	1999	Change
Household heat bill subsidy (%)	67	<5 (1994)	
Heat bill charged to households (1999 US$/m^2)	13.7	6.2	-55%
Heated floor area (million sq m)	63.8	68.6	7%
Heat energy sold (gcal/sq m)	0.27	0.22	-18%
Energy savings			22%

The Government of Poland implemented energy sector reforms under which payment for heat gradually became the responsibility of households, and they began to use heat more efficiently. Households (or companies operating as their agents) invested in thermostatic radiator valves, heat allocation meters, better windows and some insulation. A key result was that the costs of heating a given apartment area fell by 55%, due to efficiency improvements by consumers, and to technical, operational and management improvements in the heat supply companies. This reduction in costs helped to make the removal of the subsidy less burdensome to households.

Nationwide, household heat subsidies, provided by municipal governments, have been reduced from 78% in 1991 to zero by the end of 1997. Installation of building-level heat meters has been mandatory for all buildings since 1999. Use of heat allocation meters has become a popular way to allocate heat bills within buildings—a total of 5.5 million were installed as of 1997 in about 30% of the dwellings nationwide. More than 10 companies have been formed and compete in the market for billing services—including allocation meter installation, meter reading, billing and maintenance. Energy savings, reflected in customer heat bills, stemming from the reform (including savings from private investments spurred by the reform) typically range from 20 to 40%.

Source: China - Opportunities to Improve Energy Efficiency in Buildings, May 2001

Beyond the Public Sector: Focusing on the Built Environment

Using their authority in enforcing national, regional, and local regulations, city governments can have a big impact in promoting adoption of sustainable energy solutions in the urban built environment. This is especially important for fast growing cities of developing countries where inaction means locking in energy waste in their new buildings for decades to come. The primary focus should be on the built-in features/functions of new buildings which impact a building's energy consumption, especially heating and cooling energy use. This would include site planning, building layouts, building envelope, heating and cooling equipments/systems, lighting fixtures, and water heaters. Much experience has been accumulated in developed-country cities in the past 30 years or so. The use of matured technologies and widely available materials is enough to make low or near zero (space heating/cooling) energy buildings.[21] Implementing building energy efficiency standards requires coordinated national/regional and city-level efforts. But city-level compliance enforcement is most critical.

China perhaps provides the best example of how such programs can succeed in fast urbanizing developing countries. In 1995 China introduced it first mandatory building energy efficiency standard for new residential buildings in cold climate regions. The compliance rate was a meager 6 percent in 2002 among northern Chinese cities where the standard applied.

[21] No Furnaces but Heat Aplenty in 'Passive Houses', New York Times, December 26, 2008

Since then the national government has stepped up pressure and assistance to local governments in compliance enforcement and inspections. As a result the compliance rate increased to about 40 percent in 2005 and further to about 70 percent in 2007, according to the estimates of the Ministry of Construction. The new buildings compliant with the current national standards on average lose 35 percent less heat than conventional buildings. The national government will soon promulgate a revised energy efficient design standard for new residential buildings in cold climate regions which will further cut heat losses by 30 percent from the level allowed by the existing standard. This time, many cities are already ahead of the national government. For example, Beijing and Tianjin, the two largest northern cities in China, already adopt building energy efficiency standards similar to the pending revised national standard in 2005. The provinces of Liaoning and Hebei did the same in 2007.

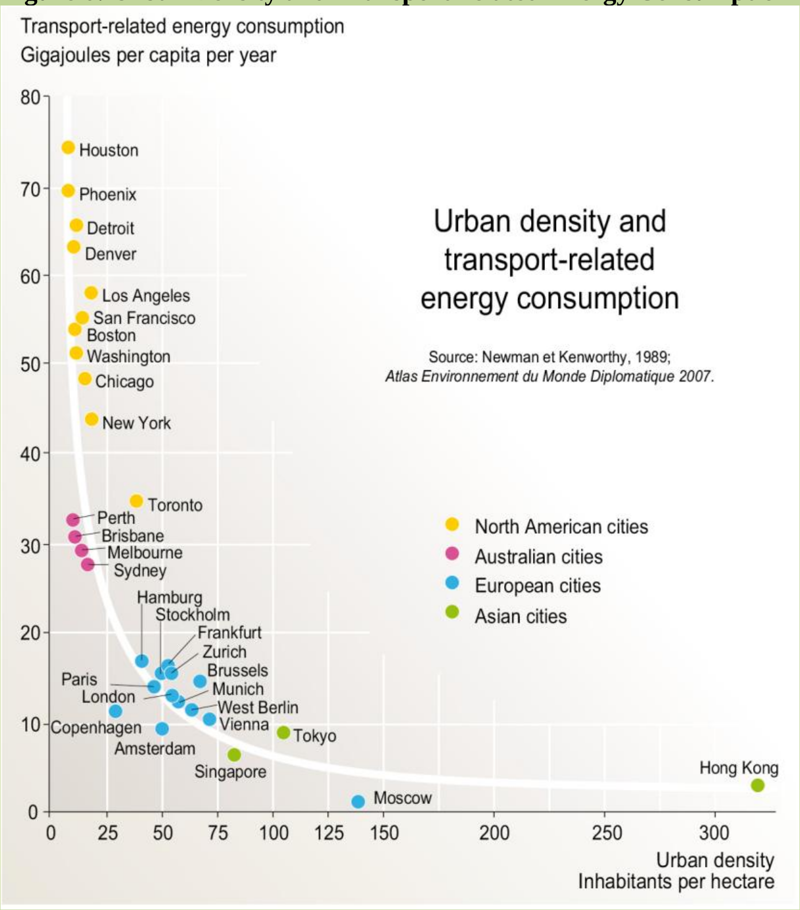
Many developed countries have broadened the sustainable buildings agenda to include additional resources conservation aspects, such as water and waste disposal, as well as indoor environment quality. For example, the State of California adopted the first Green Building Standards in the U.S. in 2008. A cautionary note for developing countries is that the necessary compliance capacity, even for building energy efficiency standard, takes years to build up. It is important to sequence sustainable building interventions in ways that suits local capacity and priorities.

<u>The Big Picture and Altogether: Urban Land Use and Development</u>

Ultimate, cities, as a whole, both individually and as a regional cluster, have to become more efficient in utilizing natural resources, including energy. For each individual city, pursing sustainable urban energy planning and practice should be an integral part of its resources-efficient smart growth, which eventually feeds into regional and national sustainable development agenda. To achieve resources-efficient smart growth, cities may need to retreat from expansionary urban land use and development afforded by motorized transportation and find inspirations from their old neighborhoods planned and built when convenience meant most of everything is within walking distance. While there is no systematic evidence to establish a clear relationship between urban density and associated energy use, it is most likely that a city's energy requirements can be reduced with increased built density, which in general would reduce the extensiveness of major municipal infrastructures, such as roads, water and wastewater systems, power lines, gas pipelines, and etc., which in turn reduces not only capital cost but also operation and maintenance costs of these systems. Figure 6 is indicative of the general relationship between urban density and transport fuel consumption. Admittedly, density has its drawbacks and limits, thus how far should a city push its density limit needs to be handled based on its existing and natural conditions.

Many new initiatives to develop eco cities are intended to demonstrate the virtues and benefits of integrated urban planning. Dongtan (China) aims to be the world's first purpose-built eco-city. The city is designed not only to be environmentally sustainable, but also socially, economically and culturally sustainable. Its goal is to be as close to carbon neutral as possible, with city vehicles that produce no carbon or particulate emissions and highly efficient water and energy systems. Dongtan will generate all of its energy needs from renewable sources including bio-fuels, wind farms and photovoltaic panels. A majority of Dongtan's waste will be reused as biofuel for additional energy production and organic waste will be composted. Even human sewage will be composted and processed for energy and composting, greatly reducing or entirely eliminating landfill waste sites. A major aspect of the program is the city design, in which the roads, public transport, schools, hospitals, commercial areas and green spaces will be designed to encourage inhabitants to travel by bicycle or public transport rather than by car. Pollution-free buses, trams and water taxis will be available and electric scooters and bicycles will be promoted. Buildings will use integrated renewable energy systems, such as small-scale windmills and solar PV panels, green roofs; up to 80% of the solid waste will be recycled, while organic waste will be used for composting and power generation; and flood control measures will be employed to reduce vulnerability to sea level rises from climate change. Overall, the city expects to use 64% less energy than a comparable city.[22] The big challenge is to internalize the good practices and principles from such demonstrations in growing cities so as to influence broad urban development practices.

Figure 6: Urban Density and Transport-related Energy Consumption



Source: Adopted from Kick the Habit: A UN Guide to Climate Neutrality

[22] C40 Cities, Buildings Best Practices (http://www.c40cities.org/bestpractices/buildings/dongtan_city.jsp).

Conclusions

Due to the cross-cutting nature of energy, realizing sustainable energy options in the urban setting is complex. Unlike many other environmental considerations, many energy investment options can be justified based on their financial and/or economic returns. However, due to many prevailing market and other barriers, these projects do not happen on their own. Some general conclusions about exploiting the potential of energy efficiency and clean energy resources in cities include:

1. Get the energy sector work properly. Energy sector restructuring, utility commercialization, pricing reforms, etc. can greatly reduce energy costs in the supply of energy services while improving incentives to reduce energy waste. This is best done at the national level.

2. Explore options to retrofit the existing stock of infrastructure. This can be done through energy auditing, changes to procurement guidelines, contracting of ESCOs, public agency targets for energy efficiency, etc. Access to financing will be a key to realizing these gains.

3. Consider options to address the new built environment. This includes adoption of building energy efficiency standards and equipment standards, improved city designs and planning, better land use schemes, etc.

4. Seek options to bundle city programs together, such as combining equipment procurement to negotiate better costs, combining similar services across cities, increase influence at the national level, etc.

5. Seek ways to better incentivize public agencies and staff on sustainable energy options, such as environmentally sustainable awards, publishing of agency energy/environmental performance, agency incentive grants, etc.

6. Create mechanisms for sharing cities experiences across the country, through associations, case studies, newsletters, etc.

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Feng Liu and Jas Singh
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