

An aerial, artistic rendering of a futuristic urban landscape. The city is characterized by a high density of greenery, with trees and parks interspersed among modern architectural structures. Several tall, slender skyscrapers with glass facades stand out, some featuring rooftop gardens. A prominent feature is a winding river or canal that flows through the city center, with small boats and sailboats visible on its surface. A multi-lane highway with a bridge section runs diagonally across the lower right, with cars and trucks in motion. The overall atmosphere is one of a sustainable, integrated urban environment.

ADB

Urban Development Series

Green Cities

Asian Development Bank



Urban Development Series

Green Cities

Edited by Michael Lindfield and Florian Steinberg

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Notes: In this report, "\$" refers to US dollars. "Hong Kong" and "Taipei" refer to the entire urbanized area within Hong Kong, China and Taipei, China respectively.

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Contents

Preface	v
Foreword	viii
Abbreviations	x
Contributors	xii
Acknowledgment	xiv
Introduction	
by Michael Lindfield and Florian Steinberg	1
1 Spatial Development and Technologies for Green Cities	
by Florian Steinberg and Michael Lindfield	23
2 Urban Metabolism and the Zero-Waste City: Transforming Cities through Sustainable Design and Behavior Change	
by Steffen Lehmann	108
3 Energy Strategy for Green Cities	
by Thomas Hurst, Debra Lam, and Malcolm Ball	136
4 Transport for Green Cities	
by Lloyd Wright	175
5 Green Cities: A Water-Secure Future	
by Alan Baird and Theresa Audrey O. Esteban	218
6 Green City Solid Waste Management	
by Reynar R. Rollan	262
7 Financing Sustainable Cities	
by Michael Lindfield, Vergel Latay, and Vince Michael Docta	296
8 Smart Concepts for Greener Cities	
by Alexandra Vogl	373
Conclusion: Green Cities Will Become a Reality	
by Michael Lindfield and Florian Steinberg	406

Preface

Asia's Green City Challenge

Asia's cities have been the drivers of the economy and have lifted millions out of poverty. However, the environmental consequences of this rapid development are apparent, and the citizens of Asia's urban areas are increasingly insistent that something should be done. And there is an investment deficit in Asian cities' infrastructure spending, mostly in environmental infrastructure, of some \$100 billion per annum.

Asian cities can be more environmentally friendly. The resources are there to achieve this. Up to 80% of gross domestic product today comes from urban areas in Asia, and its megacities are nation-sized in population and economic product. New cities, such as the innovative "eco-towns" in Japan and "eco-cities" in the People's Republic of China (PRC), have begun to put into action a sustainable urban development model.

Existing cities need to change as they grow. In particular, to maximize livability and minimize energy use and environmental impact, Asian cities need to align the planning and provision of quality, high-capacity public transport with the provision of well-serviced high density, mixed-use development. The bus rapid transit system in Guangzhou, People's Republic of China, for example, is integrated with the city's metro system and other nonmotorized means of transport. It is also integrated with the planning and zoning of surrounding areas to foster a dense, pedestrian-friendly environment which allows easy access to services and employment.

The challenge throughout the region is to provide the green infrastructure needed to maintain growth while cleaning up the environment. Anyone who has been in traffic jams in Bangkok, Beijing, Jakarta, Manila, or Mumbai will know that a new approach is needed.

Asian cities and their hinterlands also have potentially severe global environmental consequences. This can be seen in the ecological footprints of Asian cities. Although controversial as an absolute measure, city ecological footprints provide a relative measure of cities' resource use intensity and help us understand their impact. A sustainable footprint is about 1.8 hectares

per person. Today, the average in rural PRC is 1.6 hectares. In Shanghai, it is 7 hectares. The footprint of a typical city in the United States is 9.7 hectares. The consequence for the environment as the PRC urbanizes and becomes wealthier is obvious. The constraints of inter-sector and interjurisdictional coordination, exacerbated by far-reaching decentralization which has occurred across the region and which has seen capacity-strapped cities and surrounding rural local governments saddled with “unfunded mandates”, mean that even “wealthy” cities find it difficult to respond to climate change imperatives and invest in green infrastructure even if they want to.

To support its developing member countries in more sustainable urban development, the Asian Development Bank (ADB), under its new Urban Operational Plan, will analyze the urbanization process in the context of a country’s economic development and identify the main environmental, social, and economic development issues relating to the urban sector—as well as how ADB can add value in the sector—and the proposed areas of investment focus.

ADB will endeavor to develop longer-term engagements in focus urban regions. This will provide the opportunity to develop an integrated plan based on assessments of the environmental, social, and economic priorities for these regions. The assessment process will identify the key environmental issues of a city and prioritize investments to address them in an integrated way across infrastructure sectors to achieve a Green City. ADB, together with public and private partners, will be involved in investments in water supply, waste water, solid waste, district heating/cooling, urban transport (including roads), and energy efficiency.

To foster such investments, two things are needed. The first is to give cities the capacity and incentive to plan, finance, and implement needed infrastructure that provides the basis for innovation appropriate to the competitive advantages of the city and its rural hinterland. The second is to enable the private sector to participate effectively in this process, leveraging government resources.

Asia’s cities are rapidly developing in sophistication and confidence. Despite obvious shortfalls in service provision, there is a developing sense that, with the right support, incentives, and freedoms, they may be able to solve their problems and even contribute in a major way to solving global problems such as greenhouse gas reduction and climate change mitigation.

The challenge is to find ways to channel resources to effective change agents in subsovereign governments. This would encourage innovative responses and effective partnerships with both private sector and community groups. At ADB, we accept this challenge under our new Urban Operational Plan. This book is intended to provide examples of how this challenge may be met.



Bindu N. Lohani

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Foreword


We are pleased to publish this book on *Green Cities* that, in addition to *Inclusive Cities* and *Competitive Cities*, will continue to form one of three major themes of the work of the Asian Development Bank (ADB) in the urban sector over the coming years. Publication of this book is particularly timely in this year of the Rio+20 United Nations Conference on Sustainable Environment, which represents a major commitment of the international community to achieving sustainable cities.

The global challenge we face today is that of preventing catastrophic climate change. This will require ensuring that global greenhouse gas emissions peak by the year 2020. Reaching this goal will be necessary to ensure that the increase in global temperature does not exceed 2°C by the end of the 21st century. In addition to ongoing efforts to reduce emissions, adaptation measures will be required to cope with the adverse consequences of climate change that have been locked in by emissions of previous decades. Developing Asia is now responsible for 35% of worldwide energy-related carbon dioxide (CO₂) emissions, compared to only 17% in 1990. In the absence of more widespread use of energy from renewable sources as well as improved energy efficiency, this could reach 45% by 2030.

Globally, cities account for about 70% of CO₂ emissions, which comprise a significant share of global greenhouse gas emissions, the bulk of these being generated in the building and construction, urban transport, and energy sectors. Ultimately, reducing CO₂ emissions in urban areas will require (i) lowering the rate at which buildings consume energy, both during construction and operation and maintenance; (ii) encouraging use of low-carbon forms of transport; and (iii) adopting low-carbon means of energy production. However, achieving such goals will require investment on a significant scale. In fact, several tens of billions of dollars will be required annually to assist developing countries transition to low-carbon and climate-resilient economies, with \$40.0 billion being required annually for adaptation in Asia and the Pacific alone. For its part, ADB has sponsored numerous energy efficiency projects since 2002, with lending for energy efficiency reaching \$2.1 billion per year as of 2011.

One purpose of this book is to direct the green agenda toward compact, multifunctional, and efficient urban areas. It thus focuses on “greening” of a number of urban infrastructure services such as urban transport, and provision of water and sanitation services, waste management, and energy sources for urban areas.

We join the editors and authors of this book in the conviction that the Asia and Pacific region is moving toward a green economy, and that the future of cities is an important part of this shift. While a challenging process that will require time, the foundation for Green Cities must be laid today.

A handwritten signature in dark ink, appearing to read 'S. Chander', is shown within a light gray rectangular border.

S. Chander

Director General

Regional and Sustainable Development Department

Asian Development Bank

Abbreviations

3R	–	reduce–reuse–recycle
ADB	–	Asian Development Bank
ASEAN	–	Association of Southeast Asian Nations
ASrIA	–	Association for Sustainable and Responsible Investment in Asia
AWDO	–	Asian Water Development Outlook
BRT	–	bus rapid transit
CBD	–	central business district
CDIA	–	Cities Development Initiative for Asia
CDM	–	clean development mechanism
CHP	–	combined heat and power
CIF	–	Climate Investment Fund
CNG	–	compressed natural gas
C&D	–	construction and demolition
CO ₂	–	carbon dioxide
CWSI	–	Composite Water Security Index
DEMaP	–	Decentralised Energy Master Planning
EPR	–	extended producer responsibility
FDI	–	foreign direct investment
FSI	–	floor space index
GHG	–	greenhouse gas
HDPE	–	high-density polyethylene
ICT	–	information and communication technology
IRBM	–	integrated river basin management
LFG	–	landfill gas
MDG	–	Millennium Development Goal
MEP	–	Ministry of Environmental Protection
MOHURD	–	Ministry of Housing and Urban-Rural Development
MRF	–	materials recovery facility
NAMA	–	nationally appropriate mitigation action
NCBU	–	not-caused-by-us
NGO	–	nongovernment organization
NIMBY	–	not-in-my-backyard
NMT	–	nonmotorized transport
NRW	–	non-revenue water
ODA	–	official development assistance
OECD	–	Organisation for Economic Co-operation and Development
PACE	–	Property Assessed Clean Energy
PPWSA	–	Phnom Penh Water Supply Authority
PRC	–	People's Republic of China

RDF	–	refuse-derived fuel
RFID	–	radio-frequency identification
ROW	–	right-of-way
SRI	–	socially responsible investment
SSTEC	–	Sino–Singapore Tianjin Eco-City
TDM	–	transportation demand management
TOD	–	transit-oriented development
tpd	–	tons per day
WTE	–	waste to energy

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Introduction

by Michael Lindfield and Florian Steinberg

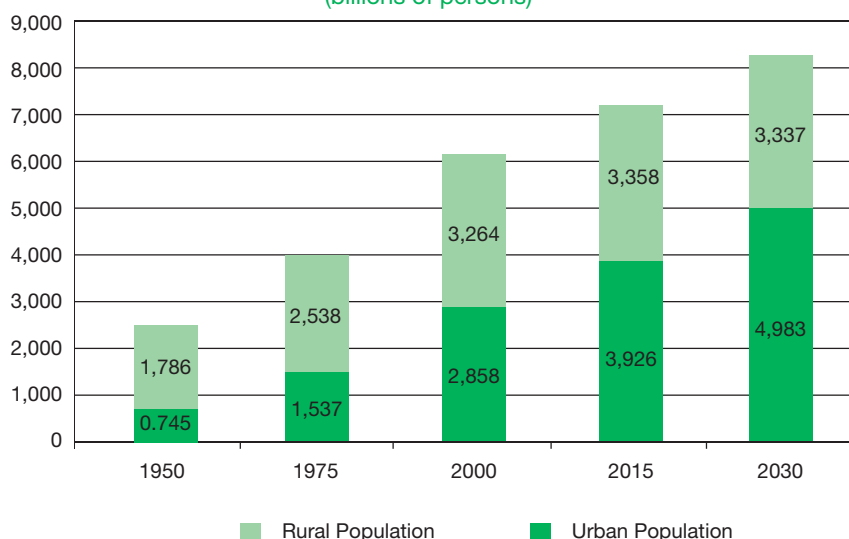
Asia's Urban Environmental Challenge

Asia is urbanizing at a rapid rate. While in 1950 the region was predominantly rural, with only 17% of its 1.4 billion people living in cities or towns, recent United Nations projections (2004) indicate that by mid-2022, 55% of Asians—2.7 billion people—will live in urban areas (Figure 1). Thus, from 2015 onward, virtually all of Asia's population growth will occur in urban areas.

But rapid urbanization poses significant quality-of-life challenges such as rising inequality and crimes. In particular, it adds tremendous pressure on the local and global environment. Today, Asia has some of the world's most polluted cities and most steeply rising greenhouse gas (GHG) emissions. And most of the unique features of Asia's urbanization tend to aggravate environmental problems. Despite these challenges, there are reasons to be optimistic, as urbanization can help address environmental degradation.

Globally, cities occupy only 2% of the earth's total land area but account for 75% of total resource use. Since waste generation roughly parallels resource consumption, urban areas unsurprisingly account for a similar share of total waste generated, the latter including air pollution, toxic effluents, and solid waste (Girardet 1996). For GHG emissions alone, which include carbon dioxide, methane, and nitrogen oxide, urban areas account for nearly 80% of total emissions globally. The environmental implication of such a statistic is that urban areas are a major contributor to climate change, particularly when loss of forest and vegetation cover associated with urban expansion is added to the air pollution impacts referred to above. Given the above, over the long term, the environmental impact of unchecked urban growth in the developing world is likely to be catastrophic (Pearce 2006). An outcome on such a scale would undoubtedly carry with it economic costs that are significant by any meaningful measure, such as in relation to a country's level of gross domestic product (GDP).

Figure 1 Urban vs. Rural Population Growth in Asia: 1950–2030
(billions of persons)



Source: United Nations, Department of Economic and Social Affairs, Population Division. 2012. World Urbanization Prospects: 2011 Revision, CD-ROM.

In fact, the costs of air pollution alone can reduce a country's annual GDP by an estimated 2%–4%, or even more for some countries. In the People's Republic of China (PRC), the economic cost of deaths and illnesses in urban areas due to air pollution is equivalent to an estimated 5% of GDP (Sheram and Soubotina 2000). Such costs are not limited to the developing world. A World Health Organization study that included Austria, France, and Switzerland found that health costs resulting from traffic pollution alone were approximately equivalent to 1.7% of GDP, this figure dramatically exceeding the cost of treating traffic accident injuries (CNN 2000). Similarly, the total annual cost of air pollution to the 12 million residents of Canada's Ontario Province is at least \$1 billion when hospital admissions, emergency room visits, and worker absenteeism are taken into account (Ontario Medical Association 2000). Such figures corroborate the findings of Ramankutty (1994), which estimate the annual cost of air and water pollution in Jakarta, Indonesia at more than \$1 billion, the corresponding figure for Bangkok, Thailand being \$2 billion.

Given the size of the population of Asian cities vulnerable to sea-level rise such as Bangkok, Thailand; Chennai, India; Dhaka, Bangladesh; Jakarta, Indonesia; and Tianjin, PRC, the impact of Asia's urban population on climate change parameters is of special concern. This is particularly true

in light of the forecast of the Intergovernmental Panel on Climate Change, which projects an increase in sea levels of 8–88 centimeters over the course of the 21st century (Watson 2001). In addition to sea-level rise, the changes in rainfall patterns and increased severity of storms associated with global warming are likely to heavily impact urban residents living in poor quality housing and informal settlements, their numbers being significant in Asia's urban areas.

Ultimately, Asia's rapid urban growth has come at significant environmental cost, this falling disproportionately on the poor, the segment of the urban population most vulnerable to declining environmental quality and negative impacts of climate change. That said, economic growth in Asia's urban areas has also improved living standards and brought millions out of poverty. Over the long term, achieving sustained growth in Asia's urban areas will require continued economic advance that brings about rapid increases in living standards, but that simultaneously addresses the environmental damage associated with such growth. In particular, this will require addressing both the waste that results from production, consumption, and provision of services in urban areas, as well as the negative impacts of climate change impacts that such waste generation entails.

Thus far, the results of specific measures for reducing the amount of waste generated by rapid urban growth have not been encouraging. These measures include encouraging the burning of clean coal, substitution of natural gas for other fuels, and use of public transport, as well as subsidies that reward environmentally responsible behavior. Equally disappointing have been the results of levying fees or taxes on polluters and command-and-control measures such as regulations that attempt to curtail specific polluting activities. In this regard, the results of measures for reducing demand for energy and other pollutants have been especially disappointing. This notwithstanding, improving the livability of Asia's cities will inevitably require expansion of green space and reductions in air and water pollution, as well as GHG emissions. Given the disappointing results of the measures referred to above, the chief means through which this desired shift is likely to be accomplished will be better planning, together with technological change that substantially reduces demand for fossil fuels while simultaneously maintaining the quality of life. Achieving such improvements will ultimately require a shift in focus on the part of policy makers from economic growth to improvement in the quality of life.

This book addresses the entire array of environmental issues associated with rapid urbanization in Asia. In particular, it focuses on (i) the environmental problems the region is likely to face as rapid urbanization proceeds, (ii) the implications of the latter for the global environment, and (iii) measures for addressing both.



Photo: AFP.

Source: ADB. 2011. Green Cities Brochure.

Overview of the Book

- **Spatial Development and Technologies for Green Cities** by Florian Steinberg examines cities from the perspective of functioning as catalysts for the creation and adoption of green technologies. While much has been written and said of late about the need for cities to be both inclusive and competitive if they are to support future rapid urbanization, this chapter explores the vital additional dimension of urban environmental sustainability. Ultimately, the chapter sees urban densification coupled with compact land-use solutions as being the primary vehicle for achieving development of environmental technology that increases both energy and land-use efficiency. Viewed from this perspective, structures cease to be merely by-products of architectural design processes, but instead function as catalysts for increasing the economic and environmental efficiency of the urbanization process. The chapter is replete with examples of initiatives that facilitate greening of urban environments while simultaneously overcoming problems commonly associated with urbanization itself. For example, creating pedestrian-friendly urban environments and healthy habitats reduces traffic density and encourages widespread use of public transport. Similarly, introduction of smart technologies that allow energy production to be distributed over a wide range of sources can potentially transform cities from voracious energy-consuming conglomerations to net energy producers. Likewise, delivery of human services through environmentally sound technologies increases ecological efficiency and reduces GHG emissions. However, adoption and application of such

principles and technologies is far from instantaneous. As green technology remains a relatively new field, its application in Asia is likely to require some time. While higher-income countries will undoubtedly lead this process, middle-income countries are likely to adopt such technologies quickly as the economic and environmental benefits of greener cities become increasingly apparent.

- **Metabolism of Green Cities** by Stefan Lehmann views the cities of Asia and the Pacific as being at a crossroad with regard to the sustainability of their development trajectories. For example, over the past 2 decades, Bangkok; Hong Kong, China; Jakarta; Kuala Lumpur; Shanghai; and Singapore have all transitioned to a high-carbon-use development trajectory that is in all likelihood unsustainable over the long term. An important feature of the chapter is that it introduces several concepts used in discerning differing aspects of sustainability as these relate to particular urban development scenarios. Examples



Photo: ADB.

Source: ADB. 2011. Green Cities Brochure.

include *green urbanism*, which refers to the ability of an urban system to exist, grow, or shrink without negatively impacting the ecosystem in which it resides, thus maintaining a healthy balance between the urban environment concerned and its surrounding hinterlands. Similarly, a *zero waste city* is an urban area that organizes flows of matériel necessary for servicing the urban area in question so as to achieve 100% recovery of all by-products of resource use. Due to the importance of urban waste generation as a driver of climate change, the strategies reviewed in this chapter are central to addressing its damaging impacts. Finally, *urban metabolism*—a 21st-century concept—relates to maintaining an appropriate balance between production and consumption of public and private goods, the built and the unbuilt environment, and local as opposed to global perspectives on environmental sustainability.

- **Energy Approaches for Green Cities** by Thomas Hurst, Debra Lam, and Malcolm Ball sees energy as a vital factor in the urban socioeconomic development process. For example, access to relatively inexpensive fossil fuels enabled the Industrial Revolution, and thence the growth of the urban areas in which it flourished. However, because fossil fuels are less abundant and relatively more expensive today than during the Industrial Revolution, security of supply, price, and reducing demand for carbon-based forms of energy have increasingly become vital factors in sustaining economic advance. This has driven not only international



Photo: Aup.

commitments and national legislation relating to energy security and self-sufficiency but, equally important, growing public awareness that a change in approach to fueling urban areas is required, if long-term environmental sustainability is to be achieved. While individual cities may have little efficacy in assuring their future energy supplies, there are numerous energy-use parameters that are within their control. Examples include the carbon intensity of their energy-use patterns, the degree to which they are vulnerable to the negative impacts of climate change, and the ability to exploit opportunities for diversifying the sources of the energy they consume. Some cities have exploited these opportunities by adopting bold policies for reducing the carbon intensity of their development trajectories and have supported implementation of these policies by investments underwritten by creative financing arrangements. Implementation of such policy initiatives is generally preceded by three phases of development. These include (i) building a knowledge base, (ii) performing a strategy analysis, and (iii) implementing low-carbon energy consumption programs. The case study presented in the chapter, which shows how London has implemented an initiative of this type, demonstrates that implementing energy-efficiency initiatives is well within the grasp of individual cities.

- **Transport for Green Cities** by Lloyd F. Wright describes sustainable transport systems as being accessible, safe, environment-friendly, and affordable. These attributes together incorporate several dimensions

of sustainability. However, because petroleum-based fuels dominate transport-sector energy consumption, Asia's rapid pace of economic advance causes it to account for a significant share of vehicular emissions, which are in turn a primary contributor to the GHG emissions that drive global climate change. Further, because Asia is projected to account for the majority of future increases in GHG emissions, addressing the region's rate of growth of vehicular emissions is a critical factor in mitigating global climate change. Because there is a direct relationship between the quantity of fossil fuels consumed by vehicular means of transport and the amount of vehicular emissions released, the future urban transport means that could significantly reduce the rate of growth of vehicular emissions include low-carbon public transport systems, expanded use of nonmotorized transport, integrated urban transport planning, and traffic management. While some transport-sector energy initiatives, such as developing new vehicle technologies, may only yield results in the medium to long term, others lead to large-scale reductions in vehicular emissions over a short time horizon. Examples include using modes of transport that consume less energy and thus release lesser emissions, and improvements in the efficiency with which existing modes of transport are used. Introducing information technology into the design and operation of transport systems in order to produce intelligent transport systems (ITSs) is likewise a promising tool for making future transport systems more sustainable than they are at present. Aspects of ITSs already in use include in-vehicle technologies that reduce energy consumption; computer-based traveler information systems that reduce the number, frequency, and length of vehicular trips; computer-based management of transport systems; and increased use of electronic-based transactions that obviate the need for vehicular trips.

- **Water Service Cities** by Alan Baird and Audrey Esteban traces the evolution of urban water supply policies that have, in turn, focused on sewerage, drainage, and ultimately *water sensitivity*. Drawing on numerous examples of initiatives undertaken in Asian cities as well as international best practices, the chapter outlines the benefits of creating water-sensitive cities, explains why water sensitivity is vital to sustainability, and describes what is required in making urban areas water-sensitive. The chapter's

descriptions of water-sensitive technologies, such as decentralized wastewater systems, rainwater harvesting, and wastewater recycling provide practical examples of the options available for creating water-sensitive cities.



Photo: Eric Salles (South Asia/Bangladesh), ADB.

- Solid Waste Management** by Reynar Rollan explains that the variety of waste management systems employed by Asian cities generally reflects each city's level of technical ability, financial resources, and environmental awareness. As a result, the standards employed and the level of environmental performance achieved vary widely between lower-income urban centers and cities in the region's developed countries. That said, many elements of green-city solid waste management systems have been adopted by most Asian cities. In fact, a legal framework for effective solid waste management was established in most Asian countries by the turn of the 21st century. Furthermore, numerous jurisdictions have launched education campaigns for increasing environmental awareness among all segments of society. Over time, these campaigns create a culture of waste management appropriate to urban environmental sustainability. Such a culture understands (i) the implications for urban sustainability of dwindling resources and space and (ii) how low utilization rates of reusable materials lead to deteriorating health and environmental conditions. Widespread awareness of both of these factors is generally what drives governments, institutions, private sector entities, and residents alike to work together in achieving the goals of solid waste management initiatives, and thus allows green cities to be achieved, regardless of the average income level of the urban area concerned.
- Green Financing** by Michael Lindfield explains that the key to sustainable provision of urban services is a service- or demand-focused institutional framework. This requires service providers that are (i) capable both technically and managerially, (ii) accountable and responsive to customer needs, and (iii) driven by performance in that the service provider in question faces incentives for providing cost-efficient service that is both affordable to customers and financially sustainable. Furthermore, such service providers incorporate innovations that produce savings and other efficiencies. Ultimately, the pool of financing available to a particular city for financing environment-related initiatives depends on the degree to which that city (i) maximizes revenue from both existing and potential sources, (ii) leverages additional resources from the private sector, and (iii) accesses funds from both international and local sources that support green investments. Aside from collecting



Photos: Green City Solid Waste Management (2012).

all mandated taxes, potential sources of additional revenue include (i) user charges, (ii) emission or effluent charges, (iii) product charges, (iv) tradable rights, (v) marketable permits, (vi) employer taxes, (vii) property development tax revenue gains, (viii) tax-increment financing, and (ix) the existence or creation of refund systems.

- **Smart Cities** by Alexandra Vogl relates how the technologies that shape urban life are becoming ever smarter and supportive of energy efficiency. In fact, numerous city systems and networks have been retrofitted with devices that count, measure, and record energy-use parameters, and connect databases and information sources. This suggests that retrofitting existing cities is a more cost-efficient and achievable option than is building entire smart cities from the ground up, since “instant” smart cities cost \$30 billion to \$60 billion on average.

Recommended Approach to Greening Asia's Cities

What are Green Cities?

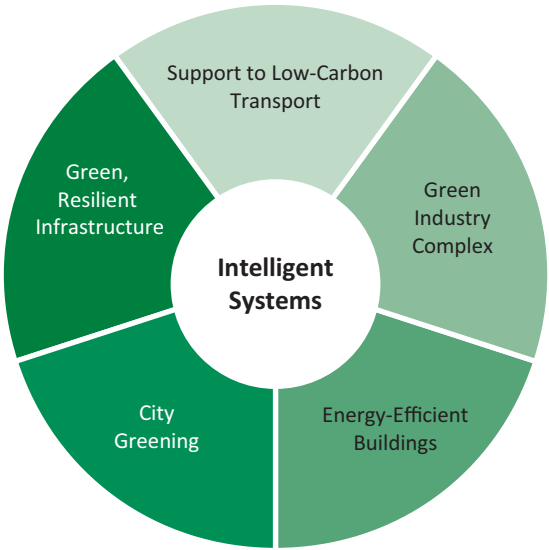
In this book, we distinguish *green cities* (cities that have already achieved, or are moving toward long-term environmental sustainability in all of its aspects) from cities that continue to pursue environmentally unsustainable development trajectories. We distinguish between these two types of cities by evaluating their actions and, in particular, how the actions they undertake either achieve or fail to achieve improvements in the living environment of their residents or to address environmental challenges. Furthermore, for a city to be considered “green” by our definition, these measures must be undertaken in a comprehensive, planned manner that not only positively impacts the city in question but also contributes to environmental sustainability at the global level. Which actions a city collectively undertakes, the manner in which it undertakes these actions, and the outcome of those actions thus form the criteria for determining how “green” a particular city is.

The structure of this book reflects the criteria for identifying green cities as outlined. As a result, the chapters that follow identify investments that might be undertaken to make a particular city more “green.” Such investments include initiatives for improving planning, transport, energy efficiency, industrial metabolism, and water supply and sanitation facilities. Because financing is necessary for implementing these investments, the book then discusses vehicles for financing environmental infrastructure initiatives. The concluding chapter then outlines governance and awareness-raising actions that may be used to mobilize the political and social resolve necessary for undertaking particular investments. A set of tools for monitoring progress in achieving environmental sustainability is then presented.

Which investments are required?

The ultimate test of the long-term feasibility of any urban development model is its sustainability, since a primary purpose of an urban area is to provide a venue for economic activity undertaken by its inhabitants. Thus, environmental sustainability holds the key to long-term survival of urban environments, as well as sustained economic advance. Six types of investments are required for achieving green cities, and thus ensuring the long-term survival of the urban environment: (i) low-carbon transport systems; (ii) a green industrial sector; (iii) energy-efficient buildings; (iv) greening of the city itself; (v) green, resilient infrastructure; and (vi) intelligent systems (Figure 2). Asia’s urban policy makers are increasingly aware of the importance of pursuing these six types of investments. This awareness is reflected in the fact that Asian cities are increasingly embracing urban development models that reduce the rate at which energy is consumed by buildings, industries, and transport systems.

Figure 2 Investments Required for Achieving Green Cities



Source: Asian Development Bank.

Low-Carbon Transport

A powerful but underused tool for creating sustainable cities is influencing the scale, location, and type of land development, and, in particular, the manner in which the city's transport infrastructure is integrated into these land-use parameters. Since resources necessary for economic activity are often channeled into locales in which ease of physical access is greatest, the planning and design of transportation networks greatly impacts the spatial dispersion of urban development. This is similarly true of water and sanitation facilities, infrastructure in general, and housing.

Unfortunately, policy makers at the urban level rarely make use of this powerful growth management tool. Using it to its full potential requires four steps, the first of which is to link planning and implementation. This is most effectively accomplished by including representatives from all segments of society, such as national and city governments, public works departments, private sector developers, and civil society in general, in the planning process. Second, the focus of both arterial and secondary road network development should be those areas in which development is desired. Third, design and construction guidelines that are consistent with the needs and means of future occupants, including low-income groups, should be formulated. Fourth, public transport infrastructure that is both efficient and environmentally sound should be provided at the onset of the physical development process, rather than in response to later congestion. Use of zero-emission vehicles and bicycles should be encouraged and private cars excluded from the urban core from the outset.



Source: ADB. 2011. Green Cities Brochure.

Green Industry

While it is true that cities with efficient recycling systems can reuse up to 75% of household waste, manufacturing and construction generate four times as much waste as do households (Girardet 1996). One way to overcome the problems associated with industrial waste generation is to turn the by-products of one industry into the inputs of another. This approach is used by “circle economy” (CE) cities in the PRC, and by Japan’s “eco-towns.”

Successful implementation of the CE approach to waste reduction requires both government involvement and well-planned institutional arrangements. While some additional costs are associated with adopting the CE approach to waste management, many CE solutions are economically advantageous in the long run, particularly when the environmental damage costs thus avoided are taken into account. CE pilot programs already in operation have confirmed the waste reduction potential of the CE approach, given that CE projects focus on

- improving the effectiveness and efficiency of CE policies;
- actively involving producers, local governments, community groups, industrial associations, professional networks, and nongovernment organizations in the formulation and establishment of CE initiatives;
- building CE implementation capacity, and monitoring the progress achieved by such programs;
- providing appropriate training programs and disseminating the results of local and international CE initiatives; and
- strengthening governance by establishing high-level leadership, coordinating implementation of CE initiatives across sectors and ministries, and promoting private sector participation in CE initiatives rather than relying on public sector agencies to directly implement such initiatives (World Bank 2007).

Japan’s Kitakyushu Eco-Town has implemented the CE approach to waste management on a large scale by creating an extensive range of recycling and environmental industries that process and produce plastic, paper, metal, office equipment, and vehicles, as well as industries that process construction waste including solvents.

Energy-Efficient Buildings

Due to the falling cost of solar energy panels, buildings can be made largely energy self-sufficient. This is particularly true when their use is coupled with the use of eco-friendly devices and practices that can cut electricity consumption by 60% or more. Incentives for constructing energy-efficient buildings and adopting energy conservation behaviors are most effective when put into place at both the national and local levels.

In addition to the transport and land-use energy conservation initiatives referred to earlier, cities can reduce energy consumption at the household and even individual level by planning appropriately, encouraging use of wind-driven and solar electricity generation, supporting development and use of efficient transport technologies, and encouraging use of energy-efficient construction materials. Many of the incentives for encouraging such beneficial changes can be put into place by appropriately modifying building regulations, utility pricing tariffs, and property taxes.

Building codes can be used to maintain densities at levels consistent with environmental sustainability, as well as to encourage use of natural light, harvesting of rainwater, and alternative energy sources. They can likewise be used to address wastewater problems in advance of their occurrence. In many Asian jurisdictions, building codes are based on those in force in countries with climates and physical and social environments vastly different from those prevalent in Asia. Adopting building codes that are appropriate



Photo: AFP.

Source: ADB. 2011. Green Cities Brochure.

to Asia's rapidly growing, population-dense cities—many of which are located in tropical or subtropical climates—provides policy makers with an opportunity to both review the building codes currently in force and revise them in a way that is consistent with long-term environmental sustainability.

An example of a vehicle for encouraging environment-friendly building construction is the US Green Building Council's Leadership in Energy and Environmental Design Green Building Rating System. This is a voluntary, consensus-based rating system that encourages builders in the United States to adopt industry-wide benchmarks for designing, constructing, and operating buildings in a manner consistent with long-term environmental sustainability. The operating costs of buildings thus constructed and operated are lower than those of conventional buildings, since they consume less water and energy, generate less waste, and, as a result, release lesser GHGs. Also, their asset values are generally higher than those of conventional buildings.

A similar approach could be adopted in Asia, though this would require national, provincial, and local governments to develop construction guidelines and rating systems attuned to long-term environmental sustainability. Such a program would achieve the greatest success if appropriate incentives were provided for encouraging private sector developers to adopt the rating system prior to both undertaking new construction, as well as upgrading the existing stock of conventional buildings. Formulation of incentives for upgrading the existing building stock should be promulgated following an evaluation of the existing building stock by local government bodies.

City Greening

Because wind speed impacts temperature, rates of evaporative cooling, and plant transpiration, it is an important factor in formulating passive cooling strategies for urban environments. A well-ventilated built environment encourages airflow, which in turn reduces ambient temperatures, and thus energy loads and air pollution resulting from energy consumption. Incorporating parks, green roofs, and bodies of water into the design of the urban environment magnifies the cooling effect of wind and leads to even lower levels of energy consumption and consequently air pollution.

This strategy of making full use of natural air circulation, fresh air distribution, and microclimate protection has been successfully incorporated into Abu Dhabi's Masdar development, as well as into the planned redevelopment of Thanh Hoa, Viet Nam (Raven 2010). Parks and open plazas are vital components of such designs, since trees absorb carbon and sulfur emissions, filter dust, cool the urban environment, produce oxygen, and help lower carbon monoxide and carbon dioxide levels.

Rapid population growth at the global level has vastly increased the amount of land used for food production. In fact, nearly 30% of the earth's total land surface is now used for agricultural purposes. This has radically altered the natural landscape and functioning of ecosystems. However, alternative approaches to food production that can prevent further encroachment on ecosystems while also increasing urban resilience are available. The experience of Shanghai, which is nearly self-sufficient in the production of vegetables and grain, demonstrates that significant amounts of food can be grown on empty urban lots. Similarly, rooftop gardens in Berlin and New York are often used for urban farming, the scale of which can range from simple balcony boxes to "vertical farms" that grow food inside environment-controlled, multistory buildings that recycle organic, human, and animal waste and wastewater (Figure 3). Such initiatives provide an alternative to trucking or flying produce in from distant locales where land-intensive methods of food production are used.

Figure 3 A Vertical Farm



CO_2 = carbon dioxide.

Source: Despommier, Dickson. *The Vertical Farm: Reducing the Impact of Agriculture on Ecosystem Functions and Services*. Columbia University, New York. Available: www.verticalfarm.com

Green, Resilient Infrastructure

The substantial amount of energy that cities consume provides a significant opportunity for energy savings, which can be achieved through technical innovations such as energy-saving lightbulbs, automatic switching for street lighting, and improvements in management and operation of commercial buildings. Optimizing the pumping operations of water supply and sewerage systems can also result in significant power savings. Smart grids, distributed power, and efficient district heating and cooling all provide examples of opportunities for reducing energy consumption by urban infrastructure facilities.

Intelligent Systems

While private citizens and commercial enterprises have traditionally interacted with government officials in public offices, personal computers can allow travel-free, 24-hour access to government services. For example, Tirunelveli, a city in Tamil Nadu, India, has undertaken a number of e-governance programs that track the condition of streetlights and status of garbage collection, monitor legal cases, allow access to land records, disseminate information regarding town planning initiatives, address complaints, and collect taxes and fees. Geographically dispersed government-agency kiosks provide both an alternative to computer-based systems, and an intermediate means of improving access to government agencies that require little or no vehicular travel in jurisdictions in which use of personal computers is not yet widespread. Use of such technologies can improve information and service delivery, encourage community participation in governance, and make government more transparent and accountable.

Financing Sustainable Cities

A city can finance initiatives that move it toward long-term environmental sustainability by maximizing the amount of revenue derived from existing sources, identifying new sources of revenue, leveraging additional resources from the private sector, and accessing international and local funding that supports green investments.



Photo: Original artwork, MAC.

Source: ADB. 2008. *Managing Asian Cities*.

Maximizing Revenue from Conventional Sources

Aside from collecting all mandated taxes, a city may expand its revenue stream by introducing the following:

- User service charges set at levels that allow recovery of the full cost of service delivery. For example, full-cost recovery in the context of user service charges for water and electric power include the full cost of supply, any damages or depreciation caused by usage, as well as the opportunity cost of denying other potential users use of the resource in question. Because “other users” includes the ecosystem itself, the full cost of long-term environmental damage incurred in service delivery should also be capitalized into the price paid by consumers of water and electricity.
- Emission or effluent charges based on both the quantity of waste generated and the degree of environmental damage caused. Such charges should be applicable to wastewater in addition to all other pollutants.
- Product charges levied on products, the consumption of which pollutes the ecosystem. For example, if consumption of the product concerned pollutes surface water or groundwater either during or after consumption,

the product charge levied on the good in question should equal the actual value of the damage caused.

- Tradable rights granting permission to use a specified quantity of a resource (e.g., water). Note that the introduction of tradable rights likewise requires establishment of a market in which such rights can be traded.
- Marketable permits that entitle the bearer to generate and release a specified quantity of pollutants. Establishing a market for such permits likewise allows the polluter in question to treat the waste he or she generates in a manner that reduces the environmental damage caused to zero, and then to sell the permit applicable to that quantity of pollution at the prevailing market price. Alternatively, the polluter in question may choose to *not* treat the waste he or she generates, and to compensate for the environmental damage caused by purchasing additional permits.
- Universal employer taxes levied on all employers except those below a specified scale (e.g., making establishments that employ fewer than a specified number of employees exempt from such taxes).
- Establishing public–private partnerships for financing green development initiatives.
- Tax-increment financing, under which a portion of tax revenues generated from improvements of a specific type are earmarked for repayment of the cost of those improvements.
- Refund systems for goods packaged in returnable containers that encourage their delivery to recycling or appropriate disposal centers.

Leveraging Private Sector Financing

Private sector participation in the delivery of basic services such as water and electricity is often forthcoming when certainty regarding the fundamental parameters that affect private sector profitability is provided. For example, such certainty is provided when the maximum price a private sector contractor may charge per unit of service delivered is transparently stated, and the time horizon over which private sector investment may be recouped is specified in long-term contracts or through a transparent regulatory system. Specification of maximum price may include such nuances as sliding scales that extend concessional pricing to low-income households. If the government itself is to subsidize such concessional pricing, provision of subsidized amounts must be guaranteed through appropriate clauses in the contract concerned.

Further private sector participation in the provision of basic services, such as water and electricity, may be forthcoming, if the components of provision of such goods to be financed by the private sector are unbundled from the components to be financed by the government. For example, investments in the establishment or upgrading of a water treatment plant can be separated from both the piped water delivery network and the infrastructure that provides the water at the point of source or collection, such as a reservoir or well. This allows private sector transactors to calculate rates of return on each component individually, and thus to invest in individual components to their liking, and to avoid investment in components that are appropriate to government provision.

Funding Green Investments

While supplemental financing for environment-friendly projects that complements conventional financing rarely covers the full investment cost of a project, such supplemental financing often allows otherwise nonviable projects to become financially viable. The following are examples of such supplemental financing:

- The Clean Development Mechanism (defined in the Kyoto Protocol), which funds projects that reduce GHG emissions through energy efficiency or through bilateral cap-and-trade systems, such as Japan's New Domestic Clean Development Mechanism or the Republic of Korea's Emission Reduction Scheme.
- Climate Investment Funds that finance improvement in fuel economy standards, acceleration of fuel-switching initiatives, and shifts toward environment-friendly operations in public transport systems in metropolitan areas.
- The Global Environment Facility, a partnership of 182 countries and international institutions, nongovernment organizations, and private sector entities, that addresses global environmental issues. Since 1991, this facility has allocated \$9.2 billion to such investments, this amount being supplemented by more than \$40 billion in cofinancing.
- The Clean Energy Financing Partnership Facility, which helps developing countries achieve significant, measurable changes in energy consumption as a means of securing a low-carbon future for the earth as a whole. This facility finances investments in energy efficiency, funds some technology transfer costs, and provides grant assistance for environment-friendly activities such as development of green technologies.
- Ethical funds, which pool the money of hundreds of investors into a single fund that makes stock market investments, the resulting overall portfolio being influenced by social, environmental, and other ethical

considerations. Specific objective criteria are used in deciding whether to include a particular company in the investment portfolio concerned.

- Export credit agencies, which are government agencies that promote exports from the home country by financing transactions for which the private sector has no taste due to the degree of risk involved, such as investments in innovative but yet unproven clean technologies. Export credit agencies collectively provide financing of \$50 billion–\$70 billion annually, and often support large-scale industrial and infrastructure projects in developing countries (Norlen et al. 2002).
- The Urban Financing Partnership Facility, which was established by the Asian Development Bank (ADB) for the purpose of raising and using development partner funds to cofinance urban environmental infrastructure projects, as well as a broad range of technical assistance that supports preparation and formulation of such projects. This facility likewise supports investment in climate change mitigation and local urban infrastructure projects that benefit the poor.

All of these financing vehicles can be used as supplemental sources of financing for environment-friendly projects. This is likewise true of the Cities Development Initiative for Asia, which is an ADB-sponsored partnership of development agencies that focuses specifically on environment-friendly investments in Asian cities.

Transforming Cities into Livable Urban Environments

Asian countries share a vision of one day making all of the region's cities livable. The knowledge and financial resources required for realizing that vision already exist. However, climate change remains a growing threat to that vision's realization, while at the same time being primarily the product of the very cities whose future it endangers. It is therefore essential that urban energy demand be reduced and the undesirable environmental impacts associated with energy production be mitigated, if long-term environmental sustainability of the region's urban environments is to be achieved. Ultimately, reducing energy demand requires more efficiently managing the urban design process overall, as well as urban logistics systems.

Rapidly growing Asian cities will contribute more than half the global increase in GHG emissions over the coming 20 years. The scale of such emissions is so great that technological innovation alone cannot be relied upon to reduce the level of such emissions by any appreciable amount. Thus, well-resourced urban institutions will, in all likelihood, be necessary for ensuring



Photo: F. Steinberg.

Source: ADB. 2011. Green Cities Brochure.

that pollution-reducing technological innovations are adopted with sufficient speed to allow long-term environmental sustainability to be achieved.

To encourage sustainable development of Asian cities, the Asian Cities agenda must ensure that the following measures are promoted appropriately:

- **Local land use and transportation patterns.** Municipal land use, population density, and transportation planning decisions directly influence whether people and businesses have transport choices that allow them to save energy and money. If long-term environmental sustainability is to be achieved by Asian cities, the goals of the urban transport planning process must include construction of low-carbon public transport infrastructure, incentives for use of nonmotorized transport, and disincentives for using automobiles for daily commutes.
- **Building construction and resilient, energy-efficient infrastructure.** Through zoning codes, building codes, and permitting processes, municipalities can encourage construction processes, neighborhood designs, and urban infrastructure that reduce energy consumption and thus financial outlays. In short, achieving environmental sustainability requires that planning for climate resilience become an integral part of infrastructure planning.

- **Local economic activity.** Municipal economic development initiatives are opportunities for encouraging low-energy, zero-carbon development, and for putting into place environment-friendly initiatives such as reduce–reuse–recycle plans. Initiatives that reduce energy consumption not only promote long-term environmental sustainability but likewise reduce financial outlays for energy over the long term.

ADB helps national and city governments to

- better target investments in capacity development that support Green City investments as mentioned earlier;
- work collaboratively in identifying infrastructure projects that improve the long-term environmental sustainability of Asian cities;
- build partnerships that include development agencies, the private sector, and governments that can be used to provide incentives for improved environmental performance; and
- develop networks that strengthen collaboration between the private sector and the governments concerned.

ADB's recent flagship publication, *Key Indicators for Asia and the Pacific 2012*, featured a special chapter on green urbanization in Asia. The interesting conclusion was that Asia's booming cities must go green or risk disaster, and particularly "megacities have no other way to go but green" as echoed in the press (*The Philippine Inquirer*, Manila, 18 August 2012). This is about these choices of Asian cities going green. Asia must act now to pave the way for green, resource-friendly cities, or face a bleak and environmentally degraded future.

CHAPTER 1

Spatial Development and Technologies for Green Cities

By Florian Steinberg and Michael Lindfield

Visions of the City of the Future

About 2 to 3 decades ago, the topic of building the future city was largely conceived as an agenda of inclusiveness and equity to help the urban poor and the marginalized become part of mainstream urban life (Satterthwaite and Hardoy 1997, Satterthwaite 1999). Today, as cities prepare to design their futures, urban complexities have grown, challenging cities to achieve not only inclusiveness but also resilience to climate change. Cities need to transform themselves for a greener future, consuming less carbon and reducing their ecological footprints on surrounding hinterlands. There is thus now a demand for low- or zero-carbon cities. Glimpses of that vision emerged in 1992 at the Rio Earth Summit as Local Agenda 21, which cited the need to develop local agendas for sustainable living in the 21st century, alongside commitments to achieving the Millennium Development Goals (MDGs). This vision was renewed during the Rio+20 United Nations Conference on Sustainable Development in June 2012 (UN 2012).

Urbanization is now recognized as a defining feature of the 21st century, thus turning attention toward the quality and nature of new cities and communities around the world. According to World Bank (2009a) estimates, the number of urban areas in developing countries will triple between 2011 and 2030 (UN-HABITAT 2010, Angel 2011, McKinsey Global Institute 2011). By 2025, 16 of the world's 27 megacities (cities with more than 10 million inhabitants) will be in Asia (ADB 2011). With the urban population expected to grow from 3 billion to 4 billion over the next 15–20 years, cities are faced with the unprecedented challenge and opportunity of planning, developing,

and managing an ecological, economically sustainable, and inclusive future (ADB 2008, Steinberg and Lindfield 2011). Urban growth projections imply that cities will need to increase densities and grow at their periphery. However, countries such as the People's Republic of China (PRC) and India will have to build hundreds of new cities to accommodate the bulk of their new growth (McKinsey Global Institute 2009, 2010). By 2030, it is predicted that the PRC will have an urban population of 1 billion people and 221 cities of more than 1 million inhabitants. The way these cities are managed will affect efforts toward climate change mitigation and adaptation.

The development of comprehensive and sustainable green city models, or eco-cities, will be vital for the urban future of Asia and the Pacific, which has the fastest-growing regional economy, and hence the fastest-growing energy and carbon consumption, and greenhouse gas (GHG) emissions. Though some see cities as a major problem of humankind, others consider them the best cure for our planet's growing pains (Kunzig 2011). The sustainability of their futures will depend on their urbanization patterns, spatial structures, transportation patterns, management of resources consumed, and waste generated.

The United Nations Framework Convention on Climate Change recognized that GHG emissions have grown by 70% since preindustrial times (IPCC 2007). By 2015, carbon dioxide (CO₂) emissions would have to be stabilized if global temperature increases were to be contained within a range of 2–4°C. Climate change impacts and their mitigation, therefore, represent a massive challenge for the urban future of the fast-growing Asia and the Pacific. Since cities are today becoming home to about half the population of Asia and the Pacific taken together, their land-use patterns are subject to tremendous change (International Bank for Reconstruction and Development/The World Bank 2010a, 2010b; JICA 2011; UN-HABITAT 2011; UGEC Viewpoint 2010). Climate change is adding another layer of challenges, with coastal cities becoming particularly vulnerable to the impacts of sea-level rise. However, in addition to the latter, it is equally changes in weather patterns that have brought drought and desertification to some higher continental locations that have presented unprecedented challenges. Sustainable development of cities will require a balancing act in supplying food and water, and managing wastes, air pollution, and environmental health. Cities are the first to react to any policy measure and are thus prime candidates for piloting projects.

The greening of cities will require some, or preferably all, of the following: (i) reduction of chemical and physical hazards, (ii) control over environmental impacts on health, (iii) creation of quality environments for all, (iv) minimized ecological footprints outside the urban area, (v) ensured

sustainable consumption, and (vi) adaptation to climate change impacts (Satterthwaite 1997).

Sustainable urban lifestyles can be created through effective urban planning and management (Girardet 1992). There exist options for an urban future that supports green city development that leads to health gains, in addition to high levels of productivity and competitiveness. In this context, it is evident that traditional political and spatial boundaries, as well as traditional planning and development paradigms, will become obsolete. Classical parameters of urban design and developmental control are irrelevant, and will undergo a drastic evolution as the green city concept takes root.

Cities and the Green Economy

The United Nations Environment Programme (UNEP 2010) defined the “green economy” as one that results in “improved human well-being and social equity, while significantly reducing environmental risks and ecological scarcities.” This stands for a low-carbon, resource-efficient, and socially inclusive economy, wherein growth in income and employment is driven by public and private investment aimed at reducing carbon emissions and pollution, enhancing energy and resource efficiency, and preventing the loss of biodiversity and ecosystem services” (UNEP 2011b, 16).

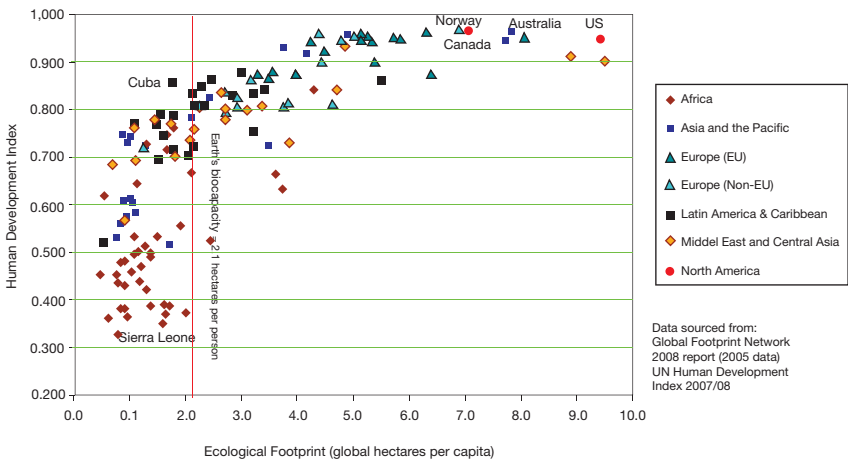
The green economy, which has entered policy discourse in recent years, is expected to provide a more constructive pathway for the future, replacing existing economic practices that have led to growing environmental risks, ecological scarcities, and social disparities. For example, cleaner and more efficient transport can improve access to services and other amenities, and can help reduce local pollution levels and health inequalities. Residents and their children who live in the vicinity of greener urban areas can become more resistant to stress, and have higher measures of self-worth and social cohesion. These impacts of greener cities and improved environments can increase social equity and the quality of life. Transitioning to a green economy has sound economic and social justifications. However, there is currently no consensus on how crises, such as the global food security crisis, scarcity of fresh water and a renewable supply of clean water, and the need for improved sanitation and renewable energy, can be brought into the mainstream discourse of societies and cities. These crises are severely impacting the possibility of sustaining prosperity and achieving the MDGs.

While the global population increased from 29% to 49% between 1950 and 2005 (United Nations Population Division 2010), global carbon emissions from the burning of fossil fuels increased by almost 500% (Boden, Marland,

and Andres 2010). Furthermore, rapid urbanization is creating pressure on the supply of fresh water, sewage treatment infrastructure, the overall residential environment, and public health—all of which affect the urban poor the most. Urban sprawl and unplanned urban expansion increase energy demand and carbon emissions, thereby distorting the ecosystems of which they are part and making cities socially divisive places in which to live. This process has been called the “negative ecological footprint” (Figure 1.1, Rees 1992, Rees and Wackernagel 1994, Wackernagel 1994, Wackernagel and Rees 1996, Wackernagel et al. 2002).

Cities are undoubtedly among the various pathways to a green economy. For the first time in human history, more than half the human population lives in urban areas. As a result, cities account for 75% of energy consumption (UN-HABITAT 2009) and 75% of carbon emissions (Clinton Foundation 2010). The implication of this is that the evolution of the green economy depends on cities acting as incubators for innovation (Kamal-Chaoui and Robert 2009). The innovativeness of cities promises unique opportunities for them to take a lead role in the greening of economies. The Organisation for Economic Co-operation and Development estimates that there are 10 times more renewable energy patents in urban as opposed to rural areas (IPCC 2007). Fast-growing clean technology initiatives in economic clusters and city regions of innovation are a clear indicator that cities foster innovative

Figure 1.1 The Ecological Footprint of Cities



EU = European Union, US = United States.

Source: United Nations Development Programme. 2010.

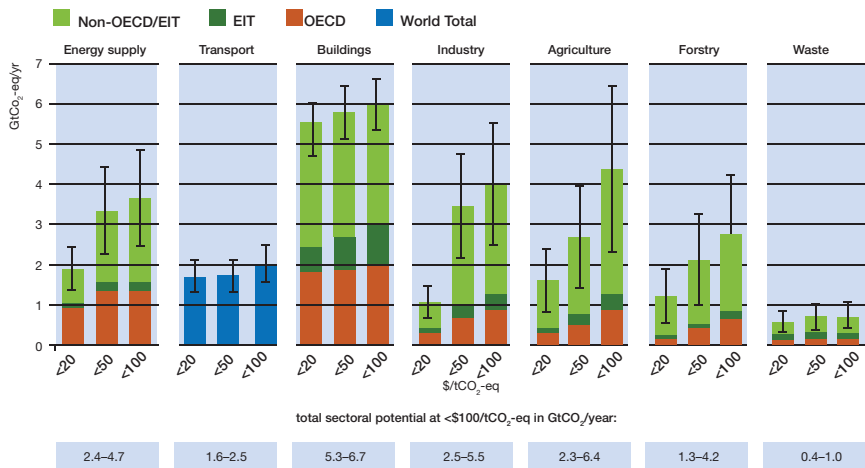
activities (UNEP 2011). Thus, in most countries, cities will be important locations of the emerging green economy for several reasons. First, cities are the home of innovators. Second, cities have the advantage of scale economies in sectors, such as public transport, energy provision, and retail consumer markets. Third, urban clusters draw in knowledge from universities and research laboratories (Seto and Satterthwaite 2010).

The environmental performance of cities can be influenced by a combination of physical structure and green economy strategies. Compact and densely populated cities with mixed land use will be the basis for a more resource-efficient settlement pattern with high levels of economic output. Urban form, size, density, and configuration can be planned and managed to limit resource consumption and hence carbon emissions. Existing design strategies and technologies can improve the efficiency of building construction, urban transport, energy generation, water supply, and waste management systems so that they use less energy and natural resources. Relatively higher population densities are a central feature of green cities. This implies gains in energy efficiency, as well as innovation through the proximity of activities. Similarly, per-household infrastructure costs can be lowered substantially as population densities rise. More compact cities can reduce travel distances, and heating and cooling requirements, while application of green transport modalities can reduce energy consumption. More efficient use of energy leads to lower levels of energy demand and hence carbon emissions. The spatial structure of cities can facilitate the use of green grid-based energy systems, such as combined heat and power generation, micro-generation of electricity through solar or wind generation technologies, as well as rainwater harvesting and efficient waste management. Thus, higher-density cities combine the benefits of increased productivity, innovation at lower costs, and reduced environmental impacts. The conclusion of the Intergovernmental Panel on Climate Change (IPCC 2007) is clear: buildings, energy, and transport are the largest CO₂ emitters. However, this means that these three sources hold the greatest potential for mitigating CO₂ emissions, provided that green city principles are adopted (Figure 1.2).

Sustainable urban lifestyles can thus be created through effective urban planning and management, and lifestyle changes based on more efficient individual consumption patterns.

As referred to briefly, the inherent innovativeness of cities facilitates their taking a lead role in the transition to a green economy. Compact and densely populated cities based on mixed land-use patterns allow for a more resource-efficient settlement pattern with higher levels of economic output.

Figure 1.2 Buildings, Energy, and Transport with Highest CO₂ Mitigation Potential in 2030



EIT = economies in transition, OECD = Organisation of Economic Co-operation and Development.
Source: IPCC 2007.

Design strategies and technologies exist to improve the construction of buildings, the efficiency of urban transport, as well as the manner in which energy is generated, water and other services are supplied, and waste is managed. Such changes would reduce the rate at which energy and natural resources are consumed. Because of the higher population densities of green cities, energy-efficiency gains are possible from the proximity of activities. Infrastructure costs can likewise be lowered substantially as densities rise. Thus, higher-density cities allow increased productivity and innovation at lower costs and reduced environmental impact.

Increasing economic density, one of the features of a green city, has been described by the World Development Report of 2009 as a “pathway out of poverty” (World Bank 2009b). Greening cities can create jobs in various sectors, including urban and peri-urban agriculture, public transport, renewable energy, waste management and recycling, and green construction. Empirical evidence suggests that economic clusters, or agglomeration effects, are labor-intensive and offer many employment opportunities. Green urban agriculture may involve the reuse of wastewater and composted solid waste, the preservation of biodiversity and wetlands, and the productive use of green areas and belts. Transport-related employment, typically in decentralized small-scale systems, could provide many employment opportunities. A shift from conventional to renewable energy sources may

result in new forms of employment in decentralized power generation, such as installation and servicing of facilities. New waste management practices of recycling and reuse have massive employment potential, as has been well demonstrated. Lastly, many countries that have started to apply green construction principles through retrofitting of the existing building stock—such as Germany, the United Kingdom, and the United States—have experienced a substantial increase in employment. New standards, such as those for air conditioning, building insulation, water heating, and fluorescent lighting likewise generate employment on a large scale (section on green construction).

Application of green economy approaches should be tailored to the local context for it to be successful. It is important to note that while the role of cities as powerhouses of the world economy, even within developing economies, is undisputed (World Bank 2009b), so is their role in the greening

Box 1.1 Climate Change: Cities Are the Answer

“Many of the world’s most difficult environmental challenges can be addressed and solved by cities. This may come as a surprise to those who think of environmental issues largely in the context of wild places and open spaces. Cities, often congested, dense, and enormous consumers of resources, would not be the place one might first turn for environmental solutions. In fact, cities are inherently the ‘greenest’ of all places. They are more efficient in their use of energy, water, and land than suburbs. They provide transportation services in a remarkable equitable and democratic fashion. Cities can help save natural areas and open space by relieving growth pressures on the countryside. And cities will be pivotal in fashioning solutions to the growing problem of climate change...Carbon dioxide, the dominant greenhouse gas and the primary cause of global climate change, comes largely from the combustion of fossil fuels such as coal, oil, gasoline, and natural gas. Nearly half of all the energy those fuels produce is used in buildings—heating, cooling, and lighting our homes, factories, and offices. Another third of all the energy consumed is used for transportation, primarily fueling automobiles, trucks, and transit fleets.

In order to address the challenge of climate change, it is imperative that we make both buildings and transportation vastly more energy efficient. And cities are the place to start. In a way, cities are the Saudi Arabia of energy efficiency—vast mines of potential energy savings that dwarf most of the supply options... The old paradigm of the pollution-filled city as a blight on the landscape and the leafy green suburbs as the ideal is outdated and does not lead us to a future of energy independence, clean air, and a stable climate. Cities are the best hope to realize our need for a bright, sustainable, and promising future.”

Source: D. Foy and R. Healy. 2007. Cities are the answer. *International Herald Tribune*. 12 April.

of economies and the environment. However, as they have to confront a myriad of challenges, mostly because of rapid growth in population, income, and unplanned built-up areas, they need to find their own pathways to becoming green cities. Given the wide variation in the economy, culture, history, climate, and topography of cities, green city solutions need to be situation specific.

A number of generic issues need to be considered when developing green futures for Asian cities. These include each particular city's approach to spatial structure, transport, housing, urban services, and technological change. There thus cannot be a single model to follow. Instead, cities should be selective in applying any of these universally valid principles and approaches in shaping their own futures. Space and technologies will have an important role. Technologies will be dealt with inasmuch as they affect urban development and spatial planning.

The Spatial Structure of Cities

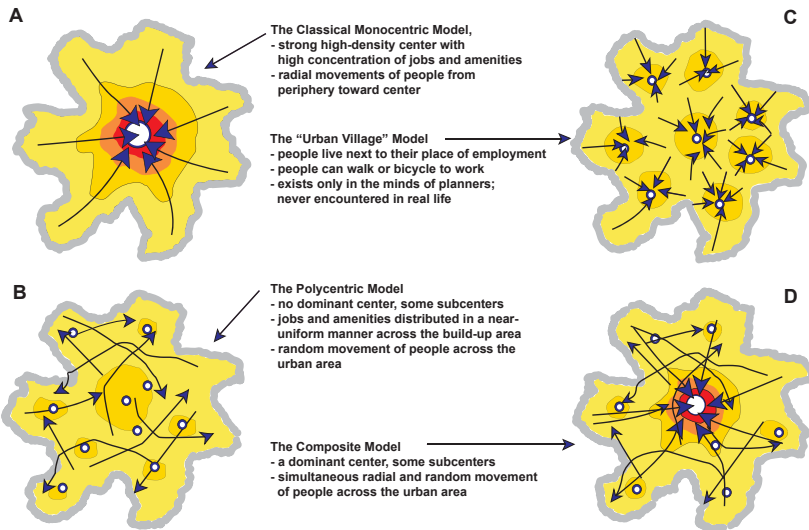
In generic terms, there exist only three principal city models: (i) the monocentric city, (ii) the polycentric city, and (iii) variations of the second model in the form of a conurbation of "urban villages". A fourth model, which is the composite model, is a combination of the three principal models (Figure 1.3).

The monocentric city model (model A) requires long-distance mass transit systems because jobs and services are concentrated in the city center. This creates high-level transport requirements, particularly since a large number of commuters come to the central business districts from distant suburban locations.

In the polycentric model (model B), mass transit is more difficult to rationalize because businesses and jobs are less concentrated in the city center, and travel and movements are more between or within subcenters. In this model, private or small-scale public transport may dominate (Suzuki et al. 2010).

The decentralized "urban village" model may lend itself to reduced travel. The decentralized spatial model, often favored in modern master planning, may contribute little to create harmonious space and transport relationships, because it does not automatically lead to self-contained communities with local residences and work places. However, in some cities, residents from the suburbs continue to commute to the city center while a select group may even travel in the reverse direction, from the center to the suburban regions in pursuit of daily work.

Figure 1.3 The Most Common Urban Spatial Structures



Source: H. Suzuki et al.

Altogether, the composite model, a combination of all the above, may appear to be the most common in many urban cultures and nations. As cities grow, particularly when not planned, the polymorphous city pattern may prevail in many urban contexts and may turn out to be the dominant model across those countries where planning is difficult. Decay of city centers and peripheral urban growth have contributed to a proliferation of the composite model in the real-world cities of the modern era.

This evolution of urban spatial structures in a rapidly urbanizing world demonstrates that urban structure matters a lot. The spatial model and existing densities generate traffic volumes and have a decisive impact on the performance of cities. Spatial form and transport make up a nexus, which, though well known, needs to be addressed as part of retrofitting of cities or in future planning (Kahn 2006).

In Australia, the size of houses and sprawl of suburbs have encroached on the green edge of urban centers and agricultural lands alike, destroying or degrading existing fauna and flora. The typically large houses have increased carbon emissions due to their size and higher cooling requirements, their embodied energy, and increased reliance on the motor car. These

developments raise questions about the environmental affordability of such settlement patterns and technologies (Fuller and de Jong 2011).

The opposite scenario exists in Singapore. Singapore has shown that dense cities can be green, and has achieved this by building upward, preserving land for greenery through compact high-density urbanization. The compact pattern is said to have advantages for the provision of services and in reducing pollution. "... [D]ense, compact, connected, and integrated cities are in fact the most sustainable and green way of life in the future" (Chan 2012).

Why Do Spatial Structures Matter?

If the creation of green cities is the overarching goal, then spatial planning and proactive application of transport models are required to achieve efficiency in the use of space and in the provision of transport services. This direct relationship between urban space and the evolution of urban services is highly relevant for the quality of future cities and how "green" these cities can become.

The location of activities for work, business, and residence is essentially determined by land-market forces and planning. Over centuries, planners have tried different zoning concepts, and social-minded planners have attempted to create proximity between housing and workplaces. Modernist urban planners of the 20th century, led by the International Congress of Modern Architecture, had a strong belief in the advantages of monofunctional sectors in urban plans, but reality proved their abstract ideas unrealistic in today's complex world.¹ In general, across many cultures, mixed land-use patterns appear to have been the most successful and are likely to prevail for centuries to come. However, as predicted by the modernists, the arrival of the automobile has changed the functioning of cities.

Separation of land uses in modern cities may only be required to separate environmental hazards from other land uses. If economic developments and external conditions change, industries, trade, and business zones transform more rapidly than residential areas. The modern age has brought mobility and the need to commute long distances between residential locations and

¹ The work of the International Congress of Modern Architecture has been closely associated with the modernist Swiss architect-urban planner Le Corbusier. Since his death, Le Corbusier's contribution has been hotly contested as the architecture values and accompanying aspects within modern architecture vary between different schools of thought and among practicing architects. At the level of building, his later works expressed a complex understanding of modernity's impact, yet his urban designs have drawn scorn from critics. One social commentator writes that "Le Corbusier was to architecture what Pol Pot was to social reform" (Dalrymple 2009).

work. Modern cities and modern transportation systems are expected to facilitate mobility. However, the concept of mobility varies across societies with regard to what is acceptable. Ideally, planners say, nobody should have to commute for more than 1 hour per trip, and any point within a metropolitan region should be accessible within such a margin.

Land development patterns and transport modes determine the functional performance of cities. The spatial efficiency of certain land development patterns is thus under scrutiny. Low-density urban development, practiced both in the United States and in some regions of Asia, may be attractive for those who can afford long and costly commutes. However, its efficiency is questionable. Beyond functional implications, the low-density development model lacks inclusivity and fails to cater to the poorer or middle-income groups. Low-density spatial development prevents easy access to job opportunities and is likely to generate monofunctional neighborhoods and townships. It is closely associated with privatized modes of transport and high-energy costs. The recent increases in energy prices worldwide have already raised concern about the low-density settlement pattern. The question currently being asked is whether further increases in the price of carbon-based fuel will drive residents away from sprawling suburbs. The trend seems to indicate that even middle-income residents are evaluating the performance of this spatial arrangement (Goodman 2008), leading many families in the United States and Asia to seek residential areas in more convenient areas. In 2012, United Nations Human Settlements Programme has also joined those who advocate densification and who have pronounced for years that world class cities will need good planning and that good planning will transform cities, introducing an education approach to city leaders. "The decisions on density, land-use and spatial patterns that local leaders take have a major impact on energy consumption, CO₂ production and cost of construction" (UN-HABITAT 2012).

It has been rightly observed that the spatial structure of cities represents a nexus of three fundamental factors: mobility, transportation-related energy efficiency, and affordability (Suzuki et al. 2010, 316). Existence of mass transit systems is a precondition for many urban forms, particularly for monocentric cities, which are now losing their dominance. As new town developments in the PRC illustrate, the polycentric model is the favored and more rational choice.

Monocentric cities such as Beijing (PRC) and Mumbai and New Delhi (India) are increasingly relying on mass transit systems. However, more dispersed cities like Bangkok (Thailand) or Kolkata (India) still struggle with efforts to build systems that bridge significant distances and inefficiencies. But even cases of some polycentric cities, such as Metro Manila (Philippines) and Jakarta (Indonesia), demonstrate higher degrees of inefficiency as road space is insufficient and long-distance mass transit systems need to be subsidized. Technological change has impacted many cities, such as Beijing

and Jakarta, where individualized car usage has become a dominant mode, and the traditional use of bicycles and nonmotorized transport was driven away. Cheaper cars, like the recently developed Nano, the low-cost car made in India, the low-cost electric car in the PRC, and electric motorbikes and bicycles, are likely to have massive impacts on cities. Their arrival may reverse some of the recent trends favoring mass transit systems and may lead to new waves of congestion through massive private car use.

Box 1.2 Density, Land Use, and Spatial Patterns Are the Most Important Elements

UN-HABITAT's *Urban Planning for City Leaders* (2012) has outlined the need to make informed decisions on the preferred spatial structure. This concerns (i) densification of existing built-up areas, (ii) extension of the city at the fringes of the built-up area, and (iii) creation of new development by building satellite towns.

Compact patterns are recommended because they can form a solid footprint with medium to high densities and mixed land use. Compact patterns are thought to improve accessibility, induce more cost-effective use of infrastructure and urban services, reduce erosion of natural resources, lower business costs, and improve social equality. Benefits of compact patterns include

- better accessibility,
- lower infrastructure costs and more efficient use of urban services,
- preservation of land resources,
- lower cost of economic transactions, and
- social integration.

It is recommended to define and enhance public space. This means to secure sufficient public space in advance and to plan a system of public spaces and well-designed streets. The provision of planned green spaces—9 square meters per capita as recommended by the World Health Organization and within a 15-minute walking distance—is seen as an essential ingredient to improved environmental conditions.

A compact pattern adjacent to a public transport node has many benefits, and a well-connected grid supports public transport and decreases congestion. Thus, spatial planning can reduce the need to travel.

Source: Adapted from UN-HABITAT. 2012. *Urban planning for city leaders*. Nairobi.

Regulating Spatial Development

Governments play an important role in regulating urban spatial development and land development patterns through infrastructure development, taxation, and land-use regulations. The government, however, is often not the dominant force; instead, the real estate market affects developments and sets trends. Despite this, the government can still either favor or discourage concentration or sprawl. These choices are supported through strategic decisions relating to transport systems or the development of ring roads. Ideally, these strategic decisions are supported by regulations that determine floor space indexes (FSI), or the density of built-up urban areas.

However, experience in India and other countries indicates that FSI regulations have been inefficient in guiding and directing growth and allocating land among alternative uses. Market forces, including factors such as vicinity and location advantage, prevailed more strongly than permits for higher land-use density. Yet, government investment in infrastructure still impacts urban spatial structure and the real estate market. Interventions that regulate FSI may be well intended as a contribution to urban design and zoning, but many of these interventions fail to achieve their desired impacts. In general, there are four types of land-use regulations: (i) regulations that establish minimum plot or apartment size, (ii) regulations that limit FSI, (iii) zoning plans that limit the type and density of land use, and (iv) land subdivision regulations that regulate percentages of sellable land in new “greenfield” developments (Suzuki et al 2010, 322).

Over recent decades, many cities in Asia have demonstrated that residential densities have declined as incomes have risen, and that traditional centers have lost importance as individual mobility has increased through car ownership or improved public transport systems. In the PRC, urban sprawl has become so accentuated that authorities have become alarmed about the increased costs of these developments. Recent measures to limit urban sprawl through development borders have not proven sufficient.

Few governments in Asia have achieved guidelines for optimal land use and densities, though the Government of India has tried to use floor area ratios (FARs) to regulate development. Over time, FARs have increased and financially optimum densities have been achieved when economic densities were maximized. As many monocentric cities have gradually become less dense and more polycentric, a significant amount of workplaces and services remain in the traditional centers, causing continued commuting and congestion as in the case of Shanghai and Singapore. The number of trips may still grow, even though governments seek ways to curb and reduce individual car use. Singapore is a leader in the application of a congestion pricing system for individual cars, which, like London, places a high price tag on travel to the

central business district. As cities keep growing, continued traffic congestion may drive more and more consumers and employees to subcenters.

Despite attempts to define optimum levels of FAR and FSI, there can be no optimum value that is universally valid for all cities, or for the whole of Asia. What has been observed over recent decades is that FAR and FSI levels in many cities, such as Metro Manila or Mumbai, have been far too low, leading to decay in the old city center, sprawl, and eventual nascence of new subcenters that replace the old centers (Ng 2010, Hasan et al. 2010).

In addition to density criteria (FSI or FAR), there exist zoning plans that regulate areas covered and can include regulations regarding plot coverage, maximum heights, setbacks, and FARs. For greenfields, or new development areas, zoning plans may be expressed in terms of land subdivision regulations. These regulate the percentage of sellable land (commercial and residential plots) as opposed to circulation space and open areas. The standards being applied determine the chances for “green” development. Only high densities in combination with the right means of green transport permit reductions in commuting and individual trips.

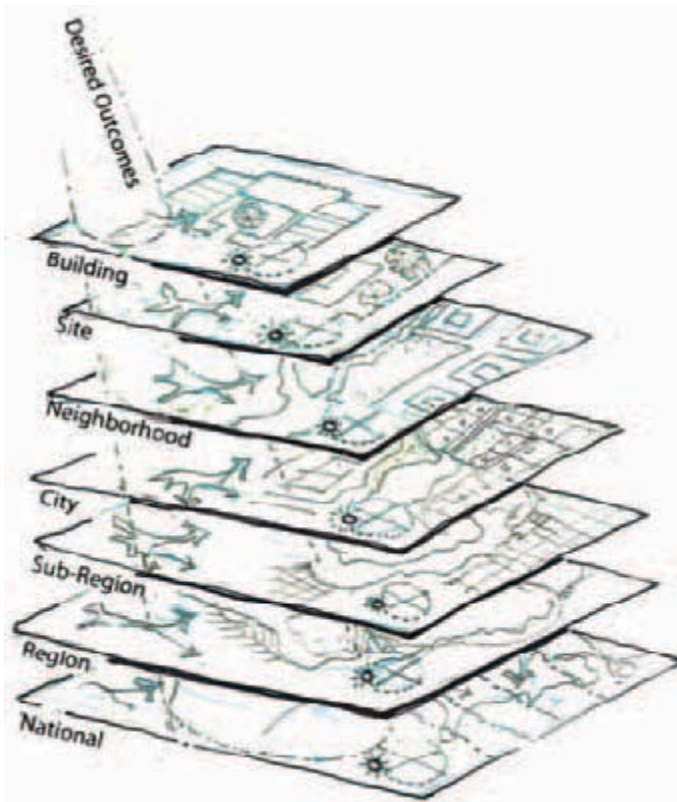
Countries, such as India where population densities in urban areas are relatively low, tend to generate more vehicular traffic and thence more transport-related pollution than do countries with higher urban population densities. To demonstrate this, ADB’s Green Urbanization Study (ADB 2012) compared the floor-to-area ratio of a number of Asian cities. The ratio is calculated as the amount of habitable space within a particular city’s geographic boundaries measured in square kilometers divided by the average distance that residents settle from the city center measured in kilometers, higher values for this ratio indicating greater urban population densities. While the floor-to-area ratio estimated under the study for Tokyo was 20 and that for Shanghai was 8, the building restrictions enforced in India caused the values for Chennai, Delhi, and Mumbai to be only 1. In fact, only 12% of Mumbai residents live within 10 kilometers of the city center, whereas 39%–64% of the residents of Bangkok, Jakarta, Seoul, and Shanghai do so. This illustrates the need for densification and higher space efficiency as a precondition for higher energy efficiency of cities.

Standards that are too high and unaffordable cannot be implemented and force people to seek solutions in the informal sector. For example, despite the legitimate goal of regulating density through plot size, many standards do not apply to poor households. As a trade-off, they may opt to escape standards that are too high for them by moving into informal settlements that are closer to job opportunities. Thus, instead of being a trade-off between density and distance, it becomes a trade-off between legality and illegality. It is therefore recommended that “regulations should be tested using land and infrastructure price models to establish the minimum household income

Resilient urban design can also be seen as an important passage toward better managing the microclimate of public urban spaces, thus reducing the need for managing microclimates through cooling or heating. “Despite its enormous potential for city adaptation to climate change, climate-resilient urban design has not yet emerged as a major consideration in standard urban design practice” (Raven 2011).

Climate-resilient urban designs need to cover energy, transportation, waste, water, green infrastructure, and natural resource systems, since these are all parts of a physical urban network (Figure 1.5, Raven 2011). These different scales are interrelated and equally relevant in achieving climate-resilient outcomes.

Figure 1.5 Various Spatial Scales Relevant to Climate-Resilient Designs



Source: J. Raven. 2011.

Building Competitive, Green, and Climate-Resilient Cities

Rapid urbanization is continuing in Asia and the Pacific, with the pace of urbanization expected to accelerate in the coming decades. New urban growth in the next few decades will primarily take place in small- and medium-scale cities and in peri-urban areas along existing and new growth corridors. As many countries are initiating a new development phase that takes development one step further toward a low-carbon economy, urban development will make a crucial contribution.

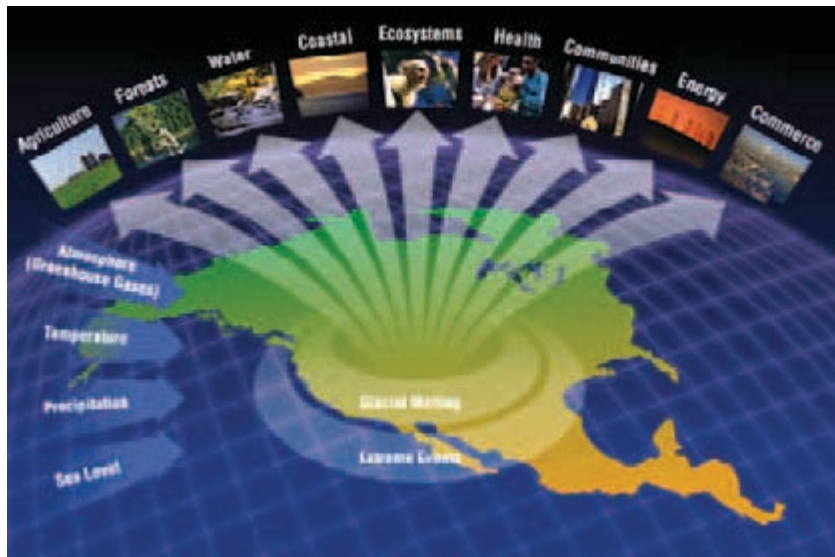
The competitiveness of urban areas will depend on their investment in urban environmental infrastructure, as well as improvements in their regulatory frameworks and human resources. As urban development evolves as a new approach to competitiveness, efforts will be directed toward harnessing the potential of value chain development, export-processing zones, and heritage promotion for tourism. As industrial development progresses, many Asian countries are hoping to embark on the path toward green and clean industrialization that can become one of the trademarks of Asia's "green economy".³ Clean technologies of eco-industrial development can lead the way in this effort to take full advantage of new technological initiatives (mobile communication networks, energy savings, fuel-efficient freight engines, low-carbon fuel supply chains, and flexible-fuel hybrid vehicles).

Climate change presents an added layer of complexity to the development process, which requires multiple adaptation and mitigation measures to cope with existing and future impacts (Figure 1.6). A green-growth strategy is expected to contribute to making urban areas along economic corridors competitive, green, and climate-resilient cities, distinguished by more efficient allocation of natural resources, innovative public-private partnerships or private sector participation, and creation of green jobs and appropriate skills.

The move to make existing cities more energy-efficient is presenting itself as a constant task of urban renewal and regeneration. Adaptive reuse and retrofitting, rather than demolition of existing structures and neighborhoods, is likely to be more energy-efficient. Reuse and adaptation will be the predominant approach to environmentally sustainable regeneration and will help maintain the identities of existing cities (Steinberg 2008).

³ The Republic of Korea is a good example of this strategy (R. S. Jones and B. Yoo 2010).

Figure 1.6 The Global Impacts of Climate Change



Source: J. Shah. 2011.

Advantages of Compact Neighborhoods and Mixed Land-Use Patterns

Compact cities with higher-density environments and efficient public transport systems and neighborhoods that are walkable or cyclable are more energy-efficient and reduce the energy footprint to a greater degree than do lower-density sprawling urban landscapes (Newman and Kenworthy 1989, Owens 1992, Burgess 2000, Bertaud 2004). Per-capita carbon emissions are lower as long as efficient and attractive public transport is provided. Highly concentrated urban areas produce transport efficiencies. Medium-sized cities tend to perform better than very large and very small cities when it comes to public transport-related energy efficiencies. Compact and mixed land-use neighborhoods also lead to mixed housing typologies and income groups, a social objective that facilitates more inclusive development.

However, as Hong Kong, Mumbai, Seoul, and Singapore have shown, densities cannot be increased indefinitely. Experiences of crowding in public housing complexes have shown that there can be negative behavioral impacts of crowding (Wong et al. 2009). In many low-income housing areas in Asia, densities have reached 3,000 persons per hectare (Ng 2010).

Some cities appear heading in the opposite direction with reduced urban densities such as Kuala Lumpur, which is slowly becoming Southeast Asia's Los Angeles. A recent report on Malaysia by the World Bank (2011a) stated that there is a need for Malaysia's cities to adopt more compact urban forms and to start investing in "smarter cities" to improve livability and attract talent. In their current form, each of Malaysia's cities looks less like a densely populated Asian city and more like a chaotic "mini-Los Angeles," with "significant urban sprawl" and declining population densities. The World Bank report cited the need for Malaysia to go green, thus following the drive across the globe to create more sustainable cities.

In contrast, various cities in Europe (Amsterdam, Copenhagen, Freiburg, Madrid, and Stockholm) and the United States (Portland), as well as in Latin America (Curitiba and Bogota) have set their course to become green cities and have prioritized compact development. The rich United Arab Emirates (Masdar) as well as the PRC, with its various eco-cities such as Tianjin; Dongtan, Shanghai; and Anting New Town-Jading District, Shanghai, are now following suit (Figure 1.7).⁴

Figure 1.7 High-Density New Towns in the People's Republic of China: Shizimen in Zhuhai—Economic Engine of the Pearl River



Photo: Atkins.

Source: Atkins. 2011.

⁴ Dongtan Eco-City near Shanghai, the largest of its kind, designed by Arup, the giant British engineering company, was shelved in 2008. However, this does not alleviate the country's need for sustainable cities to accommodate the influx of people to urban areas (Brenhouse 2010 and Brass 2007).

The Eco-City

The United Nations Development Programme (UNDP) and Renmin University (2010) define an eco-city as “a city that provides an acceptable standard of living for its human occupants without depleting the ecosystems and biochemical cycles on which it depends.” Another definition of the eco-city has identified it as “an ecologically healthy city. Such a city is the result of a healthy human ecological process leading to sustainable development within the carrying capacity of local ecosystems through changes in production modes, consumption behavior, and decision instruments that are based on ecological economics and systems engineering” (Wang and Ye 2004).

The development of eco-cities is tied to the three goals of *eco-industry* (industry metabolism, life-cycle production, resource conservation, and use of renewable energy), *eco-scape* (built environment, open spaces, connectors, and maximizing accessibility, while minimizing resource use and urban problems), and *eco-culture* (understanding of the balance between humans and nature, and understanding of environmental ethics in order to enhance people’s contribution to maintaining a high-quality urban ecosystem) (Shen and Song 2010).

Others categorize eco-cities as eco-managed (e.g., new city, livable city, healthy city), eco-built (e.g., landscape city, garden city, green city), and integrated development (e.g., sustainable city, environment-friendly city, eco-city).

Several requirements have been identified for low-carbon eco-city planning. These include green energy planning; green transport planning (modifying existing transport modes and introducing innovative green transport options); promotion of green buildings; making industries more environment-friendly; promotion of green consumerism through eco-friendly design and production, as well as consumption; water management and conservation through an efficient water resource strategy; and making public services and infrastructure more environment-friendly, especially with regard to waste management, management of air pollution, and wastewater management.

Masdar: A Prototype of One-Planet Living

When completed in 2015, Masdar will become the world’s first zero-carbon, zero-waste development city, while maintaining the highest quality of living. Its master plan claims to “meet and exceed” One-Planet

Living,⁵ a set of 10 guiding principles of sustainability, proposed in a joint initiative by the World Wide Fund for Nature and the global conservation organization Bioregional Development. Under these 10 guiding principles of sustainability, all live within their fair share of the earth's resources. These principles include zero carbon, zero waste, sustainable transport, sustainable materials, sustainable water, and sustainable culture and heritage.

As planned, Masdar City is expected to be home to 50,000 people and to attract an additional 60,000 daily rail commuters employed in its planned 1,500 businesses. The project, which occupies a site 6 square kilometers in area, is expected to cost \$22 billion, which will be financed by a mix of government and private investment funding. Masdar City's design is based on the fundamental principles of low-rise, high-density residences, sustainable transportation, controlled growth, and balancing of land for energy generation with development that is consistent with the principles of One-Planet Living.⁶ Its designers claim that their designs are rooted in the tradition of walled *Medinas* (historic, compact city centers). They thus have used passive design strategies inspired by traditional designs in the region.

The city's low-rise, high-density compact design will encourage energy efficiency and use of recycling systems. Its permeable north wall will let in cool northern breezes, and its narrow pathways will provide shade. Building materials with a high thermal mass will considerably reduce energy requirements, and its wind towers will be used for ventilation and cooling.

The city's design allows it to use a quarter of the energy required by conventional city designs to reduce waste to a quarter and water demand to a third of that of conventional cities. However, Masdar City's design is by no means limited to traditional strategies. In addition to its reduced energy requirements, its remaining requirements will be fulfilled by on-site generation. As part of Masdar's drive to develop new energy sources, the city's design will adopt a host of alternative and renewable energy sources. Masdar City's stone-and-mud walls will be covered in photovoltaic panels and its pathways draped with fabric that converts sunlight into electricity. The city's perimeter wall will form an intelligent outer shell, housing its energy, environmental, and recycling services.

Electricity will also be provided by a mix of alternative and renewable solar-power sources, such as the largest grid-connected photovoltaic plant

⁵ Principle number 1 refers to "Making buildings more energy efficient and delivering all energy with renewable technologies." <http://www.oneplanetliving.org/index.html>

⁶ Photo illustrations of the Masdar Headquarters are available at: http://smithgill.com/work/masdar_headquarters/ and <http://www.carboun.com/sustainable-design/masdar-headquarters-the-first-positive-energy-building-in-the-middle-east/>

in the Middle East, a giant solar thermal power plant, a large wind farm on the city's outskirts, and a waste-to-energy power plant. All of these facilities, as well as the solar-powered water desalinization plant, will occupy no more than 10% of the site's total area. The solar plant is already being manufactured and installed to ensure that the city's power requirements will be provided for during its construction phase. The city is also to have the world's first CO₂ capture-and-storage plant and the world's first hydrogen power plant.

In addition, the compact high-density city is planned to be completely free of cars. Cycling and walking will be the most common means of travel, and will be complemented by a personalized rapid transport system with a maximum walking distance of 200 meters to the nearest transport link. An underground light railway transport system will link Masdar to adjacent developments, the airport, and Abu Dhabi. The city designers have also planned mechanisms for addressing the highly saline ground water, and for capturing fog and humidity for use as drinking water. They are also looking at measures for reducing or offsetting the carbon footprint of transporting food to the city from outside.⁷ An illustration of these integrated technologies and features is shown in Figure 1.7.

The Eco-City Concept in the People's Republic of China⁸

The PRC alone houses more than 20% of the world's population and is urbanizing faster than any country in history. Its cities will require huge amounts of nonrenewable materials, resources, energy, and water, thus providing the rationale for green cities approach. In 2009, the PRC had 120 cities over 1 million population and 36 cities with over 2 million. By 2030, the PRC will have an estimated urban population of 1 billion, and 221 cities of more than 1 million (Lehmann 2009, 677).

Since its introduction at the 17th National Congress, the low-carbon eco-city model has been touted officially as the answer to the PRC's urban development, social, economic, and environmental problems. This position is reflected in a preliminary scan of PRC literature on eco-cities and sustainable urban development, where the model is frequently cited as the strategy for overcoming the PRC's myriad urbanization problems. Some are high-profile international ventures led by the central government, such as the Sino-Singapore Tianjin Eco-City (Boxes 1.3–1.5), Caofeidian Eco-City (Boxes 1.6–1.8), and Dongtan Eco-City (Box 1.9), while others are

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⁸ The following section is adapted from Chia (2010).

driven primarily by local authorities and local entrepreneurs. Although the idea of adopting ecological principles in urban planning had surfaced in the PRC in the late 1980s, it was only in the last decade that eco-cities were seriously considered and implemented as an urban development model. In 1995, the State Environmental Planning Agency, now renamed the Ministry of Environmental Protection (MEP), issued guidelines for the building of demonstration eco-communities and environmental protection model cities under its eco-construction program (Liu 2009, Zhou 2008).

By one count, 135 cities or local municipalities were planning or developing some type of ecological settlement (Yip 2008). The MEP also listed 389 counties and cities as approved national ecological demonstration sites and 629 towns as environmentally beautiful towns (Wu 2009). In addition, the MEP (2010) named 67 cities and 5 municipalities as national environmental protection model cities in its efforts to promote environmental protection by showcasing model cities. These efforts had served as a precursor to the emergence of eco-cities, as MEP-accredited eco-cities were selected from the more advanced eco-communities and model cities.

The PRC has chosen to frame the eco-city concept through the Utopian ideal of an “eco-culture.” The concept of an eco-culture was first officially cited at the 17th National Congress of the Communist Party of the PRC in 2007. An eco-culture calls for the building of “a harmonious world characterized by sustained peace and common prosperity.” Eco-culture, as defined by the central government, is a broad concept of mutual respect for fellow human beings, nature, and society at the material and spiritual levels. Human beings are at the center of the eco-culture system but do not dominate nature. When the central government introduced the “scientific development concept” as a new development paradigm, the concept of an eco-culture provided another way of articulating the central government’s goal of establishing a well-off *xiaokang*⁹ society in which people are able to live relatively comfortably albeit with modest means. The amended constitution emphasizes “balancing urban and rural development,” and developing an “innovative country and resource-conserving, environment-friendly society.” The eco-culture supports the positive circular material flow (circular economy concept). The first batch of 33 national ecological demonstration sites was announced in March 2000 by the MEP. As of May 2010, there were 389 such sites.

The eco-city model can also be interpreted as a realization of the PRC’s “dual-oriented” society, which combines conservation orientation with an environment-friendly society. Two challenges have been identified in the implementation of a dual-oriented society (Zhou 2007): (i) the need to internalize environmental externalities through government regulations,

⁹ *Xiaokang* society is a Confucian term.

Green Building Concept in Practice—Juiting, People's Republic of China



Source: Crone, Sydney.

whether these operate through market mechanisms, such as emissions trading, renewable energy allowances, or through direct penalties, taxes, and technical standards; and (ii) the need for a more robust regulatory and implementation structure, as well as more comprehensive public education on environmental issues.

In concrete terms, an eco-city is expected to provide a vibrant economy by promoting environment-friendly production and industry that delivers above-national-average per-capita gross domestic product levels. It is likewise expected to deliver a healthy environment, effective environmental protection, resource and energy conservation that meets international standards, a reduction in emissions, high-quality air and water, an above-national-average per-capita green ratio, social harmony with adequate educational and employment opportunities, a social safety net, housing, public infrastructure, public services, cultural protection of physical and nonphysical cultural legacies, promotion of green lifestyles, and regional integration.

Characteristics of PRC Eco-Cities

Research in the PRC regarding defining, designing, developing, managing, and measuring the performance of eco-cities has experienced explosive growth in recent years. The term “eco-city” now appears as a catch-all phrase for a variety of new urban development models. Although there has been a proliferation of eco-city research in recent years (Shen and Song 2010), there has been comparatively little research on the practical aspects of urban planning as this relates to concrete eco-city development in the PRC.

The country's Low-Carbon Eco-City Development Report in 2010 describes a low-carbon eco-city as an innovative type of urban development model based on the principle of balance with the natural environment. Here, it is defined as a low-carbon eco-city aimed at minimizing resource consumption and generation of emissions, while conserving energy and focusing on environmental protection.

An assessment of low-carbon cities in the PRC identified three types of low-carbon eco-cities: (i) the *technologically innovative eco-city model*, which is usually neither replicable nor scalable and tends to require substantial funding; (ii) the *livable eco-city model*, which is replicable and sustainable, typically designed for population of up to 300,000, employs green building technologies, focuses on developing service industries, and emphasizes that urban planning is based on transit-oriented development and green transport modes (e.g., walking, cycling, public transport); and (iii) the *progressive evolution eco-city model* (or “retrofit” model), which refers to rehabilitation and renewal of “old” cities toward more sustainable urban development (Qiu 2009).

The absence of a commonly accepted definition of an “eco-city” has contributed to the proliferation of variations of the eco-city model observed in the PRC, including the low-carbon eco-city model and the livable city model. Other urban development models suggested by PRC planners are the *garden city*, where the focus is on integrating greenery and landscaping into the urban areas; the *landscape city*, which harmonizes the cityscape with the surrounding natural landscape; and the *historical and cultural city*, where conservation of historical and cultural sites within the city is a priority.

In addition, the MEP has an approved category of national ecological demonstration sites, defined as administrative areas targeting promotion of coordinated economic, social, and environmental development based on accepted ecological and economic principles. Such zones typically promote eco-agriculture; eco-tourism; eco-restoration; the integration of agriculture, industry, and commerce; and attempts at employing the principles of the circular economy.

While the characteristics and objectives associated with eco-cities are varied, a crucial thread runs through these variations in the PRC context. It is adherence to ecological principles, resource and energy management and conservation, waste minimization, and recirculation of materials and energy in an urban context that makes an eco-city. Characteristics of an eco-city identified by PRC authors include harmonious relations and cohesiveness, high efficiency in energy and resource use, multifaceted approaches, zero pollution, and continuous circulation of material flows.

Localizing the Eco-City

Variations on the low-carbon eco-city model and corresponding performance measurement systems would be needed to match local conditions. Though the eco-city model can be applied under two fundamental scenarios—greenfield projects and retrofitting of existing cities—there is no single applicable solution. Differences in geographic landscape, for example, would necessitate different approaches. Low-energy green buildings and eco-friendly transport would be more suited in the southern part of the country, whereas in the northern part, traditional heating could be replaced with solar thermal heating and geothermal heating. In the water-scarce western part of the country, water conservation and wastewater recycling would be particularly important.

Clearly, industrial restructuring, and even changes in consumer behavior, would need to accompany the development of eco-cities. Building an eco-culture is the “most difficult task for eco-city development, which needs both top-down and bottom-up strategies” (Wang and Ye 2004). The fact that the central government has chosen to advance eco-culture as part of its development policy suggests substantial hurdles involved in refining the ecological consciousness of a nation. The government (Vice Minister of Housing and Urban–Rural Development) has conceded that the “pathway for eco-city development is still unclear” (*Guangzhou Construction News* 2009).

A low-carbon economy necessitates low-carbon consumerism, and this would provide opportunities for restructuring the economy and the PRC’s industrial base. The appropriate eco-city model for the PRC should be replicable and self-sustainable in terms of the costs of both economic development and operations. In the PRC context, an eco-city is not necessarily a high-tech one, but instead one that focuses on the use of appropriate technology (Wang and Ye 2004, MOHURD 2009).

Eco-City Standards in the PRC

In addition to local governments, there are primarily two central government bodies engaged in the promotion, development, and evaluation of eco-cities in the PRC. These are the Ministry of Housing and Urban–Rural Development (MOHURD) and the MEP. The regulatory and approval framework for the development and construction of government-sanctioned eco-cities appears to fall under the purview of MOHURD. MOHURD (2007) issued a policy directive, which served to guide local planning authorities with regard to key performance indicators for master plan preparation and monitoring. These highlighted new resource management performance measures

covering water resources and reuse, land resources, energy efficiency, emissions reduction, and materials recycling (Annex).

On the other hand, the MEP accredits national-level eco-cities and various other ecological demonstration sites such as eco-provinces, eco-counties, and national environmental protection model cities throughout the PRC. Both ministries are involved in the setting of eco-city performance standards. The MEP recommends performance standards for eco-cities, eco-counties, and eco-provinces. These standards, which were first issued in 2003 and revised in 2007, cover social, economic, and environmental aspects, with the highest number of 36 indicators at the eco-county level, 28 at the eco-city level, and 22 at the eco-province level (MEP 2008).

The MEP's per-capita-based eco-city standards, such as annual per-capita income, energy and water consumption, and the compliance rate for clean production, have yet to be pronounced. Environmental indicators include proportion of forest cover, proportion of protected areas, air- and water-quality levels (per CNY10,000), municipal and industrial solid waste treatment rates, noise pollution, per-capita urban green space, and level of investment in environmental protection. Social indicators include the urbanization level, the Gini coefficient (at the provincial level), and public satisfaction with the environment. At least 80% of counties within the administrative control of the city should meet eco-province standards, and the primary city should have national environmental protection model city status awarded by the MEP. Although local governments are expected to lead such projects, performance evaluation and monitoring are carried out by the local MEP offices and reported back to the central MEP.

MOHURD embarked on a 5-year project when it signed an agreement in July 2009 with United States-based United Technologies Corporation and the PRC Society for Urban Studies to launch an "Eco-city Assessment and Best Practices Program" in the PRC. The project is in its preliminary phase, and a survey has been released to obtain feedback from various parties on their perspectives regarding key performance indicators for eco-cities in the PRC. The eco-city index system to be developed is intended as a measurement tool to guide and measure the PRC's progress in eco-city planning and development, as well as existing eco-city practices.

CSUS will also publish an annual report on best practices in the PRC's eco-cities and propose policy and development strategies for PRC eco-city planning and development. The MEP's standards have a broader scope and include targets relating to energy- and resource-use efficiency, as well as measures of economic and social improvements, while MOHURD's standards will likely focus on aspects relating to the construction of urban

infrastructure. This is largely a reflection of the differing mandates of each ministry. However, some aspects of environmental sustainability, such as GHG emissions, utilization of renewable energy, and green transportation, which are usually included in the development of eco-cities in other countries, appear to be missing (Box 1.4).

Currently, no consistent framework of performance benchmarks by which so-called eco-cities in the PRC may be evaluated. Ongoing eco-city projects appear to be adopting their own performance benchmarks and priorities, many of which may not be officially endorsed by MEP or MOHURD, this potentially leading to uneven quality in the development of eco-cities (GEF 2010).

Eco-City Case Studies

There are varying reports regarding the number and progress of eco-city projects in the PRC. One count of eco-city projects at various stages of development by Tongji University puts the total at 168 (Shen and Song 2010). The OECD (2009) report indicated that by 2008, there were about 60 cities in 22 provinces that announced plans to build eco-cities. The Joint United States–PRC Collaboration on Clean Energy puts the number of eco-cities in development in the PRC close to 40 in 2009 (*The Economist* 2009). By 2010, the MEP accorded eco-provinces status to 14 provinces, including autonomous regions and municipalities, such as Hainan, Jinan, and Heilongjiang, all of which have announced eco-city projects. Meanwhile, 11 of more than 500 cities (county and district levels) with plans for developing eco-cities have been recognized as national eco-cities, eco-districts, and eco-counties (Wu 2009). While a definitive answer regarding the number of eco-city projects in the PRC remains elusive, this number is clearly on the rise. However, there also exist cases of serious setbacks such as the Dongtan Eco-City near Shanghai, which did not materialize despite substantial support from the government and the private sector (Tianjin Eco-City, Box 1.3; Caofeidian Eco-City, Box 1.4; Dongtan Eco-City, Box 1.5).

Box 1.3 Sino–Singapore Tianjin Eco-City

Tianjin, the third largest city (population 11.8 million in 2008) of the People's Republic of China (PRC), is developing the Sino–Singapore Tanjin Eco-City (SSTEC) in collaboration with Singapore. The SSTEC will be constructed on non-arable salt land located in the Tianjin Binhai New Area, which already has one of the fastest economic and demographic growth rates in the PRC. By 2020, the 34.2 square kilometer SSTEC area will be home to 350,000 people. The project's mixed land-use plan will accommodate not only housing but also service-oriented, high-technology, environment-related industries, which will create 190,000 jobs. This includes a large-scale National Animation Center to be built during phase 1 of the SSTEC's development that will create jobs for 12,000 people.

The total investment cost for public infrastructure and facilities for the entire SSTEC area will be CNY25.5 billion (\$3.8 billion) according to preliminary estimates. Construction began in September 2008, with completion of phase 1 comprising 7.8 square kilometers scheduled for 2015.

The SSTEC is intended to be an energy- and resource-efficient model eco-city that will release relatively few greenhouse gases, while maintaining economic viability and social harmony. Several features of the SSTEC are noteworthy. First, it was selected from a pool of four candidate cities, with political support from the Prime Minister. Second, it will convert nonarable salt land into urban land with a high economic value. Third, by partnering with Singapore, the SSTEC will avail of global experience and scientific knowledge. Fourth, its transport-oriented development plan, which integrates transport with land use, includes a higher floor area ratio allocation in the areas near metro stations, thus allowing population densities approximately equal to those of the Tianjin city center. Fifth, the SSTEC's mixed land-use plan will reduce the need for workers to commute from outside the SSTEC area. Sixth, its building standards require greater energy efficiency than do corresponding national standards, thereby promoting renewable energy use. Seventh, its planned per-capita water consumption is capped at 120 liters per day, thus allowing more than 50% of water use to be derived from nonconventional sources. Eighth, social harmony will be maintained, since affordable public rental houses will comprise at least 20% of the SSTEC's total housing stock. It is planned that 90% of all trips will be made either in clean, energy-efficient public transport on foot or by bicycle.

Source: ADB. 2011b.

Box 1.4 Caofeidian International Eco-City

Located at the south of Tangshan, Caofeidian is a small alluvial islet facing the Bohai Sea, about 80 kilometers from central Tangshan in Hebei Province. The Caofeidian Eco-City is located near the industrial zone of the Caofeidian New Area. The industrial zone was established under the jurisdiction of Tangshan, with the zone being designated as a pilot site for promoting the circular economy. Since 2003, more than 50 square kilometers (km²) of land have been reclaimed for Caofeidian's development. The People's Republic of China (PRC) port construction, steel, and power enterprises, including Beijing Capital Iron and Steel Group, Huadian Power Group, and Petrothe PRC, are reportedly investing CNY192.9 billion in Caofeidian for construction of infrastructure. Beijing Capital Iron and Steel Group's steel plant was moved from Tangshan city to the Caofeidian industrial zone in 2007 as part of overall plans for Caofeidian to become the largest steel production base in the PRC by 2010.

The Caofeidian Eco-City is one of the largest eco-city developments in the PRC. It is envisaged to be a new subcenter for Tangshan located on the seacoast to help alleviate increasing urban pressures, while at the same time supporting the area's industrial development. The first stage is expected to house a population of 400,000 within an area of 30 km². When fully completed in 2020, the eco-city will be home to 1.3 million residents within its total area of 150 km².

Launched in 2006, the strategic plan for the southern coastal area of Tangshan was formulated in collaboration with the Urban Planning and Design Institute of Tsinghua University, CAUPD, and the Shenzhen Planning and Design Institute. Sweco, the Swedish sustainable engineering and design firm, likewise brought international expertise into the project's concept planning. The area's master plan is currently being developed by a team from Tsinghua University.

Eco-City Master Plan

The site faces a number of difficulties, including shortages of fresh water, salination, and possible storm surge owing to its coastal location. The planning framework used addresses these issues in terms of four aspects: biodiversity, eco-shelter, eco-safety, and eco-repair. The master plan promotes eco-repair by conserving existing green corridors and wetlands with buffers to protect these ecologically rich areas from further damage. For flood control and prevention of soil salination, two dikes were proposed with an inner sea formed between the two dikes and an artificial lagoon. The lagoon would store freshwater from rivers and mitigate salination of the soil and groundwater. The inner sea will be used for recreational purposes, such as water sports.

continued on next page

Box 1.4 *continued*

The master plan for Caofeidian would also feature green transport modes and transit-oriented design to create a “city of short distances” (Ma 2009). The city center and subcenters would be served by light rail and bus rapid transit systems, making the eco-city pedestrian-friendly and livable, while reducing transport-related emissions.

For generation of electricity, wind power is planned to provide at least 80% of Caofeidian’s energy requirements due to the city’s coastal location. Other clean-energy sources to be used include gas, as well as biogas from waste-to-energy plants, which, in addition to wind, will primarily be used for heating and electric power generation. Given the area’s water-supply constraints, water conservation and reuse will be heavily promoted with a target of 50% of all water use being derived from reclamation and reuse.

Source: Adapted from J. Chia. 2010. *How Can ADB Better Support the PRC’s Sustainable Urban Development? Selected Themes in Sustainable Urban Development in PRC*. Intern Report. Manila: ADB.

Box 1.5 Dongtan Eco-City

Initial plans for Dongtan Eco-City, the first eco-city project to be announced in the People’s Republic of China (PRC), were unveiled in 2003. Proclaimed as the world’s first purpose-built carbon-neutral eco-city, Dongtan’s first phase was targeted for completion in 2010 to correspond with the Shanghai World Expo. Dongtan was also presented as a demonstration project for eco-city development at the Third UN-HABITAT World Urban Forum in 2006.

Aside from construction of Chongming Island Bridge 13 which links Shanghai to the mainland and a wind farm, Dongtan Eco-City has largely failed to materialize for a number of reasons. As a result, Dongtan was not mentioned at the Shanghai World Expo. Its site is located on an estuary tidal flat at the east end of Chongming Island, which lies at the mouth of the Yangtze River, about an hour’s ferry ride from Shanghai. The project’s phase I, which was scheduled to be completed in 2010, was to accommodate up to 10,000 residents in an area of 1 square kilometer (km²). Targeted for completion in 2020, the start-up area comprising 6.5 km² was to house 80,000 people, while the completed eco-site to be completed by 2050 was to be home to 500,000 residents within a total area of 30 km².

continued on next page

Box 1.5 *continued*

Dongtan was envisaged as a small, pedestrian-friendly self-contained town with an ecological footprint of 2.6 hectares per person, which is 60% less than conventional PRC cities. Its energy demand was likewise to be 66% lower, with 40% of all energy supplied coming from bioenergy. As a result, it was to produce zero carbon dioxide emissions, and the proportion of its total waste generated going to landfills was to be 83% less than in conventional PRC cities.

The project was perhaps ill-considered from the outset. Chongming Island is the most rural area of Shanghai. Thus, its economic sustainability was questionable in that it would most likely have had to rely on Shanghai for most of its employment opportunities. Furthermore, displaced farmers were not likely to be able to afford housing in Dongtan, even with 20% of dwelling units designated as affordable housing. Management problems likewise contributed to the demise of the project. According to one report (Brenhouse 2010), there was confusion between the city's design firm, Arup, and the state-owned developer, Shanghai Industrial Investment, as to the source of funding for the project, which was estimated to cost \$1.3 billion (Cheng and Hu 2010). Political backing for the project also evaporated when Chen Liangyu, the former Shanghai Communist Party chief, was imprisoned on corruption charges in 2008.

The proposed eco-city was sited next to the Dongtan National Nature Reserve, a Ramsar Convention wetland site. Thus, construction of an eco-city would likely have had a significant adverse impact on the adjacent protected wetlands. The Dongtan site did, however, have the potential to tap renewable energy sources such as solar and wind, since a wind farm began operations at Dongtan in June 2008. Eco-farming activities have also taken root at Dongtan.

However, participation by the local community was lacking, this problem not being unique to the Dongtan project. The land-use regulations also posed difficulties as the land on Chongming Island was originally intended as compensation for agricultural land lost to Shanghai's urbanization, and should therefore have been used for agricultural production rather than further urban development.

Source: Adapted from J. Chia. 2010. *How Can ADB Better Support the PRC's Sustainable Urban Development? Selected Themes in Sustainable Urban Development in PRC*. Intern Report. Manila: ADB.

Location and Site Plan for Dongtan



Source: J. Chia, 2010.

Photos: Cheng and Hu.

Dongtan—An Artist's Impression



Source: Arup.

The PRC cities will densify, with about 1 billion people by 2030. With the proliferation of new cities in the country, thousands of skyscrapers are expected to be built, illustrating the drive for even higher densities.

Eco-city development in the PRC is still very much at the experimental stage (Woetzel 2011). As can be gleaned from the case studies, appropriate management and policies to drive and support eco-city development are as important as, if not more so than, technology or financing factors. For example, managerial failures were the contributing factor to the situation in Dongtan. In contrast, with the project being driven by a joint venture enterprise, the Sino-Singapore Tianjin Eco-City has strong political backing and a clearly defined administrative and operating structure. The project also leverages expertise

from both the PRC and Singapore. Similarly, the Caofeidian Eco-City benefited from foreign expertise. However, this advantage could also turn into potential weakness if such collaboration falls apart. Moreover, since greenfield projects are being constructed on undeveloped or underdeveloped land, it raises the larger question as to how eco-cities can be replicated in existing urban areas that are already well developed (Chia 2010). This articulates the question of retrofitting and transformation of existing cities and their gradual adaptation of green technologies and green-economy mechanisms, as attempted in Chongqing (Liu 2011).

“Over the next coming years, India and the PRC will continue to urbanize rapidly. Their decisions about land use will have a significant impact on energy consumption and carbon emissions. If they live at high densities and use public transit, then the whole world will benefit. If they sprawl, then we will all suffer from higher energy costs and higher levels of carbon emissions. One important reason the West must shrink its own carbon footprint is to reduce the hypocrisy of telling India and the PRC to be greener while driving our SUVs to the mall” (Glaeser 2011).

While the PRC is experimenting with eco-cities on a large scale, other East Asian countries, such as Japan (Box 1.6) and the Republic of Korea, are venturing in the same direction.

Box 1.6 Kitakyushu, Japan – Model Eco-Town



Japan's Kitakyushu Eco-Town has developed the most extensive range of recycling and environmental industries in the country in that these recycle a wide range of materials and products. Current recycling includes PET

continued on next page

Box 1.6 *continued*

bottles, office equipment, vehicles, fluorescent tubes, medical equipment, construction waste, solvents, paper, food residues, styrofoam packaging, cans, and metals. The total collective investment for these activities was ¥430 million (\$390 million, at ¥110 per US dollar), of which ¥82 million came from national source and ¥56 million from local public source.

The following aspects are relevant to the Kitakyushu systems approach:

Supply. Recycling depends on obtaining sufficient raw material of acceptable quality. This in turn depends greatly on citizens' cooperation in separating waste. At the time of the eco-town's creation, preexisting collection systems were not capable of delivering the required quantity and quality, and the city of Kitakyushu thus worked with neighboring local authorities to establish a sufficiently large catchment area to supply eco-town recycling businesses.

Markets. Although much of the recovered products are of low value (e.g., fuel), where higher added-value markets have potential, the city acts as a green purchaser (e.g., of clothes using PET-derived fiber, and recycled fluorescent lights).

Local agglomeration. The eco-town demonstrates the importance of localization. The local cement and steel industries allow low-grade recycled plastics and other combustibles to be used for fuel, thus avoiding significant transport costs. A local vehicle-recycling cluster has developed spontaneously at the Hibiki site, where a group of car disposal companies have formed a cooperative that provides common services to all of the local vehicle recycling businesses.

Regulatory interaction. Technology development has interacted with national regulatory standards in a synergistic manner in the eco-town's operations. For example, a shredder-less recycling process was developed for vehicles that avoid the air pollution problems of standard recycling processes. This allowed the Ministry of Economy, Trade and Industry to incorporate this technology into a revision in the Auto Recycle Law then being drafted for the purpose of setting more stringent standards for vehicle recycling.

Process innovation. Process development (learning by doing) in office equipment disassembly has increased the recycle rate to 96% and halved the time needed to recycle each machine. High-quality recycled plastics are returned to the manufacturer to make new equipment, while low-quality plastics are recycled into fuel. Experience in disassembly allows feedback into materials selection and design, thus allowing the subsequent generation of equipment to be designed in a way that optimizes resource efficiency over the entire life cycle of the product concerned.

Source: <http://www.city.kitakyushu.lg.jp/english/index.html>

Green Transport

The metropolitan cities in developing countries are choking with traffic, particularly with cars and buses, and are suffering from the impact of too little regulation and too little enforcement of traffic rules (Agarwal, Sharma, and Roychowdhury 1996). There have been many calls for alternatives to the heavily car-based transport modes, including calls for a limitation of car ownership and car movement. Singapore is an example of a city that has invested heavily in public transport, while making access to the city center by car more difficult and costly through its digitally monitored congestion charge. However, for many cities, it is investment in green public transport infrastructure that is being called for.

The dominant approach to green transport can be summarized by the formula of *avoid-shift-improve*. This means improved spatial configuration, i.e., more compact and multifunctional urban areas that would reduce or avoid the need to undertake lengthy commuter trips. The notion of a *shift* supposes that a gradual shift can be undertaken to modes of transport that are cleaner, eventually utilizing nonfossil energy sources. The intention to improve transport modes hints at possible improvements in energy efficiency and use of clean-energy modes.

London's attempt to keep private vehicular traffic away from the city center through a hefty congestion charge provides an excellent example of the *avoid* approach to transport. Singapore has copied this with its electronic road pricing system and a vehicle quota system that attempts to reduce the use of automobiles in downtown areas.

The bus rapid transit (BRT) systems of Bogotá, Curitiba, and Quito have been imitated in Asian cities, such as in Ahmedabad, Guangzhou, Istanbul, and Jakarta, with more cities working on their own versions of the BRT. These schemes are still the vanguard of modern transport and represent a modest level of investment in comparison with the more capital-intensive underground metro systems of Beijing, Hong Kong, Kolkata, Nanjing, New Delhi, and Singapore, to name a few, or the mass rapid transport lines in Metro Manila.

However, Asian cities have not tried to follow their European counterparts in controlling emissions through low-emission zones and timed delivery permits for commercial deliveries. Cities in temperate climates in Europe and South America have experimented with cycling as one of the greenest forms of transport,¹⁰ but in tropical Asia such initiatives appear idealistic and far-fetched as comfortable transport is associated with air conditioning.

¹⁰ Bogotá, Mexico City, and Rio de Janeiro have car-free days and weekends.

Busway in Jakarta, Indonesia



Source: F Steinberg.

Bus Rapid Transit in Lanzhou, People's Republic of China



Source: ADB, 2010.

Since the car is still the dominant mode of private transport, much hope is directed at innovations that will come from the industry. Hopefully, within a few years, polluting carbon-intensive cars will be replaced with better and cleaner technologies. The arrival of electric cars seems imminent, and their supposed success is expected to initiate a new era of clean private transport. While this will not solve issues of congestion and commuting, it will at least help to clear the skies and will usher in a new era of technological innovation with massive and still-unforeseeable implications. It is time that obsolete carbon-intensive forms of mobility be replaced with energy-efficient vehicles that use renewable energy sources.

Fuel conversion, as done in Delhi, can have impressive environmental impacts. Switching the fuel used by a city's vehicle fleet from petroleum to compressed natural gas (CNG) can produce impressive reductions in air pollution levels, as Delhi's experience has demonstrated. However, few city administrations have the political will to effect such a change. In Delhi's case, this obstacle was overcome by a Supreme Court decision in the late 1990s that forced conversion from petroleum to CNG for a substantial portion of the city's vehicle fleet. Thus within a few years, 10,200 buses, 51,623 auto rickshaws, 10,350 private cars, 4,497 mini-buses, 5,043 taxis, 5,909 light commercial vehicles, and 689 other commercial vehicles were all converted to CNG. As a result of these developments, Delhi's entire public transport fleet is now powered by CNG (Ferris 2012). In 2012, India introduced the first hydrogen-powered auto rickshaws, which will run on clean, efficient, and naturally abundant hydrogen (Yee 2012). More cities in Asia and the Pacific are expected to follow this example of Delhi. But to get started, it needs committed leadership.

When the cities of Curitiba (Brazil) and Bogota (Colombia) introduced the BRT systems, these motorized transport innovations were accompanied by establishment of wide-scale networks of bike lanes, which have become an

emblematic side of a healthier, eco-friendly, green nonmotorized transport option. This mirrors the experiences of many European cities where chief executives, housewives, and schoolchildren ride bicycles as their daily routines. This lifestyle is common in many modern cities and represents multimodal transport options, ranging from nonmotorized cycling to the use of public transport (BRT, metro, or an underground rail system), to privately driven cars. The egalitarian nature of public transport, its quality and affordability, has been praised at the core of its success. In urban Asia, Singapore, Japan, the Republic of Korea, and, to a growing extent, the PRC and India are following suit in matters of public transport. However, in the hot and humid climates of tropical Asia, nonmotorized transport stands little chance of becoming as attractive as it is in European or Latin American cities that enjoy relatively cooler climates. Instead, a hybrid solution in the form of an electric bicycle is expected to conquer Asia as its cities go green.

The emergence of cars that are fuel-efficient, carbon fuel-based, and electric or hybrid (fuel-based or electric) is another indication of the greening of urban transport. Modern industry standards have come a long way from the heavy consumers of gasoline to more highly efficient cars, and there is tremendous pressure to come up with innovative electric cars that can compete in performance (e.g., speed and range of operation after charging) with conventional fuel-based vehicles. The race is on, and the likely winner is going to be the cities that will become greener and healthier places to live in.

Electric Tricycle: Pilot Model in Manila



Source: ADB. 2010. *ADB Today*. 6 October.

The Hybrid Car



The fully electric car is still elusive.
Source: Asian Development Bank.

While some countries such as Singapore limit vehicular access to the central business district by levying a fee for entering the urban core, other cities have simply attempted to control speed and improve traffic safety in downtown areas. In this regard, accident rates have been reduced through

the use of speed controls enforced by means of radar and strategically placed fixed-location cameras, as well as onboard cameras built into cars. To reduce the overall volume of vehicular traffic, Guangzhou strictly controls the number of vehicles on the city's roads by limiting the number of license plates issued. Distribution of license plates takes place either through lotteries or auctions, this traffic reduction measure being complemented by the city's upgraded BRT system. Although this negatively impacts car sales, it has resulted in significant environmental and health benefits for city residents.¹¹

Green Building

Architecture in the 20th and 21st centuries has seen a dynamic evolution toward ecological and green building. While modernist and post-modernist architectural trends have waned, the trend toward green building has become an important feature of the construction industry.¹² "Environmental architecture is now in an evolutionary stage that parallel[s] the growth of early modernism..." (Wines and Jodido 2000, Jodido 2009). In reflecting on green design, the pioneering Malaysian architect Ken Yeang stated that "Ecosystems have no wastes, everything is recycled within. ... All emissions and products are continuously re-used, recycled within, and eventually reintegrated with the natural environment. This is the fundamental premise of eco-design... Our built environment must imitate ecosystems in all respects" (Yeang 2005). The issue of green building is a matter pertaining more to the building industry, technologies, and vested interests than to engineering and architectural design. In the case of asbestos, vested interests in the building industry took decades to eliminate asbestos from construction markets in most countries. However, unhealthy building materials are still produced and consumed in large quantities (Miranda Sara 2008).

For about a decade now, governments in Europe and North America have sponsored energy-efficient building practices in order to reduce fuel consumption associated with heating or cooling. Energy-efficient building design, including orientation, selection of heat-reflecting materials, optimization of solar benefits, use of green roofs (and facades), water harvesting, and sustainable urban drainage have become the mainstay of the new green architecture. Decentralized electricity generation, mainly through combined cooling, heat, and power systems at times linked together in

¹¹ *International Herald Tribune*. 2012. [The People's Republic of] China's car producing hub puts growth in back seat. 6 September.

¹² Numerous publications have appeared dealing with "biological" or green building: US Environmental Protection Agency (2009), Hopkins (2002), Allen and Iano (2008), and Kennedy (2004).

decentralized neighborhood schemes, complement innovation in building technologies. London's Green Homes Program has financed loft and cavity insulation. In the United States, the Clinton Climate Initiative led to the energy-efficiency building-retrofit program (Gavron 2009, 383–384).

There has been a surge in energy-efficient engineering and construction technologies, and governments have taken the lead in designing tax incentives and stricter building codes for retrofitting and new construction. More so, the contribution of buildings to the CO₂ performance of cities is being recognized. Buildings contribute about 50% of urban CO₂ emissions through the construction materials used; the carbon consumed in their manufacture; construction-related cooling or heating requirements; the energy requirements of services, such as water supply, wastewater, and solid waste disposal; and general energy efficiency. Addressing the energy demand of existing buildings is therefore a high priority on the path to green cities. Their conversion to greener buildings should start with building materials and later extend to internal infrastructure, such as water supply, cooling and heating systems, and their processing of wastewater and solid wastes (*Philippine Daily Inquirer* 2006). Passive design solutions, as already proven by many innovative architectural projects, have helped to improve the energy performance of buildings.

Green buildings are estimated to save “on average 30% of electricity, 30%–35% of water, and 50%–90% of waste discharge costs.”¹³ More has been done in the developed countries, but the developing world, particularly Asia, is fast catching up. Green design and technology inspired by biological forms and resource-efficient construction are taking their inspiration from nature. “Buildings that adapt to changing conditions is the way we have to develop if we are to mimic truly the low-energy ways in biology works.”¹⁴

Building codes, mandatory energy certification, financial incentives, and support, which have had a significant and measurable impact on building performance in Europe and the United States will reach the developing world as well. Examples from Germany indicate that energy-efficient construction standards have brought down average energy consumption in housing by 80% (von Weizsäcker et al. 2009). Obviously, the private sector has to lead this process, but the public sector can also set important standards and examples by converting its own publicly

¹³ Yannik Millet of the Viet Nam Green Building Council, in Bao (2011).

¹⁴ M. Pawlyn, in Miles (2011b).

owned building stock into exemplary cases of green and energy-efficient buildings.

The United States-based certification methodology of the Leadership in Energy and Environmental Design (LEED) is fast evolving as the new benchmark for smart buildings, and across Asia the first built examples are being registered (Box 1.7).¹⁵ The Philippines, for example, has one of the first Asian Green Building Councils, working toward sustainable and net-zero buildings.

Box 1.7 Leadership in Energy and Environmental Design Green Building Rating System™

Leadership in Energy and Environmental Design (LEED) is a voluntary, consensus-based national rating system under the United States Green Building Council that promotes a “whole-building approach” to sustainability. The rating system was created to transform the built environment toward sustainability. It is developed and continuously refined via an open, consensus-based process that has made LEED the most used green-building standard. The first step in obtaining LEED certification is to register a project. To earn certification, a building project must meet certain prerequisites and performance benchmarks (“credits”) within each category. Projects are awarded silver, gold, or platinum certification, depending on the number of credits they achieve. LEED certification provides independent, third-party verification that a building project meets the highest performance standards. LEED-certified buildings are leading the transformation of the built environment in that they have lower operating costs, increased asset values, reduced amounts of waste that is sent to landfills, well-conserved energy and water, and reduced greenhouse gas emissions. Often, they qualify for tax rebates, zoning allowances, and other incentives.

Source: United States Green Building Council.

Due to the inclination of the Philippines toward United States standards and legislation, the country has decided to follow the LEED pattern (Gonzales and Torres 2010; De Jesus 2010a, 2010b; Salazar 2010, 2011). As the movement toward green cities unfolds, so has a whole school of new architecture, which is dedicated to the practice of green architecture. In recent years, it has been stated that “nobody knows what a sustainable human settlement looks like or how it functions. Some people say that small

¹⁵ In the Philippines, the ADB Headquarters was the first building to receive in 2011 a Leadership in Energy and Environmental Design certification.

European towns in the Middle Ages, or prehistoric hamlets, for instance, were ‘sustainable.’ Both models, however, were based on the same non-sustainable paradigm: resources were extracted from the environment, while waste was thrown back. The fact that they were very small is what made such settlements apparently sustainable, since disruption of the natural environment was minimal” (Ruano 1999 in UNEP 2011, *International Herald Tribune* 2011a, Siegel 2011). In the past few years, there has been a growing movement of examples of eco-urbanism, or cities that set out to prove that they can become sustainable, as low-carbon or carbon-free cities, with regenerative alternative sources of energy. Eco-urbanism defines the development of multidimensional approaches to transport, energy, urban greening, urban agriculture, and modern but passive energy architecture in compact high-density communities.

Encouraging examples from the developing world are now coming up in larger numbers: innovations in green construction are being worked on in Bangalore, Bangkok, Beijing, Delhi, Guangzhou, Ha Noi, Hong Kong, Jakarta, Karachi, Kolkata, Kuala Lumpur, Manila, Mumbai, Nanjing, Osaka, Seoul, Shanghai, Singapore, Taipei, Tokyo, Wuhan, and Yokohama. Innovative projects are worldwide and manifest a growing global concern for the green city that transcends political and cultural boundaries (A. G. Siemens 2011, *Heritage Magazine* 2011, Wines and Jodido 2000, Jodido 2009, *International Herald Tribune* 2007).

In a number of Asian countries, the real estate, property development, and construction industries are moving toward green growth through application of low-carbon technologies, energy-efficiency initiatives of various types, and installation of systems for mitigating or preventing floods. Manila’s property developers, in particular, have shown enthusiasm for participating in the green building movement (Samaniego 2012a). While some developers are quick to label green technology a new luxury (Arthaland 2012), others refer to their new upmarket residential townships as “sustainable eco-city development” (Samaniego 2012b). In countries with a building stock of widely varying vintages, such as Australia, Europe, and the US, retrofitting of existing buildings is increasingly popular principally through modifying buildings in a way that makes them more energy-efficient, and reducing energy demand through the use of green roofs and facades. This trend toward retrofitting of existing buildings has been significantly facilitated by formulation of quantitative rating systems for measuring the relative energy efficiency of individual buildings. Examples of such rating scales include the LEED system used in the US and Australia’s system, the latter holding significant potential for wide application in Asia and the Pacific (Green Building Council of Australia 2012). However, the experience of initiatives, such as the Philippines’ Green Building Initiative, suggests that a rating

system specifically designed for tropical climates may be more appropriate for region-wide application (De Jesus 2012). An example of a pioneering building is Bangkok's 39-storey Peninsula, which has energy-efficient features, such as a single-loaded corridor to the west to absorb heat and daylight. It is equipped with a computerized integrated building management system, a refrigerated garbage collection system, and wastewater treatment facilities (De Jesus 2005). Through heat absorbing glass facades, the Zuellig building of Manila will save 15% on annual energy consumption through heat-absorbing glass facades. It will also achieve 71% water savings through water conservation (*Philippine Daily Inquirer* 2011, Samaniego 2011).

In June 2012, the real estate firm CB Richard Ellis Philippines announced that there were 2,371 LEED-certified projects in Asia. The leaders were India (1,283 buildings) and the PRC (589 buildings), followed by the Republic of Korea and Hong Kong, China (Salazar 2012).

The greening of high-rise buildings through constructing "vertical forests in the sky" (Daily Mail 2011) or green skyscrapers (Yeang 1999) has now become as fashionable in Malaysia as in Italy. Similarly, green buildings have now become popular in both the Philippines (Samaniego 2012c) and Viet Nam, the latter's tube houses of traditional design now having gone green (*International Herald Tribune*. 2012. 8 June).

Zuellig Building in Manila—one of the Philippines' first certified green buildings



Source: F. Steinberg.

Headquarters of the Asian Development Bank – A LEED-certified building



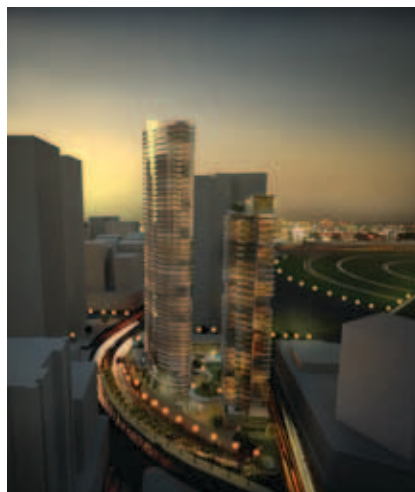
Source: Asian Development Bank.

The greening of architecture



Source: Agence France-Press.

Arya Residences, Bonifacio Global City, Manila – Working toward LEED certification



Source: Crone, Sydney.

The new eco-cities in the PRC are set to become real-world laboratories of green architecture (Ruan 2006, Alcazaren 2010, Buban 2010, *Associated Press* 2011, Wang 2011), and there is a new school of designers committed to developing green skyscrapers—sustainable “intensive” buildings (Yeang 1999). ADB is sponsoring green buildings through a financial guarantee scheme with a bank in Pudong, Shanghai (see Box 1.8), thus opening up dedicated credit lines for green building. Similarly, governments can stimulate green building, as is done in the United States and Europe, through tax breaks, or conditional bonus payments for retrofitting that increases energy efficiency, or the use of green building materials or passive energy-generation technologies. The PRC has been applying already on a large scale energy-efficient heating systems in new buildings as in Tianjin (World Bank 2011b) or in Sanxiang, Shanghai. Also, as part of the 2010 EXPO Initiative a demonstration eco-building in Minhang District, Shanghai was constructed. “The prototype of the case pavilion is a demonstration eco-building in Minhang District, Shanghai. As the first zero-energy building in the PRC, it uses solar thermal equipment to provide energy for the entire building. Green and energy-saving technologies integrate solar energy into the building and make full use of rainwater, natural ventilation, and shallow geothermal energy, thus demonstrating the concept of eco-housing and the pursuit of livable housing on a universal basis. The building has a shading system composed of shutters, French-window curtains, and balcony awnings. Flowing liquids in the blue tubes on the wall can adjust the temperature of the entire building.” (Wang 2011, p. 303)

Energy-Efficient Housing in Sanxiang, Shanghai—solar thermal system integrated in balconies



The Sanxiang, Shanghai technology can be used for retrofitting water heating systems in existing buildings



Source: J. Masic.

Box 1.8 ADB Supports Shanghai Pudong Development Bank Lending for Green Buildings

The Asian Development Bank (ADB) is providing CNY300 million in partial credit guarantees to Shanghai Pudong Development Bank (SPD Bank) to support private sector financing of energy-efficient buildings across the People's Republic of China (PRC). SPD Bank is the first PRC partner in a program set up by ADB to encourage financial institutions to lend to companies seeking to retrofit old buildings so that they use less energy, or to construct green buildings that are designed, constructed, and maintained so as to optimize energy and water efficiency. Retrofitting buildings typically leads to energy savings of 20%–40%.

Source: ADB Press Release. 2011. Manila. 16 May.

Viet Nam Tube House—Going Green

This house in Ho Chi Minh City (Saigon) is a typical tube house constructed on the plot 4 meters wide and 20 meters deep. The front and back façades are entirely composed of layers of concrete planters cantilevered from two side walls. The distance between the planters and the height of the planters are adjusted according to the height of the plants, which varies from 25 centimeters to 40 centimeters. To water plants and for easy maintenance, the owners use automatic irrigation pipes inside the planters. This house is a unique tropical and green house: “Vertical Green” because its façades are filled with greenery. The green facade and rooftop garden protect its inhabitants from the direct sunlight, street noise, and pollution. Furthermore, natural ventilation through the façades and 2 top-lights allow this house to save big on energy in the harsh climate of Saigon. The principles of the house represent passive cooling principles and energy efficiency, as earlier only known in the traditional Vietnamese courtyard house.



Source: Vo Trong Nghia Architects, Ho Chi Minh City.

Energy-Saving Home for Kuala Lumpur, Birds Island—Project Proposal



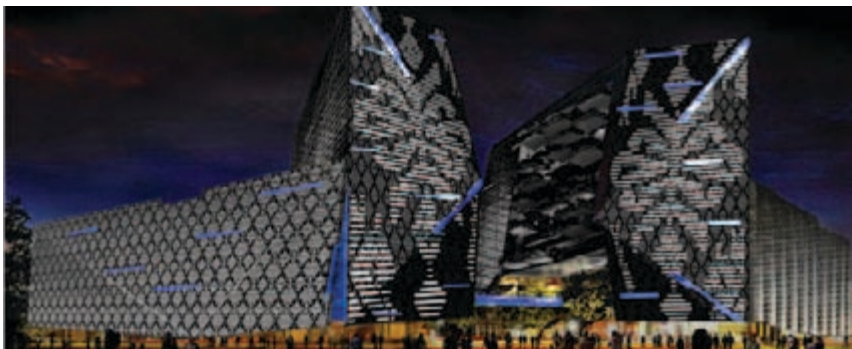
Source: Graft Architects, Berlin.

Construction Industry Going Green

The construction industry is an important economic field, contributing 5%–10% of gross domestic product in many countries. In most countries, the construction sector has an oversized ecological footprint. It is estimated by UNEP (2011b, 328–371) that the construction sector is actually the single largest global GHG emitter, with about one-third of global energy used in buildings. Even with regard to other environmental impacts, construction has a large footprint, with 12% of all freshwater being consumed and 40% of solid waste originating from it.

With the expected upsurge in urban expansion and the need for new cities and some million homes in 2010, developing countries have a unique opportunity to enter into efficient and green construction, while expanding their building stocks. From 2010 to 2050, worldwide investment in buildings will range from \$300 billion to \$1 trillion (depending on assumptions used) per year (UNEP 2011b). This includes new construction and retrofitting of existing building stocks. Creating more energy- and resource-saving buildings could result in about one-third savings in energy consumption and transport costs (*International Herald Tribune* 2011d, Medina 2012). As a result, the Holcim Foundation of the Swiss cement producer Holcim has created an award for sustainable construction in Asia, to “celebrate innovative future-oriented and tangible sustainable construction projects.”¹⁶ In 2012, it awarded a design of retail and commercial building by “green” architect Kenneth Yeang of Malaysia, and an “Urban Farm Barn” in Bangkok, Thailand.

Retail and Commercial Building in Putrajaya, Malaysia



Source: www.holcimawards.org/apac

¹⁶ www.holcimawards.org

The greening of the construction sector will have significant impacts on labor and income opportunities. The UNEP report estimated that in Europe and the United States alone, an additional 3.5 million green jobs can be generated by switching to improved energy efficiency in construction, in both new construction and retrofitting. This includes resource-efficient building materials and appliances, expanded use of renewable energy sources, and services including recycling and management of construction wastes. The greening of the building industry in developing countries provides new opportunities for engaging microenterprises and the informal sector. It could also improve working conditions and enhance the skill profiles of skilled construction labor and others in the building profession, such as electricians, energy specialists, facility managers, civil engineers, and architects.

The greening of building industry practices, and the use of more healthy biological materials can also add health benefits that improve livability and productivity. In many countries, indoor pollution from poorly combusted solid fuels (e.g., biomass, coal, kerosene) combined with poor ventilation is a significant contributor to illness and premature death. Pneumonia and tuberculosis, which are often linked to indoor pollution, cause about 11% of all human deaths globally each year. Women and children tend to be more at risk due to higher daily exposures.

The greening of construction can also be achieved through the innovative use of recycled products as building materials. In Hong Kong, a glass-recycling firm produces bricks from recycled glassware. In 2010, the Government of the Hong Kong Special Administrative Region of the People's Republic of China allowed the use of these bricks for pavements (Wassener 2012). While moves toward acceptance of recycled materials seems slow, this is an important start in that it suggests that other product innovations may follow.

Energy

Cities are consumers of energy, and they typically obtain energy from distant locations. Lighting, heating, air-conditioning, and other uses of electricity consume more than half the world's energy, with a further quarter consumed by vehicles and other forms of transport. With 75% of energy consumption, cities' contribution to global pollution is also significant (Battle 2009). For some, the challenge is to reduce energy consumption by cities and to link them with the production of energy from renewable sources. The recent evolution of renewable energy technologies has posed the question as to whether cities have the potential to become more independent from distant

sources of energy, and whether they could become producers of their own energy (Grubler and Fisk 2012).

Micro-generation of renewable energy through wind-power devices (Galbraith 2011) or solar-power technologies are being discussed for urban applications, and combined heating (or cooling) plants are being assessed in combination with decentralized energy plants (Edwards 2010, Powers 2010, Jenkins 2012). Rizhao City in the PRC already uses solar power for water heating in 99% of all households (ICLEI, UNEP, and UN-HABITAT 2009, Plafker 2010). In Malaysia, many examples can be found of energy-efficiency innovation in office buildings and even in shopping malls, which have reintroduced fans for cooling in order to promote a greener lifestyle (*New Straits Times* 2011).

Innovation is also required in the context of home appliances. These are under scrutiny for their energy performance. This covers particularly air conditioners and cooling devices like fridges but also improved cooking devices. With demand for cooling devices skyrocketing in countries such as India and the PRC, developing nations have become dominant sources of CO₂ emissions, and of late the coolant gas HCFC-22, which is heating up the planet. Similarly, refrigerators are known for their high levels of CO₂ emissions. The electrical home appliance industries have been working for years to develop ozone-friendly air conditioners, but efforts to regulate the negative impacts of traditional coolants used in air conditions on the earth's ozone layer have led to uncontrolled global warming through widespread use of the coolant gas HCFC-22.

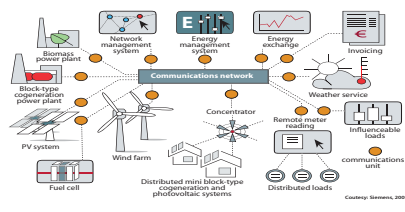
The Montreal Protocol originally gave developing countries until 2040 to get rid of HCFCs, but in 2007 the timetable was accelerated. Now HCFC gas emissions are intended to be stabilized by 2013 and reduced by 2015, which would imply a 40% reduction in consumption. Meeting these targets will be hard to achieve since technological innovation is still lagging (*International Herald Tribune* 2012). Cooking devices, particularly those used by poor urban households, remain largely carbon-based and contribute substantially to air pollution and pollution-related health risks. After waterborne diseases, pollutants from carbon-based cooking devices rank as the second leading cause of death among many poor urban inhabitants. Innovations, such as creating solar stoves or energy-saving healthy cooking devices, have been worked on for years, and experimental work on such devices continues (Smith et al. 2007).

Renewable Energy in the City



Source: S. Lehmann. 2009.

Renewable Urban Energy Options



Achievable, realistic renewable energy targets for eco-districts

Courtesy: Siemens, 2009

Few cities are being supplied by nearby power plants, or derive a significant portion of the energy they use from renewable sources. Manila receives about 7% of its electricity from geothermal sources (ICLEI, UNEP, and UN-HABITAT 2009), while other reliable and low-cost sources are being explored for other cities. In Germany, decentralized energy production has become officially accepted, with surplus energy being sold to the common grid. Other form of emerging energy-efficiency measures is district heating, as practiced in the cities of the PRC and Mongolia. Better networking and transfers of locally generated low-carbon energy will have great relevance for the cities of the future.

In 2011, in the aftermath of the Japan earthquake and tsunami and atomic energy disaster, much interest was focused on wind energy as a source of renewable energy. While debating its financial feasibility, technology developers continue to work on wind power, which will transform not only Asia's countryside but also its cities.

Building energy-efficient homes for low-carbon cities in the PRC has become the approach taken under a recent project funded by the World Bank and the Global Environment Fund that aims at modernizing heating systems and energy efficiency in urban homes. Heating is vital to surviving winters in the northern PRC, where temperatures can plunge to -30°C . Most of the heating systems there are fired by coal and are thus centralized and inefficient with poor emission controls. Buildings also lack proper insulation. Furthermore, there is little incentive for people to cut energy consumption, since their energy bills are determined by the size of their apartment not by how much energy they use. On average, residential buildings in the PRC use twice as much energy to heat than homes in Europe or the United States where temperatures drop to the same level as the PRC's. The project referred to above will (i) improve enforcement of energy-efficiency standards for buildings, as well as the design and use of insulation and other energy-

saving measures; (ii) implement heat metering, cost-based pricing, and consumption-based billing; and (iii) modernize heat supply systems so that residents can control the heat being turned on or off (World Bank 2011).¹⁷

Solar Energy



Wind Energy



Photovoltaic Roof Elements



Energy-Efficient Lighting



Source: Agence France-Press.

¹⁷ www.worldbank.org/en/new/2011/11/09/building-energy-efficient-homes-for-low-carbon-cities-in-china

Toward Carbon-Neutral Cities: Glass Facades as Solar Panels

A major challenge remains in converting existing glass facades into sources of energy. Development of solar panels as integral parts of glass facades is expected to revolutionize our cities, their energy consumption patterns, and thus their ecological footprints. Glass facades of the future will not only transmit energy but become sources of energy generation as well. Once glass facades become solar panels that convert solar energy into electricity, it will be possible to create carbon-neutral buildings that not only can generate their own energy but can produce energy in excess of their own consumption as well. This excess energy would then be fed into national electric grids and ultimately be used to power public infrastructure such as street lighting, or even the movement of private electric cars.

This would revolutionize our perception of glass facades, which are currently seen as a major source of energy waste in urban areas. Additional features, such as ray-absorbing glass panes, will help reflect the sun rays outward, thus lowering energy requirements in such buildings during warm weather (Box 1.9).

Box 1.9 Wuxi Suntech Solar Photovoltaic Research and Development Center

Early 2009 saw the inauguration of the Wuxi Suntech Solar Photovoltaic Research and Development Center, which is the first zero-energy building in the People's Republic of China. As a world market leader in solar energy industry, Suntech offers affordable energy conservation solutions.

The newly built center has a total area of 64,000 square meters, and features facades that incorporate 20,000 square meters of photovoltaic materials that collect solar energy and transform it for use in the daily operation of the building.

Source: www.suntech.com

Photovoltaic Window Panes— Amsterdam Airport



Source: Agence France-Press.

Revolutionary Technology: The Solar Panel Double Facade



Source: Agence France-Press.

ADB Headquarters in Manila: Solar Panels on Roof Top



Source: F. Steinberg.

ADB Headquarters in Manila: Solar Panels on Roof Top



Source: Asian Development Bank.

Solar Architecture in the Green City Freiburg, Germany



Source: Agence France-Press.

Water and Wastewater

Cities are large users of water drawn from surrounding hinterlands. Many developing countries not only have a large demand for water, but their consumption patterns result in unintended wastage through water losses. Known as “non-revenue water,” such losses include all water that enters municipal water supply systems and not paid for by users. The extent of such losses is large in that an estimated 30%–50% of business opportunities are foregone in many cities of Asia and the Pacific.¹⁸ However, Tokyo and Phnom Penh are examples of cities that have successfully reduced water losses, largely through volumetric water charges and meticulous maintenance of networks.

Measures for decreasing the utilization of fresh water include implementation of a cascading approach in which lower quality, semitreated wastewater is used for watering public parks and greenery. Singapore introduced its “active, beautiful, and clean waters” design guidelines (Public Utilities Board 2009), which offered design options for cleaning and using rainwater in biotopes and water bodies. Harvesting rainwater for drinking or nondrinking uses are examples of resource management measures that maximize water-use efficiency. For example, in New Delhi, buildings with roof areas larger than 100 square meters and plots greater than 1,000 square meters are required to harvest rainwater. An estimated annual harvest of 76,500 million liters of rainwater in Delhi could be made available for recharging groundwater resources in this manner (ICLEI, UNEP, and UN-HABITAT 2009). In Chennai, recharging raised city groundwater levels by 4 meters (Sakthivadivel 2007).

Similar reductions in water use can be accomplished through new technologies, such as waterless urinals and toilets. In poor households, about 50% of water consumption is accounted for by toilet flushing. While waterless urinals have already been developed and are being tested in public buildings, they have yet to be down-marketed to the homes and settlements of the urban poor. Thus, the challenges of reducing energy consumption in water distribution and adaptation to climate change offers new business opportunities for future entrepreneurs (Gies 2011).

Flushing toilets with less or no water is one of the concrete challenges which cities are facing today. In poor households, about 50% of water consumption is for toilet flushing. While waterless urinals have already been developed and are being tried out in public buildings, these have yet to be down-marketed to homes. Creative solutions are being awaited.

¹⁸ An estimated \$10 billion worth of treated water is lost every year from Asia's towns and cities. See *International Herald Tribune* (2011b).

Waste Management

Modern lifestyles and increasing wealth in Asia and the Pacific have resulted in rapid expansion of waste streams. This has had a major adverse impact on the urban hinterland, as cities export their waste to outlying rural and less-developed areas. In recent years, considerable attention has been devoted to addressing waste management issues, with the use of sanitary landfills becoming a universal goal of Asian cities. Cities such as Singapore have opted for high-tech solutions such as waste incineration. However, more cost-effective waste management practices through recycling are currently being mainstreamed.

The long-term vision of some waste management companies is that of (i) using 100% recycled or renewable materials for packaging, (ii) zero consumer and manufacturing waste going to landfills, and (iii) products that maximize resource conservation (Procter & Gamble 2011, De Jesus 2006). After decades of informal sector waste picking, waste segregation, and waste recycling, these practices are now considered important elements of the development of green cities.

Since 2005, ADB has supported the 3R principle (reduce, reuse, recycle).¹⁹ This means providing storage facilities and markets for compost and recyclable materials and encouraging community-based waste processing and recycling initiatives. Recycling in urban areas remains relatively limited. For example, only 4%–6% of the total amount of solid waste generated in Manila is recycled. However, development of green cities will require that recycling forms an important part of local government solid waste management plans, and that these plans are supported by materials recovery facilities that allow hygienic separation and processing of recyclable articles. Some European cities such as Copenhagen have made dramatic progress in recycling, with only about 3% of the total amount of waste generated being dumped in sanitary landfills. This suggests that in addition to increasing the efficiency of resource use, well-organized recycling programs can also dramatically reduce the amount of waste that must be dumped into landfills. However, achieving this will require progress in the degree to which recycled and biodegradable materials are used in manufacturing consumer goods.²⁰ In short, a combination of product

¹⁹ The initiative was launched in 2005 in Tokyo, based on an agreement of the Group of 8 industrialized nations to promote more efficient production and consumption and environmental conservation (ADB 2007).

²⁰ As urban consumption patterns have created new forms of waste from electrodomeestic articles, computers and cellphones, it is important to devise good and healthy use of obsolete and discarded “e-waste” which contains elements of primary materials like gold, silver, copper, and rare earths. The growing availability of these minerals has provoked the term “urban mining.” In the PRC, “just one year’s mobile phones and computers generated e-waste which have a value of 4 tons of gold, 28 tons of silver, and 6,000 tons of copper” (De Jesus 2012b).

design and lifestyle changes will be required to bring us closer to the ideal of the zero-waste city (Zaman and Lehmann 2011).

Vegetation and Landscape

Cities are usually not perceived as a necessary series of green outdoor spaces for air circulation and recreation. But if well planned, about 10%–20% of a city's space can be public green areas. Some cities such as Bangkok and New Delhi have maintained a significant amount of open green space, while others such as Tokyo and Manila hardly have any open areas remaining. Singapore, on the other hand, has increasingly developed parks and open green areas. The city's new land reserve located at Marina Bay, partially on land reclaimed from the sea, provides but one example of this trend. Similarly, Singapore is developing new green vertical buildings that maximize the amount of foliage to which occupants are exposed (Architecture and Urbanism 2012). These open spaces act as “green lungs” that filter air pollution in addition to absorbing rain and wastewater. Parks, gardens, street greenery, and trees can effectively act as carbon storage, water regulation, and filtration facilities, thus playing a positive role in flood control efforts. As such, open green spaces are an important urban asset and have an important role in maintaining the health of urban ecological systems.

However, with the quest for higher urban densities and increases in sellable and usable land, the days of conventional city parks seem numbered. To compensate for this loss, architects and engineers have been developing facade greenery and hanging gardens, rooftop garden terraces, and green-grass roofs.

Manhattan, New York, Rooftop Greening—Ideal For Heat Absorption



Source: S. Lehmann. 2009.

Grass Roofing: Science Museum, San Francisco



Source: F. Steinberg.

Green Facade: Quay Branly Museum,
Paris



Source: F. Steinberg.

Green Roof – UNESCO Building,
Paris



Source: F. Steinberg.

Green landscaped areas help regulate and mitigate urban temperature extremes. Urban vegetation and open spaces help decrease storm water volumes and thence floods. New design strategies in cities such as Beijing and Tokyo (Box 1.10), as well as in Italy (Box 1.12) have promoted “green curtains” around public buildings and private homes to avoid overheating of buildings in summer and to limit the need for air conditioning.

Green Facade in Europe—Passive
Climate Control



Source: Agence France-Presse.

Green Facade in Manila



Source: F. Steinberg.

Vertical Greening in Singapore's
Marina Bay Gardens



Source: Agence France-Press.

Green Roof on Rockefeller Center,
New York



Source: Agence France-Press.

Box 1.10 Green Roofs in Beijing's Central Business District

The accelerated urbanization process in the People's Republic of China (PRC) has increased pressure on the environmental quality of cities, leading citizens to demand not only economic development but also a better quality life. This includes better air quality and more leisure space, especially in the central business districts (CBDs) of major cities. In the case of Beijing, despite the city's having a green coverage ratio of 45%—well above the average green ratio of 30% in most of the country's cities—its CBD has limited green area coverage. Beijing municipality is trying to solve this problem by promoting the use of green roofs that also help mitigate climate change impacts and improve environmental quality. Beijing municipality is using both regulatory instruments and policies in promoting green rooftops and the greening of city walls. Regulatory instruments are mainly used in public offices, educational buildings, and sanitation and other infrastructure facilities. Regulations include compulsory inclusion in new public buildings of a certain percentage of green



continued on next page

Box 1.10 *continued*

roofs or walls, as well as the use of green infrastructure solutions. Compliance with these measures is checked when building permits are applied for. In 2005, the city issued local standard “green roof specifications” (DB2005/11-23) that indicated the basic requirements for green roofs, planting designs, and plant selection. The main bottlenecks identified in promoting green roofs in Beijing were regulations and techniques that are still relatively immature in the PRC, green-roof policies and subsidies that focus only on public buildings, and lack of coordination among various city departments that promote construction of green roofs. Thus far, few private green roof projects exist in Beijing. If the government wants to expand the city’s green roof coverage, particularly in the CBD, it needs to focus on the considerable potential market that the private sector offers by opening up the green roof subsidy scheme to private sector enterprises.

Source: J. Wang 2011.

Urban Farming

Urban farming, an old topic of the ecologists of the 1970s, is making a comeback but this time with more technology and sophistication. While many of the urban agriculture experiments have emerged as means to address food security and the agricultural crisis, many of them today incorporate bolder environmental targets that include CO₂ capture and city greening (Bakker et al. 2000, Mollison and Holmgren 1978, *The Economist* 2010). Vertical farming is back and is being experimented with in Europe, Republic of Korea, and the United States (Boxes 1.11–1.12, Baum 2011).

Some agricultural experts argue that building indoor farms in urban areas will help ensure a reliable food supply for a growing global population. While it is true that vertical farms could theoretically feed billions of people and release food production from dependence on weather patterns and the necessity of long-distance transport of food, the current energy requirements of vertical farming vastly exceed those of conventional farming. This makes price competitiveness of indoor farming dependent on significant expansion of renewable solar- or wind-generated energy delivered at prices comparable to those of nonrenewable sources.

Nevertheless, providing food for the earth’s projected population of 9 billion in 2050 will no doubt require a revolution in agricultural production of one type or another, which suggests that use of vertical farms may be given increasing attention by policy makers concerned with national food security. The Government of the Republic of Korea is currently exploring the use of vertical farms as a way of feeding an expanding population in the

face of the country's relatively short growing season and limited amount of uncultivated arable land. The vertical farm laboratory in operation in Suwon is currently testing vertical farming technologies, the major constraint to expansion of production being efficiently replacing sunlight with artificial light, for example, through the use of light emitting diodes (Der Spiegel 2011). Vertical farming is being developed for Bangkok through an Urban Farm–Urban Barn” project (www.holcimawards.org/apac), and rooftop farms flourish high above Hong Kong (Hui 2012).

Box 1.11 Urban Agriculture



Urban Agriculture on the Mekong River Kaysone Phomvihane, Lao People's Democratic Republic.
Source: F. Steinberg.

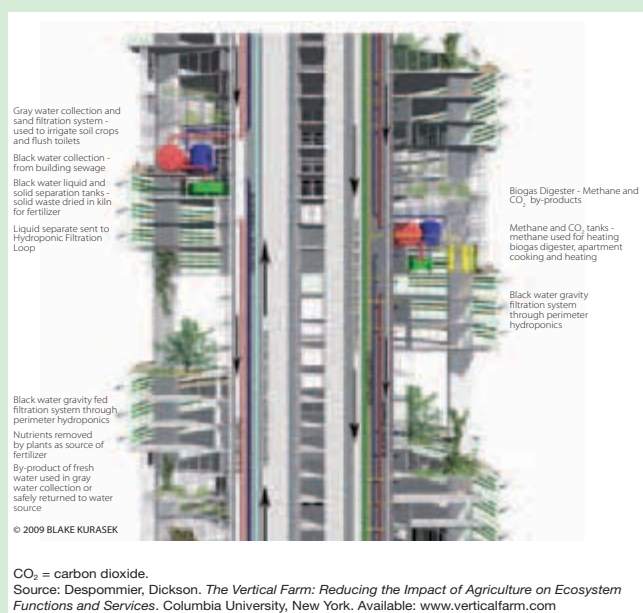
Box 1.12 Urban Farming Going Vertical and High-Tech



Source: Kenn Brown Monolithic Studios.

Box 1.13 Vertical farms

Vertical farming involves growing food within towns and cities inside environmentally controlled multistory buildings that recycle organic, human, and animal waste, and wastewater. Indoor farming is not new, but existing operations need to increase substantially both in terms of output and the range of products produced. The concept offers urban renewal, sustainable year-round production of food, and employment. But government-supported economic incentives are needed so that the private sector, universities, and local entrepreneurs can develop the concept. However, in the end, vertical farm must be efficient, cheap to construct, safe to operate, and independent of public subsidies and outside support.



Source: ADB. 2011b.

Cooling the Public Realm

As the climate heats up, a central challenge for city planners will be to create compact, cool communities whose natural amenities offer alternatives to urban sprawl. However, climate-resilient urban design—drawing from urban climatology and sustainable design—is not well understood, although considerable technical knowledge exists within these fields. There are, however, a number of barriers to implementing climate-resilient design on a large scale, including lack of institutional capacity.

Wind affects temperature, rates of evaporative cooling, and plant transpiration. It is therefore an important factor in implementing district-wide passive cooling strategies at the microclimate level. Air flow across parks, green roofs, and water bodies can accentuate the cooling effect of the wind, while the alignment and design of streets can reinforce external cooling.²¹ It is also important for passive cooling in buildings. For example, streets in Masdar City and in the planned redevelopment of Thanh Hoa in Viet Nam are used to encourage air circulation, fresh air distribution, and microclimate protection (Raven 2010). Parks and open plazas are vital components of such designs (Box 1.14).

Urban ventilation is being proposed in a comprehensive urban development project for Thanh Hoa City in Viet Nam, through urban passageways that enhance wind circulation and improve the microclimate through passive cooling. “Urban morphology is responsible for varying the surface roughness and ‘porosity’ of the city, impacting airflow’s effectiveness in passive cooling and reducing energy loads in the built environment” (Raven 2011).

²¹ Advection, in chemistry and engineering, is a transport mechanism of a substance by a fluid, due to the fluid’s bulk motion in a particular direction. An example of advection is the transport of pollutants or silt in a river.

Box 1.14 City Greening: Thanh Hoa, Viet Nam



Two green park bands in Thanh Hoa City, Viet Nam that stretch throughout the city are oriented toward the sea breeze and the cool night winds. Green and blue fingers – Linear parks and urban forests: Contiguous green corridors, canals and open space networks; conceiving storm water retention as urban design amenities; and enhanced connectivity and transportation.

Source: Raven. 2011.

Smart Technologies: Infrastructure and Digital Technology

Rapid technological developments are exerting profound impacts on urban systems (OECD 1992). Information technology and communication have revolutionized how we can manage the flow of people and goods, and how these are transported. Smart technologies are already utilized for satellite-based surveillance of public transport for the operations of certain logistics and for management of home-based technologies. Intelligent infrastructure that is digital and internet-based complements conventional physical infrastructure as cities and homes become smarter and more sophisticated (Keijer and Sandstrom 2007). Advocates of smart technologies have recommended that more smart technology will help achieve sustainable green cities. Thus, it is suggested to “decrease energy and increase technology” (Albert Speer & Partner 2009). Smart technologies have been

utilized in Singapore and Stockholm²² to administer road user charges and to address traffic congestion in central city areas. In the Republic of Korea, the U-City Initiative has set itself the target of developing “smart” or “ubiquitous” cities: by 2015 some 60 cities will be converted into “U-cities”. One of these is New Songdo in Incheon, where a complete networking of all urban services through sensors is being piloted (Hatzelhoffer 2011). A similar project of the “i-City” is under development in Malaysia.

Intelligent systems such as e-systems and e-governance systems support adoption of information technology systems that integrate these activities, increase efficiencies and cost recovery in each sector, and enable better management of service delivery. These systems provide the backbone of a green city and enable synergies to be achieved across sectors (e.g., more efficient transport and higher-density buildings provide additional energy-efficiency benefits (Espinoza 2011)).

“As cities grow more crowded and complex, they try to keep their residents as constantly connected as possible through cables, wireless networks, and even such traditional tools as call centers, in order to compete with other global cities, but also to stay livable and, to some extent, governable. The urban quest is increasingly that of making high-speed connections available anywhere, at any time, and at a reasonable price. Seoul leads in this regard ...” (*International Herald Tribune* 2011e).

In 2011, the Japanese technology group Panasonic introduced the plan to build Japan’s first smart city “from scratch” by 2013. Located in a Tokyo suburb, the smart town in Fujisawa City, 40 kilometers southwest of Tokyo, will be a showcase of new technologies. Other high-technology companies are also working on their own projects: Honda in Saitama, Hitachi in Yokohama, and Toshiba in Kashiwa. Their aim is to reduce carbon emissions through an intelligent network of electricity grids and new equipment (Tanikawa 2011).

E-Governance and Accountability: The Basis for More Effective Coordination

E-governance is public sector use of information and communication technologies, such as wide area networks, the internet, and mobile computing, to improve information and service delivery, encourage citizen participation, and make government more accountable, transparent, and

²² www.symbiocity.org for SymbioCity, Sustainability in Sweden—Get More for Less, The Swedish experience in urban development.

effective. It generally leads to an improved interface with business and industry, and increased transparency in operations that can lead to reduced levels of corruption.

In general terms, there are three forms of communication flows which can be improved through e-governance:

- government-to-government (G2G), involving the sharing of data and conducting electronic exchanges between public agencies;
- government-to-business (G2B), which offers considerable opportunities for improving procurement practices and increasing competition; and
- government-to-citizen (G2C), which facilitates citizen interaction with government, particularly in making transactions less time-consuming and easier to carry out, improving access to public information, and increasing citizen participation.

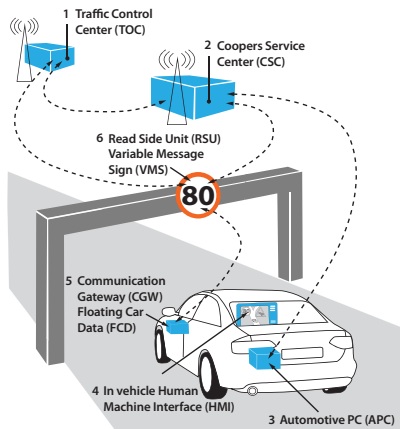
Box 1.15 E-Governance Initiatives in Tirunelveli Corporation, Tamil Nadu, India

e- Governance initiatives for transparent, accessible, and user-friendly citizen services:

- **Street Electricity.** Details of 40,000 streetlights were computerized, and citizens can register complaints about their condition.
- **Compost Yard Online Weighing System.** The weight of collected garbage is posted electronically and uploaded, along with the details of the collecting driver and vehicle.
- **E-Legal Seva.** This intranet-based system tracks legal cases. It handles the corporation's estimated 1,000 cases and is programmed to produce daily alerts of which ones will be heard, in which court, and through which advocate.
- **E-Survey.** A web-based, land-use, and reserved land and land schemes reporting system, e-survey maintains records of land use.
- **E-Town Plan.** This web-based system tracks and processes new construction and renovation applications and posts the details on the internet.
- **Citihelp.** Using this web-based system designed to redress general complaints, citizens can register complaints and download forms with proper help on how to fill them up, the payment required, and to whom they should be submitted.
- **E-Cash Collection Center.** This is a single-window online tax and services collection center.

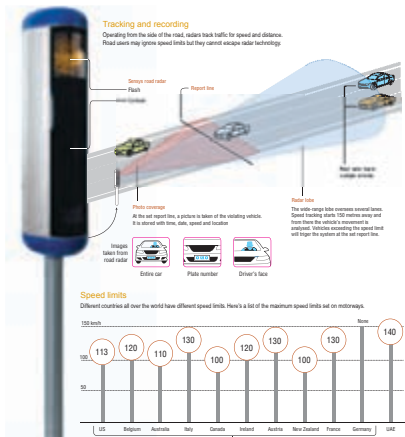
Source: ADB. 2011b.

Traffic Management System being developed by COOPERS, a European research initiative



Source: P. Gilka. 2011.

Road Radar and Speed Limits

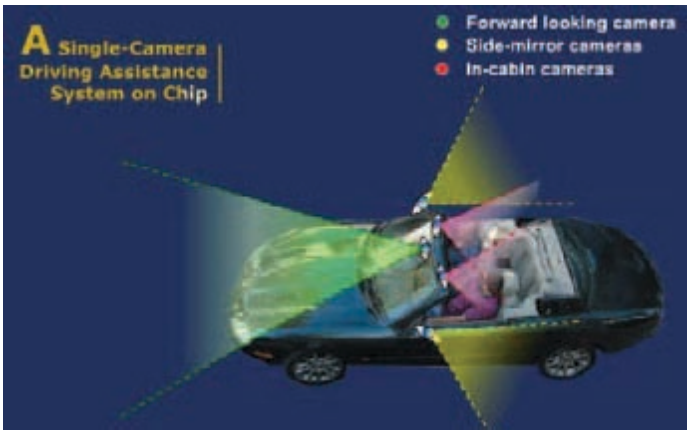


Adapted from: Sensys British Columbia Ministry of Transportation

Source: Sensys, British Columbia Ministry of Transportation, Rhinocarhire.com

“Some cities emphasize the environment, others, infrastructure—whether transportation or information technology—and still others favor other aspects of urban quality of life. While success has been mixed, the trend for cities, rather than nations, is to compete in attracting global investment and skilled professionals” (*International Herald Tribune* 2011c). The plan is to remake our cities and, through them, our lives.

Smart Technologies Assisting Improved Road Safety



Source: www.mobileye.com

Greenfield Development: Overcoming the Ills of Today's Cities?

The Green Cities agenda is most viable as an option for middle- and higher-income countries, as these are developing new towns that will become the cities of the future. Both the PRC and India will have to undertake massive investments in these areas. The growing concern for cleaner and more competitive cities suggests that investing in green and sustainable environmental development will give such cities a competitive edge over conventional high-carbon cities. But also in middle- to lower-income countries, moving upward in urban environmental quality will emerge as aspiration that will foster the gradual transformation of high-carbon cities toward low-carbon performance.

The goal for urban development is to create high-density, efficient space use that can generate attractive mixed land use in urban environments. Compact urban life will reduce the need for commuting and transport, simultaneously reducing carbon emissions. Instead of building cities for cars, there will be mutually interrelated pedestrian-friendly environments. High energy efficiency will be achieved through a high degree of alternative energy forms or the broad application of low-energy or passive energy systems. Urban infrastructure and basic services will become sustainable green services, which will be determined by water availability, water potability, wastewater treatment and waste removal, air pollution, and traffic congestion. The type and quality of such infrastructure will be the benchmark for ecological efficiency and reduction of GHG emissions.

As space requirements for mobility (traffic and parking) are reduced, there will be more options for generating open and green spaces for leisure, sports, and cultural outdoor activities. Development of more compact communities will accommodate affordable habitat in more conveniently located sites. The use of more ecological green and low-carbon building materials will contribute to healthier habitats and working environments, and the application of smart technologies will contribute to higher energy efficiency and increased levels of comfort and efficiency. Many urban studies demonstrate that more dense and compact cities are better cities, but very high density may not be the best option. Rather, it is suggested that compact development and green transit-oriented development are the preferred options, and may be the best model for the PRC's cities and new towns (Lehmann 2009, 713). Preparation of cities for the impacts of climate change and their increased resilience to adapt to new safety requirements will also have spatial implications, affecting zoning and land use. This serves as a reminder that the best cities of the future will be those that are ready and willing to adapt to constant change.

Enabling Green Cities

The greening of cities will be a complex, fragmented, and multisector process. Among the constraints and barriers will be fragmented governance, issues of affordability, and consumer preferences, all of which can lead to lack of investment and risk aversion. Vested business interests in conventional technologies and irrational behavioral patterns will also affect the cost of switching to new green technologies and green lifestyles. Advocates of green city development on the government, nongovernment, and business sides are increasingly joining hands as the rationale for green technologies, energy savings, and a sustainable urban future become evident.

The strategic Plan Sydney 2030 (“a green, global, and connected city”) is oriented to making Sydney a low-carbon city, as Australia’s contribution to fight climate change and global warming (City of Sydney; Siegel 2011). Similarly, Freiburg in Germany, which labels itself as a green city, has become one of the biggest pioneers in “passive energy” solar-based architecture and is home to the German solar panel industry. For coalitions and advocacy to work, practical approaches with mass appeal are needed, which can be funded through user contributions or private sector investment. On the planning and regulatory side, it will require basic ground rules, such as urban growth boundaries, land-use regulations, density regulations, encouragement of density through rewards and bonuses, establishment of entities with special planning and implementation powers, traffic and vehicular control, parking standards, car-fee developments, and emission controls (UNEP 2011, 477). This can go together with public awareness and information campaigns that monitor environmental performance, the carbon budget of a city, and its environmental quality. But the most clearly and well understood measures are incentives or financing instruments.

Incentives and disincentives include (i) fuel taxes that internalize the external costs of vehicle use and provide the financial capacity to invest in green development; (ii) reduction of perverse subsidies such as fuel subsidies, which support long-distance commuting; (iii) tax incentives for investments in energy-saving home technologies and retrofitting of buildings; (iv) road user charges in city centers and peak hours; (v) parking charges for on- and off-street parking; and (vi) limitations on the number of car license plates and auctioning of new ones.

Financing tools for green city developments include (i) value-capture-after-public-transport investments to finance transport investments through land-related taxes; (ii) cost recovery of green infrastructure services; (iii) encouragement of private sector participation through innovative public-private partnership projects; (iv) pooled purchases of technology to bring down individual costs of investment; and (v) carbon credits under

the Clean Development Mechanism for green investments by cities or the private sector.

Lifestyle Changes

Behavioral changes by all urban citizens will be vital (McDilda 2008), but this does not suggest a need to reduce the quality of life. There is merely a need to adjust to new environmental realities, such as how we use water and energy, how we insulate homes and work spaces, how we travel, what goods we buy, and how we process and recycle our wastes. Green is the new way of living; sustainable solutions are the new goal (Von Weizsäcker et al. 2009).

Many private sector corporations and industries that are ready to go green have started to market green as a fashionable and necessary style of life and consumption. Politicians are also joining this trend. European companies have set their eyes on exporting green solutions to emerging markets, and see this as a new export opportunity to the PRC, India, and South America. In turn, even the PRC is banking on development of environment-friendly, green, industrial products. Going green is not only a matter of following and implementing new environmental legislation. Achieving a green lifestyle and green economy will also create new forms of wealth. Urban planners and designers will take this into account. Our future cities will need to become carbon-free, with carbon-negative buildings. New technologies will help, and new social patterns of green city life will complement these developments (Battle 2009). With the speed of developments in turbulent times, however, it appears as if we are crossing a watershed, not being aware of it.

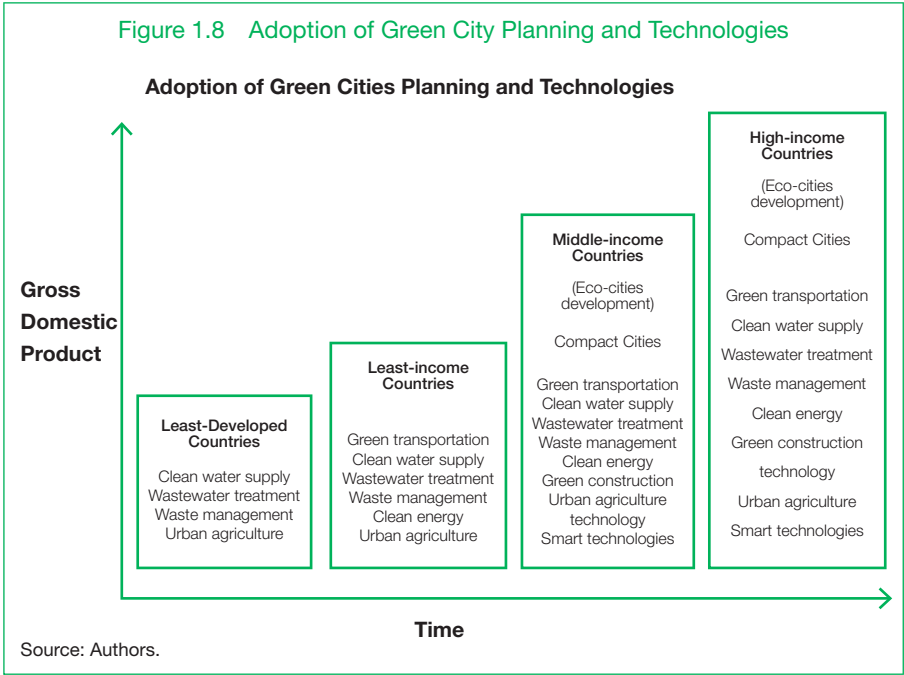
The Political Scenario for the Carbon-Free City

The role of leadership by example and public policy is vital to introducing the greening of cities to the building industry. Government-owned public buildings (administrative complexes, schools, hospitals, cultural buildings, public housing) or government-initiated projects are important opportunities for introducing green construction practices, and for implementing innovation and green public procurement procedures. Regulatory measures and controls should be the most effective and cost-efficient interventions in bringing about the transformation of cities. These need to be combined with pricing instruments to achieve greater impact from the private sector and local communities. Innovative private sector initiatives and green building councils can initiate the gradual transition to lower carbon usage, application of more energy-conscious technologies, and more resource-

efficient buildings. Some industrial corporations have committed to promoting innovative technologies, working toward technologies that foster sustainable urban development through green transport, green energy, and green building technology.²³

It seems that much of what developing Asia has seen during the 20th century is the proliferation of the industrial megacity. The 21st century will see a rollback that tests the sustainable green city, for example, by rolling back carbon emissions. Governments around the world are giving more influence to their lead cities, which, in partnership with the private sector, reinvent the environment of the future. “Cities are essential in the fight to save our planet for future generations...” (Figure 1.8 and Gavron 2009, 385).

Given the urgency of transitioning to green development, and despite the constraints that exist, we can say that it is too late to be pessimistic; there is a need now to be positive and proactive.²⁴



²³ Siemens, which promotes green cities and sustainable urban development globally, is one such example of a corporation working on multiple technology innovations for cities of tomorrow.

²⁴ <http://www.youtube.com/watch?v=jqxENMKaeCU>

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Annex

Sino–Singapore Tianjin Eco-City technical performance standards

Natural environment

- ☐ Air quality should meet at least the National Ambient Air Quality Grade II Standard of the People's Republic of China (PRC)
- ☐ Water bodies should meet Grade IV of the PRC's national standards
- ☐ Carbon emission per unit of gross domestic product should not exceed 150 tons of Carbon (tons-C) per \$1 million

Human-made environment

- ☐ Buildings should meet green building standards
- ☐ At least 12 square meters of public green space per person

Economy

- ☐ At least 20% of energy to be derived from renewable sources
- ☐ At least 50% of water supply to be derived from nontraditional sources
- ☐ At least 50% of employable residents have jobs

Lifestyle

- ☐ Daily water consumption per person should not exceed 120 liters
- ☐ At least 60% of total waste recycled
- ☐ At least 90% of trips within city should be green trips
- ☐ At least 20% of the housing stock will be subsidized public housing

Qualitative Indicators

- ☐ Safe and healthy ecology to be maintained through green consumption and low-carbon operations
- ☐ Development of recycling industries to be promoted, as well as orderly development of surrounding regions

Source: Adapted from the Sino–Singapore Tianjin Eco-City.



CHAPTER 2

Urban Metabolism and the Zero-Waste City: Transforming Cities through Sustainable Design and Behavior Change

by Steffen Lehmann

Introduction and Definitions

By the year 2025, the world's population will reach 8 billion, and almost 60% of those people will live in metropolitan regions, i.e., in cities. Around the globe, urbanization and the growth in metropolitan areas is already affecting nature, biodiversity, food supply, the built environment, and society in profound ways. However, the international community has made little progress over the last 20 years in restraining global carbon dioxide (CO₂) emissions, while an increasing amount of emissions is coming from large developing nations, such as the People's Republic of China (PRC) and India. Because of human activity, the planet is reaching a potentially catastrophic tipping point. Several scientific studies indicate the estimated biodiversity loss between 1996 and 2011 to be around 12%.

An increasing proportion of research in climate change mitigation and adaptation in certain disciplines focuses on the future of our cities and how we will design, build, operate, maintain, and recycle products, as well as on buildings and city districts in a low-carbon urban future. Our research at the University of South Australia examines rapidly urbanizing and changing cities in Asia and the Pacific, and involves not only architects but also cultural studies researchers, contractors and developers, economists, engineers, health professionals, planners, psychologists, and sociologists. Such

interdisciplinary research includes issues of sustainable design and behavior change. It thus aims to rethink the way we deal with material flows; outlines why rapid urbanization is a problem; and discusses possible solutions, new models, and opportunities.

Many Asian cities have existed for a very long time, and one can learn a great deal from their history, such as how such cities became resilient when faced with extreme situations and challenges, and how they have developed in the face of the ecosystem's finite resources. Today, we stand at a crossroads concerning the future of Asian cities. Most cities in Asia and the Pacific have experienced rapid urbanization over the last 2 decades, while growth of the cities in Europe and Northern America has slowed, requiring a renewed focus on urban renewal. Shanghai, for example, has transformed rapidly during this relatively short period, as have Bangkok, Hong Kong, Jakarta, Kuala Lumpur, and Singapore. But are these changes in the right direction and sufficient to achieve the necessary reductions of CO₂ emissions? Are they part of the transition we need to make toward a low-carbon world? I suggest not.

In 2010, our research in the Centre for Sustainable Design and Behaviour examined the concept of *green urbanism*, which is a principle-based, step-by-step approach for urban transformation and retrofitting of existing cities toward sustainability (Lehmann 2010a). This concept has now been developed further into the *zero-waste city* model, which is outlined in this chapter. *Urbanism* is the academic discipline concerned with understanding the spatial organization and dynamics of urban areas, and with comparing, analyzing, evaluating, and inventing new ways to maintain the balance between public and private, the built and the unbuilt, and local and global perspectives. *Green urbanism* is the holistic concept of urban systems that exist and change (grow or shrink) without negatively impacting the ecosystem. It is a particular form of urbanism that is concerned with a healthy balance between the city and its surrounding hinterland. It underpins practical action in order to shape the urban environment in a sustainable way. The *zero-waste city* model takes the concept further, and optimizes all urban material flows in a way that leads to 100% resource recovery, and does away with landfill. *Zero waste* has become a worldwide movement. It considers the entire life cycle of products and buildings, and expresses the need for industrial and societal systems and construction processes that are based on this life cycle. It means that 100% of waste is diverted from landfills, and that all products, buildings, and cities have been designed in a way that allows all resources to be recovered without negatively impacting the ecosystem. Today, raw materials are extracted and processed at an accelerated rate, and substances not directly useful to a factory become unwanted waste, thus polluting the air, rivers, landscape, and soil. The alternative "cradle-to-cradle" system seeks to build integrated, closed-loop systems in which the by-products of one factory become the feedstock of another, so that there is *no* waste. Just as in the natural world, in

which one organism's "waste" is another organism's opportunity, the goal of such systems is zero waste.

Cities are complex systems under stress. Clearly, the current development paradigm in most of the world's cities, which is based on ever-increasing consumption of resources, is unsustainable, and humanity has to find a new paradigm of urban development. In this chapter, we will explore some linkages between material consumption, urban development, and possibilities for resource recovery. The chapter will also suggest zero waste-related principles that can apply to both industrializing Asian cities and existing cities in developed countries such as Australia or the United States. "Waste" has been described as a "misallocated resource" (Lehmann 2010b); however, there cannot be a unified definition of "waste," as each city has different circumstances and waste streams, and needs to identify its particular (localized) waste management solutions. Since climate change is closely related to waste production in cities, the strategies suggested in this chapter address both issues.

Rethink, Reduce, Reuse, Repair, Recycle: the Concept of Zero-Waste Cities

Why is the concept of zero-waste cities important? When we look at the ecological footprint of a city, we need to consider people's behavior, lifestyles and values, policies and legal frameworks, and the future of waste reduction and resource recovery in households and urban settings. *The Principles of Green Urbanism* (Lehmann 2010a) defined the triple-zero frameworks for sustainable urban development as

- zero fossil-fuel energy use,
- zero waste, and
- zero emissions.

Zero waste is an essential part of a holistic design framework that increases a city's capacity to absorb change (e.g., the impacts of climate change). Sustainable urban development that moves toward zero waste includes three high-level, information-rich principles:

- increasing resilience;
- strengthening the interconnectivity of all systems and networks; and
- identifying particular localized solutions that are shaped by relevant site-specific parameters such as climate, context, or site.

Wasteful consumption is defined as the purchase of goods or services that are not used at all, or are not used to their full potential, which results in increased waste. Across the industrialized world, food and energy are the most common examples of wasteful consumption. For example, in Australia and the United States, more than 40% of food purchased is not eaten; instead, it is thrown out (Sharp et al. 2011). More than one-third of all energy used in Australia could be saved if more efficient energy use patterns were in place. The concept of zero waste includes recycling rates above 80%, combined with legislation against all landfills and waste incineration, which produces toxic ash and air pollution, and burns material resources instead of recovering them. The concept of zero waste likewise includes advanced waste treatment processes that allow all resources incorporated into waste to be fully recovered, thus looping and completely closing material cycles (Grosse 2010, Lehmann 2010b).

Implementing material efficiency in the construction sector requires a change in how materials are approached throughout the supply chain. The appropriate selection and use of materials for construction has a significant ecological and financial impact on the construction industry. For example, Santamouris (2001) estimates that each year, more than 3 billion tons of raw materials are used worldwide to produce construction materials, which represents almost 40% of the total flow of resources into the global economy, while the building sector is responsible for 50% of material resources taken from nature. Research by Harland (1993) and Tucker and Treloar (1994) has shown that a high proportion of this material is wasted during the construction phase. In fact, Harland has calculated the total proportion of material wasted as a result of damage or offcutting at the installation stage, spoilage during transport or storage, and inaccuracies in ordering and specifying at about 20%. Similarly, Tucker and Treloar have calculated the embodied energy of construction materials in Australia at 19.5% of total energy use, meaning that a significant amount of the energy that went into producing these construction materials is wasted when these materials are dumped into landfills. Using fewer materials by increasing material efficiency and using deconstructable (reversible) joint systems for easy reuse of entire construction components are promising strategies for achieving significant material—and hence emissions—savings in the construction industry.

To reuse existing buildings would mean to build much less new buildings. Even if the energy-efficient homes are environment-friendly 'passive houses,' it takes a lot of embodied energy to construct them new. Embodied energy includes all energy required for the production of the materials, transport and construction, which are all sources of CO₂ emissions. The balance is even worse if one first needs to demolish a building in order to erect a new one. As a consequence, rather than constantly building new buildings, it is much more sustainable to adaptively reuse existing structures, because

making better use of existing structures means one does not consume so much energy and generate huge amounts of waste. Building waste has emerged as an immense problem. For instance, in Germany, construction-related waste represents 23% of the total waste; and 57% of all waste from construction and demolition cannot be recycled, ending up as landfill. The situation is similar in other developed countries. Therefore, it is timely to focus more on the existing building stock and on upgrading districts rather than on demolition.

Transferring the waste hierarchy (rethink, avoid/reduce, reuse, recycle) into architecture is a radical approach to avoid material and energy waste. Adaptive reuse and retrofitting work done on an existing building requires the architect to consider much more carefully what has already been built and how to best take advantage of the existing structure. Usually, the less change needed when adaptively reusing a building, the lower the amount of energy required, the better the entire process.

Why the Concept of the Zero-Waste City Is Important

While there have been major changes in the way society manages waste streams over the past 2 decades and recycling rates have increased, we are still generating more waste per person each year (Australia's National Waste Report/EPHC 2010). Zero waste is therefore a timely and necessary goal. Materials and resources are being depleted at an accelerating rate, and rising consumption trends across the globe have placed material efficiency, waste avoidance, and recycling at the center of many governments' policy agendas. Resource recovery and the optimization of material flows can only be achieved only through behavior change that reduces both the creation of material waste and wasteful consumption.

Humanity has borrowed from the planet for a long time by exceeding the planet's carrying capacity. Thus, if our societies and the global economy are not transformed, we risk further depletion of virgin materials and even descent into unhealthy urban conditions (Meadows et al. 1971; Callenbach 1975; Von Weizaecker, Lovins, and Lovins 1997).

Each year until 2030, at least 150 million people will be entering the middle class. This will bring almost 60% of the world's population into a middle-income bracket. However, over the same period energy demand is projected to increase by 40%, and water demand is expected to outstrip supply by 40% (WEF 2010).

All this illustrates that our current model of economic and urban growth is driving an unhealthy system, and, as a consequence, we have now passed the limits of our planet's capacity to support us (Wackernagel

and Rees 1996, Brown 2009, Lovelock 2009). If we continue on our current trajectory of population growth, material inefficiency, and increasing resource consumption, there will be an even greater disparity in resource availability between the rich and the poor. For example, over the past 20 years, the amount of waste Australians produce has more than doubled, and it is likely that this amount will double again between 2011 and 2020, since the amount of waste generated in Australia grows by 6%–7% per year. Only about 52% of all waste generated in Australia is currently recycled, which means that 48% of it becomes landfill (EPHC and DEWHA 2010). The situation in cities in the PRC is now becoming similar to that of the developed countries, as the industrialized world's high-consumption development model is now driving gross domestic product growth in the PRC (McKinsey & Company 2009).

In *State of the World 2010: Transforming Cultures from Consumerism to Sustainability*, the Worldwatch Institute (2010) lists many of the environmental and social problems we face today as being symptoms of a deeper systemic failing, which is a dominant cultural paradigm that encourages living in ways that often run directly counter to the realities of our planet's finite resource base. Consumerism has spread around the world, and hyper-consumerism (an extreme form of overconsumption) has led to ever more unsustainable consumption levels. The report states that if this pattern spreads further to rapidly developing and urbanizing societies in the PRC, India, and Viet Nam, there will be little possibility of successfully addressing climate change, or any of the other environmental problems that are poised to disrupt human civilization. The Worldwatch Institute's program director, Eric Assadourian, notes: "It will take a sustained, long-term effort to redirect the traditions, social movements, and institutions that shape consumer cultures towards becoming cultures of sustainability" (Worldwatch Institute 2010, 36).

We are recycling more waste per person, but we are also producing more waste. Increasing consumption is not always visible because "the increase in recycling and the reduction of waste sent to landfill can hide our increased levels of consumption and waste generation" (Zero Waste SA 2010). Recycling is an important part of waste management, but it is far better to avoid waste creation, reduce resource and material usage, and reuse components and materials in remanufacturing. Far too much toxic e-waste (i.e., waste from discarded electronic devices such as mobile phones, computer monitors, and the like) still ends up in our soil and rivers, potentially polluting our drinking water, soil, and air; and organic waste ends up in landfills, emitting methane (National Waste Report/EPHC 2010).

In 1974, Californian environmentalist Paul Palmer coined the notion of "zero waste." Two decades later, the German philosopher and urban planner Karl Ganzer came up with the concept of "change and prosperity without growth," something still unimaginable today for most politicians and

economists (Hannemann 2000). Instead, hyper-consumption continues. Passing sustainable limits has consequences, as we see in increasing global warming and changing weather patterns, declining availability of natural resources, loss of biodiversity, and an increase of desertification. Things have to change.

We must make every effort to future-proof the built environment by designing and building more resilience into urban systems. By doing so, we will learn from nature's complex ecosystems and natural ordering principles (i.e., nature knows no waste) and will redefine our industrial ecology to change the way we produce, manufacture, package, transport, and reuse products and materials. We are involved in a green revolution, which has already started to transform our society, economy, energy and transport systems, waste management systems, and our design of products and buildings in a way that makes them more modular, thus facilitating their easy disassembly at their end of life so that they can be reused. New strategies for reorganizing the urban landscape are emerging, and the logical next step is to go further and rethink industrial systems, production processes, and construction methods.

Waste recycling alone is insufficient. Programs for sustainable consumption, waste avoidance, and resource recovery are needed to allow humans to enjoy material well-being as well as environmental quality (UN-HABITAT 2008, Grosse 2010). Changes at the cultural and behavioral level—beyond the usual emphasis on technology and efficiency—should help develop less materialistic values that support people's lifestyles without reducing our living standards.

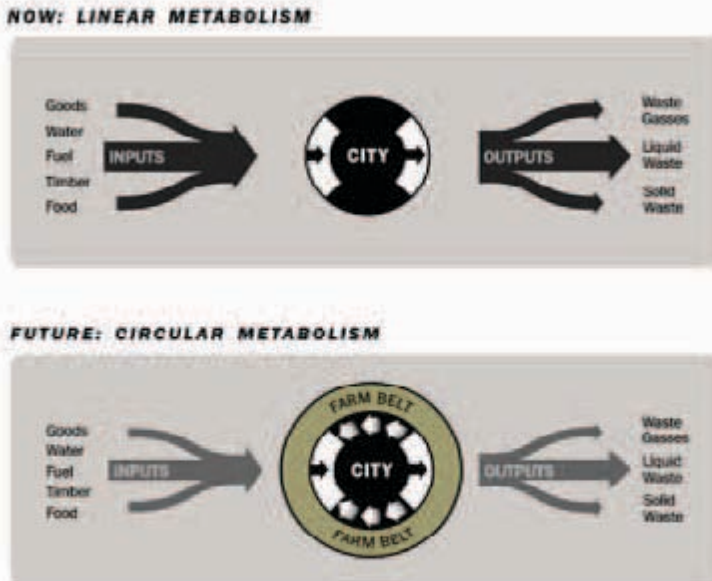
Transformative Change at Systemic Levels toward Sustainable Consumption: From Consumers to Citizens

Over the past 2 decades, a transformation has taken place, as hundreds of millions of people moved from a rural existence to an urban and increasingly globalized one, thus contributing to a rapid rise in consumption. This transformation, combined with growth in the global population forecast to reach 9 billion by 2050, has led to increasing scarcity of some natural resources and escalating global warming. Today, humanity's ecological footprint is in ecological overshoot: not only is it 50% greater than the earth's capacity to support it, it is forecast to rise by an additional one-third by 2030.

How can sustainable consumption be achieved? A rethinking of the idea of seemingly "endless growth" began in 1972 with the Club of Rome's report *The Limits to Growth*, which argued that urban development and lifestyles should move toward the creation of value and well-being. Now,

transformative change at the systemic level is needed to shift the global population from being passive consumers to active citizens, fully aware of their choices and abilities in contributing to a less consumptive future. The theoretical concept of *decoupling* consumption and gross domestic product growth (which see throughputs as the sole measure of economic progress) from the use of natural resources and its broader environmental impacts has been understood for some time. However, implementations of such a notion have proved difficult and slow (Figure 2.1a).

Figure 2.1a Urban Metabolism



Source: Lehmann (2010a).

The city of tomorrow must be transformed from an unsustainable linear throughput of materials to a closed-loop circular metabolism, in which materials, energy, water, food, and other resources are fully recovered and continuously circulated for material gains and greenhouse gas reduction. The Centre for Sustainable Design and Behaviour is researching the transformation of existing cities at the neighborhood level by envisaging and designing new models of low-carbon cities (Lehmann 2010a).

The waste hierarchy, which assigns the highest priority to waste avoidance and (adaptive) reuse, can be applied to both architecture and urban planning.

Figure 2.1b Waste Hierarchy



Source: Lehmann (2010a).

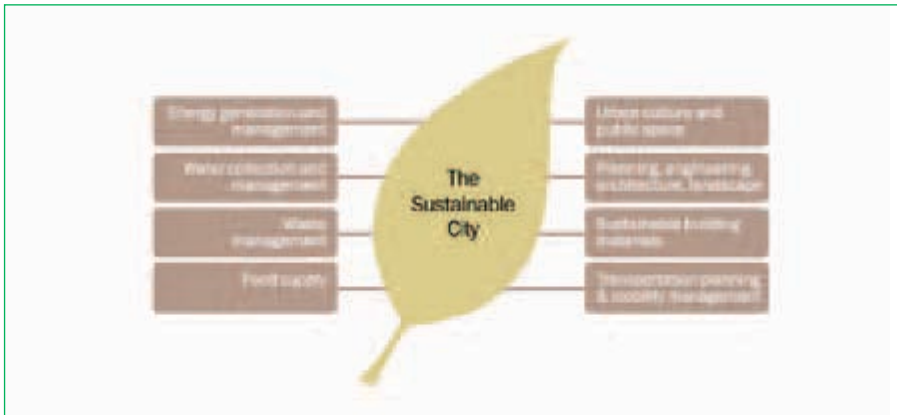
Applying the principles of design to recycling and disassembly allows existing buildings to be upgraded, reused, and retrofitted. The most sustainable building is the one that already exists (Lehmann 2010a).

The sustainable city requires holistic systemic solutions as well as targeted action at the local level (Lehmann 2010a).

The question is: Will we be able to *decouple* rising levels of affluence and consumption from waste of materials and products fast enough? It is well documented that higher levels of extraction, processing, and use of materials have led to increasing levels of environmental degradation. Yet, the pace of environmental change has been too slow to keep up with the increases in consumption levels, and thus to curb the escalating use of natural resources and rising tide of environmental degradation that we are now facing. Some businesses and industries have already moved to more resource-efficient production processes that incorporate whole-life cycle approaches (including extended producer responsibility), improved transparency, and adopted more sustainable supply chain management (and sourcing decisions). However, this transformation is proceeding at too slow a pace to counterbalance the rate at which consumption is expanding in the developing world.

This is why it is time to accelerate, scale up, and most effectively implement sustainable consumption that empowers consumers to act

Figure 2.1c Holistic System Thinking



Source: Lehmann (2010a).

as citizens and help change public policy. To achieve this, we need to change our approach to start catalyzing the transformation needed. Values and behaviors are relatively difficult to change, as they are often instilled in childhood and acquired in the early years of education. Implementing sustainable consumption will require a shift in focus in the following areas:

- shifting from defining and analyzing the case for “sustainable consumption” to identifying and accelerating the policies needed to drive the change that is required;
- moving beyond the discussion of why sustainability is important, toward identifying leverage points that will allow us to tip the global economy as a whole toward sustainable consumption;
- integrating the concept of sustainability into innovative business models and product design, creating new markets based on different models of value, identifying new ways to engage with consumers (e.g., incentivizing environmentally preferable behavior);
- influencing values and attitudes in a way that encourages reconsidering what consumption means, thus beginning a transition phase of reduced, decoupled consumption (e.g., using products for longer periods and producing more durable products);
- implementing public policy that includes sustainability incentives that help transform the context in which consumer decision making takes place;

- encouraging industry and business to transform their practices and to improve investor accountability by reporting outcomes in terms broader than shareholder financial return; and
- encouraging a new generation of products and buildings that are designed with resource recovery in mind—designing for modularity and disassembly, reuse, and zero waste; closing recycling loops; and using fewer materials to deliver the same quantity of products or services (Lehmann 2011b).

In *Designing for Zero Waste: Consumption, Technologies and the Built Environment* (Lehmann and Crocker 2012), I discussed the need to fundamentally change the way we consume, by designing for human experience rather than acquisition. This is about reconceptualizing the consumer as a citizen. Usually, after our fundamental needs have been met, the acquisition of more “stuff” is unlikely to make us more satisfied or happy, since ownership often brings with it more concern than happiness. Consumption has been described as a fundamental human cultural expression with a short time horizon that serves many goals or aspirations, including status, wealth, celebration, or success. Yet, if the trend of growing consumption continues without a fundamental change in the way we consume, we will face a very challenging future (McKenzie-Mohr and Smith 1999, Cooper 2010, UN-HABITAT 2010).

Therefore, the greatest potential for environmental sustainability lies in our ability to transcend existing paradigms and to influence the values and consumption patterns of citizens, thus motivating a change in behavior (Lehmann 2011a). Today, consumers have emerged as the key shapers of the global economy through their product choices, consumption patterns, and engagement as members of communities. Setting social norms for sustainability and recognizing the influence of context on decision making could offer a new way of unlocking citizen engagement that leads to reduced consumption.

This might be accomplished through the use of environmental standards, or public awareness campaigns that support environment-friendly behavior. Such campaigns have now become increasingly commonplace and can be highly successful. For example, the total amount of waste recycled in the United States increased by 24.4% from 1995 to 2000 following the launch of a public awareness campaign proposed by the nongovernment organization Environmental Defense (AD Council 2001).

Cities as the Solution: Urban Form, Sustainable Consumption, Inefficient Suburbs, and Localized Responses for Waste Management

Cities with the largest ecological footprints have a sprawling urban form, their maintenance requiring vast tracts of land, a relatively high degree of automobile dependency, and massive energy consumption. Living in distant suburbs far from workplaces is costly for residents, takes a health toll in daily traffic congestion, is inefficient for infrastructure provision, and consumes significant amounts of space and precious farmland. A successful city has a high-quality public space network that makes walking pleasant, something totally missing in suburbs. Investigations by my research center suggest that as density decreases, per capita demand of resources such as land and energy, and costs for infrastructure increase. Furthermore, suburbs often end up becoming social wastelands, in which people are disconnected from neighbors and television becomes a substitute for personal interaction. Politicians should prioritize finding solutions to urban sprawl, an important part of any program aimed at this goal being to revitalize city centers, and to transform already-built suburbs into more dense and mixed-use subcenters.

Compact, mixed-use, transit-served infill development has been proven to be both sustainable and more likely to result in social contacts. In fact, Australian cities are now witnessing more and more people moving from the suburbs to city centers (Mees 2010). We know that the sprawling model of American urbanization that features automobile dependency, inefficiency, and consumption of agricultural land is not sustainable. More population-dense Asian cities such as Hong Kong, Seoul, and Singapore can teach us much about successful integration of public transport. High-rise living in tall towers might not be the solution for Australian cities, but our aging population and increase in the proportion of single-person households requires us to develop better models for inner-city living, preferably in compact three- to eight-story infill buildings. Urban planners, developers, and municipalities need to end unsustainable land use, and replace the 20th century greenfields-turned-into-suburbs development model with something more sustainable.

The urbanized environment is increasingly where waste reduction solutions must and will be found. Every city will have to find its ideal set of solutions, or localized responses, to resolve questions of material flows and the management of waste streams (Lehmann 2010b). Local responses to globalizing forces will depend partly on the inter-linkages in governance from international structures, through multilateral organizations to nation-states, regions, and localities, as mediated through social-local identity (i.e.,

identity derived from the connection between where we are and what we believe (Cherni 2001). It is possible, as Stasinopoulos and his colleagues (2008) point out, to apply a “whole-system design” approach alongside a more integrated approach to engineering. They argue that “whole system design is increasingly being seen as one of the most cost-effective ways to both increase the productivity and reduce the negative environmental impacts of an engineered system” (Stasinopoulos et al. 2008, 32). The focus on design is critical: the output of the design stage of a project locks in most of the economic and environmental performance parameters of the designed system throughout its life cycle, which can span from a few years to many decades. It is now widely acknowledged that all designers—particularly engineers, architects, and industrial designers—need to understand and implement a whole-system design approach, because as Stasinopoulos and his colleagues (2008) explain: “advances in energy, materials, and water productivity can be achieved through applying an integrated approach to sustainable engineering, to enhance the established systems engineering framework, from passenger vehicles and computer systems, to the temperature control of buildings and domestic water systems.”

William Rees (1996) noted that the ecological footprint of high-income, high-consuming cities is approximately 200 times their physical land area. This means that the amount of land required to produce all the resources consumed in these unsustainable cities is 200–300 times greater than the physical space the city actually occupies. If one excludes food and energy from this estimate, the amount of goods consumed and the resources required to produce them along with the materials used to physically construct the city would require an ecosystem area (assuming global average bio-productivity) of more than 40 times the city’s physical size. Of this amount, approximately half is attributed to the consumption of goods and half is attributed to the materials used to construct the city (Young and Sachs 1994).

Household Behavior and the Impact of Everyday Lifestyles

The other important aspect of creating zero-waste cities is individual consumption, which is driven by affluence, as residents of wealthier cities consume far more and have larger per-capita ecological footprints (Wackernagel and Rees 1996). We must avoid generalizing with regard to inner-city living. Individual consumption levels must be factored into overall ecological footprint calculations. For example, Sydney’s land-efficient city center has residential high-rise buildings with a larger ecological footprint overall than its inner-ring suburbs that are connected to public transport.

This is because of the high-consumption lifestyle of the wealthy population that inhabits the city's towers and the additional energy needed for lighting large common areas and lobbies and the running of elevators (Perkins et al. 2009, Major Cities Unit 2011). Inner-city high-rise apartments may cater to high-consumption lifestyles, but at the same time, Perkins and his colleagues (2009) note, urban consolidation through more compact inner-city mid-rise housing developments provides opportunities for significant reductions in energy use and greenhouse gas emissions.

An important issue in the discussion of zero waste is therefore the analysis of consumerism, consumption patterns, and lifestyle and behavior change, particularly at the household and building scale. This requires more research to explore the complexity of how urban form influences and drives consumption and lifestyle, people's motivations and attitudes, values and behavior, and the dynamics of social change.

Household daily behavior is increasingly seen by researchers as the starting point for change. There is a complex interplay between policy initiatives and individual behavior which points to the difficulty of mobilizing shifts in beliefs, lifestyle values, and consumption patterns. Our behavior in our homes (e.g., our recycling habits, consumer choices, and transport preferences) has a significant impact on the environment, both locally and globally. This is clearly visible in household behavior as regards waste and recycling, food consumption and food waste, and transportation patterns and mobility choices. Among the researchers who have explored these links is Patrik Söderholm (2010), who argues that "we need to gain a better understanding of how environmental policy enters the private, domestic sphere, and how it influences household behavior, to generate behavior change at the household level and the move towards sustainable societies."

Our experience at the University of South Australia is that the most successful research projects relating to sustainability are those in which the community is involved, and those that enable stakeholders to identify with the outcomes of their activities. Changing behavior is not easy; it usually begins with greater awareness (e.g., enabling consumers to visualize carbon emissions and energy use through the use of smart meters). Education for raising awareness is essential, but equally important is the necessity of explaining the rules and benefits of waste separation. This suggests that the problem is not solely technology but also the acceptance of behavior change. It appears that changing behavior is easier in smaller towns and more difficult in larger cities (Taylor and Philip 2012).

Sustainability theorist Tim Jackson (2006) notes that "[c]onsumption drives our economies and defines our lives; making it sustainable is an enormous and essential challenge" and that "the problem of changing

consumer behavior and making our lives more sustainable continues to challenge opinion-formers and policy makers alike.” The question of how best to build cities, buildings, and products, and the issues of lifestyle and behavior are what will likely make the difference between the irreparable destruction of our ecosystem and the healthy evolution of our civilization.

Zero-Waste Concepts for the Future: State-of-the-Art Approaches and Future Possibilities

The concept of the zero-waste city is based on zero use of landfills and a circular closed-loop ecosystem in which waste is constantly recycled, recovered, and turned into resources. Similarly, urban planning in the context of the zero-waste city includes reducing, recycling, reusing, remanufacturing, and composting waste and materials. This significantly reduces the overall volume of waste, since waste is diverted from landfills and is not incinerated. Likewise, all goods and building components produced are fully recyclable, and waste is constantly turned into new products. Finally, extended producer responsibility and product stewardship principles are in place for all products, and “waste” is seen as a resource that must be recovered (Lehmann and Crocker 2012, Figure 2.2).

Figure 2.2 The Six Categories of the Zero-Waste City Model



Source: Lehmann and Crocker (2012).

The holistic zero-waste city model, has six interconnected categories (indicators) that need to be addressed simultaneously to recover 100% of resources used. "Waste" is a misallocated resource that is precious (Zaman and Lehmann 2011).

Recycling metals, glass, and cardboard became common practice in the 1980s. The most serious waste management challenges today are the immense quantity of materials and the ever-increasing complexity of the waste mix (e.g., plastics and e-waste). Energy, water, and material use are all closely interconnected. The limited emphasis of industrial economies on productivity necessarily results in large volumes of waste, as whole-of-life approaches are not incorporated into its narrow definition. Products and services with a lighter ecological footprint must replace less efficient ones. New advanced waste treatment technologies such as anaerobic digestion of organic waste, biofuel production from sludge, and new composting methods are constantly being developed, as are more efficient production methods.

The toxic substances contained in dumped e-waste are poisoning humans, animals, soil, air, water, and food. However, while the unbridled consumption of information technologies destroys the ecosystem, we are made to believe that rapid technological turnover is necessary and is an indicator of "progress." Maxwell and Miller (2012) note that "e-waste has mostly been produced in wealthy nations (Australasia, Western Europe, Japan, and the United States) and dumped in emerging economies in Africa, Asia, Eastern Europe, and Latin America, and in the PRC, though this is changing as India and the PRC generate their own deadly media detritus."

Future ecological models of business and urban development will be about systems integration and innovation at all levels:

- Existing communities will be retrofitted at the same time as we develop new ones. Architecture and design will be less about new buildings and more about retrofitting, urban renewal, and adaptive reuse of existing buildings and neighborhoods as vehicles for increasing resource efficiency. We already see examples of old shopping malls being converted into high-density, mixed-use developments.
- Food production will be returned to the city through urban farming. Building efficiency will be improved, and public transport will be given priority over private vehicles. Increased investment in food security and public transport will become common practice.
- Private cars will increasingly be seen as a waste of urban space, and public spaces will be upgraded to make walking and cycling more pleasant and safer. In most Asian cities, public space needs significant

upgrading such as improving waterfronts and the amount of space between buildings, and creating better opportunities for intergenerational social interaction.

- Sustainable designs will be developed inspired by nature, where waste is seen as a resource and organic waste is used as a fertilizer. Recycled waste will create new building materials, and renewable energy's potential will be fully unleashed, harnessing wind, geothermal, solar, and biomass resource technologies to feed into a smart grid that allows feeding-in of energy from decentralized renewable sources. We will change the way we generate energy and see more and more decentralized systems on roofs and facades. Cities will become power stations, and citizens will become energy producers as well as consumers.

Cities need to be reengineered to become more sustainable and resilient. The public space network of a city is also very important. It can be observed worldwide that vibrant and successful cities have a high-quality public realm as their centerpiece, with well-developed pedestrian connectivity, beautiful green spaces, and well-designed public waterfronts.

Residential building construction is also about to change, as mid-rise (4- to 8-story) insertions within the existing urban fabric are gaining in popularity. This will help reduce unsustainable suburban housing built on greenfield sites and precious farmland. The inner-city residential infill buildings of the future will focus on weight reduction by using lightweight construction systems and cladding, these buildings being constructed with low-carbon construction systems that use high-performance timber panels (cross-laminated timber). Building more mid-rise infill housing using prefabricated modules with timber is essential, as carbon sequestered in trees becomes stored in wood products for the duration of the product's useful life. This stores carbon and has the potential to turn buildings into "carbon sinks," while increasing resource efficiency and reducing the waste of materials associated with current construction methods (Figure 2.3).

Modular prefabrication using low-carbon construction systems such as cross-laminated timber panels will enable zero-waste construction, thus making a high degree of material efficiency and control of reduced embodied energy possible.

Figures 2.3 Prefabricated Engineered Timber Buildings Store Carbon



Photos: Lehmann, 2012.

Multistory inner-city housing project on Wagramerstrasse, Vienna (2012): 100 apartments have been built in 3- to 8-story timber buildings, storing approximately 2,400 tons of carbon dioxide in the construction system and creating significantly less waste. The system uses prefabrication and on-site assembly.

Overcoming Barriers to an Energy- and Material-Efficient Low-Carbon Future

Growth in human consumption is the transcending problem of our times. Peter Newton (2011) points out that in the short span of 50 years, high-income societies have shifted from an era when a simple life was the norm, to one in which material consumption is pervasive and consumption is the engine that drives postindustrial societies. The livability of cities in these societies is directly attributable to the consumption of resources, indirectly via their built environments and directly by their residents. He concludes that this pattern of development is not sustainable nor equitable.

However, designing with an eye to resource and energy efficiency is not straightforward. In *The Myth of Resource Efficiency*, Polimeni and his colleagues (2009) describe what is known as the *Jevons Paradox*, which was first identified in 1865 by Australian engineer William Stanley Jevons in relation to the use of coal. The paradox Jevons observed is that an increase in the efficiency of using a resource frequently leads to increased use of that resource rather than to a reduction in its use. This phenomenon is also referred to as the “rebound effect,” which causes previous gains in efficiency to be overwhelmed by increased use of the resource in question. The paradox has been proved to apply not just to fossil fuels, but also to other resources. Many scientists and policy makers argue that future technological innovations will reduce consumption of resources. However, the Jevons Paradox explains why we have to examine such an assumption carefully.

Because of the Jevons Paradox, researchers are increasingly focusing on behavior change and reuse of materials as a means of reducing the resource intensity of production processes and consumption patterns. However, such a shift in focus raises the questions as to how you engage those who cannot or do not want to imagine a different future.

Behavior change has frequently been listed as the main hurdle to a more energy- and material-efficient, low-carbon future. We therefore need to plan better cities and design better buildings and products that need less energy, water, materials, and other resources, thus generating less waste while at the same time facilitating positive behavior change through innovative design. We also need to enable people to identify the consequences of their activities. For example, we can help people living in city centers to be less dependent on air-conditioning and automobiles by offering attractive new types of housing that are based on passive design principles.

Materials and goods are often discarded long before their usefulness is exhausted. There is thus enormous potential for waste reduction by reusing and remanufacturing materials, construction materials in particular (Lyle 1994, Girardet 1999). However, designing for reuse at the household level remains under-researched. Products, packaging, and even entire buildings can be reused and recycled through adaptive reuse, this goal being embodied in the slogan “Every reused item is another item not purchased” (a slogan which was popular in Singapore in the 1970s). A good example of the practical implementation of adaptive reuse principles is the legislation recently proposed by the Government of Australia that encourages reduced packaging and introduces extended producer responsibilities (GPSC n.d.).

Fisher and Shipton (2009) have explained that “the reuse of packaging has a significant effect on the quantity of material that enters the waste stream, and the energy, and consequently carbon, that is expended in its production.” Most of the factors influencing the potential for reuse relate to design specifics, including the type of materials used, the flexibility and adaptability of a building’s plan and section, or the symbolism of the product’s branding. Other factors are more social, such as the effects on reuse of the perceptions of different groups of consumers. Research in consumption patterns and behavior change is still in its infancy, but is growing in importance. Fisher and Shipton (2009) point out that “understanding consumers’ behavior is significant for moving towards sustainability through design.” Recent research suggests that we have to increase our resource efficiency by a factor of five. This means using five times less material and fewer resources to produce the same quality of life (Head 2008). In addition, since being resource-efficient in this way requires innovation, it will probably create new areas of employment.

Both short-term and long-term strategies capable of implementation in both the developed and developing world are required to bring about the desired change toward zero waste. If we can bring about a cultural shift that makes living sustainably as “natural” as today’s consumer lifestyle feels, we will not only address urgent environmental crises but also create solutions to problems not usually seen as environmental issues, such as income inequity, housing affordability, obesity, and social isolation.

Globally, consumption continues to increase. How people consume resources matters more than the sheer number of people on the planet, or the population of a particular city. While wealthy nations have for quite some time consumed more resources than emerging economies, the resource consumption levels of emerging economies are increasing rapidly. It is becoming clear that the consumption of resources now enjoyed in the wealthiest nations will be impossible to sustain for all nations. Developing countries still have the advantage of low consumption and a smaller ecological footprint per person. It is important to understand that cities in today’s developing countries simply cannot develop in the same way that car-dependent Australian or US cities developed in the past. Instead, they need a model of urban development that transforms the emissions-intensive industries, wasteful supply chains, and outdated construction methods of today’s developed countries into production and consumption patterns that lead to long-term environmental sustainability.

To implement such a holistic model, we will have to abandon the aspiration to consume ever more and begin the transition to a low-carbon world. This means both making better, more efficient technologies available, and also mobilizing changes in behavior and attitudes. Indeed, approximately 25% of the reduction in emissions will have to come from behavioral change. A recent study in the United Kingdom (Seyfang 2009) indicates that unsustainable habits, behavior, and consumption patterns are responsible for up to 40% of CO₂ emissions.

Research That Meets Global Challenges

Universities are leading the search for low-consumption, low-carbon, and zero-waste solutions. Advances in knowledge, together with an awareness of the complexity of today’s world, have led scholars to pursue multifaceted problems that cannot be resolved from the vantage point of a single academic discipline. Therefore, universities are increasingly engaged with industry, governments, community groups, and other institutions to support multidisciplinary and integrated approaches to research in urban systems thinking. Now is the time to scale up the scholarship in low-carbon urban solutions and sustainable consumption patterns to match the magnitude of

the challenges we are facing, and to support the development of appropriate policies. Collaboration across sectors is critical, because in addition to influencing policy and legislation, collaborative research into a low-carbon and zero-waste future will facilitate development of a responsive plan for transforming existing cities. It is therefore critical that our efforts support long-term planning and research that is consistent with agreed national priorities, if holistic whole-of-life cycle approaches and a transformed construction and development sector are to be achieved.

We need a new, higher-quality level of debate and discussion between economists, planners, scientists, social scientists, and decision makers that leads to transparent governance, smart regulations, scientific accuracy, and broad participation. We should also broaden our definition of gross domestic product to take account of natural resources and view economic growth and sustainability as complementary rather than competing goals. To do this effectively, we need research that helps us understand motivation and commitment, so that we can better understand what motivates people to aspire to sustainable living. This involves technological change, but much more importantly behavioral change.

In order to meet the global challenges identified in this chapter, more investment is also needed in research, innovation, education, and training. Much of the work being undertaken at the University of South Australia is about developing better models, making recommendations, and establishing best practice guidelines to help cities and municipalities improve their urban governance and sustainability plans during this difficult transition phase. We are convinced that the cities of Asia and the Pacific can use rapid urban development to their advantage, and possibly become global exemplars of green eco-cities (Figures 2.4 and 2.5).

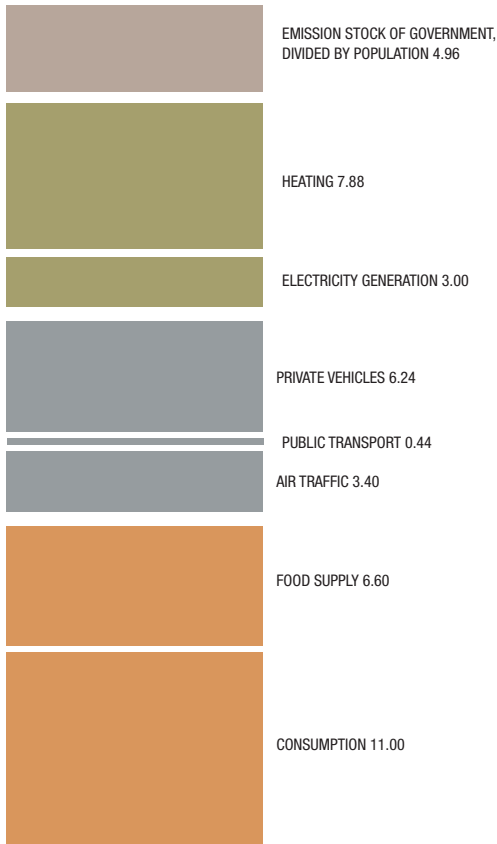
Figure 2.4 Diagram of the Eco-City



Source: Lehmann (2010a).

Figure 2.5 Annual CO₂ Emissions

An average 4 person household in Germany produces around 43.5 tons of CO₂ emissions per year



Source: Lehmann (2010a).

The eco-city is characterized by interlinked challenges and a healthy balance and equilibrium (symbiosis) between the urban core and its rural hinterland. There is an urban growth boundary that respects and protects precious farmland and forests, and prevents the city from growth at the expense of its surrounding landscape and supporting agricultural system (Lehmann 2010a.)

Annual CO₂ emissions of an average four-person household in Germany produce approximately 43.5 tons of CO₂. At 25%, the percentage share

of general consumption in total CO₂ emissions is by far the largest of all sources of CO₂ emissions, and is also the source that is most influenced by behavior and lifestyle (Lehmann 2010a, after Umweltbundesamt 2009)

Conclusion and Outlook

The challenge is that almost every aspect of modern civilization is still powered by fossil fuels, and the abatement in CO₂ emissions has thus far been minuscule. The ideas in this chapter are an initial step to improving understanding of the complexities of city dynamics within the context of urban material flows and waste management. Additional research is needed to gain a better understanding of the drivers influencing the sociopolitical, economic, and environmental aspects of urban waste: the urban metabolism.

To resolve the issue of global warming, we need to concentrate on innovating more affordable green technology through a massive increase in research and development. It has become obvious that we will get nowhere until we can make green technologies and processes less expensive than fossil fuels. Recent history suggests that when living standards in the developing world go up, people and societies reduce their polluting behavior, stop cutting down forests, and have fewer children. In short, helping people in the developing world to emerge from poverty is one of the best things we can do for the environment.

This chapter advocates an innovation-centered approach that focuses on material efficiency, construction technology, and behavior change as the primary vehicles for scaling up clean-energy and zero-waste technologies. Each city needs to develop its own targets and implement its own low-carbon development plan to become a low- to no-carbon and zero-waste city. We have now reached a tipping point at which our larger agenda of sustainable urban development requires the planning and urban design professions to take a leading role in working with the government to reduce our high levels of consumption and resource waste.

Zero waste requires new designs for the built environment that address resource scarcity in order to influence our behavior in a way that reduces our consumption of materials and ecological footprint, and thence greenhouse gas emissions. The concept of the zero-waste city is a way of thinking that will become even more commonplace and important as our cities, urban population, and related consumption levels keep increasing.

The rapidly growing cities of Asia and the Pacific are in a unique historical position to define and shape forward-thinking ideas about optimized urbanization and urban management that avoid the mistakes made in the

western world during the 20th century. Our governments need to implement visionary policies that draw on available research in order to achieve an energy-efficient, low-carbon, zero-waste economy that is not dependent on fossil fuels.

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CHAPTER 3

Energy Strategy for Green Cities

by Thomas Hurst, Debra Lam, and Malcolm Ball

Introduction

Energy has fueled societal development since time immemorial. However, only when we learned to harness, store, and use energy on a significant scale did the pace of development accelerate. One of the major factors that facilitated the Industrial Revolution was access to cheap and plentiful fossil-fuel energy. This revolutionized the way we traveled, worked, and consumed goods and services—indeed, every aspect of our lives. Fossil fuels enabled rapid personal transport over long distances, machines with more power than any team of horses, and mass production of materials and products that raised our quality of life. However, all of this increased our demand for energy.

Ultimately, the creature comforts that widespread access to energy delivered came at significant social and environmental cost, including climate change, air and water pollution, acid rain, and deforestation. In the political sphere, the realization that fossil fuels are ultimately finite in supply created international political upheaval and war. However, as long as the fossil-fuel energy kept flowing, we were able in the short term to ignore the inevitability of its depletion, that it would become increasingly difficult and expensive to extract, and that one day our energy supply would become open to disruption by parties over whom we had little or no control.

While our societal development continues to depend on access to energy, three issues surrounding it have changed the way we think about it and use it. These are (i) security of supply, (ii) price, and (iii) the carbon intensity of our development trajectory. Nowhere are these issues more pressing than in our cities, which account for the bulk of the greenhouse gas (GHG) emissions that drive climate change. International pressures, national legislation, and growing public awareness of climate change, air pollution,

and environmental degradation are all requiring a change in approach to fueling our cities, and ultimately, energy-use solutions consistent with long-term environmental sustainability.

While individual cities have traditionally had limited control over their energy-use patterns, today's urban air pollution levels and degree of vulnerability to the long-term negative impacts of climate change have caused cities to take a greater leadership role in their modes of energy use. In addition to formulating carbon-use targets and seeking opportunities for green urban development, some cities are implementing bold policy regimes and investments that support low-carbon growth trajectories, these being underpinned by creative financing arrangements.

However, formulating a holistic, long-term, urban energy strategy appropriate to a particular city's context requires considerable effort. In fact, successful strategies of this type are preceded by three major phases of development: (i) building a knowledge base, (ii) performing a strategy analysis, and (iii) formulating low-carbon-use programs. In this regard, many cities can make use of the experience gained in other urban settings throughout the world.

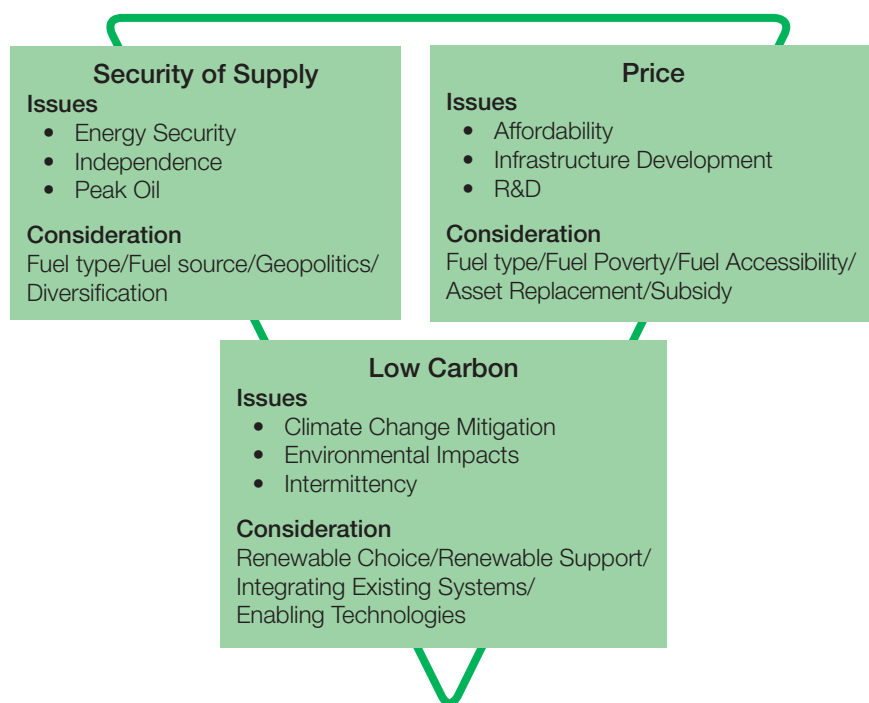
While this chapter is replete with numerous examples of energy strategies that have been successfully implemented in cities around the world, the examples presented by no means represent an exhaustive list of opportunities for formulating urban energy-use strategies. Cooperation at the international level in this regard has allowed successful energy-use strategies and best practices to be shared globally. Ultimately, a key goal of this chapter is to demonstrate that the cities of Asia and the Pacific are well positioned to achieve their energy-use goals.

The Three Factors that Impact Energy Strategy

Three major factors determine both attitudes toward, and decisions regarding, energy use, supply, and sustainability. These are (i) security of supply, (ii) price, and (iii) the carbon intensity of the development trajectory. Each of these three factors is associated with a particular set of issues and considerations (Figure 3.1).

Security-of-supply issues are driven by concerns regarding (i) energy security, (ii) independence, and (iii) the finite nature of the global oil supply. The considerations relating to security-of-supply issues that must be addressed include (a) the type(s) of fuel to be used and their source(s) of supply, (b) the degree of diversification of the energy supply by fuel type that is desired, and (c) the geopolitical context and changes in it that impact the supply of energy.

Figure 3.1 The Three Factors that Determine Energy Use, Supply, and Sustainability



R&D = research and development.
Source: Arup.

Price issues are driven by concerns regarding (i) the affordability of energy, (ii) the need to fund infrastructure development, and (iii) the need for research and development. The considerations relating to price issues include (a) fuel costs, (b) fuel accessibility, (c) replacement of assets, and (d) the level of fuel price subsidy to be applied and how this subsidy is distributed across a country's social strata.

The carbon intensity of the development trajectory factor is essentially driven by the (i) security-of-supply and (ii) price-issue factors referred to above, as well as (iii) climate-change and pollution issues. The considerations relating to this factor include (a) choices regarding renewable energy technology, (b) the degree of support given to the latter, (c) the means of integrating renewable energy technology into the existing energy supply, and (d) development of technologies that further enable reductions in carbon-intensive, energy-use patterns.

The three factors that impact energy strategy are closely interrelated (see Box 3.1). They thus interact with one another, as well as with the wider urban system. Further, a change in the parameters affecting one of these factors can cause a reaction in one or both of the others. Similarly, the relationships between these three factors manifest themselves differently

Box 3.1 The Trilemma of Energy Sustainability

The manner in which the three factors impact a particular country's energy strategy has been assessed by the World Energy Council (WEC). Specifically, in its 2011 Assessment of Country Energy and Climate Policies (WEC 2011), the WEC used quantitative analysis to assess the attitude of particular countries toward (i) energy security, (ii) environmental impact mitigation, and (iii) social equity (i.e., affordability of and access to energy).

WEC's use of quantitative analysis in performing this assessment allowed the results for each country to be reported in a single summary statistic known as the Energy Sustainability Index. Because of the inherent trade-offs between (i), (ii), and (iii), when referred to as a group, these three variables are often termed the "trilemma of energy sustainability" that all countries face. In comparing the Energy Sustainability Index of the countries included in the assessment, the WEC found that the countries assessed fell into three distinct groups.

Group 1 countries are heavily focused on social equity. Since this goal is usually achieved through the use of energy subsidies, performance in the other two indicators is generally poor. Group 2 countries are, for the most part, resource-poor, and have achieved only low levels of industrialization. Nevertheless, some of the Group 2 countries are significantly focused on adopting low-carbon technologies, which results in high scores in environmental impact mitigation for Group 2 overall, but poor performance in social equity. Group 3 largely comprises developed countries that are attempting to maintain or improve energy security and social equity, while simultaneously improving low-carbon performance and planning for future reductions in carbon-use intensity. As a result, Group 3 scores in social equity and energy security are relatively high, with scores in environmental impact mitigation being somewhat lower.

For purposes of demonstrating the diversity of energy strategies within Asia and the Pacific, the groups into which some of Asian Development Bank's developing member countries fall are shown below.

Group 1: the People's Republic of China; India; the Republic of Korea; Mongolia; Pakistan; Taipei, China; Thailand

Group 2: Nepal, Sri Lanka, Tajikistan

Group 3: Indonesia, Japan, Kazakhstan, the Philippines

Source: World Energy Council. 2011. *Policies for the Future: 2011 Assessment of Country Energy and Climate Policies*. London.

in different cities and countries. The manner in which these relationships manifest themselves is often influenced by the income level of the country concerned. However, other variables, such as geography or even type of governance system, may likewise profoundly impact the manner in which the three factors interact with one another. These three factors that impact a particular jurisdiction's energy strategy are discussed in greater detail.

Security of Supply

Global demand for energy is increasing rapidly and is forecast to grow by 1.2% annually between 2010 and 2035. Further, more than 90% of this projected growth is expected to come from countries other than those belonging to the Organisation for Economic Co-operation and Development (OECD) grouping (IEA 2011). As energy supplies from conventional sources become more constrained, fossil-fuel reserves become increasingly unable to meet global demand. The inevitable result is rising energy prices (BP 2011). Finally, the fossil fuels on which many countries have placed great reliance are still mainly sourced from areas of increasing political instability, which translates into price volatility over the medium term.

As a result of the above, many leaders now face difficult decisions as to how best address the possibility of their energy supplies becoming prohibitively expensive or cut off altogether in the face of international political upheaval. Many countries are attempting to address this security-of-supply issue by increasing the supply of energy drawn from sources within their own borders. The growing interest of the United States (US) in exploiting its Alaska oil reserves and its enthusiastic pursuit of shale gas provides but one example of this (*The New York Times* 2012). Others are forging closer political ties with energy-abundant countries, such as the interest of the People's Republic of China (PRC) and India in oil-rich African nations (*BBC Business News* 2012). However, such a strategy supports continuing dependence on traditional sources of energy.

Ultimately, the key to meeting growing future energy demand lies in obtaining energy from clean, nontraditional sources, particularly those that are effectively limitless and unimpacted by geopolitical considerations. However, diversification of energy supply must transcend traditional fossil-fuel and nuclear sources and extend into solar, wind, geothermal, ocean-wave, and tidal energy sources. One important medium-term constraint to such diversification is that large-scale integration of renewable energy sources stresses the existing transmission and distribution infrastructure. Additional investment in such facilities is thus required to relax this constraint. Further barriers to diversifying the sources from which our energy supply is drawn include the time cost and monetary cost of further technological development of renewable energy sources, and the time intensity of inducing

behavioral change at the societal level. While relatively cheap fossil fuels might seem an attractive low-cost, short-term solution to meeting growing energy demand, its benefits must be weighed against possible uncertainty of supply or unexpected price fluctuations resulting from unforeseeable geopolitical events. Ultimately, the cost of adapting existing infrastructure to expand the supply of energy from renewable sources might in the end turn out to be a small price to pay for increased security of supply.

Price

It is difficult to separate security-of-supply and price issues, as they are closely related. However, the manner in which energy has traditionally been priced causes the financial cost of energy from renewable sources to exceed that of fossil fuels. This makes it particularly difficult for developing countries with limited funds to transition to large-scale sourcing of energy from renewable sources. This is likewise true of developed countries recovering from economic recession, and particularly so for those accustomed to relatively cheap energy sourced from fossil fuels. The geopolitical difficulties associated with securing what was once an easy and accessible supply of fossil fuels have caused prices to increase, particularly in the face of regional upheavals such as the Arab spring (Middlebrook et al. 2011).

As a result of the above, policy makers at the national level must now address a number of cost-related issues simultaneously. Examples include (i) how to price energy from traditional versus renewable sources, (ii) which renewable energy technology to invest in or catalyze investment in, (iii) whether to invest in maintaining existing infrastructure or installing new equipment that facilitates obtaining energy from renewable sources, and (iv) the degree to which financial or other support should be provided to research and development. Perhaps the most important questions of this type relate to social equity. For example, to what degree should such additional costs be borne by energy consumers? And, given that consumers are to bear them, which consumers? In other words, should energy use be subsidized at all? If so, to what degree? Which consumers should be subsidized and to what extent?

Given the important role that energy plays in achieving and maintaining the quality of life and alleviating poverty, many governments have historically subsidized fossil fuels. However, recent research has shown that such subsidies (i) often fail to meet their stated objectives, (ii) are in some cases detrimental in that they encourage lavish energy use, (iii) discourage investment in energy infrastructure, (iv) drain the state budgets of net energy importers, (v) increase GHG emissions, and (vi) increase air pollution at the local level (IEA 2011b). Finally, with fossil-fuel subsidy levels 12 times those of energy from renewable sources in 2009, energy from renewable sources

faces unfair competition with fossil fuels, the prices of which have been artificially lowered in relative terms (Bloomberg 2010, EurActiv 2011).

Historically, the pricing of fossil fuels has failed to take into account the full cost of their use. Instead, fossil-fuel prices have only captured the costs of extraction, downstream processing, and transport. Such a pricing regime ignores (i) the length of time required for the production of fossil fuels, which is measured in thousands of years; (ii) their finite supply; and (iii) the environmental costs associated with their use. Pricing fossil fuels in this manner further results in unfair price competition between fossil fuels and energy produced from renewable sources.

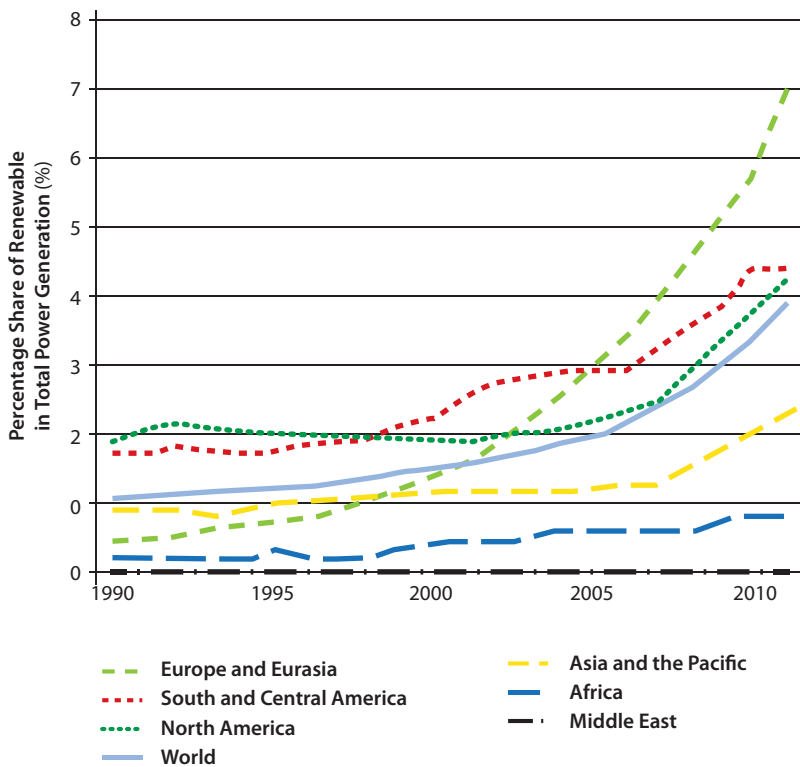
Nevertheless, the cost of energy generation from renewable sources has fallen considerably in past decades, and is likely to continue falling. Indeed, on a per kilowatt basis, newly installed onshore wind power generation is now actually cheaper than generation from newly installed coal power plants, while at the same time, global fossil-fuel prices have risen to record levels (BNEF 2011b, BP 2011). These changes suggest that it may soon be appropriate to reassess levels of support for traditional fossil fuels and energy from renewable sources. The significant increases in the level of support for renewable energy that have occurred in the face of recent economic events seem to be vindicated by the forecast that every additional dollar spent on clean energy could produce \$3 worth of fuel savings by the year 2050 (UNEP 2011a, IEA 2012).

Carbon Intensity of the Development Trajectory

Security of supply and price are the two major factors driving increasing interest in low-carbon forms of energy. Together with socio-environmental concerns and growing public awareness of the unsustainability of large-scale fossil-fuel use, these two factors are driving both city-level and national governments to increasingly turn to low-carbon, renewable sources of energy. At the city level, the low-carbon interventions commonly pursued include photovoltaic panels, solar water heating, combined heat and power generation (CHP or cogeneration), use of biofuels, and smart-grid technology, all of these being discussed in detail in section VII.

As a result of both falling costs and increasing policy support, growth in energy output from low-carbon, renewable sources is unprecedented (Figure 3.2). Between 2005 and 2010, global grid-connected photovoltaic capacity grew by 60%, while global wind power capacity grew by 27% (REN21 2011). At nearly \$187 billion in 2010, total clean-energy asset finance and small, distributed-capacity investment (mainly rooftop solar panels) nearly matched the amount invested in fossil-fuel generating capacity at \$219 billion (UNEP 2011b). This translated into nearly half of

Figure 3.2 Percentage Share of Non-Hydro, Renewable Energy Sources Used in Total Power Generation by Geographic Region



Notes:

1. Renewable percentages do not include generation from hydropower.
2. Except for minimal negative growth for Central and South America during the period 2010–2011, all regions show positive growth in the percentage share of energy derived from non-hydro renewable sources.

Source: BP. 2012. Statistical Review of World Energy 2012.

the 194 gigawatts of new power generation capacity installed globally during 2010. Despite this recent growth in renewable energy capacity, the percentage share of fossil fuels in global final energy consumption in 2010 still reached 80.6%. Thus, in terms of global final energy consumption, fossil fuels still dominate (REN21 2012).

While the growth in the share of renewables in total power generation in Asia and the Pacific has been less rapid than that of other regions, this is likely to change substantially of the coming decades. By 2014, the PRC will most probably lead the world in investment in renewable energy, though the

greatest overall growth will likely occur in Africa, India, the Middle East, and Latin America (BNEF 2011a).

In addition to falling costs and contribution to energy self-sufficiency at the national level, renewable energy sources have the added advantage of independence from aging, strained electricity transmission networks since they generate energy on-site rather than at a distant location. This gives an additional layer of security of supply to the urban areas that employ them that fossil-fuel sources cannot.

There remain questions concerning the intermittency of renewable energy sources, as well as their integration with existing infrastructure, that must be addressed before renewable energy can achieve its full potential in a city's total energy supply mix. However, current research suggests that at least 30% of generation can be met by wind and solar using existing infrastructure and currently available technologies (NREL 2010). Given that non-hydro renewables contributed only 5% to global electricity production in 2010, there arguably remains significant room for expansion before integration issues become widespread (REN21 2012).

Impact on Cities

As national economic hubs and the source of most economic growth, cities are the locales in which initiatives for improving the quality of life are likely to have their greatest beneficial impacts. Similarly, because they drive much of a country's total demand for energy, they typically exert significant influence over national energy policy. They can thus play an important role in developing a resilient national energy strategy. Likewise, due to their high concentrations of population, assets, and goods, and their tendency to be located near deposits of natural resources and bodies of water, they often are particularly vulnerable to climate-related disasters. They are thus the locales in which initiatives for mitigating the negative consequences of climate change are likely to have their most beneficial effects.

The Contribution of Cities to Global Greenhouse Gas Emissions and Climate Change

Because of their role in driving economic growth as well as social and technological development, cities are major consumers of both natural resources and energy (IEA 2008). However, the rapid economic and social development cities have produced has often taken place with little regard to either the direct or indirect impacts of their resource consumption. This has led to resource depletion, climate change, air pollution, and negative

changes in land-use patterns, these ultimately becoming some of the greatest international concerns of the modern age (UNEP 2011a). Cities may therefore be thought of as one of the major causes of the difficulties we now face with regard to the widespread use of traditional sources of energy. That said, in high-income countries, per-capita energy intensities are typically lower in cities than for the country overall. However, in developing countries that are urbanizing rapidly, such as the PRC, rising per-capita income translates into significant increases in the demand for energy, thus raising urban per-capita energy intensities relative to rural areas (IEA 2008).

While cities today account for only 2% of the earth's total land mass, they are home to roughly 50% of the world's population. They thus account for approximately two-thirds of total global energy consumption, and approximately 70% of total GHG emissions (UN-HABITAT 2011, IEA 2008). Current urban population forecasts suggest that by 2015, the population of 23 of the world's cities will exceed 10 million, 11 of these being Asian cities (CITYNET 2012).

Ultimately, there is a direct relationship between the amount of energy consumed and the amount of pollution released. Thus, if the global urban population growth referred to earlier continues to rely on historical urban energy sourcing and consumption patterns, the amount of emissions that would be released would greatly magnify the air pollution and GHG challenges we face today. Preventing future environmental challenges on such a scale implies an urgent need to decouple our desired future economic growth and quality of life from our reliance on traditional sources of energy (UNEP 2011a).

Cities Will Be Most Affected by Climate Change

In the absence of the decoupling referred to earlier, global climate change will intensify, and, along with it, its negative environmental impacts. Due to their inherent concentrations of population, infrastructure, and cultural wealth, it is the world's cities that will bear the brunt of such impacts. Seventy-five percent of the world's cities are located in coastal areas. These are thus the areas that will be the most vulnerable to sea-level rise, storms of increasing ferocity, and inland flooding (C40 2011).

The United Nations Economic and Social Commission for Asia and the Pacific (2010) reports that the frequency of global disasters has increased markedly over recent decades. While 1,690 such events occurred during 1980–1989, the corresponding number for 1999–2009 is 3,886. Furthermore, the people of Asia and the Pacific were four times more likely to be affected by such events as those living in Africa, and 25 times more likely than inhabitants of Europe and North America. Similarly, while Asia and the Pacific

generated one-quarter of the world's gross domestic product (GDP) during 1980–2009, it suffered 85% of the deaths and 38% of global economic losses over that period. The implication of such statistics is that over the past 12 years, such disasters occurring in developed areas caused some of the greatest economic impacts, while disasters occurring in developing countries led to the greatest losses of human life (UNISDR 2012).

Overall, the implication of the above is that cities can be the most dangerous places to live in terms of losses from climate-related disasters (IFRCRCS 2010). This is particularly true in light of the prospect of increasing intensity of climate-related disasters in the future, and greater temperature extremes. Unfortunately, it is the urban poor, and particularly those living in slums in developing countries that are likely to be the most affected by the negative impacts of climate change (UN-HABITAT 2012).

Cities Have the Greatest Opportunity to Prevent Climate Change

The above notwithstanding, the fact that cities account for the bulk of global GHG emissions gives rise to a unique opportunity for urban areas to take the lead in their reduction, and thus to contribute significantly to mitigating both climate change and its negative impacts. This is particularly true when urbanization is coupled with good governance. This opportunity has not been lost on policy makers in numerous cities around the world. In fact, in many cities, interest in the notion of “green growth” is growing, as it is seen as a viable path to sustained economic growth and quality of life (GGGI 2012). The successes of Copenhagen's green sector in producing a wide range of benefits for both the environment and the economy alike provides but one example of this change in perception (GGL 2011).

Ultimately, switching to environment-friendly sources of energy can bring benefits in addition to those accruing to the local and global environment, as it has the potential to create “green collar” jobs in environment-related businesses that would not have otherwise existed (GFA 2012). In some cases, the desirability of “green growth” has even been recognized directly at the national level, such as in the declaration of the Government of the Republic of Korea that low-carbon green growth is a national vision (GGK 2012).

Annual investment in low-carbon technology is expected to grow rapidly in the future, with up to \$460 billion being invested globally in renewable energy projects by 2030 (BNEF 2011a). This represents an immediate economic opportunity for cities, in that building a broad base of expertise in this area now would provide such cities with a competitive advantage in the renewable energy industry in the future. Another benefit of such a

strategy is the future capability to export green-growth knowledge and intellectual capital to other locales. This would be particularly beneficial to a city's economic base, since the export market for green-energy technology is likely to be global, thus allowing this economic sector—as well as the jobs it creates—to grow without limit (GFA 2012).

In the same way that the Stern Review (Stern 2006) has quantified the value of global climate change mitigation, carbon savings have been found to directly generate financial value for cities that undertake them (Gouldson 2012). For example, exploiting profitable opportunities in decarbonizing the Leeds City Region of the United Kingdom would require investments of 0.9% of GDP each year for 10 years, but would generate direct annual savings of 1.6% of GDP. Thus, every \$1.6 billion invested in low-carbon solutions would generate \$350 million in energy cost savings per year. It would likewise create 1,000 jobs and deliver other benefits to the economy valued at \$80 million annually (Gouldson 2012).

Realization of such benefits without restricting access to the social and economic benefits of urban areas is a key goal for the future. Decoupling energy use from economic advance is possible, given well-planned, concerted, energy-related initiatives on the part of urban policy makers (UNEP 2011a).

City Leadership

In light of the information presented thus far in this chapter, cities without doubt face considerable challenges. However, in the past few years alone, impressive initiatives for addressing climate change have been undertaken by cities. For example, according to a report by the C40 Cities Climate Leadership Group (C40), its participating members have collectively implemented more than 3,500 climate-related initiatives since 2005 (C40 2011). Given that the group's member cities represent 8% of the global population, 21% of global GDP, and account for 12% of global GHG emissions, the potential impact of such initiatives is likely significant.

A key finding of this research was that different types of energy-related initiatives are undertaken by cities in low-income countries versus higher-income countries. While the former focus on projects and programs, the latter also focus on changes in policy and regulation that are coupled with financial incentives.

Appropriate changes in policy and regulation have been relatively successful in driving uptake of renewable energy technologies, and at the city level, have led to desired changes (IEA 2012). However, the impact

of national-level policies has been weaker in this regard. These changes in energy-related policy support behavioral change in innovative ways, particularly when coupled with appropriate funding.

C40 Report Findings

The C40 report summarized the findings of a survey of member cities that evaluated the policies, programs, and powers of mayors in a number of sectors, including transport, planning, food and urban agriculture, energy supply, finance, and adaptation to climate change (C40 2011b). In the majority of the cities surveyed, the powers that mayors held over matters relating to energy supply were relatively weak. This outcome was mainly due to several factors. First, the electric power transmission and distribution infrastructure is usually administered by government agencies at the regional level or above. Second, most electricity generation takes place outside city boundaries, which restricts the power of mayors over such activity. Further, power generation, transmission, and distribution are typically undertaken by private companies.

Nevertheless, in a number of cases, mayors had some influence over generation of both electricity and heat within the city limits. Furthermore, because cities typically exercise significant control over waste management activities, the report found that member cities had taken the most direct action in putting into place waste-to-energy and landfill gas-capture initiatives. Similarly, the influence of member cities over solar power generation was significant, as cities generally exercise direct control over the placement of solar panels on the rooftops of buildings. Finally, one of the areas in which member cities were able to exercise the greatest amount of influence was that of policy at levels of government above their own. This was mainly due to the fact that such member cities were able to formulate a long-term vision applicable to their broader jurisdictions.

Despite the limitations on the various powers discussed above, a number of member cities were still able to implement ambitious energy-related initiatives, thus demonstrating the potential beneficial impact of green-energy policies in other locales. Indeed, based on the initiatives either under way or committed to by member cities, the reduction in the collective annual emissions of the C40 cities will total 248 million tons of carbon dioxide (CO₂) by 2020 (C40 2012).

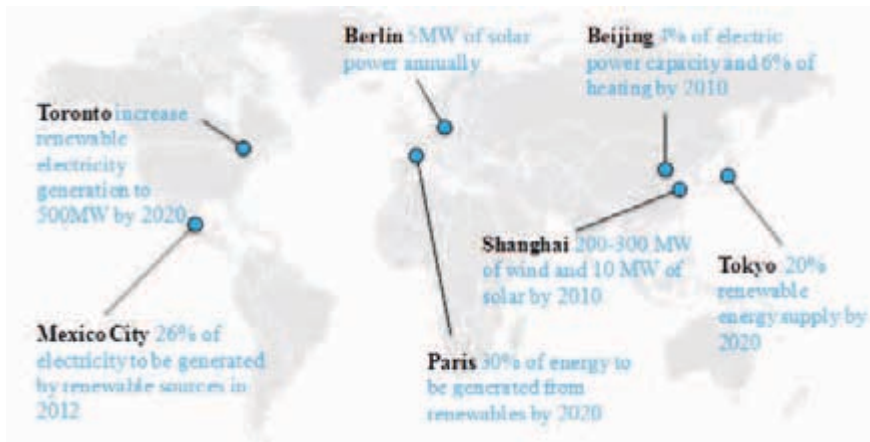
Policy and Regulation

Since cities are often at the center of policy and regulatory activity relating to energy, the impact of policy and regulation on the uptake of renewable

energy technology has been significant throughout the world (REN21 2011). This suggests that their impact on the uptake of other low-carbon interventions would be similar. This is partly because well-formulated and -implemented policy and regulation can directly address security-of-supply issues, and ensure a plentiful supply of affordable energy while simultaneously successfully implementing a low-carbon agenda.

Globally, 98 countries had policy targets relating to renewable energy in 2010, with 87 states, provinces, or countries supporting these targets with feed-in tariff policies, and 63 supporting such targets with renewable portfolio standards or quotas (REN21 2011). This suggests that to successfully achieve their goals, national policies must ultimately be supported by implementation at the city level. In cases in which national energy-related policies are either weak or do not exist at all, cities have implemented their own energy policies and set their own targets. Cities are thus implementing national renewable energy targets, and in some cases, exceeding them (Figure 3.3).

Figure 3.3 Renewable Energy Uptake Targets for Select C40 Cities



MW = megawatt.

Sources: Renewable Energy Policy Network for the 21st Century (REN21). 2011. *Renewables 2011 Global Status Report*. REN21 Secretariat, Paris; Green For All (GFA). 2012.

The C40 report lists numerous incentives for the uptake of renewable energy technology that are either in place, or are being planned. Examples include feed-in tariffs, generation incentives, investment incentives, and promotion of smart metering (C40 2011).

Changing our Relationship with Energy

In addition to encouraging the uptake of “hard” renewable energy technology, achieving long-term environmental sustainability will require addressing “soft” energy challenges as well, such as the need for society-wide recognition that fossil-fuel energy is finite in supply, and that it is therefore a precious resource that must be used sparingly.

Ultimately, the purpose of all policy and regulation is that of changing some aspect of the behavior of the general populace. Indeed, up to 30% of some cities’ carbon-use reductions are expected to result from behavioral change (Arup 2011). As regards energy policy in the urban context, its goal is largely that of changing behavioral patterns relating to energy consumption. Examples include the choice of transport mode, the temperature at which dwellings are maintained, or the timing or total magnitude of the demand for energy of a particular type. Given that our current level of energy consumption is unsustainable, a major target of behavioral change is that of lower per-capita energy consumption levels (IEA 2011a). In some cases, such as the majority of developed-country cities, the reduction in per-capita energy consumption required for achieving long-term environmental sustainability may be considerable, while that required of inhabitants of cities in a developing country may be less substantial.

Such reductions in per-capita energy consumption will likely be achieved through a combination of financial incentives such as tax rebates or pricing tariffs that reward the use of energy from renewable sources, and penalties such as increased tax levels or fines in cases in which statutory per-capita consumption limits are exceeded. The optimal mix of financial incentives and penalties is likely to vary considerably from jurisdiction to jurisdiction, and in large measure to be shaped by current per-capita energy consumption and income levels in the jurisdiction in question. It is, of course, important to remember that the benefits of altering the behavior of energy suppliers is likely to produce environmental benefits of a similar—or in some cases greater—magnitude as the benefits resulting from altering consumer behavior.

Clean-Energy Investment in Cities

Because investment in clean-energy projects in cities typically results in cash savings or direct profit, the scope for such investment by both the public and private sector is substantial. According to the United Nations Environment Programme (UNEP), at the end of March 2011, \$63.2 billion in private and public sector money was managed by “clean-energy funds” (UNEP 2011b).¹

¹ “Clean-energy funds” are defined as those that invest more than 50% of their total funding in energy efficiency or clean-energy projects.

Figure 3.4 Investment in Renewable Energy by Region, 2004–2010
(\$ billion)



Source: United Nations Environment Programme (UNEP). 2011. *Global Trends in Renewable Energy Investment 2011: Analysis of Trends and Issues in the Financing of Renewable Energy*.

While some of this funding was used to finance larger-scale, extra-urban projects, a substantial portion of it was channeled into investment in urban areas where the demand for renewable energy is greatest. The fact that for-profit financing for clean-energy initiatives even exists demonstrates that such investments are not as risky as they are sometimes portrayed.

UNEP (2009) finds that private sector investment in renewable energy initiatives in emerging markets can face numerous barriers, including unstable political systems; lack of transparency in the legal, regulatory, tax, or business environment; exchange-rate fluctuations; and undeveloped energy markets and infrastructure. However, appropriate due diligence can mitigate such risks. Furthermore, public sector funding can be effective in financing renewable energy projects in such markets. In particular, well-thought-out direct grants and loans at concessional or even commercial rates can be excellent methods for bridging funding gaps, or for encouraging commercial cofinancing that reduces private sector investor risk by shouldering a portion of the total investment.

Despite the perceived riskiness of investment in clean-energy initiatives in developing countries, in recent years, the greatest growth in such investment has occurred in Asia and Oceania, with \$59.3 billion being invested in 2010, though of this amount the PRC accounted for \$49 billion.

Investment in renewable energy projects by multilateral development banks has likewise been significant in recent years. In 2010, \$11 billion was collectively invested in such projects by the Asian Development Bank, BNDES (the Brazilian Development Bank), the European Investment Bank, and KfW (the German Bank for Reconstruction and Development), this collective amount mainly comprising loan financing (UNEP 2011b). While these institutions in some cases offer loans at concessional rates, all of the investments they underwrite must be profitable to some degree.

Energy efficiency funds are an increasingly popular means of financing energy efficiency measures, particularly in Europe,² but also in Asia. Usually supervised by a professional fund manager, these funds make relatively low-interest loans for the installation of medium- to large-scale energy efficiency measures. Technical due diligence is typically undertaken prior to funding such investments to ensure that an appropriate level of emissions savings is achievable within a specified cost limit. For example, London's Energy Efficiency Fund requires projects to deliver energy savings of at least 20% to be eligible for investment. The fund aims to maximize carbon savings return on investment by targeting projects that would be expected to deliver CO₂ savings at no more than \$2,400 per ton of CO₂ (LEEF 2012).

Given appropriate verification of the viability of the energy efficiency projects they finance, energy efficiency funds could theoretically be used to finance such initiatives anywhere in the world. These financing vehicles are particularly beneficial because they offer a stream of financing for energy efficiency initiatives that is in addition to that provided by public sector agencies. Further, because the financing they provide is sourced from the private sector, it is immune to the political pressures that public sector energy agencies often face in allocating funding among projects.

One of the reasons energy efficiency is seeing growing interest from numerous investment sources is the level of profitability it offers. For example, appropriate energy efficiency investments can permanently reduce the annual energy demand of commercial buildings by 30% or more. Depending on the type of technology installed, such investments have a payback period of approximately 1–2 years (SDCL 2012).

Similarly, Gouldson and colleagues have found that by 2022, some cities could reduce their 1990 levels of carbon emissions by 35% simply by undertaking clean-energy investments that yield a positive rate of return.

² London's Energy Efficiency Fund (LEEF), the Scottish Central Energy Efficiency Fund (CEEFF), the European Energy Efficiency Fund (EEEF); part of the European Energy Efficiency Facility (EEE-F).

When such investments that yield a zero rate of return—i.e., cost-neutral investments—are likewise included in those undertaken, the 1990 levels of CO₂ emissions for the cities in question could be reduced by up to 40% (Gouldson 2012).

Energy Strategy

Collectively, the participating members of the C40 Cities Climate Leadership Group have implemented more than 3,500 climate-related initiatives since 2005. While this is an admirable achievement, fully addressing the energy-related challenges that all cities face—whether members of the C40 grouping or not—requires formulation and implementation of a holistic energy strategy that is based on three stages of development.

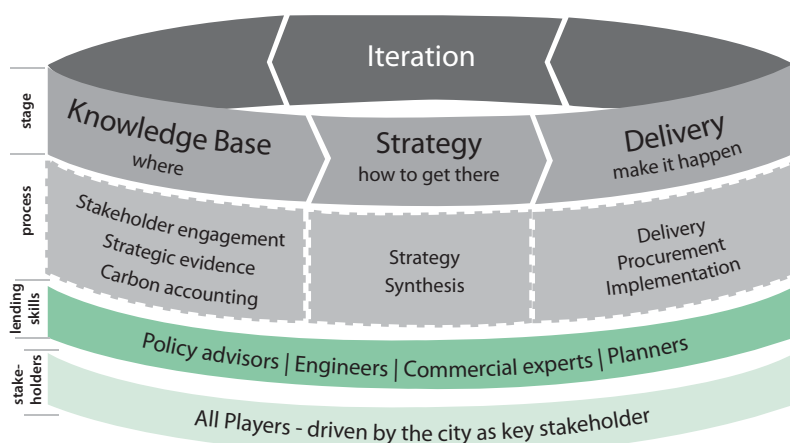
The first of these is developing an appropriate knowledge base. This is necessary to ensure that future energy-related decisions are based on appropriate understanding of the challenges that must be addressed, full knowledge of the impacts of the measures undertaken, and appropriate criteria for measuring the degree to which such initiatives have achieved their intended results.

The second stage is strategy synthesis, which entails determining the most appropriate strategy for the city in question in all relevant dimensions. The third stage consists of delivering the chosen strategy, which entails implementing the measures the strategy comprises.

Figure 3.5 portrays the Energy Strategy Continuum and briefly describes these three stages of development, the key or “leading” skills required in formulating and implementing such an energy strategy, and the stakeholders involved during each developmental stage.

This process of strategy development is iterative, meaning that the output of each initiative that comprises the strategy ends up informing the next cycle of strategy development, thus increasing the efficiency and effectiveness of future iterations of strategy formulation and implementation.

Figure 3.5 The Energy Strategy Continuum



Source: Arup. 2012.

Developing a Knowledge Base

Unfortunately, quantitative targets for energy consumption are often set without relating them to the current situation of the city concerned. Such targets may thus be inherently unachievable, or it may be impossible to measure the progress made in achieving them. This outcome can be avoided by ensuring that the knowledge base underpinning the energy strategy in question is complete, meaning that it is based on appropriate analysis of all of the factors likely to impact the strategy's successful implementation.

For example, this would include the degree to which relevant stakeholders—and in particular, political interests—are aware of the energy strategy's goals, and are in agreement with them. In this regard, the potential contribution of political stakeholders—both positive and negative—to implementation of the strategy should not be underestimated, since leadership that is committed to the strategy is vital to its successful implementation.

All stakeholders should be involved to the maximum degree possible from the outset of the strategy development process, their likely contribution to this process being identified and openly communicated to them. Ultimately,

it is the degree to which stakeholders are—and have been—involved in the strategy development process that determines the degree to which they will feel responsible for, and committed to achieving the quantitative targets the strategy embodies.

Similarly, all gaps in the skill-base or other resources necessary for successfully implementing the strategy must be transparently identified, and measures for closing such gaps formulated and implemented. In this regard, provisions must be made for any training required for the strategy's successful implementation.

Once all relevant stakeholders have been identified and committed to the strategy's successful implementation, work on the quantitative aspect of the knowledge base underpinning the strategy must be completed. For example, historical data pertaining to energy consumption should be disaggregated by all variables relevant to the strategy. Similarly, all current and future energy initiatives relevant to the strategy should be mapped in a way that provides a graphic or otherwise easily grasped overview of their interrelationships. Likewise, current and future supplies of energy should be evaluated with regard to their likely future availability and reliability.

All sources and consumers of energy within the city must also be identified. This requires assessing the existing building stock, mapping of energy consumption and intensity by fuel source and mode of delivery (electricity, gas, biomass), as well as mapping the availability of sources of renewable energy, such as annual wind-speed and solar intensity levels. Current and likely future levels of CO₂ emissions must also be assessed, as should all other technical variables relevant to the strategy's successful implementation.

It is equally important to identify all current and future obligations of the city in question, as well as all policies currently in place at the regional, national, and international levels that might impact the strategy's successful implementation. The aspects of the energy system over which the city has operational control should also be identified. For example, are transmission and distribution grids controlled by the city government, the central government, or a private sector monopoly provider?

From the above information, the CO₂ emission levels associated with historical energy consumption patterns can be determined for all major end-use consumers such as commercial buildings, transport facilities, and industrial enterprises. This in turn allows the city's energy and carbon footprint to be defined.

In short, an appropriate knowledge base would include all data and information relating to the current status of energy use and emission levels, as well as their likely future values. This is necessary to allow appropriate assessment of both the current and future position of the city in question under alternative energy-use and carbon-intensity scenarios. In the absence of comprehensive baseline data and information such as those described, measuring the progress achieved in meeting quantitative targets previously set would be impossible, thus rendering the strategy in question meaningless.

Strategy Synthesis and Delivery

Strategy synthesis and delivery begins with identifying the major energy-related issues the strategy is to address. These issues, as well as the considerations that relate to them, will in all likelihood include the following at the minimum:

- **Energy supply.** Major considerations include (i) how expansion of energy supply produced from renewable sources might be encouraged or achieved; (ii) how decentralized energy sources might be further developed, (iii) how development or expansion of CHP (Combined Heat and Power) plants and district heating networks might be achieved or encouraged; (iv) how access to alternative forms of low-carbon energy, such as nuclear energy, carbon capture, or storage plants, might be secured such as through feed-in tariffs that encourage installation of domestic rooftop solar panels.
- **Resources.** Major considerations include (i) how the energy intensity of major end users, such as industrial facilities, might be reduced; (ii) how waste management or recycling might be expanded to reduce solid waste, for example, by restricting use of landfills or discouraging their use through increased landfill tariffs; and (iii) how waste-to-energy infrastructure might be developed or expanded.
- **Building retrofit.** Major considerations include (i) how the energy efficiency of existing buildings might be encouraged, for example, by mandating the use of building-integrated renewable energy sources; and (ii) how differentials in energy intensity between the public, private-commercial, and domestic sectors might be reduced, for example, through performance assessments of energy efficiency measures currently in place in commercial buildings.
- **New construction.** Major considerations include (i) what the form and content of construction requirements that encourage reduced energy consumption, lower carbon intensity, and increased energy efficiency might be; and (ii) how holistic spatial strategies that address multiple issues might be developed, for example, through planning regulations

that specify minimum requirements for use of on-site sources of renewable energy.

- **Smart solutions.** Major considerations include (i) how implementation of smart grids might be undertaken; (ii) which options are available to policy makers for encouraging demand-side energy management and energy storage; (iii) how information and communication technology might be used to reduce consumption of energy by end users, for example, through the installation of smart meters; and (iv) how behavioral change on the part of all energy users might be encouraged, for example, through the use of citywide information displays that show real-time levels of energy consumption for the various economic sectors or for individual buildings.
- **Links with transport.** Considerations include (i) how the energy intensity of public transport systems might be reduced through the use of hybrid or electric vehicles; (ii) how price incentives for reducing energy consumption or disincentives for excessive consumption might be implemented; and (iii) how shifts in preferred modes of transport might be induced, for example, by levying city-center congestion charges or emissions penalties on vehicles.

Once the major energy-related issues to be addressed have been identified and the considerations relating to them have been assessed, proposals for specific initiatives that address these issues should then be formulated. However, in formulating specific initiatives, it is important that these not be developed in isolation of one another. Instead, the likely impacts of each initiative on the successful implementation of each of the others should be assessed. The viability of each initiative should then be validated through the use of cost-benefit analysis. Once each of the initiatives has been thus validated, the design of the overall strategy can be completed, and quantitative targets set with reference to the baselines values previously defined.

Delivery trajectories for the overall strategy that include the phasing and timing of the initiatives it comprises should then be developed, and implementation proposals outlined, these proposals then being subjected to review by all stakeholders and verification of their financial viability.

A plan for financing the overall strategy should then be developed that takes into account all finance options available to the city concerned. These might include financing from pension funds, other publicly available money, or even venture capital. Other sources of finance might include national-government agencies, international finance corporations, or private sector charities. Specific governance or delivery vehicles may be required to satisfy the demands of particular stakeholders. Once appropriate financing

has been obtained and any required governance or delivery vehicles have been formulated, procedures for managing procurement will need to be formulated and put into place.

Ultimately, some form of project management is generally required to ensure successful implementation of all projects undertaken under the strategy. This includes monitoring, evaluation, and reporting procedures for ensuring that project milestones are achieved, or that policy changes result in their desired impact. This also allows any errors to be corrected in a timely fashion, and lessons learned from strategy implementation to be transparently communicated.

Delivery of the strategy will in all likelihood require a broad range of skill-sets. This often includes those of accountants, commercial experts, lawyers, policy analysts, project managers, and technical advisers. All of these experts must be able to work effectively with the entire range of stakeholders involved in delivering the strategy. If implemented appropriately, this final stage results in a seamless transition back to the first stage of the strategy formulation process. At this point, quantitative baseline values should be updated and targets reset, thus allowing identification of the goals of the subsequent round of strategy formulation by policy makers, and hence its implementation.

Toward Energy-Smart Cities

Ultimately, technologies for reducing the carbon footprint of cities already exist, are in use, or are under development (OECD 2011). Thus, “energy-smart cities” are those that implement all of these technologies that are appropriate to successful implementation of their energy strategies, and that consider any complementarities between these and other vehicles for achieving long-term environmental sustainability such as waste and water management.

This section briefly reviews the state-of-the-art energy technologies that are currently in use worldwide, as well as those in advanced stages of development that might be used during the strategy delivery stage of the Energy Strategy Continuum described earlier. It also provides examples of interventions used by cities to encourage uptake of these technologies.

Energy Efficiency

Because energy efficiency always carries with it negative rather than positive abatement costs, it should always be given high priority by policy makers. That is, rather than requiring a financial outlay to reduce CO₂ emissions

by, say, 1 kilogram, energy efficiency initiatives instead achieve this goal by actually *reducing* financial outlays, thus saving money (McKinsey & Company 2009). Further, energy efficiency is a powerful tool for reducing GHG emissions. For example, the International Energy Agency (IEA) estimates that when combined with power-generation efficiency and fuel-switching, end-use fuel and electricity efficiency can contribute up to 43% of GHG emissions savings to the year 2050 (IEA 2010).

Energy efficiency also produces additional economic benefits in that by reducing demand it postpones or negates the need for expanding electrical generation capacity. However, this is only true if the manner in which it is implemented prevents rebound effects. Such effects occur when behavioral considerations prevent energy efficiency improvements from delivering expected reductions in energy consumption. For example, if efficiency improvements lower the cost of electricity, this could cause power consumption to increase, thus offsetting—or even overwhelming—any potential savings from the energy efficiency improvements undertaken (WEC 2011).



Photo: Aup.

While skyscrapers in Hong Kong, China use significant amounts of energy, the city's Buildings Energy Efficiency Funding Schemes program has reduced CO₂ emissions by thousands of tons since 1995.

The long-running Buildings Energy Efficiency Funding Schemes (BEEFS) program in Hong Kong, China, which ran from 1995 until early 2012, provides an excellent example of a successful energy efficiency initiative. Under the program, existing building owners were encouraged to carry out energy and carbon audits, and to use the information generated by them to identify opportunities for energy efficiency improvements and emissions savings, regardless of whether these buildings were used for residential, commercial, or industrial purposes. Matching funding was provided under the scheme, which ultimately saved 140 million kilowatt-hours of electricity, and thus 100,000 tons of CO₂ (Government of the Hong Kong Special Administrative Region of the People's Republic of China 2012).

Decentralized Energy

Formerly, electricity networks typically generated power at central locations, and then transmitted it over long distances to end users (World Alliance for Decentralized Energy 2012). This led to significant transmission and distribution losses (EIA 2012). By generating electricity on-site, such losses are avoided, as are any costs associated with expanding transmission capacity. On-site power generation is also less impacted by extreme weather events and is less likely to be affected by sabotage (Greenpeace 2005).

Decentralized energy systems are small-scale distribution networks operating at the local or subregional level that deliver electricity from local sources to end users. Energy technologies that can be used to power decentralized energy systems include a range of renewable sources of electricity generation such as wind turbines, solar panels, biomass, biofuels, and geothermal energy. It is also possible to generate electricity for powering such systems from waste, or in fossil-fueled CHP plants.

Small-scale wind turbines can be integrated into the urban environment in a number of ways, such as installations on building rooftops or along road or rail lines. While urban wind generation facilities must address issues such as air turbulence, well-designed, well-located vertical-axis wind turbines can contribute to urban low-carbon power generation (Babinsky 2012).

Solar power, particularly that provided from rooftop panels in urban areas, can meet a portion of a city's energy requirements. In many locales, solar-generated electricity power costs are approaching or have reached parity with the cost of electricity supplied from national grids. Encouraged by feed-in tariffs, European rooftop solar power generation increased by 120% between 2009 and 2010 (BNEF 2011c). In addition to rooftop panels, integration of solar panels into glass building facades is one way of expanding solar power generation in cities through retrofits of existing buildings.

While energy sourced from biomass began with the human use of fire, it is the use of biofuels that has experienced particularly rapid growth in recent years (REN21 2011). Other efficient non-fossil-fuel means of generating energy include anaerobic digestion and gasification, both of which produce biogas for use in existing natural gas applications (WEF 2011b). As long as the biomass in question is sourced sustainably, these technologies can contribute to a city's energy requirements in a way that leads to long-term environmental sustainability.

Similarly, geothermal energy can be used for both heat and electricity generation. Ground-source heat pumps can also harvest a form of geothermal energy through shallow-depth boreholes. Such installations can support citywide heat networks, or those of individual buildings. Iceland, where 90% of the housing stock derives its heat from geothermal sources, is sharing this technology with the PRC city of Xian, which is to be the PRC's first geothermal energy city (WEF 2011f).

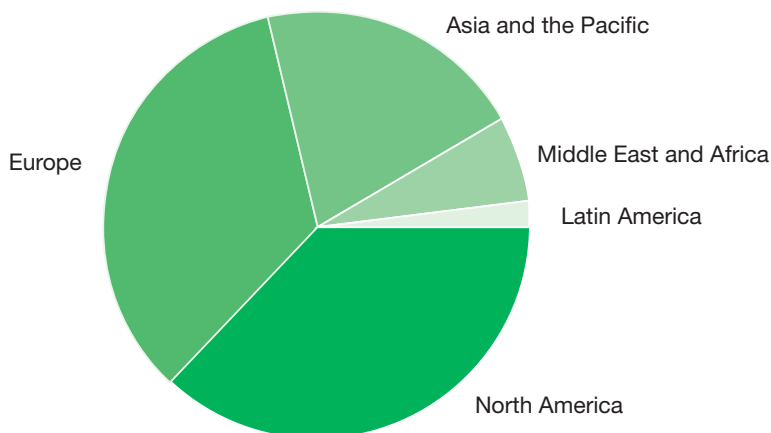
Waste-to-energy technologies convert waste materials that would otherwise be dumped in landfills into heat, gas, or electricity. As with biomass, these technologies can convert numerous types of waste into heat or electricity through anaerobic digestion, gasification, or direct combustion in incinerators. Additionally, since the methane gas that landfills produce has a chemical composition similar to that of natural gas, it can be trapped and burned to produce heat or power (Adu-Gyamfi 2010).

An excellent example of the widespread use of solar power is that of Rizhao City in the PRC, which has promoted the use of solar technologies since 2001 through building regulations, and public engagement and education. Current building regulations require solar energy equipment to be designed, constructed, examined, and approved during new construction to ensure that any technical problems are resolved prior to installation. Currently, 99% of the buildings in Rizhao's urban areas and more than 30% of houses in rural areas use solar water heaters (UNEP 2012). Furthermore, most of the city's traffic signaling, street lighting, and park illumination is powered by photovoltaic panels (WEF 2011g).

Energy-Smart Technologies

Energy-smart technologies are those that facilitate the efficient use of energy. While in 2004, an estimated \$1.3 billion was invested in energy-smart technologies, this had grown to \$5 billion by 2010, the corresponding estimate for 5 years hence being \$39.5 billion (UNEP 2011b). More than 100 energy-smart city projects are already under way worldwide, these being particularly concentrated in Asia and the Pacific, Europe, and North America (Figure 3.7; Greenbiz 2011). These include electricity storage, demand-response systems, electric vehicles, smart metering, and smart grids.

Figure 3.7 International Distribution of 102 Current Smart-City Projects



Source: Greenbiz. 2011. *Investment in Smart Cities on the Verge of a \$40B Boom*.
<http://www.greenbiz.com>

One of the issues that must be addressed if the use of renewable sources of energy continues to increase is that of intermittency. For example, periods of calm cause wind-turbine generation to cease, and hours of darkness prevent generation from solar panels. Moreover, during periods of low demand but significant availability from renewable sources, electricity may be wasted. Similarly, during periods of high demand but low availability of power from renewable sources, generation capacity is insufficient to meet that demand. Electricity storage technologies address this problem through a wide range, such as pumped-hydro storage, compressed-air energy storage, batteries, and, to a lesser extent, flywheels (WEF 2011e).

Demand-response includes a range of technologies that address fluctuations in both demand and supply. Traditionally, peaks and troughs in electricity demand have been managed on the supply side by generating more or less power as appropriate. However, this causes large plants to run inefficiently at low levels of output. Demand-response technologies work on the demand side, both at the consumer and industrial levels, by automatically reducing consumption during periods of peak demand by shifting demand to a time period during which more energy is available. This can be achieved actively through connection to an information network, or autonomously through the use appliances, such as refrigerators, that slightly increase temperature set-points when the generation network is operating at full capacity (WEF 2011d).

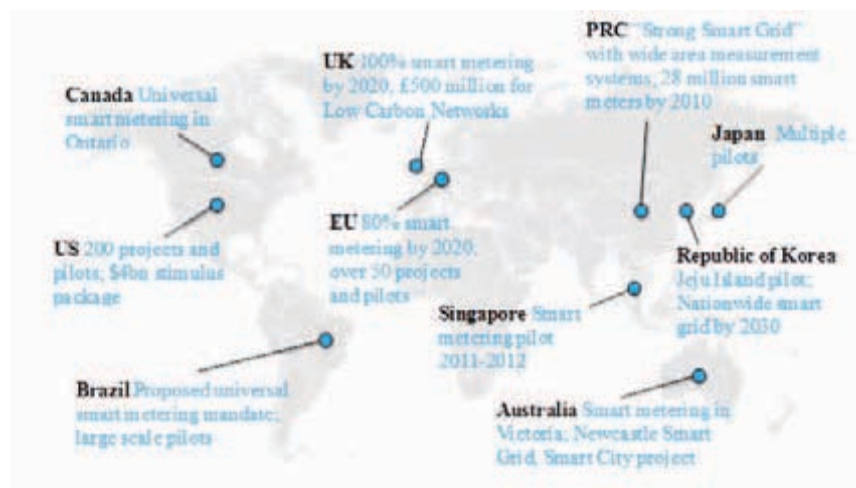
Because electricity from both fossil fuels and renewable sources of energy can be used to charge their batteries, electric and plug-in hybrid vehicles actually employ a combination of energy-storage and demand-response technologies. Further, shifting their charging periods to times of minimal electricity demand greatly reduces peak-system power consumption. Similarly, during periods of peak demand, electric vehicles connected to their charging units (i.e., operating in the “vehicle-to-grid” mode) dispatch energy back through the network, thus reducing peak-demand power-generation capacity requirements (V2G 2012).

Until recently, residential gas and electricity consumption was read manually and periodically from meters. Consumers thus had little information regarding the amount of energy they consumed or its cost during a particular time period. This wastes money and causes CO₂ emissions that might otherwise be prevented. Smart meters that provide real-time information concerning energy use to consumers and suppliers alike enable consumers to better manage their consumption, and suppliers to manage their systems more accurately. Worldwide demand for such meters is growing rapidly (WEF 2011a).

In many respects, smart grids incorporate a number of the energy-smart solutions referred to above. By combining electric power networks with advanced, two-way information communication technology and several of the solutions described earlier, energy-smart grids are able to respond to fluctuations in both demand and supply, and encourage the use of renewable energy technologies. As a result, energy-smart grids are being established through the world (Figure 3.8).

An initiative of the city of Amsterdam, Amsterdam Smart City provides an excellent example of the large-scale use of renewable sources of energy and energy-smart technology (City of Amsterdam 2012). By generating public interest in energy efficiency, Amsterdam Smart City was able to incorporate sustainable energy practices into virtually all aspects of the urban setting on a significant scale, including domestic and commercial buildings, public spaces, and transport facilities. By creating partnerships with technology providers, a number of energy efficiency initiatives were able to be tested on a commercial scale. This included smart meters and other energy management technologies in homes, smart building technology in office towers, and testing of smart electric-vehicle charging stations that ensure that cars are not overcharged.

Figure 3.8 Smart Grid Projects Around the World



EU = European Union, £ = pound sterling, PRC = People's Republic of China, UK = United Kingdom, US = United States.

Source: Bloomberg New Energy Finance (BNEF). 2011. *Imperial College Energy Futures Lab Annual Lecture*. Presentation by Michael Liebrich, Chief Executive, BNEF.

Heating and Cooling Technologies

While heating and cooling is necessary for human comfort, it contributes significantly to global warming. Together with water heating, space heating and cooling are estimated to account for half of global energy consumption, buildings themselves accounting for approximately one-third of global final energy consumption (REN21 2011). Because they account for such a large share of total energy consumption, heating and cooling are components of energy consumption that present significant opportunities for reduction in global emissions. Technologies that reduce the amount of energy consumption required by heating and cooling include CHP plants, heat pumps, solar water heating, and thermal storage.

CHP includes a number of technologies for simultaneously generating heat and electricity, the benefit of this being that simultaneous generation of both is more energy-efficient than producing heat and power separately. CHP plants use steam turbines driven by a heat source to generate electricity, while simultaneously delivering the waste heat generated as a by-product of electricity generation through a district heating network in the form of either hot water or steam. While in some cases this waste heat is transmitted over

long distances to final consumers, smaller, decentralized CHP units are also used to supply heat to a single city through a local district heating distribution network. In regions with significant differences between annual minimum and maximum temperatures, combined cooling, heating, and power (CCHP or tri-generation) plants may be appropriate, although CCHP thus far remains an emerging technology (WEF 2011c). While CHP and district heating networks are in use worldwide, they are particularly popular in the Nordic countries and parts of the former Soviet Union. For example, in Ulaanbaatar, Mongolia, central CHP plants supply approximately 1.8 gigawatt-thermal (GWth) of district heating (Government of Mongolia 2011).

Currently, most CHP plants are powered by fossil fuels. However, it will be possible in the future to power them with waste energy, large-scale CHP plants that incorporate carbon capture and storage technologies, or large-scale heat pumps driven by electricity supplied from low-carbon sources. Using such energy sources to power CHP plants will result in significant carbon savings (DECC 2012).

Because of their inherent efficiency, heat pumps deliver space heating and cooling or hot water to the point of use, while simultaneously saving significant amounts of energy. In use worldwide for decades, they are entirely compatible with using low-carbon, renewable energy sources since they are powered by electricity (REN21 2011).

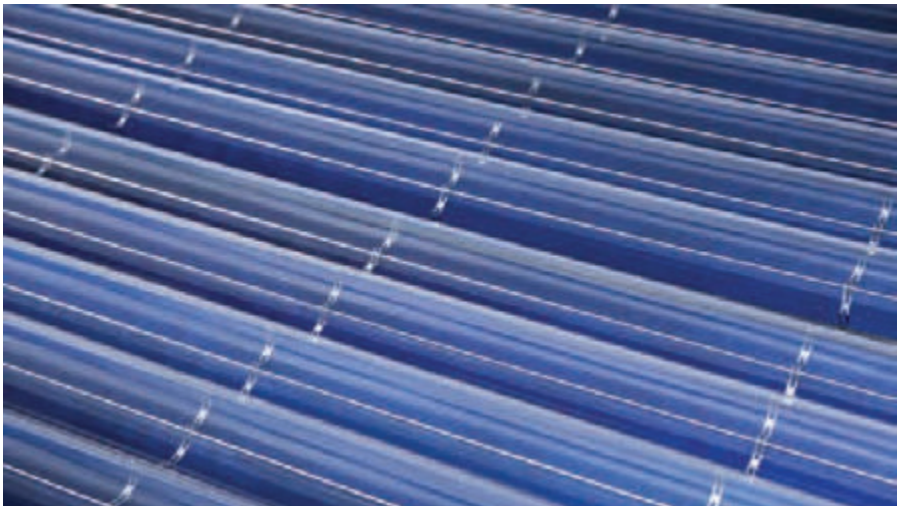


Photo: Gilles Rocholl Photography.

Solar water heating panels similar to these now provide 60% of the hot water used in Barcelona's newly constructed buildings.

The use of solar water heating is increasing rapidly, particularly in developing countries, such as the PRC, where units totaling 118 GWth of power are now installed (REN21 2011). This technology directly transfers heat from the sun to water as it passes through special panels mounted on rooftops, the hot water thus produced being stored in tanks.

An excellent example of the use of solar water heating on a significant scale is that of Barcelona. Following mapping of the city's solar resource availability, engineers determined that 1 square meter of solar water heating space was, on average, required to fulfill the domestic hot water requirements of each of the city's inhabitants. The engineers also determined that the city's existing housing apartments on average had 43 square meters of terrace available for solar water heating units. Following this, the city began requiring all new buildings to provide 60% of the hot water they used from solar water heaters. This resulted in a significant amount of rooftop space being used to generate hot water (WEF 2011g).

In addition to solar heating, solar cooling has seen significant growth worldwide in recent years (REN21 2011). This technology allows heat within buildings that has been generated by the sun's rays to rise through vents into the attic where it is subsequently expelled through an opening in the roof. Provided that a building using this technology is tightly enough sealed against air leaks, the escaping heat generates a slight vacuum that is filled by air that has been cooled by passing through pipes buried in the ground prior to entering the building through floor vents.

Thermal energy storage allows waste heat, or heat generated from off-peak electricity generation, to be stored for significant periods until demand for it arises. It can thus be used to significantly increase the efficiency of a district heating or cooling network while simultaneously reducing capacity requirements, as well as the costs associated with building additional capacity (WEF 2011h).

Real-World, Large-Scale Application of Decentralized Energy Technology

London's decentralized energy and district heating development program provides an excellent example of simultaneous application of a number of energy-efficient technologies that is replicable in virtually all cities, regardless of the income level of the country in which they are located.

Following development of a public knowledge base relating to district heating, the city implemented a number of policy measures. The initiatives of varying scales that were undertaken as a result of these policy

measures were financed from external funding sources to ensure their ongoing financial support.

In 2007, the Mayor of London set the ambitious target of procuring one-fourth of Greater London's energy from decentralized sources by 2025, which is equivalent to more than 10 gigawatt-hours of electricity per year (DECC 2011).

To ensure that this goal was achieved, the Decentralised Energy Master Planning (DEMaP) program was introduced by the London Development Agency (LDA) in 2009. The LDA allocated nearly \$8 million to support decentralized energy over 4 years beginning 2009. These funds were used to build capacity, catalyze decentralized energy development, and finance CHP plants that fueled district heating networks in London.

The DEMaP program enabled boroughs to identify decentralized energy opportunities, and to develop the capacity to exploit those opportunities. Comprising three energy strategy phases that included initial capacity building, preparation of feasibility studies, and project delivery, the DEMaP program defined an entire trajectory of work packages. This required generating a significant amount of information regarding London's heat loads to ensure that the city's overall capacity would, in the end, be sufficient to meet its heating requirements

Ultimately, this information was presented in the form of the London Heat Map, which provided baseline information concerning public, commercial, and domestic fuel consumption in London. Made accessible to the public online, this map allowed users to zoom in to street level to quickly identify concentrations of heat demand where the installation of district heating facilities would likely be appropriate. Initially intended as a tool for policy and decision makers, the London Heat Map helped the general public identify opportunities for employing decentralized energy in particular neighborhoods. This assisted the development of new decentralized energy initiatives by enabling market participants to make informed investment decisions at almost zero cost.

Development of new decentralized energy initiatives was further supported by publishing a free tool kit, known as the Decentralized Energy Networks Masterplanning Guidance (DENet), which allowed local authorities and other stakeholders to quickly carry out pre-feasibility assessment of potential district heating schemes. This likewise had the beneficial impact of further reducing uncertainty and investor risk (Arup 2012).

Further to the DEMaP program, in late-2011, the Greater London Authority initiated the Decentralized Energy for London program, which

supported delivery of more decentralized energy schemes (GLA 2012). The Decentralized Energy for London program was funded by €3m, 90% of which was secured from the European Local Energy Assistance (ELENA) facility of the European Investment Bank. This program provided project sponsors—particularly London boroughs—with technical, financial, and commercial assistance in developing and bringing decentralized energy projects to market.

London has been home to district heating networks for a number of years, with active schemes in Barkantine, the City of London, Pimlico, and Whitehall, and more to be implemented in the near future. Growth in interconnections between some of these existing schemes is anticipated, along with potential development of a number of high-capacity networks that will transport industrial volumes of heat from power stations to users over long distances, thus allowing significant carbon savings to be achieved. Both existing and planned initiatives of this type can be viewed in greater detail in the London Heat Map's vision layer.³

London's pursuit of decentralized energy and district heating independently of national targets is an excellent example of the low-carbon achievements possible at a city scale, and the use of innovative financing and support mechanisms for implementing such initiatives. Indeed, many of the initiatives implemented in London have now been taken up at the national level, with the introduction of the National Heat Map for England and Wales, as well as the push for national development of heat networks in other United Kingdom cities (DECC 2012).

Conclusion

Despite the fact that cities have traditionally had limited power over energy-related issues, they nevertheless hold the promise of slowing or halting climate change. Innovative strategies and initiatives based on sound knowledge and thorough analysis of the experience of model cities around the world are ultimately the key to a low-carbon future.

While vital to human comfort, energy use is at present intrinsically linked to climate change, which ultimately makes it a threat to continued prosperity. Through improved living standards, cities are significant users of energy and are therefore primary contributors to climate change. The implication of the rapid rates of urbanization that are forecast for the world's cities is that unless energy consumption is decoupled from economic advance, the

³ www.londonheatmap.org.uk

climate-change impacts that result from the energy consumption that fuels it could have catastrophic consequences that, in the end, might threaten economic advance itself.

Though some of the examples used in this chapter have their roots in high-income countries, most are transferable elsewhere, especially to the cities of Asia and the Pacific. In fact, research shows that Asia's energy strategy potential will increase rapidly in coming decades. This will in all likelihood be driven by rapid uptake of renewable energy technologies and policies that lead to a low-carbon future.

The threat of climate change is too great for nations and cities to work in isolation, particularly in light of current information technology that allows technology transfer on an unprecedented scale. The nascent cities of developing regions have a unique opportunity to benefit from the knowledge gained and lessons learned elsewhere. This places them in an excellent position to leapfrog over obsolete technologies and inefficient practices, and thus to become world leaders in securing long-term environmental sustainability for the entire planet.

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CHAPTER 4

Transport for Green Cities

by Lloyd Wright

Introduction

Movement enables development. To undertake commercial exchange, access public services, or engage in recreation and entertainment, society relies on the ability to move persons, goods, or information from one location to another. The concepts of exchange and movement can be viewed as core elements in defining a city:

Cities are an invention to maximize exchange opportunities and to minimize travel. These exchanges may be exchanges of goods, friendship, knowledge, culture, work, education or emotional and spiritual support... Cities are a deliberate concentration of these exchange opportunities in order to increase both the diversity and accessibility of exchange opportunities... The role of transport is to help maximize exchange... (Engwicht 1999, 19).

Figure 4.1



Photo: Lloyd Wright.

Cities are an invention to maximize exchange and minimize travel, as demonstrated by Shanghai's Nanjing Road.

Thus, mobility and accessibility are intertwined with development. And yet, paradoxically, transport conditions tend to worsen as economic development increases:

While sanitation, health, education, and employment tend to improve through economic development, transport problems tend to worsen (Peñalosa 2003).

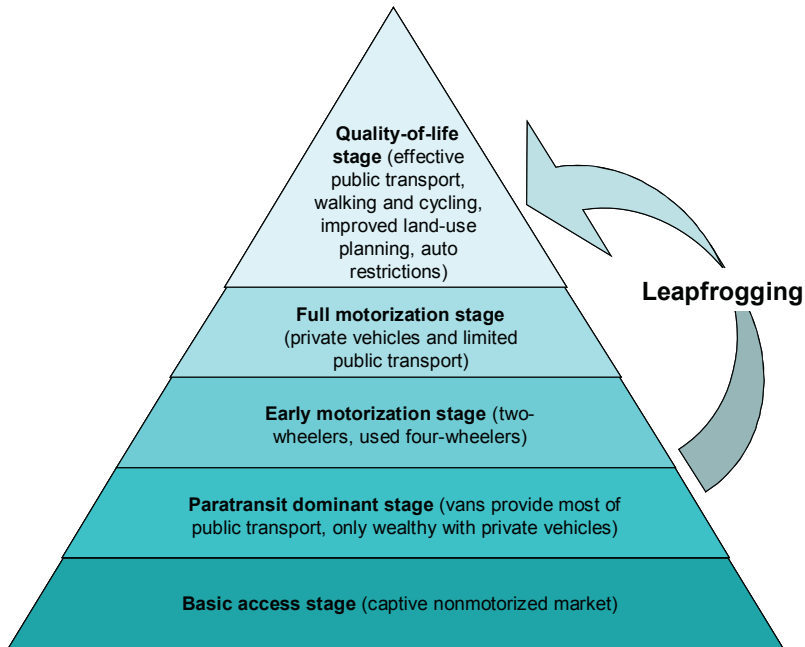
Transport is the only major sector in which base conditions tend to worsen as economic performance increases. As incomes rise, so do levels of car and motorcycle ownership, which leads to heightened levels of congestion and other problems associated with motorization. In the cities of the developing world, increased private motorization tends to decrease exchange and accessibility.

Developing-nation cities, though, are in a unique position to shape their form before a culture of motorization becomes fully established. Convincing individuals to leave their cars and motorcycles for alternatives is far more difficult and costly than retaining current users of sustainable transport options through improvements in quality. Instilling smart growth design principles into city expansion, maintaining public transport, and retaining nonmotorized users through service quality are proactive measures that are perishable in some ways if the opportunity is missed. Since major investments in road-based infrastructure are relatively irreversible over the medium term, decisions made by developing-nation officials today will likely determine the shape and direction of the future urban form.

Technological leapfrogging refers to a process by which developing countries can bypass intermediate development steps and progress directly to more advanced technological options. With regard to urban transport, this process implies a move directly to more sustainable transport options rather than committing to a predominantly car-based urban form. The evolutionary path ahead for developing-nation cities may be akin to a sort of hierarchy of needs for urban mobility. Historically, this evolutionary perspective has assumed that quality-of-life considerations will only be addressed after severe problems force change. Figure 4.2 outlines this process.

Implicit in the notion of Green Cities for developing nations is the idea that development and motorization can be decoupled. Sustainable transport options offer an alternative path for Green Cities. A complementary package of public transport, quality footpaths and cycleways, vehicle-restriction measures, clean fuels, safety programs, and high standards can constitute a new paradigm for urban mobility and access.

Figure 4.2 Hierarchy of urban transport through an evolutionary process



Source: Wright (2005).

Urban Transport Trends and Conditions

Since the first Earth Summit in Rio de Janeiro in 1992, understanding of the relationship between urban sustainability and the transport sector has improved significantly. Moreover, renowned examples of quality sustainable transport now exist in several locales, such as Amsterdam (Netherlands), Bogotá (Colombia), Brisbane (Australia), Copenhagen (Denmark), Curitiba (Brazil), Guangzhou (People's Republic of China [PRC]), Portland (United States), and Seoul (Republic of Korea).

Despite these gains in understanding and in delivering a few quality examples, the overall trends are toward greater private motorization, along with increased congestion, accidents, fuel consumption, and pollutant levels.

Transport may well be the weak link in terms of a broader realization of Green Cities. Cities may make significant strides in energy and water resource efficiency, waste management, green buildings, and even urban agriculture, but without land use planning and investment commitments to

sustainable access and mobility, congestion, pollution, and accident levels will undermine competitiveness in terms of livability.

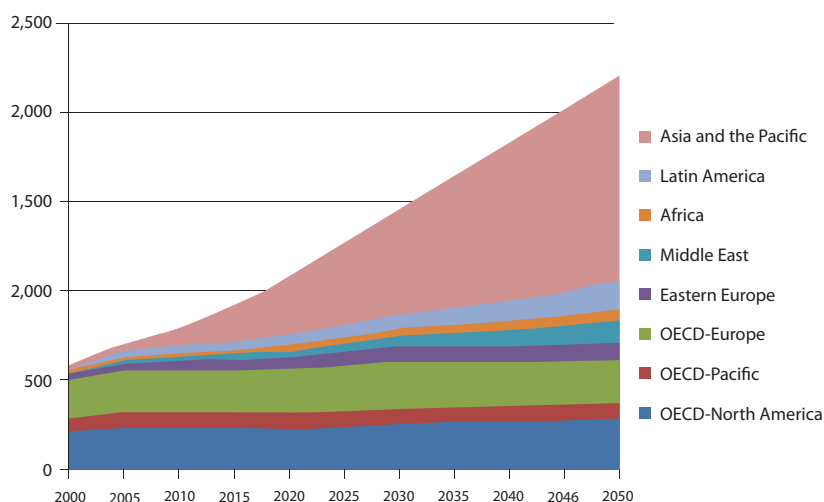
Growth in Private Motorization

Urbanization and private motorization are inextricably linked. As the world's population has become more urban, the global fleet of cars and motorcycles has followed in numbers. The world's urban areas will increase by 2.8 billion between 2010 and 2050 (UNDESA 2011). Of this, 96% will be living in low- and middle-income countries (ADB and World Bank 2012). At that point, the world's urban population will total 4 billion. The PRC alone is currently absorbing approximately 13 million rural residents every year into cities (Baeumler, Ijjasz-Vasquez, and Mehndiratta 2012).

The planet is currently home to approximately 1.2 billion vehicles, including light-duty cars and motorcycles, freight vehicles, and public-transport vehicles. This figure is projected to climb to 3.1 billion vehicles by 2050 (IEA 2011a).

The growth in motorized vehicle ownership has largely followed trends in per capita income, which is also associated with growing levels of urbanization. Dargay and Gately (1999) show that in the per capita income range of \$2,000–

Figure 4.3 Projected size of global passenger vehicle fleet by region
(in millions of light-duty vehicles)



OECD = Organisation for Economic Co-operation and Development.
Source: IEA (2011a).

\$5,000, vehicle purchases jump sharply. Several major developing nations are now entering this development zone of rapid motorization.

Impacts of Motorization

The impacts of dependence on private motorized transport are quite evident in much of the world today, especially in the rapidly growing economies of the developing world. These impacts of the growing use of cars and motorcycles appear in the economic, environmental, and social dimensions of urban life (Figure 4.4).

Figure 4.4 The many negative impacts of unsustainable transport

Air quality

Vehicle emissions harm human health and the natural environment

Noise and vibration

Noise affects productivity and health

Accidents

Each year 1.2 million lives are lost due to vehicle accidents

Global climate change

Vehicles are responsible for roughly 25% of fossil-based CO₂ emissions

Natural habitats

Roadways disrupt habitats and open areas to exploitation

Waste disposal

The disposal of vehicles and vehicle parts contributes to landfill problems



Congestion

Time lost in congestion affects overall productivity

Energy security

Dependence on petrol-based mobility affects national security

Economic efficiency

Financial capital consumed by car expenditures reduces capital for other investments

Severance

Roadways sever communities and inhibit social interactions

Visual intrusion

Cars, roads, and parking areas are all detractors from a city's beauty

Loss of living space

Roads and parking lots consume large amounts of urban space

Source: Wright (2005).

The smooth and timely movement of goods and people is a significant determinant of productivity and overall economic efficiency. The cumulative financial impact of traffic delays can be staggering. In 2010, traffic congestion costs in the United States totaled an estimated \$101 billion, principally in the form of passenger time and wasted fuel (Schrang, Lomas, and Eisele 2011). Bangkok's notoriously congested roadways are estimated to result in delays and inefficiencies totaling the equivalent of 6% of Thailand's gross domestic product (Willoughby 2000). Congestion also tends to exacerbate other negative impacts of private-vehicle use, such as the quantity of air pollutants (Figure 4.5).

Despite more than 100 years of technological refinement, emissions from a vehicle's tailpipe remain a serious health concern. Air pollutants from transport are linked to a long list of serious ailments, most notably, respiratory illnesses and cardiovascular disease. Epidemiological studies have directly linked transport-related contaminants to asthma, bronchitis, heart attacks, and strokes (Dockery and Pope 1994). Respiratory ailments

Figure 4.5



Photo: Karl Fjellstrom.

Trends in congestion, pollutant levels, and road accidents are all intensifying, especially in developing nations

and other diseases due to vehicle-related air pollution lead to 500,000 premature deaths each year, reducing global economic output by an estimated 2%–4%. In addition to premature mortality, there are also other economic costs of private-vehicle use that result from pollutant-induced illness. Hospital admissions, lost workdays, discomfort, and stress are just a few of these impacts.

Global attention is increasingly fixed on the tremendous human and material losses incurred from road accidents. The decade from 2011 to 2020 has been proclaimed the United Nations Decade of Action for Road Safety with focus on safety investments and interventions from national and international organizations. Road accidents result in nearly 1.3 million fatalities and approximately 50 million injuries and disabilities each year. Low- and middle-income developing countries account for 90% of road deaths, although these countries only account for 50% of the world's motorized vehicle fleet (WHO 2004). By 2020, road crash fatalities are projected to increase by 80%. Globally, road accidents will become the fifth leading cause of death in all age groups by 2030 (WHO 2009).

Noise is also a growing concern from both the perspective of health and economic productivity. Noise from vehicle operation, horns, and car alarms can all bring negative health consequences. The World Health Organization (2012) has documented the most common problems associated with sustained and/or excessive noise levels. These include pain and hearing fatigue, hearing impairment such as tinnitus, impacts on social behavior, sleep disturbance, cardiovascular effects, and immune system impairment. Sustained exposure to noise has been associated with delays in cognitive development and reduced classroom performance on the part of children (Evans and Maxwell 1997).

As noted above, while transport's impact on the local environment in terms of congestion, pollutants, and road fatalities is directly affecting development, the sector's most profound impacts may be those at the regional and global levels. Increasingly, transport has become a principal obstacle to achieving progress in areas such as energy security and global climate change.

Transport represents the fastest-growing source of greenhouse gas emissions. In 2009, transport was responsible for 23% of global carbon dioxide emissions from fossil-fuel-based sources, while the energy sector accounted for 41% of these emissions (IEA 2011b). However, by 2035, transport is expected to become the single largest greenhouse gas emitter, accounting for 46% of global greenhouse gas emissions (Clarke and Calvin 2008). Transport's relative rise as a leading emitter of greenhouse gases stems from the sector's reliance on oil as its principal fuel.

Transport's focus on oil as a principal fuel has meant that national energy security issues are also most closely associated with the sector. Oil-consuming nations that rely significantly on imported fuels are at risk in terms of consumer price increases, balance-of-payment impacts, and national budget shortfalls. The growth of motorization in countries such as India and the PRC has placed strains on regional and global energy security. Asia and the Pacific produces only 9% of the global supply of oil, but accounts for 26% of all oil consumed (IEA 2006). The region's oil-importing countries are particularly vulnerable to rapid changes in energy and fuel supplies, volatility of global fuel prices, and imbalances in the supply and demand for oil.

Transport Conditions in Developing-Nation Cities

The sharp growth in private motorization levels has not translated into improved mobility for much of the world. As noted above, increases in congestion, road accidents, and pollutants have meant that increasing investments in private motorized mobility are meeting with diminishing returns in terms of travel times and comfort.

While trends indicate continued growth in private motorized vehicle ownership, this implies another type of trend for nonmotorized options (walking and bicycling) and public transport. These modes are being discarded as soon as persons have the economic capacity to switch to motorcycles and cars. This exodus is to an extent tied to the increasing unsafe, insecure, and uncomfortable nature of streets and services.

Despite its economic importance to the poor, both as a mode of transport and a source of income, and its environmental advantages, the potential of non-motorized transport is often unmobilized or even positively suppressed... As a consequence, non-motorized transport becomes less safe, less convenient, and less attractive, making the forecast decline of non-motorized transport a self-fulfilling prophecy (World Bank 2001, 131).

If pedestrian infrastructure is of poor quality, then motorization can be the mode of choice even for very short distances. Pedestrians are typically faced with the following challenges:

- Complete lack of pedestrian pavements
- Poor quality of pavements, often of dirt or mud
- No physical separation from high levels of traffic and from high-speed traffic
- Extreme levels of noise and air pollution

Figure 4.6



Photo: Carlos Pardo.

The lack of adequate pedestrian facilities discourages walking as a viable option in many developing-nation cities

- Lack of infrastructure for crossing streets
- Obstructed pavements due to illegal (or legal) car parking, poor design, or uncollected rubbish
- No protection from harsh climatic conditions
- Lack of pedestrian-support infrastructure such as street lighting
- Pedestrian overcrowding due to narrow or below-capacity pavements
- High levels of robbery, assault, and other types of crime befalling pedestrians

Adapted from Vasconcellos (2001, 113) and Hass-Klau et al. (1999, 105)

The lack of formal pedestrian pavements in developing nations is relatively common. Hook (2003, 1–2) notes: “Over 60% of the roads in Jakarta, for example, have no sidewalks, and those that exist are heavily obstructed by telephone poles, trees, construction materials, trash, and open sewer and drainage ditches.” Crossing a street can be particularly difficult in low-income cities with a lack of formal crossings. In some instances, pedestrian

overpasses or underpasses are provided, but pedestrians often eschew such infrastructure due to reasons of safety and convenience (Figure 4.7). Pedestrian overpasses and underpasses in developing-nation cities are often either filled with informal merchants, or are inherently dangerous from a crime and safety standpoint. Darkened underpasses put pedestrians at particular risk to criminal elements. Not surprisingly, many developing-nation residents choose to take their chances crossing through the chaotic and dangerous maze of traffic. Vasconcellos (2001, 114) also notes that even when crossings are provided, they rarely give priority to the pedestrian:

Crossing facilities are also inadequate. Zebra crossings are rare, and signals rarely consider pedestrian needs. In such cases, pedestrians are seen as something that might be “stacked” until some gap is available in the traffic stream: “second-class citizens” have to wait until first-class ones exert their rights to use roads.

The poor pedestrian conditions in developing-nation cities can result in pedestrian trip distances that are considerably longer than those endured by motorized vehicles. Hook (2003) documents how sidewalk barriers and other detours in Surabaya (Indonesia) result in substantially longer journeys for pedestrians:

...pedestrian barricades and one-way streets have been used to facilitate long-distance motorized trips, but which simultaneously impose huge detours for short distance cycling and pedestrian trips. People wishing to cross a main shopping street often find it easier to take a taxi two kilometers than to walk across the street. In Surabaya, the World Bank estimated that these measures generate an additional daily 7,000 kilometers of needless vehicle traffic.

Likewise, public transport is undergoing a continual loss of mode-share across developing-nation cities (Wright and Hook 2007). The following are among the contributing causes of this trend:

- Inconvenience in terms of location of stations and frequency of service
- Failure to service key origins and destinations
- Fear of crime at stations and within buses
- Lack of safety in terms of driver ability and the road worthiness of buses
- Service is much slower than private vehicles, especially when buses make frequent stops
- Overloading of vehicles makes riding uncomfortable

Figure 4.7



Photo: Karl Fjellstrom.

Informal and dangerous roadway crossing in Dhaka, Bangladesh

- Public transport can be relatively expensive for some developing-nation households
- Poor-quality or nonexistent infrastructure (e.g., lack of shelters, unclean vehicles)
- Lack of an organized system structure and accompanying maps and information make the system difficult to understand
- Low status of public transit services

In many cases, collective transport services are provided principally by informal or paratransit operators, who are often given little investment support to deliver quality and safe services (Figures 4.8a–d).

Figures 4.8a–d



Photos: Lloyd Wright.

Collective transport services as operated in (clockwise from upper left): Nairobi (Kenya), Surabaya (Indonesia), Manila (Philippines), and Santo Domingo (Dominican Republic)

Sustainable Urban Transport

The concept of “sustainable transport” encompasses modes, practices, and policies that maximize the economic, environmental, and social benefits of access and mobility while minimizing negative externalities. In recent years, a framework for sustainable urban transport has emerged under the name “Avoid–Shift–Improve.” This framework highlights several dimensions of sustainable options while also indicating an order of priority for achieving improved transport services.

“Avoid” Strategies

“Avoid” refers to interventions that eliminate unnecessary trips or introduce travel substitutes that replace the need for physical movement. Avoiding or reducing travel needs is the first priority in a package of sustainable transport interventions, as “avoid” strategies produce the most complete sustainability benefits. Among the interventions that “avoid” or “reduce”

travel are improved urban design and use of information and communication technologies (ICTs).

Table 4.1 summarizes many of the types of “avoid” strategies, which typically fall into the categories of land-use measures and ICTs.

Recently, particular attention has been paid to the role that transit-oriented development (TOD) can play in both promoting sustainable urban form as well as providing a financing mechanism for implementation. TOD involves a package of measures that both eliminate trips and reduce trip length. A cornerstone of any TOD project is the development of commercial and residential property investment around public transport stations (Figure 4.9). Investment from TOD initiatives can be used to finance the public transport system itself.

Telemobility encompasses activities that use ICT as an alternative to physical travel. Some of the potential applications of telemobility include telecommuting, telework, teleconferencing, teleshopping, and telemedicine.

Figure 4.9



Photo: Lloyd Wright.

High-rise development along Bangkok's SkyTrain corridor

Table 4.1 “Avoid” strategies for achieving sustainable transport

Measure	
A. Land-Use Measures	
1. Integration of land use and transport	Integrated land use-transport planning Land use-transport institutional integration
2. Smart growth	Transit-oriented development zoning regulations Mixed development policies and incentives Densification policies and incentives Eco-blocks Developer incentives Land-benefit levies Location-efficient mortgages Development of greenbelts and urban boundaries Inner-city regeneration policies and programs
B. ICT Measures	
1. Information and communication technology	Internet bandwidth improvements Internet accessibility improvements Mobile-telephone market penetration Video-teleconferencing/Telepresence Telecommuting Telework Teleshopping

Source: Wright (2012).

Telemobility uses technologies such as telephone, email, and video teleconferencing to reduce transport needs. Telecommuters may still physically travel to their work headquarters on an occasional basis for face-to-face contact with colleagues, but in general, ICT is used to replace the daily work commute.

“Shift” Strategies

“Shift” refers to interventions that encourage market share to transfer to more environmentally and socially sustainable modes. In the context of developing-nation cities, the idea of “shift” may be more appropriately termed “maintain,” as most such cities are attempting to maintain their current relatively high share of sustainable transport modes despite ongoing market-share gains by cars and motorcycles. The transport modes typically

targeted by “shift” strategies include public transport and nonmotorized transport. Table 4.2 summarizes many of the types of “shift” strategies available to policy makers.

Public transport

Public transport systems can provide mobility for travel distances within an urban area. To succeed, though, public transport must be designed to be car-competitive. The following key customer-oriented features can make a public transport system car-competitive:

- Existence of an integrated “network” of routes and corridors
- Enhanced stations that are convenient, comfortable, secure, and weather-protected
- Stations that provide level access between the loading platform and vehicle floor
- Special stations and terminals that facilitate easy physical integration between trunk routes, feeder services, and other mass transit systems
- Preboard fare collection and fare verification systems
- Distinctive marketing identity for the overall system

There are many types of public transport technologies, including road-based and rail-based options. However, each type of technology is appropriate to particular technical and financial circumstances. The emergence of bus rapid transit (BRT) as a cost-effective solution to achieving a quality public transport system has particularly catalyzed new system development (Figure 4.10). BRT is “a high-quality, bus-based transit system that delivers fast, comfortable, and cost-effective urban mobility through the provision of segregated right-of-way infrastructure, rapid and frequent operations, and excellence in marketing and customer service” (Wright and Hook 2007). BRT essentially emulates the performance and amenity characteristics of a modern rail-based transit system, but at a fraction of the cost.

The BRT concept originated in a few innovative cities such as Curitiba, Brazil during the 1970s. Curitiba sought to achieve rail-like quality for public transport within a limited budget. Subsequently, BRT systems have now been developed in approximately 140 cities worldwide, with notable systems in Ahmedabad (India), Bogotá (Colombia), Brisbane (Australia), Cape Town (South Africa), Guangzhou (PRC), Las Vegas (United States), Nantes (France), and São Paulo (Brazil).

Figure 4.10



Photo: Lloyd Wright

The City of Curitiba (Brazil) pioneered the bus rapid transit concept in the mid-1970s

Nonmotorized Transport

To make public transport successful, though, integration with nonmotorized access is essential. In short, customers must be able to reach public transport stations safely, securely, and comfortably.

Nonmotorized transport (NMT) modes such as walking and cycling are the most basic and economic of mobility options. Yet at the same time, these modes are often the most ignored in terms of quality and investment. Simple, cost-effective investments in pedestrian infrastructure can make a substantial improvement in usage levels. The following menu of upgrades can achieve this:

- Repairing of surfaces and use of improved paving tiles
- Lighting
- Security cameras and presence of security personnel
- Amenity features such as street furniture, artwork, and public toilets

- Safe, signal-controlled crossings
- Covered walkways
- Direct routings for pedestrians
- Way-finding signage and information

Fully pedestrianized streets and city zones are an effective means not only of encouraging more walking but also of stimulating local economic development. Car-free shopping streets and historical centers are common in most major cities in Europe, as well as in many cities in Asia and Latin America. Kaufingerstraße in Munich (Germany) and Nanjing Road in Shanghai (PRC) are host to the world's highest pedestrian volumes. Copenhagen's (Denmark) development of pedestrianized areas began in 1962 and has continued to grow (Figure 4.11). During a typical summer's day, more than 260,000 pedestrians take to these areas (Gemzoe 2001). Other major car-free zones in Europe include the Baixa area in Lisbon (Portugal), Las Ramblas in Barcelona (Spain), the St. Germain area of Paris (France), and the central areas of Brugges (Belgium), Ghent (Belgium), Nürnberg (Germany), Obidos (Portugal), and Siena (Italy).

Car-free zones are also typical in many parts of the developing world. City centers in North Africa, Asia, and Latin America often quite naturally become car-free areas due to the narrow streets and human-scale form of such centers. Cities such as Buenos Aires (Argentina), Cartagena (Colombia), Curitiba (Brazil), Old Delhi (India), Quito (Ecuador), São Paulo (Brazil), and Shanghai (PRC) have permanent car-free areas.

Figure 4.11



Photo: Lloyd Wright.

Pedestrianized area in Copenhagen, Denmark

Figure 4.12



Photo: Lloyd Wright

Greenway corridor in Guangzhou, People's Republic of China

A relatively recent phenomenon is that of “greenways,” which are extended pedestrianized corridors that have often replaced former motorized-dominated landscapes with greenery and other public amenities (Figure 4.12). Greenways serve a multitude of purposes including mobility between key inner-city destinations, such as shopping and recreation areas. Both Seoul (Republic of Korea) and Guangzhou (PRC) have reclaimed former waterways that were previously entombed under urban highways. The razing of elevated motorways to make way for more human forms of transport is an interesting trend that has also taken place in North America and Europe. The greenways in Seoul and Guangzhou have now become iconic tourist destinations for these cities.

In many instances, pedestrian and greenway areas often also permit NMT vehicle access. NMT vehicles encompass a wide range of vehicle types including bicycles, nonmotorized tricycles, pedicabs, carts, and other human-powered vehicles. NMT vehicles are often critical in extending the effective range of the urban poor who are unable to afford private motorized transport or even public transport. NMT vehicles can increase the viable distance traveled by five times or more as compared to walking. Such vehicles can also constitute a key feeder service that links origins and destinations with public transport.

NMT vehicles are also a source of economic development in their own right, as these vehicles are often used for vending products and providing delivery services. Thus, bicycles are both a fuel security measure as well as a component of a strategy for achieving local economic development.

Other significant trends in NMT vehicle use include the growing popularity of bicycle-sharing systems and the development of modern pedicab services. Bicycle-sharing programs permit casual users to rent a bicycle at an affordable cost from rental stations around the city (Figure 4.13). Such programs thus extend the use of bicycles to those who choose to not personally invest in a bicycle. In 2005, implementation of the Paris *Vélib* bicycle-sharing system heralded a period of significant worldwide growth in such systems. Between 2005 and 2010, approximately 240 bicycle-sharing systems were established. The world's largest system operates in Hangzhou (PRC) with over 50,000 bicycles. "Fourth-generation" bicycle-sharing systems now employ modular stations that utilize smart-card access.

Figure 4.13



Photo: Lloyd Wright.

Bicycle-sharing system in Nantes (France)

Modern pedicabs hold the potential to improve the technical efficiency of the historical cycle-rickshaw, which is an important mobility option for short- to medium-trip distances. With the use of lightweight fiberglass bodies, recumbent driver positioning, and fully weather protected customer enclosures, modern pedicabs are increasingly positioned to become a high-quality mobility option (Figure 4.14). Optional electric-assist technologies also permit pedicab use in cities with hills and/or hot weather conditions. In many instances, pedicabs are incorporated into quality public transport systems as feeder services.

Figure 4.14



Photo: Lloyd Wright.

Modern pedicab technologies offer the potential to revitalize this form of transport

Transportation demand management

To incentivize users toward shifting to public transport and NMT, transportation demand management (TDM) can be an effective set of tools within “shift” strategies. TDM also functions as an “avoid” strategy by incentivizing alternatives to physical travel. TDM encompasses financial incentive schemes that discourage the use of private motorized vehicles, especially during peak periods.

The most renowned forms of TDM include congestion charging schemes that place a price on urban roadway usage. In 1975, Singapore first implemented the Area Licensing Scheme, which was a manually controlled road-pricing scheme. The scheme required motorists to pay for entry into a central Restricted Zone.

Technological advances enabled the city to implement an Electronic Road Pricing (ERP) scheme in 1998. This system utilizes short-range radio signals between in-vehicle electronic units and overhead gantries. The gantries are both on major avenues entering the central district and along certain highways. As such, charges are applied not only to the central district but also to congested highways. As of 2010, the Singapore system annually generated approximately \$46 million in revenues with operating costs of

\$9 million. The ERP scheme is credited with reducing traffic levels by 50% and increasing average traffic speeds from around 18 kilometers per hour to 30 kilometers per hour.

Subsequent to Singapore's ERP, congestion pricing schemes have been implemented in three Norwegian cities (Bergen, Oslo, and Trondheim), as well as in London and Stockholm.

Table 4.2 "Shift" strategies for achieving sustainable transport

Measure	
A. Public Transport	
1. Urban road-based	Bus rapid transit (BRT) lite Full BRT Paratransit upgrades Scholar services
2. Urban rail-based	Street trams At-grade light rail transit (LRT) Elevated LRT Personal rapid transit Underground heavy rail (metro) Elevated heavy rail Light monorail Heavy monorail
3. Fare systems	Integrated fare systems Free public transport
4. Inter-city travel	Improved long-distance bus services Improved standard inter-city rail services High-speed inter-city rail
B. Nonmotorized Transport	
1. Pedestrian initiatives	Pedestrian network development Pedestrian facility upgrades (surface, lighting) Car-free days Pedestrianization
2. Nonmotorized vehicles	Cycle-way development Bicycle parking facilities

continued on next page

Table 4.2 *continued*

Measure	
	Bicycle-sharing initiatives Pedicab initiatives E-bikes
C. Transportation Demand Management	
1. Pricing mechanisms	Congestion pricing Road tolls Parking fees Parking levies Fuel levies Removal or reduction of fuel subsidies Vehicle duties or levies
2. Regulation	Reduction in the number of parking spaces Vehicle ownership restrictions Pay-as-you-go auto insurance Restrictions on importation of used vehicles
D. Freight Transport	
1. Freight transport	Pricing incentives for road-to-rail shifts Provision of rail freight infrastructure

Source: Wright (2012).

“Improve” Strategies

“Improve” refers to interventions that increase the operational efficiency of vehicles. These types of interventions include propulsion technologies and fuels that enhance efficiency and produce fewer pollutants. “Improve” interventions can also include standards and policies such as fuel-efficiency standards and fuel-emission standards.

While transport represents a sizeable portion of national energy use and thus represents one of the largest and fastest-growing sources of greenhouse gas emissions, the sector is often ignored in terms of possibilities for mitigating energy consumption. This lack of attention to transport energy use occurs due to the difficulty of substituting other fuels for oil. Whereas power

generation enjoys a relative plethora of options (coal, hydro, natural gas, nuclear, solar, wind, energy efficiency), over 90% of transport is singularly dependent on oil.

Nevertheless, a combination of rising and volatile oil prices and new technological innovations has meant that there are increasingly viable alternatives to oil as a base transport fuel. Both hybrid-electric and plug-in electric vehicles are now commercially available. In the PRC, the government is providing incentives for increasing the market share of electric vehicles. Smaller vehicle types, such as two-wheelers and three-wheelers, are particularly suited to electric-drive systems, given lighter vehicle weights that are compatible with today's battery technologies (Figure 4.15). Lithium-ion batteries have helped to transform the electric vehicle market by offering high-energy densities, quick recharging times, and lightweight performance.

One obstacle to widespread application of new fuel technologies is the supporting refueling infrastructure required. The size and cost of retrofitting fuel stations is a daunting prospect that will likely stifle any proposed fuel transformation, even if other technological and cost barriers are overcome.

However, large fleets offer an opportunity for building up the scale of alternative technologies without the need for a mass transformation of refueling infrastructure. Large fleets typically employ centralized refueling depots, which imply only a relatively modest required investment in new refueling infrastructure. Since large fleets such as public transport vehicles and metered taxi vehicles are collective transport options, the implementation of alternative technologies in these cases coincides with the green transport agenda.

For this reason, fleet conversions to natural gas, biomethane, and hybrid technology are occurring at an accelerated rate (Figure 4.16). Compressed

Figure 4.15



Photo: ADB.

The Asian Development Bank has supported the trialing and implementation of electric three-wheelers in the Philippines

Figure 4.16



Photo: Lloyd Wright

Compressed natural gas vehicles are prevalent in the Seoul (Republic of Korea) public transport system

natural gas conversions to fleets in Delhi (India) and Dhaka (Bangladesh) during the past decade led to significant and immediate improvements in air quality. Between 2000 and 2003, Delhi (India) imposed a conversion to compressed natural gas for buses and auto rickshaws (i.e. motorized three-wheelers). The result was an immediate and significant reduction in air pollutants, including ambient reductions of 75% in carbon monoxide levels, 7% in particulate matter, and a 35% in sulfur oxides (Narain and Krupnick 2007). Compressed natural gas fleet applications in countries such as the Republic of Korea have also done much to improve national energy security.

Alternative fuels, though, can also bring unintended consequences that undermine their overall impact on sustainability. Biofuels were once hailed as a green energy solution for transport that also offered income benefits to farmers. However, the use of biofuels, both in the form of biodiesel and ethanol, has led to controversy regarding their impact on food prices. In addition to issues such as food versus fuel uses of agricultural products, biofuels have, in some cases, led to loss of key habitats through the replacement of biodiverse areas with monoculture plantations. Nevertheless, more sustainable forms of biofuel remain a major alternative fuel option.

Fuel and technology advancements can be encouraged through the implementation of fuel-economy standards, as well as fuel quality standards. Fuel-economy standards set minimum efficiency targets for new vehicles. Highly progressive standards have been established in the PRC, along with significant financial incentives for encouraging the use of electric vehicles.

Table 4.3 “Improve” strategies for achieving sustainable transport

Measure	Initial Priority for Pilot Study
A. Intelligent Transportation Systems	
1. System management and control	Public transport management systems Freight management systems Roadway incident management Traffic signal control and management
B. Fuel and Vehicle Technology	
1. Fuel switching and propulsion systems	Synthetic fuels Natural gas Biofuels (biodiesel, ethanol) Hydrogen fuel cells Hybrid-electric Electric
2. Vehicle design	Lightweight materials Aerodynamics System design for universal access
C. Regulation	
1. Standards	Fuel-economy standards Fuel-quality standards Tailpipe-emission standards Vehicle-noise standards Vehicle licensing and registration Auto-insurance requirements Driver licensing standards
2. Testing	Vehicle-emissions testing Vehicle-safety testing Driver-license testing

continued on next page

Table 4.3 continued

3. Enforcement	Traffic law and parking enforcement Vehicle-licensing enforcement Auto-insurance enforcement
D. Programs	
1. Vehicle and driving improvement	Eco-driving programs Vehicle-maintenance programs Programs for scrapping older vehicles
2. Scheduling	Alternative work schedules Alternative school schedules Flextime

Source: Wright (2012).

Green Cities and Transport

The growing emergence of “Eco-City” and “Green City” projects around the world demonstrates the new awareness being given to the fundamental sustainability of cities. These examples set the stage for wider replication of sustainable urban forms.

Perhaps the most encouraging aspect of the Green City movement is that many of these projects are market-driven. The demand for safe, secure, and clean communities gives added value to Green City designs. As families seek neighborhoods that are free from the risks of vehicle accidents and air contaminants, a market-driven housing can stimulate further development of these types of urban forms.

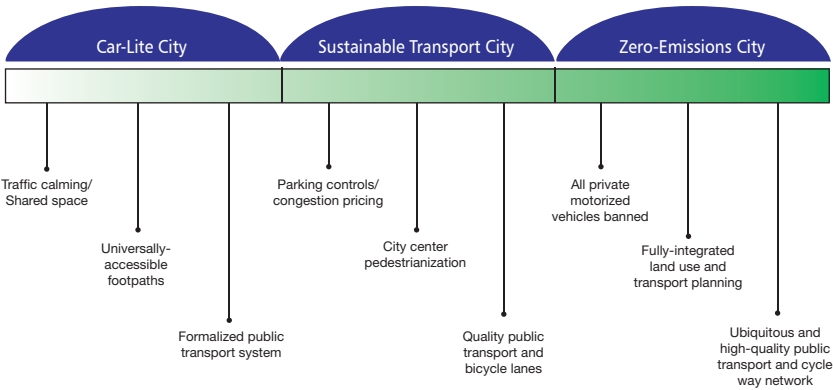
Spectrum of Transport Options Available to Green Cities

The transport systems employed in recent Green City demonstrations include a spectrum of possibilities, from relatively “car-lite” cities to fully “car-free” areas. In general, a Green City will include some form of motorized vehicle restrictions along with infrastructure and operational incentives for collective and/or nonmotorized transport. Figure 4.17 illustrates the potential spectrum of options for creating a city environment less dependent on private cars and motorcycles than at present.

On the one side of this spectrum are areas that discourage vehicle use without an absolute ban. Such areas are sometimes termed “traffic-calmed” areas or even “car-lite” areas. In this case, cities and communities permit

full motorized-vehicle access, but deter unfettered use and speeds through road design. As measures are introduced to prioritize public transport and NMT, the overall sustainability improves. Finally, on the greenest side of the spectrum are cities and communities that completely prohibit motorized vehicles, effectively creating a zero-emission city. Figure 4.18 presents a matrix that provides a sampling of Green City efforts in sustainable transport.

Figure 4.17 The spectrum of possibilities for transport in a Green City



Source: Wright (2012).

Figure 4.18 Examples of sustainable transport implementation

Strength of sustainable transport features	
Geographical coverage	Moderate sustainability impact
	High sustainability impact
Large-scale	<ul style="list-style-type: none"> • Singapore congestion pricing • Bogotá Sunday ciclovía • London bus lanes • Quito Sunday ciclopaseo
Small-scale	<ul style="list-style-type: none"> • Paris Plage • Jakarta car-free Sunday
	<ul style="list-style-type: none"> • Bogotá TransMilenio • Curitiba BRT and NMT • Song Do • Seoul Cheonggyecheon • Fez • Mascar • Venice • Zermatt • Freiburg Vauban • Houten (Netherlands) • Shanghai Nanjing Road • Copenhagen city center • Vienna Gloridsdorf • Barcelona las Ramblas • Munich Kaufingstraße

BRT = bus rapid transit, NMT = nonmotorized transport.
Source: Wright (2012).

Car-lite cities

For most cities and communities, the abandonment of motorized vehicles will not happen overnight. The funding available to create a Masdar (United Arab Emirates) or a Song Do (Republic of Korea) can be prohibitive for many cities and countries. Moreover, the political will required to transform a city in the manner of a Bogotá or a Curitiba is not always possible. However, cities and communities may choose an intermediate step that at least begins to shift the balance in urban design away from motorized vehicles. Measures which restrict private vehicle movements and speeds are a basic step in this process.

The Tianjin Eco-City in the PRC has adopted a car-lite approach to its design. Tianjin is utilizing mixed-use design to discourage car and motorcycle use, in conjunction with the provision of quality public transport and NMT facilities. The Tianjin Eco-City, though, will not restrict cars and motorcycles. Whether a “carrot-only” approach can succeed in a rapidly growing economy in which much social status is associated with vehicle ownership is yet to be seen. Placing a few “sticks” into the regulatory environment that partially or wholly restrict motorized vehicles may be a complementary approach for aspiring Green Cities to consider.

Traffic Calming

Historically, traffic-calming measures have been seen as mechanisms for improving pedestrian safety and curbing some of the negative impacts of motorization. By making the streets take on the characteristics of a yard or a park, motorists are obliged to curb dangerous speeds. The idea is to use design features such as trees, chicanes, and bumps to force motorists into acceptable behavior (Figure 4.19). Traffic calming was pioneered in the early

Figure 4.19



Traffic calming measure in Paris (France)

Figure 4.20



Shared space as practiced in Biel, Switzerland

Photos: Lloyd Wright.

1970s through “woonerf” designs in the Netherlands. Traffic calming may be a necessary first step in making residents realize that the streets are public spaces that do not belong exclusively to the automobile.

Shared Space

One of the most innovative concepts in recent years has been the idea of “shared space,” which is also known by several other names including “post-traffic calming” and “second-generation traffic calming.” With shared space, all physical differentiation between car space and pedestrian space is removed.

The concept of shared space originated in the Netherlands with applications in the cities of Drachten and Oosterwolde. Today, examples of shared space can be found more widely.

The idea is that the lack of signage and road markings increases uncertainty for motorists, who will then be more cautious within an undefined road environment. Through intrigue and uncertainty, motorists become more engaged in their surroundings (Engwicht 1999). In an area of shared space, neither pedestrians nor motorists have explicit signage to dictate who has priority. People must resort to eye contact and other forms of subtle communication to navigate the roadway, which leads to slower speeds and safer conditions (Figure 4.20).

Temporary Interventions

Annual Car-Free Days

Car-free days are increasingly high-profile events that can be useful in awakening a city and its residents to the possibilities of a different urban environment. The principal premise behind such days is the idea of creating a “pattern break” in which awareness of transport alternatives is promoted:

By creating a break in the normal pattern of behavior, Car-Free Days (CFDs) can provide an opportunity for the citizens and the municipality to take a step back and reconsider the development path of the transport sector and whether it takes into account and meets the needs of all people...On an even broader scale, CFDs can serve to spark a dialogue about the future of the city and allow citizens to ask what exactly they envision their city to become in say, 20, 50, and 70 years (UNCFD 2005).

The date 22 September is now recognized as International Car-Free Day (Figure 4.21). The scope of the day varies depending on local circumstances. In some cases, the event may be just one street in one sector of a city. In other cases, there is a more expansive effort.

Figure 4.21



Photo: Lloyd Wright.

International car-free day in Zurich (Switzerland)

Car-Free Sundays

Also increasingly common are car-free Sundays on which cities dedicate a portion of their street network to a weekly festival that promotes health, green transport awareness, and community sociability. Cities that hold such events include Bogotá (Colombia), Jakarta (Indonesia), Lima (Peru), Los Angeles (United States), Mexico City (Mexico), Montevideo (Uruguay), Pasig City (Philippines), Porto Alegre (Brazil), Quito (Ecuador), Rio de Janeiro (Brazil), Rosario (Argentina), Solo (Indonesia), and Surabaya (Indonesia).

Bogotá closes 120 kilometers of urban arterial streets during its Sunday “Ciclovía.” On this day, the city takes on a carnival atmosphere with as many as two million persons taking to the streets either walking, cycling, skating, or participating in community events (Figure 4.22). Bogota complements the Sunday “Ciclovía” with a large permanent cycleway network, as well as a quality BRT system known as “TransMilenio.”

Figure 4.22



Photo: Lloyd Wright

The car-free Sunday "Ciclovía" in Bogotá

Quito closes its historical center to traffic and becomes a focal point for families, tourists, and those attending religious services. On Sundays, Rio de Janeiro closes Avenida Atlântica along the famous beach of Copacabana.

Car-Free Seasons

More broadly are car-free seasons in which an area is closed to motorized traffic over a longer period. Since 2002, Paris (France) has created a car-free area during the summer months along the Seine River. Known as the Paris Plage (Paris Beach), the area is decorated with palm trees and sand. As many as 3 million persons per week have visited the area, making it popular with both local residents and visitors. The area has added a swimming pool as well as sand boxes for castle building. The success of Paris Plage has spawned similar efforts elsewhere. Cities as diverse as Berlin (Germany), Rome (Italy), and Soweto (South Africa) have experimented with their own forms of urban beaches.

Zero-Emission Cities

Several of the well-known Green City initiatives have created entirely car-free living spaces in conjunction with quality public transport and nonmotorized networks. These examples highlight the potential for broader implementation of zero-carbon cities.

Car-Free Cities

Masdar in Abu Dhabi has attempted to set a new standard for greenfield Eco-City implementation. Masdar has aimed to become the first major community worldwide to achieve zero net carbon emissions. The city utilizes traditional architecture to create intimate and safe, shaded streets that encourage walking. At the same time, Masdar has constructed a personal rapid transit system, which utilizes automated pod cars to take individuals between major destinations in the city. The system is powered by Masdar's solar energy infrastructure.

While Masdar and other similar efforts provide a glimpse of what is possible, for much of the world, the conversion of existing communities into Green Cities is the actual task at hand. Thus, the lessons from a few car-free historical cities are worth noting. Venice (Italy) and the medina of Fez (Morocco) are probably the closest that any major urban areas have become to true car-free cities. The central area of Fez most likely hosts the world's highest car-free population in a single concentrated area, with approximately 156,000 inhabitants (Figure 4.23, Wright 2005).

Figure 4.23



Photo: iStockphoto.

The Medina of Fez (Morocco) is the world's largest car-free city with over 156,000 inhabitants

The historic portion of Venice (Italy) is perhaps the best known of cities that are predominantly car-free. In Venice's case, this aversion to the automobile is due to its unique geography and the need to retain its historic character. Likewise, other historic and resort cities such as Louvain la Neuve (Belgium), Capri (Italy), and Zermatt (Switzerland) are essentially car-free within city boundaries. Venice, Capri, and Zermatt are also notable as locations with some of the world's highest residential property values, thus indicating that car-free locations can in fact bolster economic value.

Even within cities that are almost completely car-free, there are times when exceptions are permitted, such as the use of emergency vehicles. There are also many examples of cities that permit small electric vehicles to assist with the movement of goods and the transit of the elderly or disabled persons (e.g., Zermatt, Switzerland).

Car-Free Housing

"Car-free housing" represents a new market-driven force that allows consumers to choose a residential area without the dangers of motorization. Such housing has become popular in Europe as a niche market for families and individuals wishing to improve their quality of life through a car-free environment. The success of these developments has demonstrated that families are placing a discernible market value on neighborhoods that permit children to play without fear of the noise, pollution, and accidents generated by unrestricted car access. Such communities are typically developed around accessible and high-quality public transport systems, as well as extensive cycleway networks.

Among the most renowned examples of car-free housing projects are: BedZed (London, United Kingdom), Barmbek-Saarlandstrasse (Hamburg, Germany), Florisdorf (Vienna, Austria), GWL-terrein (Amsterdam, Netherlands), Langwaser (Nürnberg, Germany), Oyumino (Chiba, Japan), Slateford Green (Edinburgh, United Kingdom), Stuttgarter Strasse (Tübingen, Germany), and Vauban (Freiburg, Germany) (Scheurer 2002). The Vauban development in Freiburg is the largest car-free community of its type, with approximately 5,000 residents (Figure 4.24). Residents may own a vehicle, but it must be stored outside the community at an annual cost of approximately €17,500 (Autofrei Wohnen 2012).

Figure 4.24



Photo: iStockphoto.

The Vauban car-free community in Freiburg (Germany) is home to 5,000 residents

Integrating Transport and the Green City

Green transport is just one requisite for a Green City. Other chapters of this book have elaborated upon innovations in spatial development, energy systems, waste management, water systems, and information management.

However, developing each of these components individually does not make for a synergistic package of interventions. Opportunities exist for incorporating aspects of each of these elements within detailed aspects of

green transport development. This section outlines examples of how green transport planning can be integrated with these other sectors to produce a more holistic outcome.

The synergies between transport and each of the other municipal sectors will not become apparent if sector planning is conducted in isolation. The mutual benefits shared by the various sectors of Green Cities are best realized through an integrated and holistic planning process in which municipal officials, financing organizations, and private sector partners aggressively seek out opportunities.

Transport and Spatial Development

Transport and spatial development are perhaps the most inseparable components of a full Green City plan. A well-executed spatial development plan incorporating smart growth designs means that motorized travel can be largely forgone.

“Smart growth” design concepts were developed during the New Urbanist Movement of the 1990s. Smart growth seeks to counter sprawl through mixed-use, higher-density development (Calthorpe 1994, Katz 1994). Mixed-use design that allows residential, commercial, and even light industrial activities to coexist in close or even overlapping proximity permits inhabitants to live, work, shop, and recreate in the same neighborhood (Figure 4.25). Medium- and high-density development gives communities the necessary economies of scale to support quality public transport.

It is not just that well-designed spatial development leads to green transport, but rather that these two aspects of urban life interact in a way that facilitates smart-growth development. Thus, green transport designs facilitate better spatial development. Transit-oriented design focuses development around public transport nodes such as stations and interchange facilities. Since public transport nodes focus a large number of persons into a defined space, a critical mass of pedestrian numbers in turn enhances property values in a way that makes smart-growth development financially viable.

Land-use patterns are often defined around the three “Ds” of density, diversity, and design. Green transport modes, such as public transport and nonmotorized transport (NMT), are often used as tools to achieve spatial development that maximizes the potential of the three Ds.

Figure 4.25



Photo: Lloyd Wright.

Mixed-use design, as in this example from Shanghai (People's Republic of China), enables a high-quality living environment by placing public amenities in close proximity to one another

Transport and Energy

As noted in this chapter, a new mix of alternative fuels is beginning to achieve breakthroughs in the cost competitiveness and market share of environmentally sound transport modes. Among the potential alternative fuel and propulsion systems are hybrid-electric and plug-in electric vehicles, and vehicles powered by natural gas, biomethane, and biofuels. The idea of “smart grids” in which electric vehicles effectively act as batteries for the power generation system holds much potential for supporting both cleaner vehicles and the expanding renewable energy sector.

In addition to vehicle technologies, public transport systems such as bus rapid transit, light rail transit, and bicycle-sharing systems also offer other types of opportunities for showcasing alternative energy technologies. The location and power requirements of public transport stations are often well suited to renewable energy technologies such as solar photovoltaic panels. Such stations are typically located in roadway medians that provide relatively uninhibited exposure to sunlight. At the same time, the lack of existing power

connections to new station areas means that solar photovoltaic panels can compete financially with conventional options.

The exposure of renewable energy technologies at public transport and bicycle-sharing facilities also serves a key marketing purpose as well. The highly public display of solar photovoltaic panels acts to mainstream these technologies within the public sphere (Figure 4.26).

Public transport stations and corridors are also appropriate locations for investment in energy-efficient lighting, both in terms of interior lighting and street lighting. Transport facilities are ideal markets for efficient lighting technologies, such as compact fluorescent lamps for station interiors and light-emitting diode technologies for information signage and street lights. Both the technical application and the bulk procurement aspects of these facilities lend themselves to the performance and cost-effectiveness of these lighting technologies.

Figure 4.26



Photo: Lloyd Wright.

A photovoltaic panel helps meet power needs at a bus rapid transit station in Johannesburg, South Africa.

Figure 4.27



Recycling bin on the platform of a Frankfurt (Germany) rail station

Figure 4.28



Cargo bicycles are utilized to move recyclable waste materials in Johannesburg (South Africa)

Photos: Lloyd Wright.

Transport and Waste Management

Transport is well positioned to be both a catalyst and an enabler of greener waste management.

First, the rise of biomethane (i.e., biogas) as an alternative fuel option has created a new market dynamic for encouraging investment in effective waste management systems. Biomethane is a gas produced from the biological breakdown of organic matter in the absence of oxygen (i.e., anaerobic digestion or fermentation). A wide variety of waste streams are suitable to the production of biomethane, including solid consumer wastes, sewage sludge and wastewater, food and agricultural wastes, and animal wastes.

Transport gives value to implementing systems that lead to the more rational collection and processing of waste streams. Recycling programs help produce “cleaner” wastes that are more useful and valuable in producing biomethane. The capital-intensive nature of establishing wastewater piping networks can be partially financed through the use of waste as a transport fuel.

As oil prices continue to undergo increases and bouts of volatility, the competitiveness of fuels such as biomethane becomes sufficient to justify investments in better waste management.

Second, public transport and bicycle-sharing stations are also logical venues for waste management facilities. These stations attract a large number of customers, which provide the critical mass needed to cost-effectively collect and manage solid wastes (Figure 4.27). In many cases,

the dedicated lanes of bus and light rapid transit systems provide an ideal means of permitting efficient operation of waste management vehicles in urban areas. In addition, nonmotorized vehicles can be effectively employed in hauling and centralizing waste collection within urban areas (Figure 4.28).

As has been demonstrated in other sectors, greener waste management and greener transport modes share mutual synergies that result in cost effectiveness and increasing market share for both.

Transport and Water

As noted above, transport can create a value-adding opportunity for investment in wastewater systems through the production of biomethane that can be used as a transport fuel. The long-term value of biogas capture can help justify investment in a wastewater collection and processing system.

In many cases, transport infrastructure may also help catalyze investment in cleaner waterways. As demonstrated by the greenway investments in Seoul (Republic of Korea) and Guangzhou (PRC), the proper treatment of wastewater is fundamental to such waterways being utilized as pedestrian thoroughfares (Figure 4.29). Likewise, the current initiative of cleaning up the Pasig River in Manila (Philippines) can bring together efforts at both restoring an urban environment and creating a greenway network across the city.

Figure 4.29



Photo: Lloyd Wright

The Cheonggyecheon stream restoration in Seoul, Republic of Korea transformed a water resource as well as created a new greenway corridor through the city

As is also the case above with energy and waste management, public transport facilities can be a logical venue for water-capture investments. Rainwater captured from the roofs of public transport stations can in turn be used in public toilets at these stations, as well as for watering landscaping along the public transport corridor.

Transport and Urban Agriculture

Urban agriculture contributes to local food security, reduces pressures on hinterland habitats, and provides nourishment to low-income populations in urban areas. Growing food locally changes the historical relationship between transport and agricultural production.

The fact that urban agriculture makes crops and produce available in close proximity to markets means that the traditional distribution and logistics chain is no longer necessary. Instead of requiring complex distribution through shipping and trucking firms that employ energy-consuming technologies to deliver perishable products, more locally appropriate options are possible.

With food production either within a few hundred meters or a few kilometers of markets, carts and other nonmotorized cargo modes are both feasible and desirable. Urban agriculture often means fresher food quality, which can mean processing in smaller batches. This type of production is well suited to batch-type cargo vehicles that do not have large environmental footprints and depend on costly logistics.

Conclusion

Access and mobility are fundamental enablers of development. Unfortunately, as rapid urbanization has led to rapid motorization, the preferred form of mobility, specifically private cars and motorcycles, has ironically resulted in less access and mobility. Congestion, contamination, and road deaths are increasingly a defining feature of modern cities, and especially cities of the developing world.

The alternative transport pathway for green cities is achieved through designing away the need for private motorized transport in the first place. The Avoid–Shift–Improve framework articulates both the content and priorities that seem to best present such an alternative. A synergistic package of mixed-use development, integrated spatial planning, quality public transport and NMT facilities, disincentives to car and motorcycle use, and clean vehicle technologies offers a way forward toward Green Cities.

The results of experiments in car-lite and car-free environments indicate that the Green City vision is indeed realizable. The plethora of cities that have implemented car-free Sundays demonstrates the popularity of such measures with the public. The emergence of purpose-built Green Cities such as Masdar and Song Do, in addition to historically car-free cities such as Fez and Venice may indicate that a new momentum has gathered for sustainable transport as a central planning principle. The market-driven nature of car-free communities, such as Vauban in Germany, means that a percentage of the population indeed prioritizes quality-of-life in choosing living options.

Mobility and exchange were the reason for the invention of urban areas. It is therefore appropriate that a new vision for transport is the basis for transforming today's cities.

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CHAPTER 5

Green Cities: A Water-Secure Future

by Alan Baird and Theresa Audrey O. Esteban with contributions from Maria C. Ebarvia and Francisco Roble, Jr.

Water Insecurity: A Growing Threat to Economic Growth and Sustainable Development of Our Cities

An Era of Water Scarcity

Urbanization has spawned the rapid emergence of megacities. By 2015, it is expected that there will be about 60 megacities in the world. A troubling trend is that the most rapid urban growth is taking place in the economically weakest countries. Similarly, this growth is taking place in regions in which water resource endowments are limited, technical and management capacities are comparatively poor, and institutions are relatively weak.¹ This makes successful water management of the river basins surrounding the megacities of the developing world a most challenging and complex task (J. Lundqvist, J., A. Biswas, C. Tortajada, and O. Varis 2006).

Asian Water Development Outlook 2007 (AWDO 2007) published by the Asian Development Bank (ADB) indicated that Asian countries are likely to witness massive urbanization over the coming 2–3 decades. However, growth rates across the region's various types of urban areas (megacities, large cities, and other urban centers) will differ. AWDO 2007 suggests

¹ Annual per capita water endowment (or endowment) is the notional volume of water (in cubic meters) available to each resident of a city, region, or country annually. It is calculated as the volume of accessible (reliable) freshwater available each year, divided by the number of residents in the jurisdiction in question.



Photo: Eric Sales (South Asia/Bangladesh), ADB.

A woman accessing drinking water

that while megacities and large cities consume a larger share of national resources, population growth rates in these larger urban areas will be much slower than those in smaller urban centers. This implies that the region's various types of cities will face differing types of challenges.

Continuing human migration to the region's cities brings with it a parallel growing demand for delivery of basic services, water in particular. While the supply of water in some cities has kept pace with this rising demand, the question remains as to whether the water supplied will continue to be both economically accessible and fit for treatment to potable standards. However, there is an additional dimension to meeting this demand, which is its sustainability and resilience. Many cities rely on nonrenewable sources of freshwater, or supplies that lack resilience to seasonal weather patterns and/or the future impacts of climate change. This results in continual reductions in the supply of water available to such jurisdictions over time.

The importance of providing water that is "fit for purpose" underscores the fact that freshwater is a scarce resource that must be managed if it is to remain available over time. In their water-sensitive cities framework, Brown, Keath, and Wong (2009) emphasize that obtaining "water-sensitive city status" (which is roughly equivalent to a city's being livable) implies that environmental repair and protection, supply security, flood control, public health, and economic sustainability are well integrated. These factors

thus must be built into a city's development agenda, which should have a particular focus on managing dwindling supplies of accessible freshwater and on ending the practice of mining nonrenewable sources.

For a city to be green and self-sustaining, it must engage in the complex process of unbundling its water security status, and mapping out both the problems and solutions associated with it. To illustrate the issues relating to water security status, and to identify some choices and solutions regarding it, the authors have particularly focused on Asia and the Pacific.

Putting Cities in Their Place

Water security is beginning to be recognized as a significant issue for the 21st century. Until recently, water has generally been perceived as being an abundant, accessible, and renewable resource. While threats to water availability constitute a global issue, at the regional level these threats are concentrated in particular areas such as river basins and cities.²

Ultimately, cities share water with other users that are located within a single river basin, the latter often being geographically much larger than even a megacity. Thus, while cities are important users of water in terms of quantity consumed, for most river basins, they are by no means its major consumers.³ As a result, security-of-supply issues should always be set in the context of the overall river basin concerned, rather than in the context of the city in question.



Photo: Ariel Javellana (Southeast Asia/Lao PDR), ADP.

A mother and child preparing to fish in a river

² Water stress exists when per capita water endowments fall short of 1,700 cubic meters.

³ In many of Asia's river basins, agriculture accounts for up to 80% of all water used by human activity. However, this does not equate to agricultural consumption, since much of the water used by irrigation systems is returned to the river basin concerned as surface water or groundwater.

Few urban residents, businesses, or administrators even speak about their city in the context of that city's corresponding river basin. As a result, these three groups are often conspicuously absent at discussions that concern the need for robust basin-level management of shared water resources. This is unfortunate, since river basins are the source of all water used by cities. Further, if a sound approach to managing scarce water resources is absent, the city in question will not have a secure or sustainable future water supply.

As a result, economic advance in a particular city, or even the region to which that city belongs, may be constrained, since water shortages impact both a city's level of industrial productivity and local production of food and energy. Thus, the water–food–energy nexus functions as a shorthand for the links between an urban center's water, food, and energy supplies.⁴

Water Insecurity and Cities

The consequences of a particular city failing to achieve water security are profound. Cities serve as economic and political centers of the regions and countries to which they relate. Furthermore, all industrial, commercial, and domestic activities use water. While the volume of water consumed by such activities falls short of that “diverted” into agricultural uses, cities account for a significant share of total water use and, often, misuse. Because, as pointed out, unsustainable management of the water resource threatens the economic activities that take place in cities, the challenge is to prevent cities and the river basins of which they are part from lurching toward water stress, and, ultimately, water scarcity.⁵

Many cities in developing countries face challenges associated with their sheer scale, these challenges themselves making prudent planning for water security difficult. These include rapid population growth, transient communities and/or squatter areas of significant size or scale, rapid economic growth, ill-considered town planning, and the negative impacts of climate change. In such cities, simply keeping pace with the burgeoning demands that are placed on the water resource seems a nearly impossible task. This is particularly true because the pace of growth these cities are experiencing is without precedent. Thus, historical examples of how other cities have addressed the challenges that today's Asian urban areas are

⁴ The water–food–energy nexus (or water–food–energy security nexus) refers to the relationship between water use across the industrial, energy, agriculture, and municipal sectors.

⁵ Water scarcity is generally defined as availability that falls short of 1,000 cubic meters per capita per year.

facing are nonexistent. Not only did the pace of most Western European and North American cities grow more slowly than that at which today's large Asian cities are growing, but these older cities also experienced their most rapid growth during an era in which there was great public sector interest in delivering and financing municipal services.

At the basin or catchment level, some regions face a more uncertain water-security future than do others. For example, Asia and the Pacific has the lowest per capita availability of freshwater in the world (UNESCAP 2006). Further, rapid urbanization and consequent waste both contribute to pollution of dwindling supplies of accessible freshwater.



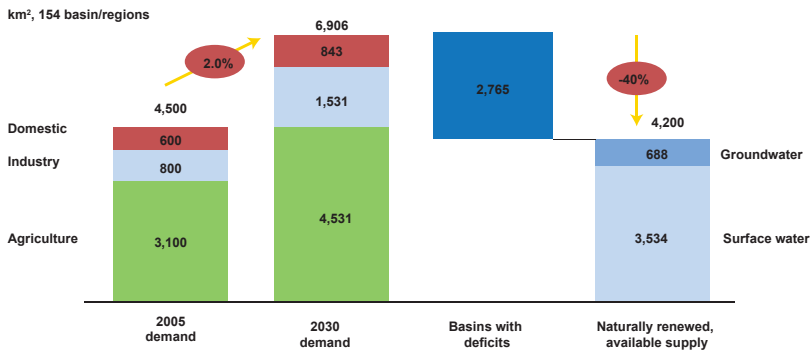
Photo: Gerard Carreon (Central Asia/Afghanistan).

Children fetching water at a community standpipe

A number of respected organizations have presented compelling evidence of either existing or emerging water scarcity. The most frequently referenced study in this regard is *Charting Our Water Future* (2009) by the 2030 Water Resources Group. In sum, their analysis shows that assuming present consumption trends continue, and that the total annual sustainable supply of freshwater remains static at 4,200 billion cubic meters (m^3), the annual deficit forecast for 2030 is 2,765 billion m^3 , or 40% of unconstrained demand. This supply gap (see Figure 5.1) has become the starting point for much of the current narrative surrounding water security. In short, the gap between sustainable supply from global river catchments and projected demand in 2030 is 40%.

In some catchments, this gap is already evident during periods of below-average rainfall. While demand from the domestic sector pales in comparison with the other sectors, water is as much a local (i.e., city-level) issue as it is a regional, national, and global one. The most significant challenge is that of how demand for water might be reduced. Because affordable supply-side options have all but been exhausted, demand-management interventions are now the focus of policy makers, urban policy makers in many cases taking the lead in this regard.

Figure 5.1 Forecast Water Shortage for 2030



Note: The analysis determined that today's naturally renewable and available supply is about 4,200 cubic kilometers (km³), being about 16% groundwater and 84% surface water. Based on the demand of the domestic (or municipal), industrial, and agriculture sectors, demand of about 6,906 km³ in 2030 would outstrip supply by that year. This shortfall of approximately 2,765 km³ is known as the "supply gap."

Source: 2030 Water Resources Group (2009).

Not Just About Quantity

Many regions face challenges regarding declining availability of freshwater. For example, while Asia accounts for only 36% of the world's total water supply, Asia and the Pacific is home to more than 60% of the world's population. Furthermore, approximately 477 million people in the region have no access to safe water, and 1.8 billion people have no access to improved sanitation facilities whatsoever (WHO/UNICEF Joint Monitoring Programme for Water Supply and Sanitation 2010). Freshwater is thus a limited resource, and one that is declining in volume in many regions because of various factors. Its availability is also increasingly threatened by rapid population growth, expanding industrial and agricultural activity, growth of urban areas, and climate change, the latter threatening to alter hydrologic cycles in major ways.

As cities grow in linear terms, the amount of waste they generate grows exponentially. Thus, rather than being simply an unsightly inconvenience, pollution depreciates property values, discourages economic development, negatively impacts health and productivity, raises municipal bills (and taxes), contaminates drinking water, spoils the water used to provide numerous urban amenities, and creates countless other hazards. Despite these

negative impacts, solid waste and wastewater from various sources continue to be discharged without appropriate treatment. In Asia and the Pacific alone, approximately 80% of all wastewater is discharged in its untreated form (Corcoran et al. 2010). Moreover, open defecation practices, lack of improved sanitation facilities, and inadequate solid waste and wastewater management systems pollute groundwater, rivers, and coastlines, which constitute the same bodies of water that are used for drinking, fishing, bathing, and swimming. Much of what water is available is thus contaminated to one degree or another. As a result, the source of the water crisis threatening many cities and regions is pollution of existing water resources.

Finally, the manner in which freshwater is allocated in the region's cities has generally assigned a low priority to environmental quality and aquatic biodiversity, which has likewise negatively impacted the sustainability of this important resource. As a result, water in many urban areas has often been used as a dump site for untreated waste to such a degree that the natural self-cleansing capacity of water bodies was exceeded long ago. In sum, if economic advance is to proceed at the pace it had in the past, cities must give high priority to protecting their water resources, most importantly by reducing the rate at which untreated solid and liquid waste is discharged into water bodies, regardless of whether this waste is of industrial, agricultural, or municipal origin.

Envisioning Water-Secure Cities

A State of Water Security

Asian Water Development Outlook 2012 (AWDO 2012) identifies five key dimensions of water security: (i) satisfying household water and sanitation needs in all communities; (ii) supporting agricultural and industrial production; (iii) developing vibrant, livable cities and towns; (iv) restoring the health of rivers and ecosystems; and (v) building resilient communities that can adapt to change (ADB 2012).

These five key dimensions in turn relate to five different types of water security as follows: (i) household water security, (ii) economic water security, (iii) urban water security, (iv) environmental water security, and (v) water-related disaster resilience.

In short, achieving all five types of water security at the city level requires that policy makers address all issues relating to (i) water supply, (ii) wastewater treatment, and (iii) flood control. However, the concrete steps necessary for addressing these three sets of issues vary widely from city to



Photo: Inna Mkhitarian (Central Asia/Armenia).

A mother and child using a public tap

city and river basin to river basin. Thus, no prescribed series of steps can be identified for consistently addressing a particular city's water security-related issues, or for formulating appropriate solutions to them.

AWDO 2012 summarizes the widely varying indicators used by the countries of Asia and the Pacific in assessing the level of water security they have attained. The wide variation in the indicators used across the region demonstrates the complexity of achieving water security by particular cities or countries.

Table 5.1 uses the Composite Water Security Index (CWSI) developed by AWDO 2012 to summarize the degree to which selected countries of Asia and the Pacific have achieved water security. The values for this index range from 1 to 5, the latter representing the highest score in achieving water security, while a value of 1 indicates that the level of water security achieved by the country in question is unsustainable.

The values reported in Table 5.1 demonstrate that no country included in the results has reached a "model" level of water security. In fact, most have yet to achieve "effective" or even "capable" status. Note that the CWSI can be used by policy makers at the city level as well as the country level.

Table 5.1 Composite Water Security Index Values for Selected Countries of Asia and the Pacific

CWSI	Water Security Status	Criteria	Number of Countries
5	Model	Sustainable financing for water security, environmental protection and management already established	0
4	Effective	Water security given high priority in the national agenda; appropriate public investment in water security; effective regulation and enforcement; public awareness and ongoing behavioral changes apparent	4
3	Capable	Increasing levels of investment and strength of regulation and enforcement; water security and environment recognized as priorities in the national development agenda; improving technical and financial capacities in addressing water-related issues	10
2	Engaged	Need to invest in water security recognized, including investment in capacity-building programs; ongoing institutional development and strengthening; improving policy environment in which water-related issues are addressed	29
1	Hazardous	Inadequate levels of investment in water-related infrastructure and poor-quality regulation and enforcement result in hazardous levels of water security	5

CWSI = Composite Water Security Index.

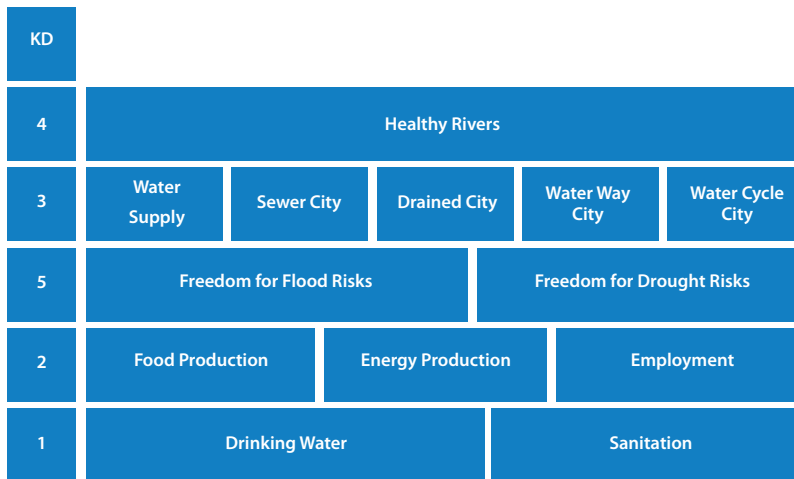
Source: Asian Water Development/ADB (2012).

In the end, the degree to which water security for the countries of the region is attained will directly depend on the degree to which policy makers see appropriate management of the region's river basins as a precondition for sustained rapid economic advance.

A Sustainable Water Future

The five key dimensions of water security referred to at the beginning of this section can be mapped in terms of their urgency, with the first of these dimensions (satisfying household water and sanitation needs in all communities) being the most urgent. Figure 5.2 depicts these five dimensions

Figure 5.2 Diagrammatic Representation of the Five Key Dimensions of Water Security and Corresponding Policy-Related Issues



KD = key dimension.

Source: ADB/AWDO (Patterned after Maslow [1943]).

in terms of their relative urgency and identifies the issues associated with each that policy makers must address if long-term water security is to be achieved.

Each key dimension referred to above relates to a set of issues regarding water management, governance, and use that policy makers must ultimately address for water security to be attained. For example, economic water security (key dimension 2) relates to water security in the agriculture, energy production, and industrial sectors.

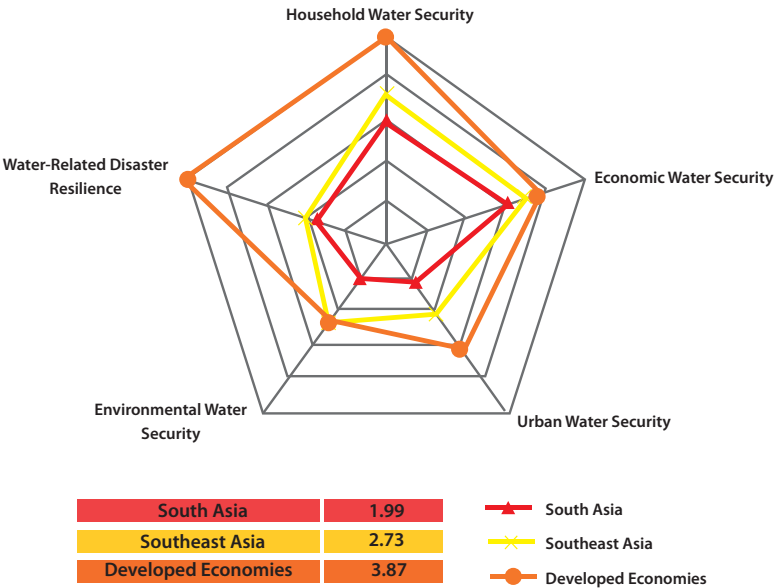
Note that while water-related disaster resilience (key dimension 5) reflects the fact that healthy rivers provide the very foundation of a water-secure future, attention to this dimension has historically only occurred when the city or country concerned has achieved a relatively high level of per capita income. While it is thus unsurprising that undertaking the investments required to restore and protect the region's river basins is long overdue, both the scale and pace of population growth in the region are of such magnitude that making these investments has now become a precondition to achieving the high levels of per capita income that are universally desired.

Pathways to Water Security

As mentioned, the responses to water-related issues required of policy makers in a particular city or country to achieve water security are widely divergent. Furthermore, to achieve this goal, these responses must be based on appropriate analysis of all data and information relating to the level of water security currently attained. In this regard, policy makers face two obstacles. First, the critical mass of data relating to water security may be absent. Second, the wide variation in the conditions faced by each city or country makes it impossible to formulate a consistent methodology for performing such an analysis. Such difficulties notwithstanding, AWDO 2012 reports quantitative values for water security indicators relating to each of the key dimensions referred to earlier for 48 countries of Asia and the Pacific. These water security indicators relating to the five key dimensions of water security referred to can be used as a starting point for city- or country-specific analysis of the degree of water security currently attained by a particular jurisdiction.

The analysis underpinning the indicators reported by AWDO 2012 was based on publicly available data, these being supplemented by additional surveys commissioned as part of the preparation of AWDO 2012. Figure 5.3

Figure 5.3 Water Security in Asia and the Pacific



Source: ADB (2012).

summarizes these indicators for both the South Asia and Southeast Asia geographic groupings, as well as for the region's developed economies taken together as a group.

It is important to remember that the variation in the CWSIs for the three groupings depicted in Figure 5.3 reflects the degree of water security achieved during a particular period. Thus, what Figure 5.3 does *not* depict is the fact that most of the region's countries have begun to take action to increase their respective levels of water security. In fact, of the 48 countries for which results are reported in Figure 5.3, 29 are actively improving their respective levels of water security. Moreover, a further 10 countries are putting into place the institutional capacity, regulatory framework, and set of investments necessary for improving their respective levels of water security (Table 5.1). While four of the countries depicted have already effectively achieved water security, none have achieved the status of "model security." Thus, all hold the potential for further improvement.

Albeit with appropriate modifications, the approach to assessing the degree of water security attained as presented can be used by jurisdictions the world over to both assess the level of water security attained and formulate the concrete steps necessary for attaining it. These latter steps inevitably include appropriate policy and legislation, institutional change, and investments by both the public and private sectors.

Delivering Appropriate Levels of Service

Mixed Results in Meeting Millennium Development Goal Targets

The Millennium Development Goal (MDG) target for drinking water was broadly met in 2010. That is, the percentage share of people without access to improved drinking water supplies was more than halved, from 24% in 1990 to 11% in 2010. However, although sanitation coverage of the region's population increased from 49% in 1990 to 63% in 2010, this still falls far short of the target of 75% set for 2015. Thus, at the current rate of progress, the target for 2015 would only be met in 2026 (UNICEF and WHO 2012).

This latter outcome has long-term implications for the pace of economic advance in the region, since inadequate wastewater management and poor sanitation in urban areas is a major barrier to attaining and maintaining water security. Furthermore, untreated waste despoils already diminishing supplies of freshwater at a rapid pace, thus threatening water security and thence sustainable development. For many of the region's cities, this latter threat to sustainable development is far more immediate than is climate change.



Photo: Gerard Carreon (Central Asia/Afghanistan).

Children fetching water

In 2010, the percentage shares of the population with access to appropriate sanitation facilities in the various subregions of developing Asia were: South Asia, 41%; Oceania, 55%; East Asia, 66%; Southeast Asia, 69%; and Central Asia, 96%.⁶ In addition, 40% of the region's population that have gained access to improved sanitation facilities since 1990 live in the People's Republic of China (PRC) and India (WHO/UNICEF Joint Monitoring Programme for Water Supply and Sanitation 2010).

While globally open defecation has declined significantly, it was still practiced by 15% of the world's population—approximately 1.1 billion people—in 2010, the majority of these persons living in rural areas. By region, rural South Asia reported the highest share of the population practicing open defecation at 55%.

Globally, 79% of the urban population has access to improved sanitation facilities, as compared to 47% of the rural population. However, the progress thus achieved in percentage share terms obscures the fact that due to

⁶ The data presented refer to subregions of Asia and the Pacific as defined by the Asian Development Bank.

rapid urban growth, the absolute number of urban residents without access to improved facilities increased from 531 million in 1990 to 714 million in 2010 (WHO/UNICEF Joint Monitoring Programme for Water Supply and Sanitation 2010).

Such statistics graphically illustrate the challenge that many developing-country cities face in keeping pace with the demands on service delivery brought about by rapid rural–urban migration. When viewed from a more positive perspective, rapid rural–urban migration expands potential economies of scale in service delivery, thus creating an opportunity for cities to become global leaders in delivering appropriate, financially viable, and sustainable water supply and sanitation services.

Making Sanitation Everyone's Business

ADB's "Dignity, Disease, and Dollars" (2007) call to action for sanitation focuses on the three variables that stakeholders at all levels of administration must focus on if appropriate sanitation is to be achieved for every village, town, and city in the region. This is because such facilities are a precondition for achieving dignity for all of the region's inhabitants, for preventing the spread of disease, and for ensuring both the financial viability of sanitation service providers and affordability of such services at the household level. In this regard, sanitation facilities include appropriately managing wastewater not just from a technical or engineering point of view but also from a perspective that addresses all of its social, political, and environmental complexities.



Photo: Lester V. Ledesma (Southeast Asia/Malaysia).

Pollution of rivers continues to challenge Southeast Asia's developed and developing countries alike

Budgetary challenges often hamper implementation of even well-thought-out sanitation agendas. For example, sanitation is often perceived to be a high-cost service and, in many cases, therefore unaffordable. As a result, even when incorporated into national plans, sanitation has not been given high enough budgetary priority by governments and city authorities to ensure that sufficient funding is available for financing the proposed improvements.

However, such a view ignores the fact that adequate sanitation facilities have been proven to be (i) affordable by most households, (ii) financially viable as a utility service, and (iii) capable of more than paying back any government investment in such facilities. In fact, the World Health Organization (2004) cites an average rate of payback in the range of \$3–\$36 for each dollar invested in sanitation. The logic of providing reliable and affordable sanitation services to entire populations as a means of accelerating the pace of economic advance is thus well founded.

Provision of appropriate wastewater management and sanitation services are not merely issues of human dignity, health, and environmental protection. They are instead preconditions to achieving water security. In East and South Asia, the percentage of untreated wastewater produced that leaches into accessible fresh or coastal waters is 89% and 85%, respectively (UNEP 2004). Surface water resources in both India and the PRC are being rapidly polluted, often irreparably. Along many stretches of both the Ganges River in India and the Yellow River in the PRC, the water is now unusable for agricultural purposes. In short, degradation of the freshwater resources of many of Asia's subregions is taking place at a rate so rapid that environmental sustainability is at risk on a large scale.

Creating Livable Cities through Provision of Water Services

While making cities more “livable” is cited as a continuing challenge confronting Asia and the Pacific, “livability” is a term that nearly defies definitive description. This difficulty in defining what constitutes an acceptable level of water supply or sanitation service is mirrored in the MDGs in that the MDGs measure progress relating to both in terms of “access” and “improved,” these terms being subject to wide interpretation.

In the context of a particular city or country, such vagaries can be avoided by focusing on what constitutes an *optimal* level of service for the jurisdiction concerned, which is inevitably circumscribed by what end-users want and can afford. Further, an optimal service is one that is sustainable over the long term—which means that providing an optimal level of service is fully consistent with attaining water security. That said, many cities tolerate not



Photo: Rakesh Sahai (South Asia/India).

A modern low-cost wastewater treatment plant—a rarity in developing Asia

only service levels that differ substantially from average national, regional, or global levels but, more importantly, marked differences in the quality of service delivered within their own city limits.

This is logical when what constitutes an acceptable level of service is set in the context of available financing. For example, approximately 60% of the region's population lacks access to appropriate water supply, and 73% lack access to improved sanitation facilities. To reduce these numbers sufficiently to meet the relevant MDG targets, approximately \$18 billion annually in additional investment would be required, an additional \$15 billion–\$20 billion annually being required to maintain and improve these services that serve the same beneficiary pool (Rao and Seetharam 2006, Toubkiss 2006).

In addition to the inconvenience caused, an intermittent water supply negatively impacts water quality. To compensate for intermittent service, many people invest in overhead tanks. While such tanks allow short-term water storage, the regular cleaning of these tanks required to maintain water quality seldom occurs, which results in reduced water quality at the household level. More importantly, together with inadequately funded maintenance of water mains, intermittently supplied water causes the pressure in water mains to fall to such low levels that sewage and other contaminants enter the urban water supply (McIntosh 2003).

In many of the region's cities, lack of wastewater treatment facilities impacts both water quality and health. Pollution wastewater may be municipal in origin (wastewater from homes and commercial establishments) or industrial and agricultural (chemicals used in these sectors impacting the quality of agricultural or industrial run-off) (McIntosh 2003). Both negatively impact water supply and quality. It has been mentioned a number of times



Photo: Abir Abdullah (South Asia /Bangladesh).

Poor maintenance of water supply and sanitation infrastructure is a major problem in the region.

that waterborne disease has claimed more lives than any war. In fact, 1.6 million deaths per year are attributable to unsafe water, poor sanitation, and lack of appropriate hygiene practices (UN Millennium Project, Task Force on Water and Sanitation 2005). Improving sanitation and delivering safe drinking water are thus critical inputs in maintaining health, combating disease, and reaching the health-related MDGs.

Appropriate and Sustainable Levels of Service

Water supply is no longer defined as simply providing water to a defined set of users within a particular geographic area. Instead, it encompasses sustainability and inclusive-growth issues, the latter implying that water is critical for meeting the growing demands of energy and food production, and more broadly, long-term sustainable development in urban areas. Thus, supplying water to cities must take account of both growing resource constraints globally, as well as the trade-offs inherent in meeting the competing demands of various classes of water users.

The fact that the “city proper” is often far smaller than the urban agglomeration in which it exists tends to complicate planning for water infrastructure and often obscures a major component of total demand. Thus, from a practical perspective, planning water supply and wastewater management services is often constrained by mismatches between service

areas and administrative boundaries. Similarly, poor governance often hampers efficient planning, nearly always prevents new approaches from being considered, and usually results in inadequate financing of the facilities required for meeting effective demand.

Due to inherent problems in defining terms such as “needs,” “equitable,” “improved,” and even “access” as these relate to water supply and sanitation services, both rural and urban low-income communities are often the most marginalized in terms of service coverage and quality.

Many water and wastewater service providers face significant challenges in delivering services to ever-growing urban populations. Many providers face additional issues such as increased precipitation rates, and more frequent and severe natural disasters and drought. Aging and often inefficiently operated systems further compound the challenges faced by such providers.

With some notable exceptions, many water and wastewater service providers in the region’s developing countries lack the human and financial capacity to cope with the challenges inherent in simply maintaining current service levels, much less addressing those resulting from growing demand. In particular, lack of appropriate financing impacts capital investment levels, capacity expansion, and maintenance, thus making it difficult to sustain current service levels.

Box 5.1 Uneven Access to Water in Malaysia

Water supply and wastewater management services have developed unevenly in Malaysia, with the more developed states achieving nearly universal coverage, while less developed states face continuing difficulties in expanding access to services, this being particularly true in rural areas. Furthermore, the country’s more developed states are able to attract private sector investment in water and wastewater services, while poorer states rely on public provision. These differences have caused levels of access to vary significantly.

For example, in 1994, 56% of the population living in the poorest states had access to improved water supply compared with 94% in the richest states. While the corresponding figures for 1999 were 74% and 96%, respectively, affordability for low-income households worsened, while it improved for higher-income households. In 1999, the poorest households spent 1.5% of their income on water, while the richest households spent only 0.7%.

Source: Derived from N. Prasad. 2007. Social Policies and Water Sector Reform. *Markets, Business, and Regulation Program Paper*. No. 3. Geneva: United Nations Research Institute for Social Development.

Moreover, local governments frequently lack the financial and human resources required for improving or expanding the coverage of wastewater services. Thus, residents of many cities in developing countries lack access to piped sewerage facilities, causing them to rely on septic tanks. In sum, in much of the region, the capacity of sewerage systems, including septage collection and treatment, falls far short of demand. Tariffs set at levels too low to permit full cost recovery and limited government subsidies similarly result in poor operational performance. Finally, cities that have invested in sewerage networks often face difficulties in promoting the services thus provided to potential customers, this resulting in low sewerage volumes and hence revenues that fall short of operation and maintenance costs.

Because of the economies of scale inherent in urban areas, provision of water infrastructure is more cost-effective there than it is in less densely populated areas. This presents megacities with significant opportunities for expanding service coverage. Conversely, achieving profitability in less densely populated areas is more difficult, this translating into suboptimal service networks in peri-urban and rural areas.

However, service provision in megacities presents providers with special challenges, such as the need for an approach to service provision that reflects a particular area's relative degree of urbanization, as well as the age and income level of its population. While socially unpalatable, differentials in service level invariably reflect income differences among the various districts of single megacities.

How Cities Can Become More Efficient and Responsible

Flexible and Nimble Approaches Are Best

In today's megacities, it is rarely possible to lay water supply mains or sewerage connections in the same manner in which it was done when the cities of the now-developed world were first emerging as urban agglomerations. This is mainly due to a lack of funding for such major works, as the price premiums that typically apply to remaining empty plots of land within megacities limit the scope for developing "low-value" services such as water infrastructure. Furthermore, the low average elevation of many of the region's megacities limits the deep-trench excavation necessary for laying large-diameter mains.



Photo: Maynilad Water Services, Inc. (Southeast Asia/Philippines).

Trunk main leak detection

Ultimately, cities must adopt a flexible approach to addressing the water supply challenges they face. In some cases, large schemes are the most efficient when economies of scale are sufficient to ensure appropriate economic returns. Conversely, when appropriate, decentralized wastewater collection and treatment systems can provide excellent investor returns, given that their specifications are correct and they are properly located.

Generally speaking, what works best is often a combination of large-scale infrastructure and smaller-scale decentralized systems, given that the overall criterion used in deciding which type of system to build is efficiency. For example, rapidly reducing high rates of water loss yields an immediate payback through improved water security and savings that can be used to finance service expansion to yet-underserved areas. In this regard, rigorous analysis can help minimize system inefficiencies and optimize the manner in which equipment, control systems, and assets are managed, this in many cases allowing significant improvements in service delivery or coverage area.

The above notwithstanding, the current water-security status of many of the region's cities is hazardous. Thus, the challenges in delivering basic services to the populations of these cities are both significant and expanding, while at the same time, the financial resources for addressing these challenges are constrained. As a result, it is unlikely that service standards can be raised uniformly across a particular city in a simultaneous manner. Thus, some areas or districts will likely lag others in receiving service upgrades.

Given this, the most efficient approach is for utility and city planners to rank all possible water supply and sanitation projects in descending order of desirability according to transparently stated criteria. However, it is far easier for utility and city planners to defend this ranking to stakeholders if all of the latter were included in the process of its formulation. In addressing this and similar water supply-related issues, it must be remembered that all users—paying or otherwise—must necessarily be included in decisions regarding the provision of water-supply services.

This necessity is illustrated by the experience of the city of Brisbane, Australia during its previous period of severe drought, which in the end impacted all of southeast Queensland. In addressing the drought, a range of responses was deployed, including a call for a dramatic voluntary reduction in consumption levels that linked conservation and responsible consumption with healthy waterways and, in particular, the city's main river and bay. In the end, this approach was particularly successful in decreasing water usage, as daily per-capita consumption levels dropped from 293 liters in 2001 and 2002 to well below 200 liters at the peak of the drought in 2007. This result was achieved despite there being no significant sanction levied against errant consumers. Further, the end of the drought in 2008 did not cause a return to pre-drought water consumption levels.

The example above demonstrates that water can never be considered in isolation of other aspects of urban development. That said, doing so is precisely how many cities attempt to “manage” their water services, their declining levels in water security status demonstrating the inefficiency of this approach. While conservation and promoting healthy waterways can achieve impressive results, this approach works best in cities that already enjoy good service, credible management of water resources, effective city management, and, most important of all, access to appropriate funding. Nonetheless, these solutions will work for cities in developing countries, given that the basic approach to management of the water resource is to improve efficiency and to ultimately make access to wastewater treatment and sanitation facilities universal; and given also that decision makers and private sector investors ultimately make appropriate levels of funding available for such activities.

In the context of the above, “efficiency” means determining which interventions deliver the greatest amount of benefits per dollar expended, and then ranking all possible interventions in descending order according to this criterion. The fact that many decisions relating to water supply are not grounded in such analysis often causes a politically popular drive for supply-side interventions and new infrastructure that crowds out simpler, more flexible, yet more effective demand-side interventions.

Use Less, Do More

Asia's urban population is expanding at an alarming rate. As population growth and urbanization rates rise and global climate-change pressures continue, stress on the region's water resources intensifies. Under such a scenario, continuing to employ current water management practices will inevitably cause the region's cities to experience future water-supply difficulties. Addressing these challenges efficiently thus requires a shift to a more integrated approach to urban water management.

On the supply side, there is in general little room for finding and extracting more water, since the water resource is, in the end, finite. Thus, achieving water security in the region's water-scarce areas (e.g., the northern parts of the PRC, south and northwest India, and Pakistan) will in all likelihood require a combination of reductions in consumption levels, improving production efficiencies, and, possibly, importing water through appropriate trade arrangements. For the region's lower-income areas (e.g., Bangladesh, Cambodia, north and northeast India, Nepal, Lao People's Democratic Republic, Myanmar, and Viet Nam), supply-side infrastructure may be improved, given appropriate levels of new investment.

In most cases, the most efficient solutions will likely be found on the demand side. Demand-management studies conducted at the global level illustrate that the level of impact per dollar expended is greatest on the demand side for a wide range of measures, whether undertaken in the agriculture sector, industrial sector, or municipal water-use sector.

Reducing Losses

One of the major challenges facing many water utilities is high levels of loss in water distribution networks, since meeting consumer demand is difficult when a large proportion of water supplied is lost. In this regard, non-revenue water (NRW) is defined as the difference between the amount of water put into the distribution system and the amount of water delivered to registered customers.

NRW is an excellent performance indicator for water supply systems, with high levels of NRW indicating poorly managed systems. Successful water supply systems continuously address NRW by controlling losses, ensuring customer meter accuracy, and containing the number of illegal connections. Furthermore, such measures increase profitability and thus can make reinvestment and productivity improvement possible.

Box 5.2 Non-Revenue Water in Manila

A former government agency, Manila's Metropolitan Waterworks and Sewerage System (MWSS), was privatized in 1997. Manila Water, Inc. was subsequently awarded the east zone concession, while Maynilad Water, Inc. was awarded the west zone concession. Manila Water provides quality water and wastewater services to more than 6.1 million people, while Maynilad Water delivers safe, reliable, and affordable water to more than 7.2 million people.

Prior to privatization, non-revenue water (NRW) system losses totaled 63% of all water entering the system, while only 58% of the city's population had access to piped water and only 25% enjoyed 24-hour service. As a result, most residents resorted to buying water at P150 per cubic meter, which was 50 times the price of piped water at the time. Other residents resorted to illegal connections with poor water quality, which led to a relatively high incidence of waterborne diseases including diarrhea.

Upon privatization, Manila Water began rehabilitating aging pipelines and installing new ones, a process that included replacement of both residential and commercial lines on a massive scale. By 2011, Manila Water has replaced and laid a total of 3,400 kilometers of pipelines.

During the 12 years following privatization, Manila Water doubled the population it served, improved average water availability from 16 hours per day to 24 hours, and served more than 6.1 million customers, including some located in the outlying areas of Rizal and Antipolo City. Furthermore, NRW was reduced from 63% in 1997 to 14% in 2010, which is a level better than that achieved by most Asian city utilities and which compares well with peak-performing utilities in developed countries.

The other concessionaire, Maynilad Water Services, Inc., has also similarly reduced NRW levels by 24 percentage points, from 66% in 2006 to 42% in 2011 (www.adb.org/water).

Sources: Fernando, Irene V. 2011. Achieving Water Efficiency. *Manila Bulletin*, 2 May 2011; Water Loss 2012 Conference. Manila Water and Maynilad.

For many cities in the developing world, reducing NRW should be the first option in addressing low levels of service coverage and increased demand for piped water, since expanding water supply networks without addressing water losses only leads to increasing waste and inefficiency. Transporting water through distribution networks and treatment facilities requires energy, the losses of the latter incurred by service providers roughly paralleling NRW levels (ADB 2010b).

Saving Energy

Approximately 2%–3% of total global energy consumption is used for providing water services, including pumping and treating water for urban household and industrial users, and providing drainage and sewerage services. Because the level of energy efficiency of most water systems worldwide is low, energy usage by these users can be reduced by significant margins through the adoption of cost-effective efficiency measures.

A survey of 40 water utilities in Asia and the Pacific estimated that the share of energy in the total cost of supplying water to users ranged from 3% to 46%. In absolute terms in 2005, this equaled \$0.002 to \$0.12 per cubic meter. This cost represents a monetary loss proportionate to the each system's NRW level (Databook of Southeast Asian Water Utilities 2005).

Box 5.3 Saving Energy in India

The Alliance to Save Energy project in Karnataka, India demonstrated that low-cost operation measures undertaken by participating utilities accounted for 15%–20% of energy and cost savings. The measures under this initiative included surrendering excess contracted electric demand, maintaining a desirable power factor for electrical equipment, improving water flow distribution, rescheduling pump operations, and improving pumping efficiencies. Measures requiring a significant capital investment included replacing pipelines and impellers, installing energy-efficient motors, and replacing old inefficient pumps with energy-efficient pumps that were better integrated into the overall system.

Source: Watergy Case Study, Karnataka, India, Watergy and Alliance to Save Energy.

Promoting Wastewater Management

One of the most significant challenges cities face is the lack of adequate sanitation facilities and wastewater management services. Despite the focus of the sanitation component of the MDGs and the progress achieved to date, the number of people who lack access to improved sanitation facilities is staggering, with wide disparities occurring between the rich and the poor, and rural and urban areas. As a city's population and economic base grows, the scale of the challenge of addressing the increasing pollution levels caused by poor sanitation and wastewater discharge increases.

In many cities of the developing world, quality and sustainability of sanitation facilities and adequate treatment of wastewater remain important issues. Currently, investments in sanitation and wastewater facilities fall far short of the amount required. This is in general due to long-standing taboos, low levels of public awareness concerning the social and economic impacts of pollution from inadequate facilities, and lack of knowledge of the menu of solutions available for addressing such challenges. Similarly, the fact that the financial returns to sanitation investments are often poorly specified, coupled with an overall inability to scale up sanitation interventions in tandem with growth of the population and economic base, as well as an overall lack of access to appropriate finance arrangements have all resulted in low budgetary priority being assigned to sanitation and wastewater investments. Such obstacles to understanding the long-term viability of such investments cause policy makers to see them as a financial dead end in that their perceived costs are high, and their returns are seen as being negligible at best to zero at worst. Thus, achieving water security for the region's cities will require a major change in the way policy makers perceive investments in wastewater management. This change in perception could be further facilitated by innovations in both wastewater treatment technology, and in the financing and delivery mechanisms that make these system cost-effective, financially viable, and environmentally sound.

That said, initiatives have already been undertaken that demonstrate that improved sanitation and, in particular, improved wastewater management and reuse can contribute to achieving energy, food, and water security. Examples include harvesting nutrients for use in fertilizers, producing methane and biogas for energy and carbon credits, and treating wastewater that can be used for irrigation, electricity generation, cooling, industrial, and other non-potable uses. All of these offer income-generating opportunities that prove that rather than being an investment dead end, sanitation can be a financially viable undertaking. Two projects, one in Viet Nam and the other in the Kyrgyz Republic, illustrate how innovative financing in this regard can be used to ensure sustainability and inclusiveness (Boxes 5.4 and 5.5). Both projects produced significant health, environmental, and economic benefits, and directly contributed to poverty reduction.

Box 5.4 Ensuring that Services Reach the Poor

Completed in April 2011, Viet Nam's Central Region Urban Environmental Improvement Project (CRUEIP) improved living conditions in six medium-sized coastal towns in the central part of the country. Representing only 1% of the total project cost, the entire community awareness program of the Household Sanitation Credit Scheme was supervised by Community Management Committees (CMC). Each of the project's beneficiary towns formed a CMC, the membership of which was largely drawn from the local chapter of the Viet Nam Women's Union. While project funds were used to provide start-up capital for the Household Sanitation Credit Scheme that operated as a revolving fund, the CMCs themselves formulated the loan and repayment conditions under the initiative and likewise defined loan eligibility criteria.

By the end of the project, approximately 2,230 houses in the CRUEIP towns had constructed new latrines and septic tanks as compared with a target of 1,220, with three-fourths of all credit recipients being women. Further, operation of the revolving fund operation is expected to continue project completion.

Source: ADB. Forthcoming. *Project Brief: Household Sanitation Credit Scheme in Central Viet Nam*. Manila.

Box 5.5 Protecting Lakes while Aiding the Poor

Not only is the poverty level of Issyk Kul considered to be high, extremely poor residents comprise 9% of the total population. However, under the project, more than 123,000 people constructed on-site sanitation facilities, and another 45,000 became connected to the sewerage system. This project also delivered environmental benefits to the entire Issyk-Kul Lake region. Ultimately, the women of the region were particularly keen to see the improvements under the project materialize, as they and their families had previously suffered from both waterborne disease and the inherent lack of dignity associated with substandard sanitation conditions. A number of vehicles for ensuring successful upgrading of the utility were introduced into project implementation, such as performance-based service contracts that incorporated targets, incentives, and penalties, all of which encouraged output-based achievements.

Source: V. Padmanabhan. 2009. Kyrgyz Republic: Issyk-Kul Sustainable Development Project. Powerpoint presentation for the World Toilet Summit and Expo 2009. Singapore. 2–4 December.

Making Technology Count

To date, neither the full potential of emerging technology nor the strengths of the private sector have been exploited in addressing the challenges cities face in the water supply and sanitation sectors.



Photo: Maynilad Water Services, Inc. (Southeast Asia/Philippines).

Trunk main inspection

The water sector is largely conservative. It is thus reluctant to change and slow to adopt new technologies. Unfortunately, it is precisely these interventions that facilitate achievement of energy balance for the sector. The landscape for technology development and finance that might underwrite initiatives for improving the efficiency and cost-effectiveness of the sector could best be described as being sterile. It is little wonder that the sector is perceived to be an unattractive venue for entrepreneurial endeavor and investment.

Awakening the sector and the decision makers that drive its behavior to its potential for technological development and innovation is thus vital to achieving water security for the region's cities. In this regard, the megacities of the region represent a potential critical mass for driving such technological development and innovation, which is an opportunity that has not been lost on a few of the region's large cities including Singapore. Because this awakening is only beginning, care must be taken to avoid solutions that are expensive in terms of benefits delivered per dollar expended, in that such investments only deliver marginal benefits.

Nevertheless, the number of initiatives available to city utilities wishing to improve cost-effectiveness and thence financial performance is relatively large and growing. However, rather than attempting to address the entire range of

Box 5.6 Technology for Change

Given the region's burgeoning demand for water, its limited freshwater resources, and the considerable socioeconomic and environmental costs of poor sanitation, proper wastewater management is critical to achieving water security for the region. This can most easily be accomplished by migrating from both high-energy-intensity forms of treatment—or alternatively, no treatment at all—to affordable and achievable forms of wastewater treatment that treat wastewater as a resource that can potentially produce competitive rates of financial return.

Ultimately, wastewater reuse expands the region's supply of freshwater. Furthermore, by lowering the energy intensity of wastewater treatment, investment in the sector can be stimulated, since it is the sector's current high level of energy intensity that in part discourages much-needed investment. This can best be accomplished by making wastewater treatment a source of both energy and income. Biogas digesters connected to sanitation facilities in rural areas in Cambodia, the People's Republic of China (PRC), India, Nepal, and Viet Nam produce cheap energy that can be used for lighting and cooking. In addition, methane capture in wastewater treatment facilities not only contributes to climate change mitigation but also generates carbon credits and a renewable energy source for use by these facilities, as well as residents of nearby communities.

An emerging critical issue concerns sludge treatment and reuse. An excellent operational example of this change in perception and practice is the decentralized sludge treatment facilities at Wuhan, PRC. Harvesting of nutrients and biosolids that can be used as fertilizers contributes to food security. Biosolids (by-products of wastewater treatment) can be treated in a manner that makes them safe to use as organic soil conditioners. Applying biosolids and urine thus treated as fertilizers helps reduce the use of chemical fertilizers, the production of which is likewise energy-intensive. Similarly, safe fertilizer produced from ecosan toilets has turned some farmers into entrepreneurs.

Further, in the face of increasing climate variability, reusing water as a means of reducing demand placed on existing freshwater resources is an attractive alternative. For example, in Dak Lak Province, Viet Nam, 5,500 households are connected to a wastewater treatment facility, the output of which is used to irrigate agricultural land of more than 100 hectares.

Similarly, many local governments are turning to decentralized wastewater treatment systems as a means of improving water quality in both peri-urban and coastal poor communities, as well as that provided to public markets and hospitals. Treated wastewater from these systems is used for flushing toilets, watering plants, street cleaning, and even fighting fires, all of these uses collectively resulting in substantial savings in monthly water bills. Similarly, the constructed wetlands in Ningbo, PRC; the reed beds of Bayawan City, Philippines; and the constructed duckweed systems in Bangladesh and India all provide low-cost, low-energy, and productive treatment of wastewater.

continued on next page

Box 5.6 continued

Treated wastewater can likewise be sold to generate revenue. For example, in Surat, India, domestic wastewater will be treated and sold for industrial use by a concessionaire, once the contract for this activity has been awarded. While the total cost of the wastewater treatment facility (with a capacity of 40 million liters per day) to be operated by this concessionaire is estimated at \$15 million, treated water sales are expected to generate revenues of \$6 million annually.

Finally, the wastewater treatment system of the Nusa Dua hotel complex in Bali, Indonesia not only provides water for the hotel's gardens and golf course but is itself a mini-ecosystem that attracts recreational-fishing and bird-watching enthusiasts, and tourists, all of which generate additional revenues for the hotel complex.

Sources: M. C. M. Ebarvia and A. Chiplunkar. 2012; A. Chiplunkar and M. C. M. Ebarvia. 2010.

technologies and solutions that might be adopted by decision makers here, the discussion in this section is restricted to what many in the sector see as its most problematic segment, which is wastewater management. Possible solutions and responses to the issues presented by this subsector are therefore highlighted in the paragraphs that immediately follow.

A range of opportunities exists that would allow cities to see wastewater as a financially viable investment rather than as a nuisance. For example, storm water run-off can be collected, and following some form of treatment, redeployed by a wide range of end users. Similarly, nutrient capture from domestic and trade waste is emerging as a profitable activity. Ultimately, all of what were once considered to be nuisance by-products of wastewater can have value, once they are treated in a way that permits their reuse.

How Cities Can Show Leadership and Drive Change

Responsible and Robust Water Management

The multiple uses of, and demand for, freshwater by the region's cities puts significant pressure on its freshwater sources. In this regard, the International Development Association notes that "while world population tripled in the 20th century, the use of water increased six-fold" (IDA 2007). Population growth increases the demand for water in two ways: through

increased personal consumption and increased economic activity. Other threats to water security include pollution and economic activities that impact watersheds such as logging and mining. Ensuring water security for the region thus demands immediate improvements in the way the water resource is managed. However, there remain significant shortcomings in its management, including lack of coordination of initiatives for improving water management itself.

Understanding the relationship between management of the aquatic ecosystem and the resources derived from it is a precondition to sustainably conserving, managing, and using the region's water resource. In the view of the International Union for the Conservation of Nature (IUCN), this link between management and conservation extends beyond merely managing water as it exists in-stream. Instead, it extends to broader ecological issues such as the health of the land and the ecosystem overall (IUCN 2004). Appropriate water resource management thus encompasses planning, developing, distributing, allocating, and optimizing the use of the water resource in a way that leads to long-term sustainability.

The ecosystem of which the region's water resource is a part is affected by changes in human activity and lifestyles that give rise to increases in the demand placed on it. Rapid expansion of the urban population places ever-increasing demands on the water resource that in turn derive from increased demand for additional food, water, living space, jobs, industries, transport, and other amenities of urban life. This forces the ecosystem to provide water to meet these demands from a resource that is finite in supply. As a result, urbanization impacts the riverine ecosystem in a negative way, such as when run-off from households, industries, farms, and sanitary landfills carries toxic materials into the streams that form an integral part of watersheds. The resulting alterations in the biological composition of the river basin reduce its ability to provide water free of such toxins, which is precisely the type of water demanded by the activities that cause these biological alterations in the first place.

Ultimately, it is more cost-effective to manage a river basin and its resources in a sustainable way than it is to reverse damage to it. Emerton and Bos (2004) note that the cost of conserving an upstream forest is less than investing in new water filtration and treatment plants in cities, or undertaking de-siltation activities when the upstream forest is no longer capable of providing such services. Furthermore, the increasing demand placed on the water resource from rapid expansion of the urban population similarly increases the necessity of properly conserving and managing the finite water resource, if the water-related requirements of rapid urban population growth are to be met in a sustainable way. Just as with any other natural resource, river basins require time to renew, reproduce, and rejuvenate themselves.

As a result, proper management of riverine ecosystems could correctly be viewed as a precondition to sustained urban growth and economic advance.

The Role of the City in Water Management

Because of the alarming rate at which the region's urban population is expanding and the demands that this expansion places on the region's water resource, cities have an important role to play in its sustainable management. In short, it is the responsibility of city administrations to conserve water, minimize its wasteful use, and ensure its equitable distribution through integrated water resource management. This requires development of a comprehensive water resource database and making the information it contains available to the public at large. Initiatives for improving management of the water resource should initially focus on improving the efficiency of water use in areas that have exploited the water resource in an unsustainable way. Promoting water resource management at the level of the river basin is key in this regard, as is promoting conservation by all users of water. Such initiatives are the core elements of India's water reform agenda that is expected to deliver significant improvements in water resource management over the coming 10 years.

Some countries have responded to their previous unsustainable use of the water resource in a responsible way, an excellent example of this being the Republic of Korea's Four Rivers Restoration Project which is to use green engineering interventions to restore the health of rivers, improve water quality, alleviate flooding, increase storage capacity, and better regulate the flow of the rivers that will be rehabilitated under the project. A major objective of the project is to provide adequate, reliable supplies of water for municipal, industrial, and agricultural uses. The initiative thus approaches management of the water resource from the perspective of rehabilitation of entire riverine ecological systems for the purpose of ensuring sustained economic advance in the areas that draw upon these systems.

Similarly, as part of its long-term community plan (*Living in Brisbane* 2026), the Brisbane City Council in Australia stated its environmental goals as a "healthy river and bay," thus emphasizing the important role that a healthy overall ecosystem plays in sustainable urban development. Further, the city council circumscribed the responsibility of each individual and agency in maintaining the health of the city's overall ecosystem. Placed on the city's official website to ensure the widest possible access by the public, the overall plan included specific projects, programs, and initiatives for ensuring a healthy ecosystem that included storm water management, erosion and sediment control, and overall health of the city's waterways (Brisbane City Council 2006). In some cases, achieving or maintaining water

security requires making unpopular decisions. For example, dams and reservoirs are sometimes required for ensuring a reliable supply of water to urban areas to counterbalance shortages that occur due to variations or changes in hydrologic cycles. While over the past 20 years, a significant amount of opposition to dams has been voiced, if properly planned, designed, constructed, and maintained, dams can provide water security to expanding urban areas. Without the farsighted decisions regarding water security made many decades ago, many of today's cities would not have enjoyed growth in the urban amenities they now offer. Thus to some extent, the inactivity in building new dams and reservoirs that has occurred in recent years could constrain future urban growth. This is an important factor for the region's urban policy makers to consider, given current urban-growth projections that forecast more than half of the region's population living in cities only a few decades from now.

The Importance of Effective Leadership and Good Governance

In large measure, the region's current state of water insecurity has resulted from poor management, political interference, and a general misunderstanding of what is required to improve water service delivery. In contrast, inspired leaders who champion appropriate reforms, mobilize resources, and involve communities in managing water resource can help address many of the region's challenges to achieve water security.

In short, what the water sector requires for achieving water security is not just more financing. It instead requires better management. Fortunately, the region already has some farsighted leaders and groups who have achieved extraordinary success in water service delivery and can help inspire improvements in management of the region's water resource. Among them is Ek Sonn Chan, Director of Phnom Penh Water Supply Authority (PPWSA) in Cambodia, who correctly identified the changes required for his organization to operate effectively as a public water service provider.⁷ He initiated a "culture of change" that began with improving staff skills and then stressed the value of good performance in service delivery. Eventually, the reforms he initiated in both PPWSA's organizational structure and operations resulted in 100% water service coverage in Phnom Penh's inner city, reduction of non-revenue water from 90% in 1993 to 8% in 2007, and a bill collection rate of 99.9%.

⁷ In 1996, the Government of Cambodia granted PPWSA administrative and financial autonomy. This allowed PPWSA to operate as independently as would a private corporation.

Others include Bindeshwar Pathak, the founder of the Sulabh International Social Services Organization, a nongovernment group that since 1970 has installed low-cost and ecologically sustainable toilets in more than 1.2 million homes in India. Similarly, Khun Chamroon Suavdee, a restaurant owner who chairs the Bang Pakong River Basin Committee in Thailand, has helped resolve community conflicts over water use. Such champions can make a city's water service function far more efficiently than previously. In the absence

Box 5.7 Instituting a Culture of Change in Phnom Penh

In 1993, the Phnom Penh Water Supply Authority (PPWSA) was heavily subsidized by Cambodia's national government. Total annual income was only KR0.7 billion, against operating costs of KR1.4 billion. The agency's more than 500 staff drew an average monthly salary of KR50,000 (\$20), while upper management operated PPWSA in a way that served their own interests. Staff members were generally underqualified, underpaid, demoralized, inefficient, and lacking discipline.

As a first step in improving water service delivery, PPWSA began a "culture of change" through educating, motivating, and disciplining both PPWSA staff and the public at large. PPWSA was restructured in a way that gave upper-level management more responsibility, promoted a superior work ethic among line staff, rewarded good performance with increased salary and other benefits, and fostered teamwork.

Next, PPWSA's revenue stream was expanded. It achieved this through five initiatives. First, PPWSA ensured that water meters were installed for all connections. This significantly improved monitoring of water use. Second, it ended illegal connections by providing rewards in exchange for information concerning illegal connections and imposing penalties for their use. Furthermore, staff suspected of illegal activities in this regard were investigated and dismissed if found guilty. Third, consumer files were computerized, updated, revised, and improved, which significantly improved bill collection. Fourth, PPWSA embarked on a public education program that stressed the importance of paying one's water bills, particularly high-ranking officials, thus making the latter role models for the public at large in this regard. Finally, in both 1997 and 2001, PPWSA increased water tariffs sufficiently to ensure that its operating costs were recovered. While a three-step increase was initially planned, following the 2001 tariff increase, PPWSA was able to recover its entire operating cost. Thus, a third increase was unnecessary.

In addition to the improvements described above, PPWSA played an important role in poverty alleviation in that by 2002 it had completed 3,046 household connections in Phnom Penh's 31 poorest communities, thus lessening the financial burden of poor families that formerly had no alternative but to buy water from resellers at rates significantly above those charged by PPWSA.

Source: A. C. MacIntosh. 2003. *Asian Water Supplies Reaching the Urban Poor*. Asian Development Bank. August.

of such leaders and appropriate political support, the changes required for achieving water security for the region cannot occur (ADB 2008).

As it relates to the water resource, good governance is equated with appropriate management, which in turn requires both effective leadership and political will. Similarly, participation by all stakeholders, transparency, predictability, and accountability are pillars of good governance as it relates to the provision of freshwater.

Adopted in 2001, ADB's Water for All policy outlines the legal and regulatory systems required for ensuring that water service providers and resource managers are held accountable by law for their performance as measured against prescribed standards (ADB 2001). A key element of the Water for All policy is participation by all stakeholders including the public at large, the private sector, local communities, and nongovernment organizations.

Ultimately, certainty in the water sector depends on consistent application of laws, regulations, and policies that regulate activities in the sector. Likewise, transparency requires timely availability of information about water policies and projects to the general public, as well as clarity regarding rules, regulations, and operational decisions that impact all consumers (ADB 2010a). Because the manner in which this policy is implemented in a particular city requires adaptation and modification in a way that serves its particular requirements, opportunities, and constraints, its implementation should occur in the absence of any preconceived dogma or hidden agenda.

In the context of water security, good governance has best been achieved through a readiness and capacity to address vulnerability. This unfortunately contrasts with the behavior of many regions and cities that face significant challenges requiring urgent action but that have limited willingness or capacity to respond to such challenges.

Starting Big: Resuscitating an Entire River

Rapid population growth and economic advance both challenge the sustainability of riverine ecosystems. Yet, the benefits of rapid economic advance that these ecosystems facilitate are not distributed equally across the world's population. The 1998 Human Development Report points out that 20% of the population of developed countries consumes 86% of the world's goods. In contrast, more than 1 billion people have no access to safe drinking water (Shah 2005, Donzier 2007), 2.6 billion people have no access to basic sanitation facilities (Donzier 2007), and 85% of anthropogenic pollution is discharged into inland, coastal, and marine natural environments without any treatment (Donzier 2007). In both urban and rural areas, the poor are most affected by these circumstances. In short, their limited access

to safe water and basic sanitation services, along with the higher levels of pollution of all types that they are exposed to cause them to suffer health-related, social, and economic hardships that higher-income segments of the global population are able to avoid.

Management, conservation, and preservation of river-basin resources are all necessary to meet both the current and future requirements of the human population, if economic advance is to continue. This in turn requires addressing issues relating to access to safe water and basic sanitation facilities, and minimizing pollution. Addressing these issues begins with management of water resources in a comprehensive and integrated way that includes planning for optimum use of water resources in accordance with existing water policies and regulations.

Integrated river basin management (IRBM) incorporates all of these management principles in a way that ensures sustainability of these vital ecosystems.⁸ In particular, IRBM coordinates conservation, management, and development of water, land, and related resources across sectors in a way that maximizes the economic and social benefits derived from water use, while preserving and, where necessary, restoring freshwater ecosystems (Global Water Partnership 2000). Such actions are of particular importance since freshwater systems account for most of the world's water supply (Mahabir 2004).

Successful IRBM initiatives support the long-term sustainability of particular river basins by involving all members of local communities that use the resources these basins provide. Such community participation forges partnerships between the government and the community that meet the objectives of both, while simultaneously sustaining development and maintenance of healthy river basins.

Much is made of the need for leadership, good governance, and decisive long-term action under well-thought out planning regimes such as integrated water resources management and IRBM. However, framing effective responses to environmental challenges at the city level requires addressing unique challenges and taking advantage of the enabling conditions that a particular environmental issue presents. Furthermore, successful implementation of any such initiative requires a serious commitment on the part of stakeholders, regardless of the fact that achieving this can be a time-consuming and complex process. An example drawn from the Philippines' experience highlights the importance to smooth project implementation of achieving such a commitment.

⁸ IRBM is under the scope of integrated water resources management (IWRM). Simply put, IRBM is IWRM performed at the level of the river basin.



Photo: Steve Griffiths (East Asia/China, People's Republic of).

Suzhou Creek's embankments have been transformed into pleasant residential neighborhoods and ecological parks.

Box 5.8 Suzhou Creek Rehabilitation Project

Wastewater discharge from industrial production, increasing water consumption by the urban population, and the consequent generation of municipal wastewater created serious water pollution problems for most cities in the People's Republic of China (PRC). Shanghai's Suzhou Creek, which is an important waterway that passes through the heart of the city, was once called "black and stink," as it was a repository for wastewater discharge from industrial, commercial, and residential areas. The most severely polluted river in the city, Suzhou Creek then stood for environmental degradation, pollution of water resources, and public health hazards.

In 1999, the Suzhou Creek Rehabilitation Project began improving the creek's water quality by strengthening management of this important resource, improving flood control, and upgrading the health standards and quality of life of nearby residents. This project was initiated under the government's Ninth Five-Year Plan (1996–2000) that emphasized sustainable development, coordinated planning, and environmental protection, the latter in particular including protection of the urban environment through establishing wastewater treatment facilities and managing solid waste.

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Box 5.8 *continued*

With the support of the Shanghai Suzhou Creek Rehabilitation and Construction Company, the project's design incorporated a number of important innovations. For example, as part of the project's embankment reconstruction component, upgrading of Meng Qing Garden included a landscaped leisure and recreational area, an equalization basin that used an underground storage tank to store excess rainwater, and a base for environmental education that focused on water resources and used the garden's ponds and streams to demonstrate the self-purification mechanisms of natural water courses.

Similarly, the Jing'an garbage transfer station was one part of a project component that removed and relocated night soil and solid waste collection wharves that were formerly located in a residential area of Shanghai's city center. A semi-underground facility, the station has aboveground facilities that include a landscaped garden, a visitor center, and an operations control room. To minimize the station's adverse environmental and social impacts, various innovative measures, such as odor control and ventilation systems, were introduced into the design of garbage collection trucks and compactor systems.

As part of the project, the Shanghai municipal government committed itself to achieving the long-term goal of water quality improvement in Suzhou Creek through implementation of a 12-year program (1998–2010). By the end of project implementation in 2010, the black and malodorous appearance of the creek's main tributaries had disappeared, a waterfront landscape corridor had been completed, and the water quality of the creek's urban reach had steadily improved up to a Class V standard. These improvements facilitated construction of a waterside housing development along the creek.

Ultimately, it was the government's political commitment and management capability that allowed successful implementation of this project, since in the end, large-scale urban resettlement initiatives were required to ensure smooth project implementation. One of the important benefits of the project was that it provided an excellent example of environmental improvement in a large and densely populated urban center.

Source: ADB. 2005. *Suzhou Creek Rehabilitation Project in the People's Republic of China*. Project Completion Report. Manila.



Photo: ADB Photo Library (Southeast Asia/Philippines).

A Pasig River cleaner

Box 5.9 Cleaning Up the Pasig River

One of the most important natural waterways in the Philippines, the Pasig River, flows through the heart of the Philippines' national capital region. While its total length is only 27 kilometers, the Pasig River is the only link between two large and equally important bodies of water, Manila Bay and Laguna de Bay. It is also heavily polluted.

In the 1990s, through technical assistance provided by the Danish International Development Agency, the Philippines' Department of Environment and Natural Resources implemented the Pasig River Rehabilitation Program, a 15-year multiproject, multisector program with the objective of upgrading the river's water quality to the Class C level, as well as improving the general condition of its riverbanks and thence the quality of life of the households that live along it. In 1999, the Pasig River Rehabilitation Commission (PRRC) was created for the purpose of harmonizing the plans of various agencies and sectors for improving the river, and for consolidating efforts in improving its water quality. This initiative built on the work of the previous river rehabilitation program.

From 2000 to 2008, the primary initiatives of the commission included reducing the volume of garbage dumped into the river and industrial waste discharged into it, together with resettlement of informal settlers to upgraded housing units, dredging, and development of the riverbanks into environmental preservation areas.

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Box 5.9 *continued*

According to PRRC, these interventions improved the condition of the Pasig River. “By 2010, approximately two-thirds of the left and right banks of the Pasig River had been developed into environmental preservation areas, or a total of 25 kilometers. Solid waste pollution load was reduced from 10% in the 1990s to 5% in 2000. Similarly, the industrial waste pollution load was reduced from 45% to 35%, which facilitated subsequent improvements in riverine biodiversity. What remained to be addressed was the issue of domestic wastewater pollution, the loadings of which swelled from 45% to 60% during 2000–2008. The source of this problem was that more than 90% of Manila’s households were not serviced by proper sanitation and wastewater treatment facilities. To address this issue, and thus to significantly reduce the domestic pollution load of both the Pasig River and its tributaries, government agencies began working with Metro Manila’s two private-sector water service providers. The challenge faced in this regard was to fast-track construction of sewerage systems and wastewater and septage treatment facilities as a means to increase coverage to the river basin’s entire population” (Tablan and Mallari. 2009. Targets, Strategies, Good Practices, Achievements and Challenges in Reducing Pollution in the Pasig River. Paper presented at the East Asian Seas Congress 2009, Manila).

From the discussions during the Pasig River Forum (held on 24 April 2012 at ADB), the following are the major lessons learned from the initiatives for rehabilitating the Pasig River over the past 20 years:

- The commitment of political leaders to the objectives of an initiative is fundamental to its success, since this requires the government assigning budgetary priority to the initiative to ensure adequate funding.
- Public awareness of the importance of proper waste management and its health and economic benefits is key to ensuring ongoing support for environmental improvement initiatives.
- Stakeholder support is likewise critical to environment improvement initiatives, particularly in the context of safeguarding infrastructure constructed under such initiatives.
- Widespread support for change in the conditions that negatively impact a community prior to undertaking an environmental improvement initiative vastly improves institutional accountability, as well as planning, project design, implementation, oversight, monitoring, and enforcement capacities. Working together with local communities and partnering with the private sector further magnify these beneficial impacts.
- Partnerships with investors and the private sector at large in implementing wastewater and solid waste management initiatives are a financing opportunity that is often overlooked. This is unfortunate because such partnerships have numerous spin-off benefits for environmental improvement, such as improved housing, and expanded livelihood and income opportunities for lower-income households.

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Box 5.9 *continued*

- Ensuring that the initiative's accomplishments are as visible as possible is an important factor in convincing local residents and businesses that change is possible. Furthermore, public exposure to the outputs of environmental initiatives often significantly increases public support and participation.
- In rehabilitating rivers such as the Pasig, water conservation has many benefits in addition to reducing stress on existing water delivery infrastructure. Lower volumes of water flowing into city sewer systems reduce storm water overflows into streams and rivers. Small-scale interventions, such as encouraging the fixing of leaks and using water-efficient faucets and toilets, can vastly reduce the volume of water consumed. In addition to saving thousands of liters of water each day, this reduces stress on sewer and treatment-plant infrastructure.
- Finally, every business and individual in a watershed affects a river's health. As a result, steps that minimize damage to water quality are within everyone's grasp. Once this awareness penetrates the consciousness of the entire public at large, other measures initiated tend to enjoy widespread support.

Source: M. C. M. Ebarvia. 2012.

Water Security for Cities of the future

What is now clear is that responding to water shortages by extracting additional water from finite resources is no longer a viable option. What is instead required in the face of the region's rapid rates of population growth, urbanization, and economic advance is a partnership of water users and managers that is informed by the content of this chapter. Such a partnership provides an appropriate foundation for interventions that lead to future water security for the region. For example, successful implementation of demand-management interventions not only reduces water use, which in turn produces a greater stream of benefits from existing water resources, but also in some cases avoids or delays costly development of new sources of freshwater, the latter being an intervention of last resort.

Only through integrated water resource management of river basins can the return on public investment in water storage, productivity, and conservation be increased. However, this requires water-management institutions capable of addressing the challenges of increasing water scarcity in the face of rapid population growth and urbanization. Such institutions see these challenges from the perspective of the water–food–energy nexus,



Photo: Inna Mkhitarian (Central Asia/Armenia).

Children drink from a public faucet.

and thus recognize that even small interventions can vastly improve the degree of water security a particular city achieves. For example, investing \$1 in comprehensive sanitation facilities that allow toilet-to-river recycling of water can deliver \$8–\$12 in health and economic benefits.

Ultimately, improving and then maintaining the health of the region's river basins is critical to sustaining its current rapid rate of economic advance. However, this represents a significant challenge in that 80% of the region's rivers are in poor health. Addressing a challenge on such a scale requires engaging all stakeholders, including the private sector, in restoring the health of the region's river basins and, with it, water security for the region as a whole. This includes increasing the level of preparedness for water-related disasters, regardless of whether these are induced by climate change, as steps such as investing in flood forecasting and early warning systems are likewise initiatives that are important to achieving water security.

Ultimately, a Green City is also a "blue city;" i.e., a city that has secured its own water future by ensuring sustainable management of its water resource. While not an easy task, achieving sustainable water security is fundamental to sustained economic growth and improvement in quality of life in both the region's urban and rural areas.

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CHAPTER 6

Green City Solid Waste Management

by Reynar R. Rollan

Introduction

As the world's population continues to grow at a rapid pace, so does the problem of solid waste management. This reality, along with its consequent negative environmental impacts, is nowhere more apparent than in Asian cities. These urban centers are expected to be home to about 2.7 billion people in 2030 (UN-HABITAT 2007). At a conservatively estimated daily average per-capita waste generation rate of 1.5 kilograms, about 4 billion tons of waste per day would be produced in that year. This is enough to build a 2-meter-high wall of waste of a length equivalent to that of the Great Wall, or to blanket the entire city of Singapore with a 1-meter-thick coating of waste in 40 days.

Asian cities generally employ a variety of waste management systems that are based on available technical and financial resources, and the current level of environmental awareness in the city concerned. The system employed by lower-income urban centers is mainly partial collection, open dumping, partial recovery of recyclables by the informal sector, limited composting, and some landfilling. Cities in developed countries have greater collection coverage, utilize landfills for disposal, operate waste-to-energy (WTE) plants, and employ composting as well as mechanized recovery of recyclable materials (Table 6.1).

Overall, in handling the bulk of waste generated, the systems in the cities of developing Asia are still anchored in waste collection and disposal. Composting and recovery of recyclables through mechanized or manual means have not reached significant rates of use relative to overall waste generation in these cities. Open dumping is prevalent, while development of sanitary landfills is constrained by limited community acceptance of these engineered disposal facilities. The limited space in most cities likewise prevents development of more landfills when current disposal facilities reach capacity. Singapore's four mainland landfills reached full capacity in 1999, following which the country began using its offshore Semakau landfill (Oh 2008).

Table 6.1 Amounts of Solid Waste Generated in Selected Asian Cities
(tons per day)

Year	City	Waste Generation	Collection	Recycling	Composting	Incineration	Disposal
2004	Bangkok ^a	9,400	7,500	No data ^b	280	20 ^c	~7,275
2004	Jakarta ^d	8,562	6,850	No data	7	22	6,000 ^f
2005	Dhaka ^{g, h}	4,634	1,946	475 ^e	15	None	1,946
2006	Beijing ⁱ	16,000	13,615	3,918	740	30	12,845
2007	Calcutta ^j	3,000	1,800	300	700	None	1,800
2009	Shanghai ^k	19,233	19,233	No data	1,923	3,077	10,193
2009	Singapore ^l	16,751	16,751	9,548	No data	6,795	408
2010	Hong Kong ^m	23,680	23,680	9,863	No data	None	13,817

~ = approximately

^a Muttamara and Leong (2004).

^b Recycling practiced by informal sector has no recorded data.

^c Hospital waste is incinerated in the facility.

^d Pasang, Moore, and Sitorius (2005).

^e Information on quantity not provided, generally limited, and undertaken by the informal sector.

^f Estimate only. About 1,700 tons per day unaccounted for and assumed to be burnt or dumped in vacant lots or waterways.

^g Japan International Cooperation Agency (2005).

^h Enayetullah and Hashimi (2006).

ⁱ United Nations Environment Programme (2006).

^j Chattopadhyay, Dutta, and Ray (2009).

^k Yoshiro, Friedrich, and Lu (2009).

^l Lim (2010).

^m Environmental Protection Department (2011).

Source: Green City Solid Waste Management (2012).

Incineration is used in highly developed cities such as Singapore and Shanghai. Issues such as high cost, perceived negative impacts on the atmospheric environment, and loss of resources are significant barriers to use of this technology in most cities in developing Asia (Visvanathan and Trankler 2000).

In the countries included in the Association of Southeast Asian Nations (ASEAN) grouping, both industrial and ordinary municipal solid wastes are usually disposed of in open dumps and landfills (UNEP 2004). However, the methods currently employed for managing the bulk of the waste generated in Asian cities will not be sufficient to manage the projected volume of waste that will be generated as a result of rapid rates of population growth and economic development.

The key to sustainable management of solid waste in these cities lies in applying the “3R principle” (reduce–reuse–recycle principle), as well as technologies appropriate to achieving acceptable sanitation conditions and facilitating recovery and use of materials in the various stages of waste

Common waste management practices in Asian cities



Open dump with waste picking



Scavenging at bins



Open dumping



Scavenging of mixed waste at collection vehicles

Source: Green City Solid Waste Management (2012).

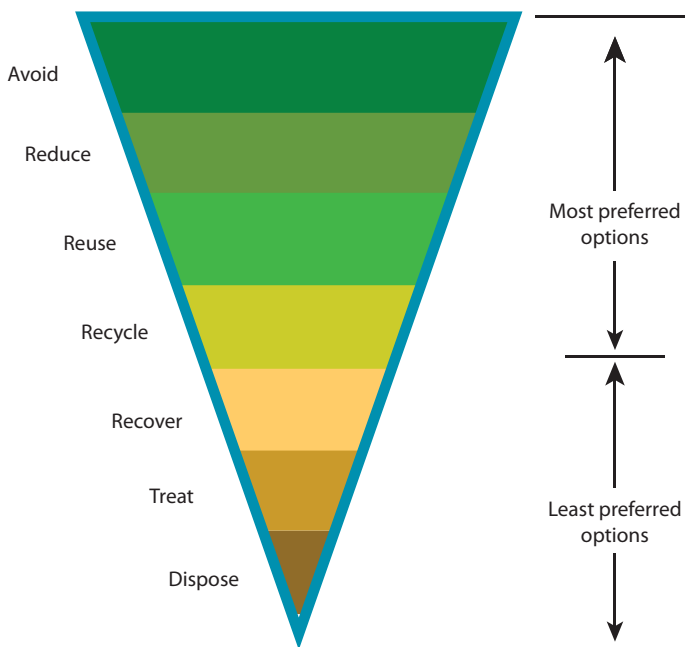
flow (Ackerman 2005). It is precisely the latter that are envisioned for the Green Cities of the future. The following sections describe the preferred flow of waste from the various generators, as well as common methods and technologies consistent with Green City environmental standards as implemented in some Asian cities. This includes the features necessary for sustaining such operations.

Solid Waste Flow in Green Cities

Solid waste management in Green Cities is anchored on avoidance and the 3R principle. These occupy the upper tiers of the solid waste management hierarchy that serves as a general guide to the various activities in the waste flow (Figure 6.1). It is based on the composition of waste from various generators and availability of conventional or new technologies where practicable.

The composition of waste from the various generators is presented in Table 6.2. The percentage shares of the various components in total waste generated vary with the level of per-capita income attained by particular cities or countries. In low-income countries, the bulk of waste generated corresponds to food and other biodegradable materials (Zerbock 2003; Visvanathan, Adhikari, and Prem Ananth 2007). Thus, organic matter makes up more than 50% of the solid waste generated in the ASEAN cities of Bangkok, Jakarta, Kuala Lumpur, and Manila (UNEP 2004). The high-income, industrialized countries have a relatively higher proportion of non-biodegradable components (ADB 2008). For any city, an updated set of waste characterization data is necessary for developing an appropriate solid waste management system. E-waste (e.g., computers, office electronic equipment, mobile phones, television sets, and refrigerators) has been included in all sources, as generation of these materials has grown in tandem with the increases in manufacturing output associated with economic advance (Pinto and Patil 2008).¹

Figure 6.1 Preferred Solid Waste Management Hierarchy in Green Cities



Source: Green City Solid Waste Management (2012).

¹ E-waste refers to equipment that is dependent on electric currents or electromagnetic fields in order to function. It thus includes discarded computers, office electronic equipment, entertainment-device electronics, mobile phones, television sets, and refrigerators.

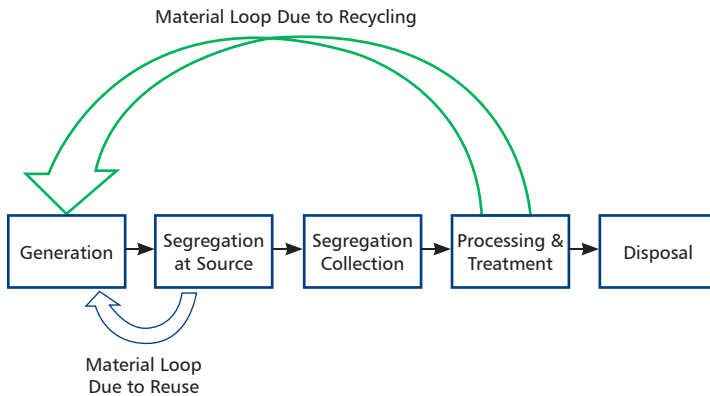
Table 6.2 Sources and Types of Solid Wastes in Asian Cities

Source	Typical Waste Generators	Biodegradable Components	Nonbiodegradable Components
Residential	Single and multifamily dwellings	Food waste, paper, cardboard, textiles, leather, yard wastes, wood	Glass, metals, ashes, special wastes (e.g., bulky items, consumer electronics, appliances, batteries, oil, tires), and household hazardous wastes, plastics, e-waste
Industrial	Light and heavy manufacturing, fabrication, construction sites, power and chemical plants	Food waste	Housekeeping wastes, packaging, hazardous wastes, special wastes, e-waste, ashes
Commercial	Stores, hotels, restaurants, markets	Paper, cardboard, plastics, wood, food wastes (unused and leftovers, expired food packages)	Glass, metals, special wastes, hazardous waste, e-waste
Institutional	Schools, hospitals, prisons, government centers, banks, offices	Paper, cardboard, plastics, wood, food waste	Glass, metals, special wastes, hazardous waste, e-waste
Construction and demolition	New construction sites, road repair, renovation sites, demolition of buildings	Wood	Steel, concrete, dirt
City services	Street cleaning, landscaping, parks, beaches, other recreational areas, water and wastewater treatment plants	Street sweepings; landscape and tree trimmings; general wastes from parks, beaches, and other recreational areas	Sludge, e-waste

Source: Green City Solid Waste Management as modified from "What a Waste: Solid Waste Management in Asia" (1999).

Depending on the waste composition and type of generator, the various components of waste are then segregated at source for eventual reuse, collection, processing and treatment, and eventually disposal. Figure 6.2 shows a generic flow of waste and materials in a Green City. Small material loops occur at source, due to reuse of recyclable components. Large material loops occur upon processing and recycling of collected waste, thus facilitating their use by the various generators. Recycling of waste materials and subsequent reuse in various forms may not necessarily be undertaken within the same city. The flow of waste depicted for the various sources of waste show the preferred route that would be taken by the various segregated components in a Green City solid waste management system.

Figure 6.2 Generic Waste and Material Flow in a Green City



Source: Green City Solid Waste Management (2012).

Residential Sector

In residential areas, the dominant waste fractions include food and other biodegradable materials, and dry potentially recyclable materials that can be segregated into five categories prior to collection (Figure 6.3). Most solid waste management systems require basic segregation into biodegradable and nonbiodegradable components. For example, in Tokyo, household waste is segregated into four fractions: (i) packaging and paper, (ii) combustible fraction, (iii) noncombustible fraction, and (iv) bulky waste (Tokyo's Waste Management System 2011).

Food waste may be directly used as animal feed. This practice is common in least-developed and low-income countries.

Other biodegradable components are composted by communities within cities such as Dhaka; Cakung, Jakarta; and in Barangay Holy Spirit, Quezon City, Philippines (Marcelo 2007, Jakarta Capital City Government 2010, and Enayetullah and Maqsood Sinha 1999).

Recovery and reuse of dry, potentially recyclable materials such as paper, plastics, glass bottles, aluminum and tin, including that contained in discarded appliances and electronic equipment, take place at source in residential areas. Recovery of similar materials takes place during collection, even before the waste reaches transfer stations, materials recovery facilities (MRFs), or disposal sites. These practices are undertaken mostly by the informal sector in cities in least-developed, low-income, and medium-income countries. The sustained operations of community-managed MRFs largely depend on the amount of recyclables that remain after waste segregation by households, commercial establishments and institutions, and at collection vehicles, less the amount diverted by buyback schemes that may be employed to attract the sale of previously recovered valuable materials.

In higher-income cities such as Tokyo and Singapore where retention of recyclables is minimized at source or by scavenging at collection vehicles, collected dry recyclables undergo final segregation and sorting in privately managed facilities. These materials are then processed in recycling plants.

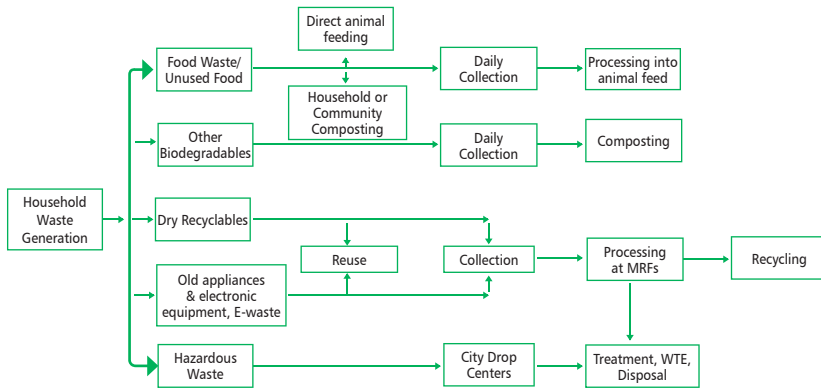
The Municipality of Teresa, Rizal in the Philippines mixes shredded nonbiodegradable materials from municipal solid waste with sand and cement to produce hollow blocks and footpath blocks.

Source: Teresa, Rizal's Successful Waste Management, <http://www.mb.com.ph/node/319116/tere>

Hazardous materials make up less than 5% of residential waste and can thus be left by homeowners directly at city drop centers. These materials are then collected and brought to a sanitary landfill for final disposal or to WTE facilities, together with residual materials from MRFs or processing facilities. Ash from WTE plants can be converted to slag and used as a substitute for sand in mixing concrete, as is done in Tokyo (Environment of Tokyo 2005).

Collection of segregated waste occurs in a manner appropriate to the waste management system employed. Food waste and other biodegradable materials are collected on a more frequent basis than are nonbiodegradable components.

Figure 6.3 Waste Flow for Residential Areas of a Green City



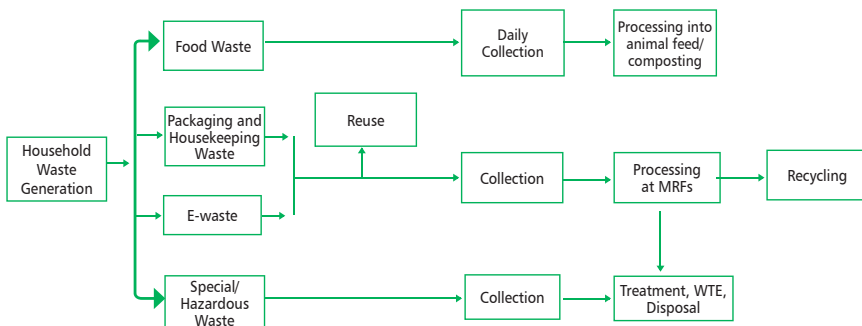
MRF = materials recovery facility, WTE = waste to energy.

Source: Green City Solid Waste Management (2012).

Industrial Sector

The industrial sector generates mainly special and hazardous wastes which are collected and ultimately disposed of at treatment facilities, WTE plants, or sanitary landfills. Packaging materials and some housekeeping waste can be reused directly at source. The remainder, including e-waste, is collected and brought to MRFs for final segregation before being sold to recycling facilities. Segregated food waste can be brought to either composting plants or facilities that process these materials into animal feed (Figure 6.4). As with residential waste, ash from incineration plants and residuals from MRFs can be used as aggregates or as ingredients in the production of glass or ceramic items (Cheng et al. 2002).

Figure 6.4 Industrial Waste Flow in a Green City



MRF = materials recovery facility, WTE = waste to energy.

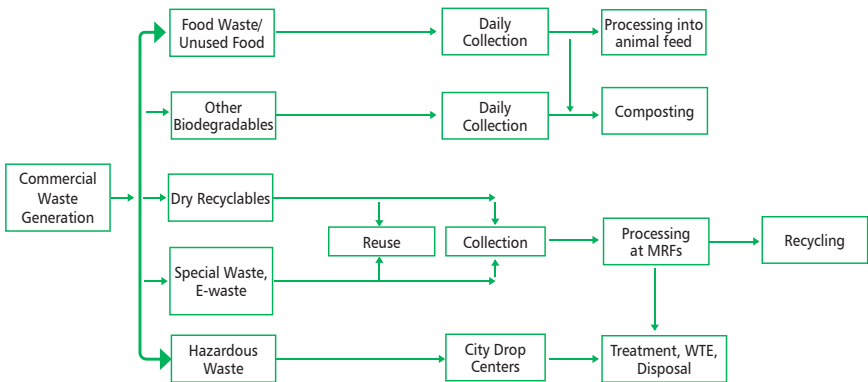
Source: Green City Solid Waste Management (2012).

Commercial Sector

Commercial establishments such as restaurants, grocery stores, hotels, and markets primarily generate food waste that can be processed into animal feed or soil conditioners in composting plants (Figure 6.5). Food waste in high-income countries is collected and processed into animal feed known as Ecofeed in Japan and Singapore (Sugiura et al. 2009, Recycling of Food Waste in Singapore 2008). As with residential waste, other biodegradable waste from commercial establishments can be processed by composting plants.

Reuse in commercial establishments is likely to be limited to paper products and packaging materials, since previously used glass and metal containers must meet stringent quality and sanitation standards. Any remaining dry recyclables and special waste, including e-waste, undergo final sorting and segregation for sale to recycling facilities. Residual materials from MRFs and hazardous materials can be used as refuse-derived fuel (RDF) for power plants, once they have undergone treatment. They can also be used as aggregate, or disposed of in sanitary landfills.

Figure 6.5 Waste Flow for Commercial Establishments in a Green City



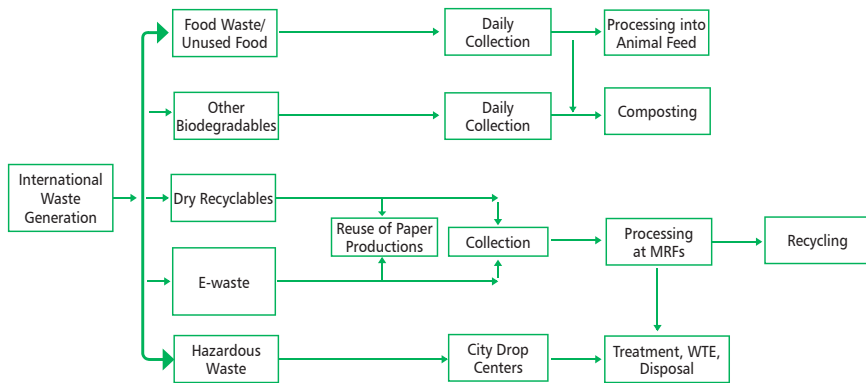
MRF = materials recovery facility, WTE = waste to energy.
Source: Green City Solid Waste Management (2012).

Institutional Sector

Waste generated at institutions consists mainly of paper products used for office operations. Currently, blank pages are used for printing draft reports and as notepads. The paper materials that get collected are eventually recycled and subsequently reused. The rest of the waste from institutions follows

the usual waste flow into composting plants in the case of biodegradable materials, animal feed processors in the case of food waste, MRFs and recycling plants in the case of dry recyclables and e-waste, and treatment or disposal in the case of hazardous materials (Figure 6.6).

Figure 6.6 Waste Flow for Institutions in a Green City



MRF = materials recovery facility, WTE = waste to energy.

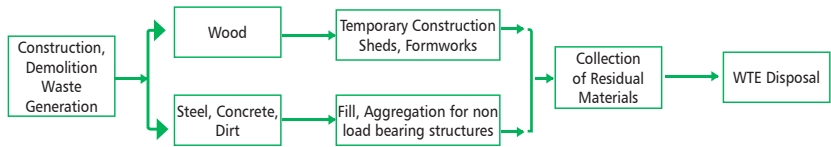
Source: Green City Solid Waste Management (2012).

Construction Sector

Construction and demolition (C&D) materials can be used for filling in low areas or as aggregates, subject to passing suitability tests. Recovery of reusable materials from industrial facilities has been achieved in Asia's developed countries. In Taipei, China, 84% of industrial waste generated in 2010 (14.2 million tons) was reused (Environmental Protection Administration 2010); and in Hong Kong, China, 66% of combined commercial and industrial waste generated in 2010 was recovered (Environmental Protection Department 2012). Similarly, the Wetland Parks in Hong Kong, China were constructed using aggregates from C&D materials (Fong, Yeung, and Poon 2004).

Residual materials from the reuse of C&D materials and from processing in MRFs can also be used as feed for WTE plants or as fuel for powering cement plants. Likewise, wood and related products can be used as temporary sheds or for building concrete forms at construction sites (Figure 6.7). The usual practice of disposing of C&D materials in sanitary landfills should be avoided.

Figure 6.7 Waste Flow for Construction and Demolition Sources in a Green City

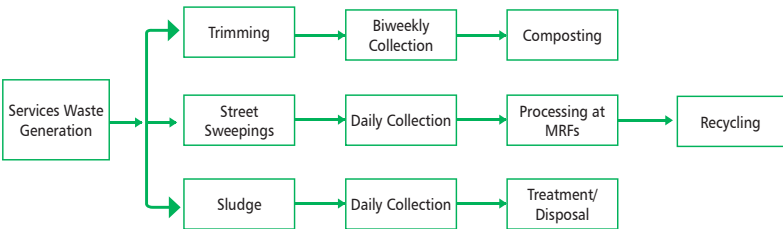


WTE = waste to energy.
Source: Green City Solid Waste Management (2012).

General Services Sector

Trimmings from parks and trees along roadways that make up the bulk of waste collected by city services can be composted to produce soil conditioners using the windrow method. Street sweepings that include various types of biodegradable and nonbiodegradable materials can be directed to MRFs for recovery of recyclable materials (Figure 6.8). Along with the sludge from processing at MRFs, the residual materials are then brought to a landfill for disposal or to a WTE facility.

Figure 6.8 Waste Flow for Waste Services in a Green City



MRF = materials recovery facility.
Source: Green City Solid Waste Management (2012).

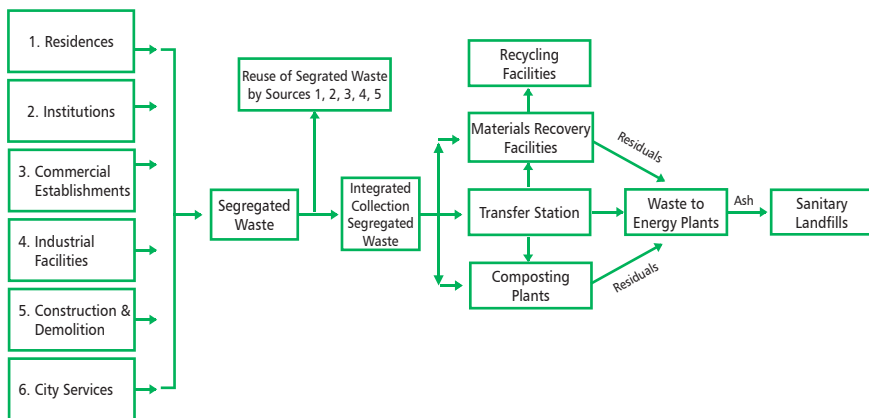
The waste flows from the various sources and the options for waste processing, treatment, and disposal should be integrated into the solid waste management system employed in Green Cities (Figure 6.9). Such a system is consistent with the solid waste management hierarchy that gives precedence to the 3R principle, and lesser preference to direct treatment or disposal wherever these are practicable.

Directly reusable segregated waste from residences, institutions, commercial establishments, industrial facilities, and construction and demolition activities is returned to the sources from which they came for reuse. The bulk of segregated waste is collected and transported directly to MRFs or composting plants, or optionally to transfer stations in the case of cities in which processing facilities are located at a significant distance from the center of waste generation. The outputs of MRFs are directed to recycling plants within or outside the city. The MRFs then produce materials that can be used in manufacturing. In the case of cities in the least-developed, low-income, or middle-income countries, recyclable materials will most likely pass through junk shops, and then directly to recycling plants or MRFs through buyback schemes.

Any compost generated can be used as a soil conditioner for farms and gardens. However, once the quality of the compost generated has improved to saleable standards through increased proficiency in compost production, it can be sold.

Residuals that cannot go into composting plants or MRFs are fed into WTE plants, or, if the latter are unavailable, disposed of in sanitary landfills. Ash produced by WTE plants can be disposed of in sanitary landfills or used as aggregate in the making of concrete. Once segregating and waste processing plants are able to process the bulk of all waste generated, the viability of operating WTE plants, incinerators, or even landfills should be evaluated.

Figure 6.9 Integrated Waste Flow Options in a Green City



Source: Green City Solid Waste Management (2012).

Methods and Technologies for Green City Solid Waste Management

The technologies available for the processing and treatment of biodegradable waste, recyclable materials, C&D waste, residual materials, and hazardous waste include basic manual, biomechanical, mechanical, and thermal methods.

Results of studies focusing on the 3R principle in solid waste management at the Asian Institute of Technology indicate that Bangladesh, Bhutan, Cambodia, the People's Republic of China (PRC), India, Indonesia, Malaysia, the Philippines, and Viet Nam are still in the developmental stage in implementing the 3R principle (Visvanathan, Adhikari, and Prem Ananth 2007). Recovery of recyclables and compost production on varying scales are mainly undertaken by the informal sector. The use of WTE technologies is currently limited to countries such as the PRC, Japan, the Republic of Korea, Singapore, and Taipei, China.

Biodegradables

In Asia, a large portion of all food waste generated is fed directly to animals or pets. Usually totaling several kilos per day per household, this manual and informal practice should address relevant health and sanitation issues.

To be financially feasible, processing of food waste from commercial establishments into animal feed is generally done by private companies, as efficient biomechanical methods of processing food waste require that significant amounts of material be processed. For example, in 2005, Singapore processed 100 tons of food waste into animal feed per day (Khoo and Tan 2005).

Barangay Holy Spirit in Quezon City, Philippines successfully implemented waste segregation at source and segregated waste collection. It established a materials recovery facility that operated six electrically powered rotating drums to process the biodegradable materials collected. The compost produced is used as soil conditioner for an urban vegetable and flower farm.

Source: Marcelo, R.F. A Garbage Success Story: How Barangay Holy Spirit in Quezon City Became a Model for Community-Based Solid Waste Management. *Tao*. June–October 2007.

Composting food waste and other biodegradable materials can be done at the community or city level. The former is typically managed by a city district and generally processes less than 5 tons of material per day.

The vermi-composting, fixed-bin composting, and manual windrow methods are generally used for composting operations on such a scale. Though the quality of compost produced using worms is high, the process

takes at least 2 months to complete and can only be done on a small scale by communities or households. The use of bins, barrels, and windrows likewise requires processing times of significant length and, if not done properly, produces lower-quality soil conditioners. Decentralized community-based, manual composting was piloted in Dhaka using the windrow method (Enayetullah and Maqsood Sinha 1999, Enayetullah and Hashimi 2006).

Medium- to large-scale composting of inputs exceeding 10 tons per day requires technologies using equipment such as electrically powered rotating bins and bioreactors with unit capacities of 1–3 tons, as has been done in selected communities in Metro Manila (National Solid Waste Management Commission 2008). Conversely, the City of Thiruvananthapuram, India uses the windrow method to process 300 tons of waste per day. Finally, Beijing's Nangong Garbage Composting Plant uses concrete tunnels to compost 1,000 tons per day (tpd) of input (eBeijing 2009). Both of the latter two plants are managed by the private sector.

Decentralized community-based composting under a public–private community partnership was successfully implemented in Dhaka. The composting model was initiated by a nongovernment organization and has been replicated 38 times in 20 towns and cities in Bangladesh.

Source: Zurbrugh et al. 2003. Decentralized Composting in Bangladesh, a Win-Win Situation for all Stakeholders. *Resources, Conservation and Recycling*. 43 (2005). 281–292.

Recyclables

Manual final segregation and sorting of recyclable materials that are segregated at source can be undertaken in community-managed MRFs at rates of 5–10 tpd using basic equipment such as sorting tables, weighing scales, and temporary storage areas. Currently, recovery of recyclables in cities such as Bangkok, Ho Chi Minh City, Jakarta, Manila, and even in Shanghai is performed by the informal sector (UNEP 2004, Edmonds 2008). Valuable recyclable materials recovered from waste bins, waste collection trucks, and open dumps include paper, bottles, plastic, and metal.

Medium- to large-scale recycling operations use mechanical equipment such as hoppers, pay-loaders, conveyor belts, Trommel screens, magnetic and density separators, weighing scales, balers, and large storage areas all located inside large MRFs (ADB Forthcoming). Operation of such facilities requires large investment outlays and highly trained personnel. Thus,

Singapore progressively increased its recycling rate from 54% in 2007, to 56% in 2008, to 57% in 2009, and then to 58% in 2010, which correspond respectively to 3.03 million, 3.34 million, 3.48 million, and 3.8 million tons per year.

Source: National Environmental Agency. 2010. Singapore 2010 Waste Statistics, Singapore Waste Statistics and Recycling Rates.



Separate Demolition of Building Components in Tokyo (Waste Management in Tokyo I)
http://www.kankyo.metro.tokyo.jp/en/attachement/waste_management.pdf

such facilities are well suited to private companies but generally cannot be efficiently operated by communities or government agencies. For example, Singapore's automated MRFs are operated by the private sector (Australian Business Intelligence 2003, French Chamber of Commerce in Singapore 2009). Similarly, in 2007, a private company opened a plastic recycling plant in Beijing with an annual capacity of 60,000 tons (China Daily 2007).

The City of Weihai at the eastern tip of the People's Republic of China's Shandong Peninsula implemented a solid waste management system based on the 3R principle. This increased the community's level of environmental awareness, improved solid waste collection, encouraged waste segregation by households, led to reuse of industrial waste, and reduced the amount of the latter that ended up in landfills.

Source: S. Pingyi. 2006. Best Practice, The Solid Waste Management in Weihai. The First 2006 Workshop, Population and Environmental Protection in Urban Planning.

Solid waste management systems in which source segregation is not enforced, or is poorly practiced, result in mixed waste or poorly segregated inputs. When used as feedstock for MRFs, such poor-quality inputs cause health and sanitation problems by emitting foul odors and generating leachate. Overloading and piling up of waste invariably occur in such facilities because of the significant differences in the amount of time it takes to process biodegradable and recyclable materials.

Optimal reuse of C&D waste requires systematic segregation of potentially useful components such as wood, galvanized iron (GI) sheets, metal bars, concrete rubble, and polyvinyl chloride or GI pipes. The practice

of separate demolition of various parts of buildings used in Tokyo facilitates higher rates of recovery of reusable materials (Environment of Tokyo 2005).

Residuals

Residual waste with a high caloric value recovered from MRFs and from industrial waste can be as used refuse-derived fuel (RDF) in thermal power plants (EC 2003).

In Manila, shredded residual materials are used in the small-scale production of hollow blocks and bricks for nonstructural use (National Solid Waste Management Commission 2008).

Hazardous Waste

Hazardous waste can be disposed of in sanitary landfills or incinerated to reduce its volume. The ash from incinerators can be disposed of in sanitary landfills or used as sand in concrete (Badur and Chaudhary 2008).

Features of Green City Waste Management

Table 6.3 shows various features of Green City waste management, including its legal aspects, various practices, the systems employed, and types of funding and facilities used. Similarly, it depicts the normal progression of waste-management activities from manual to mechanical, from community-based to private sector, and from low-technology to high-technology.

Table 6.3 Features of Green City Solid Waste Management

Solid Waste Management Components	Least-Developed Countries	Low-Income Countries	Middle-Income Countries	High-Income Countries
Ordinances/Regulations/Acts/Programs				
3R strategy programs	x	x	x	x
Garbage collection fees			x	x
Penalties for nonsegregation	x	x	x	x
Ban on open dumping, littering, waste burning	x	x	x	x
Extended producer responsibility	x	x	x	x

continued on next page

Table 6.3 continued

Solid Waste Management Components	Least-Developed Countries	Low-Income Countries	Middle-Income Countries	High-Income Countries
Practices at Source				
Waste avoidance/minimization	x	x	x	x
Segregation at source	x	x	x	x
Food waste used as animal feed	x	x		
Reuse of dry recyclables and paper	x	x	x	x
Reuse of construction and demolition waste	x	x	x	x
System				
Segregated collection	x	x	x	x
No segregation, no collection	x	x	x	x
Funding				
Subsidy from government	x	x		
Private-sector initiative			x	x
Equipment and Facilities				
Segregated waste bins (metal, plastic, concrete)	x	x		
HDPE waste bins		x	x	x
Waste collection vehicles	x	x	x	x
Transfer stations			x	x
Food waste processing plants			x	x
Community-managed composting plants	x	x		
Privately managed composting plants			x	x
Community-managed MRFs	x	x		
Privately managed MRFs			x	x
Privately managed recycling facilities			x	x
Sanitary landfills		x	x	x
LFG power plants	x	x	x	x
Waste-to-energy plants			x	x

HDPE = high-density polyethylene, LFG = landfill gas, MRF = materials recovery facility.

Source: Green City Solid Waste Management (2012).

Solid Waste Management Policies, Regulations, Acts, Programs, and Ordinances

Implementation of solid waste management programs is driven by national policy and legislation. Most Asian countries have formulated environmental and solid waste management laws that have been implemented with varying degrees of success (Table 6.4; Visvanathan, Adhikari, and Prem Ananth 2007). The degree to which implementation is successful generally depends on the effectiveness of the information and education campaigns undertaken, as well as the severity of penalties for noncompliance.

A regional effort in promoting the 3Rs in Asia was initiated in Tokyo in 2006. This initiative included Bangladesh, Cambodia, Indonesia, Malaysia, the Philippines, Thailand, and Viet Nam (Institute for Global Environmental Strategies 2009). As of 2009, these countries had undertaken surveys and needs assessments, drafted corresponding national 3R strategies, and held consultations with major stakeholders at the national level.

Table 6.4 Legal Basis for Solid Waste Management of Asian Countries

Country	Law, Act, Policy, or Program
Bangladesh	Bangladesh Environmental Conservation Act (1995)
Bhutan	Environmental codes of practice for solid waste management in urban areas (2000)
Cambodia	Sub-decree of 2009 and Sub-decree on Solid Waste Management No. 36 ANRK.BK, issued on 27 April 1999
People's Republic of China	Circular Economy Promotion Law (2009)
Indonesia	Law No. 32 for Industrial Waste (2009) and Law No. 18 for Municipal Solid Waste (2008)
Japan	Fundamental Plan for Sound Material Cycle Society (2000)
Republic of Korea	Waste Management Act (1995), Act on the Promotion of Saving and Recycling of Resources, and Ordinance on the Standards of Packaging Methods and Material (1993)
Malaysia	National Strategic Plan for Solid Waste Management (2005)
Nepal	Solid Waste Management and Resource Mobilization Act (1987) and Local Self Governance Act (1999)

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Table 6.4 *continued*

Country	Law, Act, Policy, or Program
Philippines	Ecological Solid Waste Management Act (2001)
Singapore	Environmental Pollution Control Act (1999), and National Recycling Program, Zero Landfill, and Zero Waste Strategy (2000)
Sri Lanka	National Policy on Solid Waste Management (2007)
Thailand	National Integrated Waste Management Plan (2005)
Viet Nam	Decree No. 59/2007/NĐ-CP - Regulation on solid waste management (2007) and Decision No. 03/2004/QĐ-BTNMT - Legislation on recycling (2004)

Source: Green City Solid Waste Management (2012).

The operational aspects of solid waste management include imposition of garbage fees for collection, and imposition of fines and penalties. The former contribute to waste avoidance and encourage reuse. The latter compel waste generators to comply with regulations and ordinances regarding the 3Rs, as well as prohibitions against littering, open dumping, and burning of waste, aside from generating funds for solid waste management services. Currently, collection of waste collection fees is implemented mainly in high-income countries.

Extended producer responsibility (EPR) or product stewardship should be practiced by major manufacturing companies at all levels of output. This can be attained through financial incentives that encourage the design of environment-friendly products, and by making producers liable for the costs of managing their products at the end of their useful lives. Depending on the product, EPRs may be used in reuse, buyback, or recycling schemes spearheaded by the manufacturer concerned. Such programs facilitate success of 3R efforts at the residential, commercial, and institutional levels. EPR programs have been implemented in Japan, the Republic of Korea, and Taipei, China; and beginning in the 1990s, for e-waste (Manomaivibool 2008).

The rapidly developing economies of Asia, including the PRC, Malaysia, and Thailand, have drafted EPR legislation, while the region's least-developed countries have yet to develop theirs (Institute for Global Environmental Strategies 2011a). A notable exception to the latter is Indonesia, which has addressed management of post-consumer product and packaging in Articles 14 and 15 of the 2008 Indonesian Law No. 18 on Solid Waste Management (Institute for Global Environmental Strategies 2011b). In the

least-developed countries, formulation of any legislation or program relating to solid waste management should integrate and encourage the activities of informal collectors and recyclers of all types of solid waste, including e-waste.

At-Source Best Solid Waste Management Practices

As for solid waste management practices, avoidance and segregation at source and reuse of recyclable materials can be undertaken at all waste sources, regardless of the per-capita income level of the country concerned. Use of food waste as animal feed by households will likely prevail for some time in the region's least-developed and low-income economies. Reuse of C&D waste can be practiced on a large scale by major contractors, households, institutions, commercial establishments, and industrial facilities for their respective activities.

Segregation at source is key to the success of any solid waste management system. At the very least, the waste generated should be segregated into biodegradable and nonbiodegradable components. Targeted segregation schemes for the various waste generators allow immediate reuse of reclaimed materials where practicable. As well, they facilitate preservation and non-contamination of materials prior to final sorting at MRFs, and, eventually, recycling.

Reusable and recyclable materials from the construction and demolition waste generated in cities should be recovered for subsequent use in similar, if not related, infrastructure projects. Responsibility for implementation of the above guideline for reuse of C&D waste should rest with contractors and owners, as overseen by the appropriate government agency. However, achieving successful implementation of this guideline generally depends on a high level of environmental awareness on the part of waste generators, and observance and strict implementation of solid waste management laws and ordinances through the imposition of fines or revocation of collection rights in cases of noncompliance.

Solid Waste Management Systems

An efficient segregated collection system should support segregation at source. Cities at differing levels of per-capita income may employ a wide variety of collection systems, as long as the segregated wastes are collected according to established schedules, and are delivered to waste processing, treatment, or disposal facilities. Dhaka implemented house-to-house collection of biodegradable materials from households that were used by

the city's decentralized composting system (Zurbrugh et al. 2002). In the City of Pune, India, the Pune Municipal Corporation established a unique cooperative of waste pickers and other urban poor residents that provided doorstep garbage collection services (Wikia 2008).

While makeshift equipment for waste storage is often used in the least-developed and low-income countries, rather than the synthetic bins used in middle-income and high-income countries, both satisfy the principle of providing a temporary holding area for source-segregated waste prior to collection. The major difference between these two types of collection systems is that in all likelihood the segregated recyclables recovered in the least-developed and low-income countries will be collected by informal sector operators for their own reuse, or for sale to junk shops or local MRFs. Such practices can affect the viability of MRFs in the least-developed and low-income countries in that to sustain operations the MRFs in these countries may be obliged to implement innovative buyback schemes.

Food waste for processing into animal feed should be collected on a daily basis. The remaining components of waste, including biodegradable materials, should be collected in a manner that reflects the logistical capability of the city concerned.

Funding

Some level of investment is required to establish and operate a sound adequate solid waste management system. In some countries, this investment is undertaken by the government, whereas in others it is undertaken by the private sector. Subsidies for operation of waste processing facilities, such as MRFs and composting plants, may be provided initially. However, once full-cost recovery is attained, such subsidies should be terminated with all possible speed.

Regardless of the per-capita income level of the country concerned, in large cities, either entire solid waste management systems or various components of them are funded and operated by private companies under various arrangements, including public-private partnerships. These arrangements may include build-operate-transfer schemes, or build-operate-lease or build-operate-own schemes for MRFs, composting plants, and WTE plants. Such arrangements address the usual gap in technical capability and efficiency of the government sector. Waste collection in Asian cities such as Hong Kong, Manila, and Singapore is undertaken by private haulers (ADB 2003, Bai and Sutanto 2002, Environmental Protection Administration 2010). Waste management in Mumbai is undertaken by seven municipal corporations, corresponding to the districts covered by their

respective operations (Rode 2011). Processing of food waste in Japan and Singapore is done by the private sector. Operation of Shanghai's sanitary landfill and waste to energy (WTE) plant is done by a private company (Andersson 2007).

Waste processing facilities appropriate to Green City solid waste management systems may be operated by local communities in lower-income countries. Such facilities usually employ members of the informal sector as part of an overall program for relocation of families dislocated by establishment of waste management facilities. As per-capita income rises and waste volumes increase, operation of solid waste management facilities could be progressively handed over to the private sector. Such facilities would include transfer stations, sanitary landfills, WTE plants, and even hazardous waste treatment plants.

Equipment and Facilities

Waste containers are required for facilitating both segregation at source and, later, segregated waste collection. In the least-developed and low-income countries, these may take the form of metal cans, plastic containers, drums, and concrete or rubber bins. Medium- and high-income countries employ

Various Types of Waste Bins



Plastic containers



Rubber bin



Concrete bins



HDPE bin

Source: Green City Solid Waste Management (2012).

Various Waste Collection Vehicles



Open truck

Dump truck

Compactor truck

Source: Green City Solid Waste Management (2012).

high-density polyethylene (HDPE) bins of different colors and sizes that correspond to the type of waste these will contain. The main purpose of these waste receptacles is to temporarily hold the segregated materials, to prevent their access by animals and roaming waste pickers, and to prevent foul odors or contaminated liquids from leaking into the environment. Use of plastic and paper bags and baskets is not advisable, since these are less able to prevent leaks of either liquids or odors.

Waste collection vehicles facilitate transport of segregated waste to transfer stations, processing or disposal facilities, or WTE plants. A basic requirement for these vehicles is non-mixture of source-separated waste components, reduced emission of foul odors during transport, and containment of contaminated liquid that may be generated by the biodegradable or hazardous component of the waste collected. Enclosed trucks or compactor trucks are preferred for waste collection. While open trucks will likely be used in the region's least-developed and low-income countries, these should be provided with adequate coverings to mitigate the release of unpleasant odors.

Transfer stations are intermediate facilities that link waste collection systems and MRFs, composting plants, WTE plants, or sanitary landfills. As cities become more crowded, waste facilities tend to be located at greater distances from collection areas; hence the need for transfer stations or retrofitting of existing stations to allow them to serve as MRFs. Intermediate facilities in Asian cities and their capacities in tons per day (tpd) include Jakarta's SPA Sunter Transfer Station (1,000 tpd); the Ukkadam Transfer Station at Combaitore, India (150 tpd); Bangkok's Tharaeng Transfer Station (1,500–2,000 tpd); Beijing's Datun Domestic Garbage Transfer Station (1,500 tpd); and Kuala Lumpur's Taman Beringin Transfer Station (1,800 tpd).

Food Waste–Processing Plants

Food waste–processing plants may transform these biodegradable materials into animal feed, methane or biogas, or soil conditioners by means of vermi-composting.

The production of animal feed from food waste may use fermentation (silaging) or drying through low-pressure frying, boiling, high-temperature fermentation, or high-temperature drying (Sugiura et al. 2009). In Japan, such methods are employed to produce Ecofeed, while in the Republic of Korea, lactic fermentation is used to produce feed for pigs (Yang et al. 2006).

Biogas from food waste collected in the town of Mamallapuram in India was used to generate power which was returned to the same people from a 10-kilowatt power station.

Source: Hand-in-Hand Project Turns Food Waste into Bio-Gas. *Green Thing*. 17 October 2011.

Biogas from the fermentation of food waste can be used at both the household and community levels in lieu of liquefied petroleum gas, as well as for power generation.

Good quality soil conditioners for farms and vegetable gardens can be produced using African crawlers that feed on the shredded, source-segregated food waste of even low-income communities within cities at any level of per-capita income.

Materials Recovery Facilities and Composting Plants

The successful and sustained operation of MRFs and composting plants in Green Cities depends on the level of source segregation and segregated waste collection achieved prior to the waste's arrival at such plants.

The basic process involved in MRFs at all scales of operation is systematic separation of valuable recyclable materials from the remaining waste. This can be done manually, as in community-owned facilities, by a team of sorters who also temporarily store the segregated waste components. Cities may have larger, semi-automated facilities run by the private sector that uses conveyors and balers. Large, fully automated, and usually privately managed MRFs use conveyor systems, magnetic separators, trommels, and air classifiers to separate the various waste components according to their densities and the properties of their metallic waste components.

Composting entails the controlled biological decomposition of organic matter into humus or compost that can be used as soil conditioner. The

main input of composting comprises shredded biodegradable components of the waste stream. Typically, the inputs used comprise processed and unprocessed food waste from markets, residences, and commercial establishments.

The composting technologies that can be employed depend on the waste volume, the amount of land area available, and the composition of the waste itself. Households and small communities use vermi-composting, excavated pits, and fixed bins capable of completely processing food waste within 2–3 months. Waste volumes exceeding 5 tons generally employ either the windrow method or rotating bins. Inoculants are usually added to shorten processing times and to facilitate larger throughput.

Establishment and operation of MRFs and composting plants at the community level or higher must be always guided by the results of accurate waste characterization studies and mass balance. The latter provides an indication of the outputs of these facilities, and thus the viability of the proposed operation.

Sanitary Landfills

Landfills represent one of the most common technologies used in disposing of municipal solid waste. Typically, mixed waste is tipped and compacted into engineered cells provided with liners that prevent leakage of leachate. These cells are then capped with soil to mitigate emission of the foul odor that results from decomposition of the waste's organic component. Systems for monitoring soil, air, and water contamination in the vicinity of the facility are set up in compliance with environmental regulations.

Green City landfills use the same safeguards against leaks and odor emission, but accept only the residuals from waste processing facilities and ash from WTE plants. The nature of such inputs significantly reduces generation of leachate and unpleasant smells, the latter comprising the issues raised by environmentalists against the use of such disposal facilities. These facilities can incorporate specially designed cells for accommodating hazardous waste.

Landfill gas power plants

Landfill gas (LFG) mainly consists of methane generated in capped dump sites and landfills. LFG has been used for power generation in several Asian countries in lieu of conventional fossil fuels. Using LFG instead of fossil fuels for power generation mitigates against the release of greenhouse gases that cause climate change, atmospheric pollution, and explosion hazards. As a

general rule, the minimum amount of waste in a landfill or dump site that can be tapped for LFG is about 1 million tons. Potentially, this amount and more have accumulated even in the least-developed and low-income countries. Small LFG facilities in Asian cities include the 2.096 MW Jana Landfill Plant in Kuala Lumpur and the 100 KW pilot power plant in Payatas, Quezon City (PowerPulse.Net 2005). Development of the 1 MW Rachathewa Power Plant in Bangkok has begun (Target Neutral 2011). Tapping methane generated from decomposition of biodegradable components in landfills also allows the cities using this technology to gain Certified Emission Reductions issued by the Clean Development Mechanism executive board under the Kyoto Protocol.

Waste-to-Energy Technologies

Waste-to-energy (WTE) plants generate energy through direct or indirect combustion or production of methane, ethanol, pellets, or synthetic fuel produced from municipal solid waste. In general, WTE technologies can be classified as thermochemical, biochemical, or physicochemical. Thermochemical methods include incineration, pyrolysis, and gasification. Most WTE plants in Asia use the incineration or direct combustion method. Japan is the leading user of WTE technologies with about 1,900 incinerators (Kusuda 2001). The PRC has about 80 plants (Waste to Energy Research Technology Council 2010), and Singapore has four incinerators, while Taipei, China had 18 as of 2005 (Lee 2005). Once completed, the Timarpur Okhla Municipal Solid Waste Management plant in New Delhi will generate 16 MW of electricity daily, fed by 2,000 tons of waste, the latter representing 25% of the city's total amount of waste generated (Indo-Asian News Service 2011).

With the exception of India, all WTE plants have been constructed in medium- to high-income countries, thus reflecting the scale of investment required for establishing and operating such facilities. Use of this technology as a component of a waste management system depends on a large volume of waste being generated, and the capacity of disposal sites in large cities being reached. Singapore's total land area is relatively small. As a result, the capacity of the country's on-shore sanitary landfills has already been reached; thus the necessity of building and operating incinerators.

Biochemical WTE methods include anaerobic digestion and fermentation of organic waste, the latter principally comprising animal manure. These WTE methods have not been reported as being applicable to a scale large enough for power generation from the biodegradable components of municipal solid waste.

Physicochemical methods include mechanical methods and autoclaves for upgrading the physical and chemical properties of solid waste sufficiently for the production of pellets or refuse-derived fuel (RDF) that can be used for

power generation. Since 1997, Japan has constructed 57 RDF plants (Ministry of Environment 2008).

Aside from their significant initial investment costs, the major issues mitigating against the use of WTE plants that use direct combustion is the release of dioxins, furans, and mercury into the atmosphere. The pollution control mechanisms incorporated into current generations of WTE plants have reduced the release of these pollutants to levels that fall within those prescribed by developed-country environmental standards.

The use of WTE plants that release reduced amounts of furans and dioxins is compatible with recycling under Green City waste management regimes. Studies conducted in the United States have shown increased recycling rates in cities where WTE facilities are operated relative to those lacking such facilities (Berenyi 2009).

Aside from the direct combustion method, Green Cities can also use autoclaves that allow recovery of recyclables as a by-product of producing RDFs for power generation.

The Current State of Green City Waste Management

The menu of technologies that can be used in Green City solid waste management regimes is varied, and has been partially taken advantage of by most Asian cities.

The legal framework for effective solid waste management using the 3R principle was essentially established in most, if not all, Asian countries as early as the turn of the 21st century. Presumably, information and education campaigns have been launched in most countries to increase the level of environmental awareness of the various classes of waste generators.

Collection systems have likewise been established, although in numerous countries, mixed waste is still being loaded and transported to disposal, treatment, and processing facilities. Furthermore, use of WTE facilities appears to be on the rise in the region's medium- and high-income countries.

Good solid waste management practices—notably segregation at source—have not been reported by, or observed in, most Asian cities with the exception of Singapore, which has achieved significant and consistent progress in recycling. Recovery of recyclables by the informal sector from bins, collection vehicles, and disposal sites is still dominant. Accordingly, segregated waste collection cannot be implemented, nor can MRFs and

composting plants fed with mixed waste be established or operated. Establishing and operating such facilities depends on the region's achieving Green City status with regard to solid waste management, as these facilities receive the bulk of waste generated under the preferred waste flow of a Green City. Moreover, such facilities provide opportunities for subsequent reuse of valuable recyclables from all classes of waste generators. In the absence of such facilities, the mixed waste collected ends up in landfills or open dumps, or, in some middle- and high-income countries, in WTE plants. This is unfortunate, since not even the use of technology can prevent the loss of resources inherent in incinerating mixed waste to produce power, or worse yet, disposing of it in landfills.

Notwithstanding the seeming lack of political will necessary for implementing environmentally sound waste management practices, the latter have, in some cases, been observed in several cities that, though on a small scale, are consistent with Green City solid waste management practices. These were attained in communities that fully supported specific solid waste management projects and that enjoyed the support and collaboration of numerous government institutions, nongovernment organizations, and private sector entities. It is noteworthy that most of these best practices employed only basic solid waste management methods rather than mechanized or thermal technologies.

In order to instill a culture of sound solid waste management practice among waste generators of all classes, existing laws and ordinances must be strictly implemented through imposition of fines and penalties. For example, this requires enforcement of the *no segregation–no collection rule*. Parallel to this is sustained information, education, and communication campaign, with regard to not only the negative impacts of poor solid waste management practices or complete lack thereof but also the health—and more importantly—economic benefits of recovery of valuable resources from segregated waste.

Over time and likely within a generation, a waste management culture based on sound solid waste management practices will develop as a result of an increased level of environmental awareness. The growing realization of the finite nature of both the natural resource base and available space, the low rate of utilization of reusable materials from waste, and deteriorating health and environmental conditions will collectively drive governments, institutions, the private sector, and local residents alike to actively collaborate in solid waste management initiatives. Concurrent with this will be the progressive attainment of Green City–preferred waste flows and goals, regardless of the per-capita income level of the city or country.

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CHAPTER 7

Financing Sustainable Cities

by Michael Lindfield, Vergel Latay, and Vince Michael Docta

Introduction

The array of financing mechanisms available to cities for investments relating to the environment and climate change is large. This chapter reviews three generic types of these investments. The first type encompasses funds under the direct control of local governments, or funds routinely accessible to them. Examples include national government grants for specific purposes such as improving solid waste management or addressing other urban sustainability issues. The second type comprises the range of private sector financing available, both from national and international sources. The third type includes the variety of funding vehicles available from multilateral and other public sector sources.

Each of these three types of financing includes a variety of mechanisms and instruments. This chapter therefore includes numerous examples of each, as well as some discussion of the issues relevant to each vehicle or instrument. It should not be forgotten that these financing mechanisms are not mutually exclusive. Indeed, efficiencies may be gained and costs lowered by using a mix of such vehicles to finance particular projects or initiatives. In this regard, effective and professional project structuring pays significant dividends in achieving these potential efficiencies and savings, this latter issue being discussed at greater length at the end of the chapter.

Accessing Environmental Finance Requires Sound Financial Management

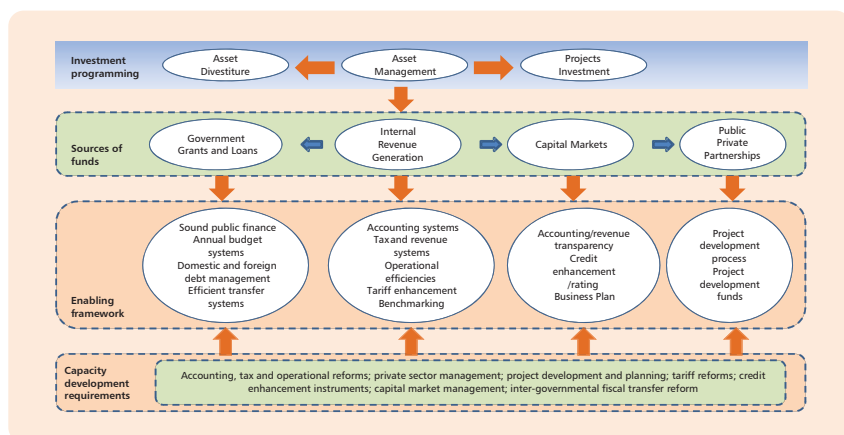
Governments and other agencies seeking to implement environment- or climate-related projects are often encouraged by the bewildering array of funding sources available. However, this variety of funding sources cannot

act as a counterbalance for poor financial management. Indeed, accessing such sources of finance often requires meeting stringent criteria relating to institutional capacity, financial systems standards, and performance. Figure 7.1 below sets out the framework for the capacity development priorities and system improvements necessary for accessing these funding sources. This chapter discusses each of the major elements in Figure 7.1 in some detail. For example, the section immediately below begins this process by discussing traditional government and own-source financing mechanisms in detail.

Ultimately, financing environment- or climate-related investments begins with the financial management of existing assets. If these are well maintained and efficiently utilized, additional investments may be postponed and even avoided. For example, introduction of water meters in Brisbane, Australia allowed users to manage their water consumption more efficiently. This enabled reductions in average consumption down to 123 liters per day, making Brisbane residents some of the best water-savers in the developed world. More importantly, this significantly contributed to deferment of programmed capital investments totaling \$3.2 billion for the whole of Southeast Queensland territory. In addition to managing and efficiently utilizing existing assets, if appropriate, these can be leased out for management by a third party to produce cost savings, or possibly to generate a profit for reinvestment in new assets.

Even with the best management of existing assets possible, new projects still require funding. Investment programs for this purpose should be based on sound asset planning that takes account of environmental, energy-efficiency, and climate-change issues. Again, the foundation for this funding is own-source resources, which in Figure 7.1 is referred to as “internal revenue generation.” Other funding vehicles are on offer, either as matching grants from other tiers of government, or from capital markets or private sector partners. However, both of the latter require a sound governmental counterparty. The need for proper financial management is thus fundamental to obtaining financing for environment-related projects, and is an unavoidable step in obtaining it.

Figure 7.1 Urban Infrastructure Financing and Development Framework



Source: Based on P. Singh. 2007. *Financing Urban Development, Infrastructure, and Private Sector Involvement*. Conference on Investing in Asia's Urban Future. Manila.

Maximizing Own-Source Financing

The amount of financing available to a particular project is based on the financial strength of the entity seeking it. In this regard, the old saying that “the less you need money, the more people want to give you” is applicable to obtaining financing for environment-related initiatives. Local governments and other subsovereign sponsors of urban environmental infrastructure are often their own worst enemies in that their willingness and capacity to collect even the revenue they are due is poor. Nowhere is this deficiency more glaring than in the case of property tax. Properties missing from the register, undervaluation of the properties that are included in it, lack of effective local government collection mechanisms, and informal payments made in lieu of tax collections all undermine the fiscal health of project sponsors and deprive them of the means they need to leverage other forms of funding.

Aside from collecting all mandated taxes efficiently, the following are several additional areas in which cities may bolster financing¹

- User charges that cover the full cost of services such as water and electricity. This includes the cost of providing supply and damage caused by usage, as well as the opportunity cost of taking the resource from other potential users, including the ecosystem.

¹ Depending on reserve powers and sharing under the relevant national and state or provincial legislation.

- Emission or effluent charges based on the “quality” or quantity of waste generated.
- Product charges on goods that pollute surface or groundwater during or after consumption, these being based on the actual value of damage caused by their use.
- Tradable rights allowing the use of a given quantity of a resource and establishment of a market for such rights.
- Marketable permits that allow a given amount of a pollutant to be released. This includes entitling an entity to treat its waste and sell its permit, or to not treat its waste and purchase additional permits sufficient to counterbalance the amount of pollution released.²
- Tax-increment financing, in which a portion of tax revenues resulting from improvements is earmarked to repay the cost of those improvements.
- Refund systems for commodities packaged in reusable or recyclable containers that ensure that these are returned for proper disposal or reuse.
- Joint development through public–private partnerships.

While numerous types of public sector funding are available for green investments, it is sound local-revenue performance that provides the basis for access to grants and other types of financing from higher levels of government. However, this is only true given the absence of perverse incentives, which effectively reward governments or agencies for poor performance. For example, a housing grant program that provides funds in proportion to the number of dilapidated dwellings in the public housing stock effectively encourages poor maintenance of such dwellings.

Leveraging Private Sector Financing

Project sponsors should explore the unbundling of commercially viable or contestable infrastructure components that can be financed by the private sector. This entails separating components that must be government-funded from those that the private sector might wish to undertake. For example, water treatment plants can be unbundled from the piped network that serves such water systems. Much has been written on private sector participation in various sectors. The Public–Private Infrastructure Advisory Facility (PPIAF) website discusses the unbundling process in detail, and provides specific examples that include (i) improving the performance and financial viability of small water utilities in the Philippines; (ii) public–private partnerships in wastewater services and solid waste management

² Managing these to reduce overall pollution over time is part of the exercise.

in India; and (iii) increasing the efficiency of service delivery and reducing public subsidies for bus transport services in Viet Nam.³ As a result, the discussion of unbundling provided by the PPIAF website is not replicated here.

Private sector participation must be supported by effective, independent regulation that mitigates the risks associated with a private entity being in a monopoly-provider role in the provision of basic services such as water and energy. The regulatory regime must contain provisions for a fair service price, sustainable service provision, and any distributional objectives. Contracts should clearly specify the funding for any public service obligation of the provider, such as lower prices for the poor to be provided through sustainable government transfers, tax-deductible cross-subsidies, or other means.

Which investments should be undertaken?

This section lists the types of environment-related projects that might receive high priority for financing, and summarizes the key issues and risks associated with each type of project, including how revenue might be generated to service debt or provide a return to equity investment.

Public transport:

- Right-of-way (ROW) and relocation risks require that funds be available for acquisition (and streamlined court processes for compulsory acquisition) of ROW, as well as relocation mechanisms that minimize disruption of low-income communities and provide alternate housing options for dislocated communities.
- Ridership projections are notoriously incorrect, with actual ridership often falling far short of projections for roads and mass rapid transit systems. Conversely, ridership projections for bus rapid transit systems typically overstate actual ridership.
- Replacement or incorporation of informal-sector service providers often requires difficult or protracted negotiations relating to governance arrangements and bridging finance.
- There exists a potential for land-based finance in ROW acquisition.

Waste management:

- The “not-in-my-backyard (NIMBY) effect” often requires that funds be provided for community liaison and acquisition, as well as streamlined

³ Public-Private Infrastructure Advisory Facility. <http://wbi.worldbank.org/developmentmarketplace/partner/public-private-infrastructure-advisory-facility-ppiaf>

court processes for compulsory acquisition of land for establishing waste disposal sites.

- Replacement or incorporation of informal-sector service providers into waste management initiatives requires funding for training and livelihood programs, as well as difficult-to-establish governance arrangements, since more than one local government is generally involved.
- The form and reliability of collection of fees from users of the proposed disposal site must be specified, and any costs of doing so included in estimated project costs.

Water supply and wastewater disposal facilities:

- Both the cost and reliability of supply of raw water must be specified, as must the ROW risk for trunk supply mains and collectors.
- Water treatment and in particular wastewater treatment initiatives are often subject to the NIMBY effect that requires the types of actions referred to above.
- Replacement or incorporation of informal-sector service providers into water supply and wastewater disposal initiatives requires funding for training and livelihood programs.
- Tariff levels and any related adjustments to them must be specified, as well as the form and reliability of collection of availability payments or treatment fees.

Energy, energy efficiency, and industrial greening initiatives:

- Project formulation and development processes are expensive, but are often recoverable.
- Bridging funds are required to finance up-front expenses.
- Savings or revenues from such initiatives may be uncertain because these depend on energy tariffs and prices for recyclable materials.

Drainage:

- ROW risk exists for large collectors.
- Identifying a potential revenue stream is difficult for some projects, but often possible.
- There exists a potential for land-based financing for dikes, drainage ROWs, and retention basins if these include a revenue-earning component such as user charges for recreational or concessionaire spaces.

- There exists a potential for levying local “rates” (increments to property taxes) for recovering costs in exchange for expanded amenities and flood-avoidance benefits.

City greening:

- As with drainage facilities, revenue streams for parks and other open spaces are sometimes limited.
- While parks and other open spaces are usually publicly funded, maintenance costs can be defrayed and amenities often expanded through appropriate concessioning (i.e., charging providers of services for use of a portion of the land).
- There exists a potential for levying local rates for expanded amenities and other benefits.

Urban agriculture:

- Some cities such as Shanghai already obtain a significant share of their total food supply from their immediate hinterlands.
- Because urban or vertical farming is currently highly energy-intensive, it is likely to be of more interest in the future, since ongoing research continues to lower its energy intensity.
- If potential energy efficiencies are achieved, conventional commercial finance may be forthcoming.

District heating and cooling initiatives:

- The energy cost for district heating and cooling and its reliability are potentially important issues, although efficiencies can be achieved through planning and the use of cogeneration.
- ROW issues likewise exist, although to a lesser degree than for public transport initiatives.
- It is often difficult to obtain the collective agreement of building owners to retrofit existing buildings, particularly if retrofitting includes insulation.
- Tariff levels and any adjustments to them must be specified, as must the form and reliability of collection procedures for availability payments or treatment fees.

Adaptation Investments:

- It is often difficult to justify capital costs for providing essentially the same service as previously, although the manner of provision is more climate-resilient than previously.
- ROW issues exist in the case of roads and dikes, as do NIMBY issues in the case of relocation of treatment plants.
- Replacement or incorporation of informal-sector service providers into adaptation initiatives requires funding for training and livelihood programs.
- Tariff levels and adjustments to compensate for resilience investment must be specified, as must the form and reliability of collection procedures for availability payments and treatment fees,
- There exists a potential for land-based financing in some circumstances.

Existing Subsovereign Systems for Environmental Infrastructure Finance

Overall Context

The practicalities of financing specific investments, or changing the pattern of investments for addressing global environmental issues such as climate change require a clear understanding of the policy context in the country concerned. The latter sets country priorities, and thus the resources available both from the public and private sectors for financing such investments. While member countries of the Organisation for Economic Co-operation and Development (OECD) grouping have effective environmental lobby groups that are often represented by “green” parties in their legislatures, if not in government, the situation in developing countries is less clear. The latter countries do have environmental lobby groups, and their citizens are aware of environmental issues, but the influence of such groups and sentiments is generally less than in the OECD countries for a variety of reasons. Because they are rarely represented in the legislature, they cannot directly influence government resource allocation or policies that determine resource allocation by other levels of government, utilities, households, or enterprises.

An important issue in this regard is one of relative poverty. While many developing countries actually have standards of living superior to that enjoyed by the OECD countries less than a century ago, their citizens feel that this is not sufficient. Budgetary priority thus goes to investments that foster growth, which is defined in materialistic terms such as roads, ports,

water supply facilities, and housing, which constitute the basic infrastructure that supports growth. If many citizens cannot access adequate housing and political awareness of this issue is great, a national or local government that diverts resources from low-income housing does so at its peril.

A second issue that compounds the “priority” problem referred to is the “not-caused-by-us” (NCBU) attitude, which is a nonconfrontation strategy that is as logically flawed as NIMBY, but one that attempts to preemptively take an even higher “moral ground.” Not bailing out the lifeboat just because you did not cause the collision that sank the ship is counterproductive. This being said, NCBU is a potent rallying cry for “the opposition,” regardless of what it opposes or whatever its political affiliation.

A third issue compounding the “priority” problem is the size of the informal sector. Much larger portions of developing country economies are in the informal economic sector—up to 60% in some countries. This means that their economic systems are much less amenable to the mechanisms OECD governments normally employ to implement policy. Legislation, tax breaks, and standards do not heavily influence enterprises that are not registered, that do not pay tax, and that have no concept of standards except as justifications for bribes.

A fourth issue compounding the “priority” problem is simply lack of capacity—technical, administrative, and, most particularly, financial.⁴ As much as a developing country government would like to act to protect the environment, it is often constrained by its human and financial resources. The (understandable) attitude is: “better to resolve immediate issues for which we have some capacity than to attempt to resolve issues for which we have few resources.”

In developing countries, we are therefore in a situation in which there are heavy disincentives at all levels of policy and action for financing-needed investments for responding to climate and the green agenda overall. What this means for financing such investments is explored in the following sections.

The Four Components of Sound Financing Systems

Sound financing systems must comprise four components if green finance is to be forthcoming. Furthermore, each of the following components helps overcome the impediments described above:

- 1) National fiscal structures that provide incentives, both positive and negative, for pollution reduction, energy efficiency, greenhouse gas

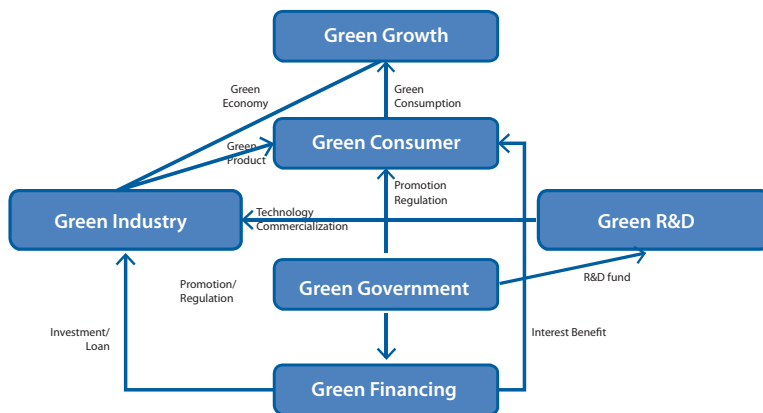
⁴ Because with money, you can usually get the technical and administrative inputs required.

reduction, and adaptive investments. Potentially, such structures can address all of the above issues if well designed.

- 2) Systems that regulate national and international private capital markets and support their capacity to formulate, promote, and deploy financial products that enhance access to green finance and its affordability. Green funds that invest in mitigation provide one such example.
- 3) Public structures at the international level such as the Global Environment Facility that help developing countries adjust to climate change or overcome the transaction costs of investing in mitigation. Such structures are often financially and economically viable in the long run, but require significant up-front outlays to implement. Such mechanisms help address priority, NCBU, and capacity issues if they are structured well.
- 4) Microeconomic structures for encouraging and supporting the private sector, as well as subnational government-agency capacities in formulating, structuring, and financing green investments.

A financing system that incorporates all four of the components above in a way that allows their beneficial interaction allows green issues to be addressed in a comprehensive way. One example of this is the Republic of Korea's financing system that includes a Green Growth Initiative. This program targets both the demand and the supply side of green products and investments (respectively referred to as Green Consumer and Green Industry in Figure 7.2). The Green Finance component both provides finance

Figure 7.2 The Republic of Korea's Green Growth Initiative



Source: D. Oh. 2011. Green Financing in [the Republic of] Korea. PhD Research Paper, Korea Corporate Governance Service.

for green investments and subsidizes consumption of “green products,” generally through tax breaks. These activities are supported by tax-revenue-funded green research-and-development funds that assist industry in developing the products, services, and infrastructure required for supporting a green economy. Under the program’s Green Government component, the government acts as a role model, a coordinator, and a standard-setter.

While government can promote change by paying for key investments directly, the most effective method of promoting green growth, as depicted in the Republic of Korea system, is through leveraging private sector funding. This is, in any case, essential in Asia. The total amount of urban infrastructure (mainly environmental infrastructure) required each year in Asia is valued at an estimated \$100 billion, while current annual urban environmental infrastructure investment is about \$40 billion (Cities Development Initiative for Asia 2012). Even though government budgets are constrained in the wake of the 2008 financial crisis and subsequent stimulus packages, and aid is squeezed by financial problems in the OECD countries, at the same time Asia’s private capital markets are flush with funds. The only viable strategy for bridging Asia’s investment gap is thus to leverage private sector funding.

Current Sources of Public Sector Financing for Green Investments

This section describes the public sector mechanisms currently available for financing green investments, including their underlying public policy aspects, as well as associated incentives for both promoting investment and leveraging private sector funding.⁵

Taxes

At the metro, city-region, and even mega-region level, planning must be reinforced by land tax policies and incentives for green development. Levying taxes on the unimproved value of land (i.e., the price the land would command for the highest and best use of the land as zoned) is essential for efficient and sustainable use of land resources. Australia uses this system relatively effectively. In practice, it means that you can have your single-story bungalow, empty industrial facility, or rice paddy in the middle of the central business district surrounded by 30-story buildings, but your land tax will be based on the value of the land as *if* you had a 30-story building on it.

⁵ Baietti et al. (2012).

Box 7.1 The Land Value Tax/Resource Rent Approach to Financing Green Development

Land value taxation is a means of shifting part of the property tax burden from land and buildings in combination, onto land values alone for the benefit of the community (Lichfield and Connellan 2000).

In 1980, Harrisburg, the capital of Pennsylvania, was identified as the second most financially distressed city in the United States. Municipal tax policy reforms were undertaken to shift taxes off of buildings and on to land. Now taxes on buildings have dropped, and land is taxed five times more heavily. The resulting effect was that potentially developable sites were freed from speculation and under-use, while with buildings less burdened by taxes, developers with viable projects began restoring the city. Harrisburg's quality of life is now one of the highest in the United States. This success prompted 17 other Pennsylvania municipalities to put this policy into place. All have evidenced benefits of economic regeneration as indicated by increased issuance of building permits and other criteria.

In Hong Kong and Singapore, city authorities capture land value primarily through renting out government-owned land at rates reflecting the economic value of the activities thereon. *The city-state of Singapore has a tax rate on land of 16%, this supplying funds equivalent to 40% of the government's total budget. Meanwhile, Hong Kong, which was founded exclusively on land owned by the government, funds 40% of its budget from site rent. The city uses land rent—not subsidy—to fund its metro system and, in turn, building the metro increased the value of land.* For Hong Kong's metro system, land value capture (known as "betterment taxes") represented a financial windfall. In the 1980s, the system was already showing a profit, partly due to the increase in land value along the metro line. However, it is interesting to observe how this income from land value increased and development was unexpected in the original viability projections. The non-fare revenue of the metro system comprises proceeds of land rent (direct betterment value), station commercial and related businesses such as retail and advertising sales (indirect betterment value), and other public mass transport investments.

Sources: M. Pauwen. 2011. *Successful Examples of Land Value Tax Reforms*. <http://www.earthrights.net/docs/fin4devt.html>; L. Coconcelli. 2011. *Land Value Capture as a Funding Source for Urban Investment*. European Investment Bank. http://www.eib.org/attachments/general/events/luxembourg_11072011_cocconcelli_en.pdf; R. T. Meakin. 1990. Hong Kong [China]'s Mass Transit Railway. *Rail Mass Transit for Developing Countries*. 19. July 1990. 125–143; Lichfield and Connellan. 2000. *Land Value and Community Betterment Taxation in Britain: Proposals for Legislation and Practice*. Lincoln Institute of Land Policy. Cambridge, Massachusetts, USA.

Practical political considerations complicate the implementation of this effective tax principle. There are sometimes shouts of "inequity" from granny, who inherited the said single-storey bungalow but has no income to support such a tax. One could retort that granny is a wealthy woman and can

live very well from the proceeds of the sale, provided the capital gains and transfer taxes are not prohibitively high. As an aside, such transaction costs *should* be low in principle, as you the policy maker *want* a liquid land market in order to encourage densification and redevelopment that embraces green principles. If you are really soft-hearted, you can defer granny's taxes until the land is sold, or, if you are soft-headed, you can exempt her completely during her occupancy. Of course, you need to check that granny is not subletting, or has not passed away some 10 years ago, and this fact has somehow escaped the knowledge of the "friends" or relatives now living in said bungalow. Effective enforcement is thus important, especially when there are exceptions to a regulation.

Resource Pricing

For water, macro-level resource pricing is also important. Yes, it is nice that all those lovely oranges are produced with all that subsidized water, but the city can use the water for more productive enterprises, and agriculture should pay the real price of the resources it uses. Cost-recovery pricing encourages water conservation, the exploitation of alternative sources (e.g., rainwater harvesting) and recycling, which becomes economic more readily given real economic pricing of water resources. We know that farmers are a powerful lobby group, but Australia's National Water Initiative shows what can be achieved with rational pricing policies when these are complemented by stringent enforcement.

The implications of rational resource pricing go far beyond the boundary of the city. Cities may make economically viable investments in upstream water resource and forest management. Preserving the water source's quantity and quality and reducing flood peaks by undertaking such investments far upstream is, for some cities such as Jakarta and Bangkok, very important—so important that such activities may have to be managed by the national government.

Air pollution has been treated as a health issue that is typically addressed by regulating emissions. In many cities, this remains a high priority. But more important to the future of the human species is the dumping of greenhouse gases (GHGs) into the atmosphere, mainly by city-related economic activity. As a result, pricing of the atmospheric resource has become an important issue. This is politically a highly contentious issue due to the NCBU principle. Thus, international efforts at correctly pricing the atmospheric resource have met with little success. However, some cities are implementing cap-and-trade schemes of their own, effectively pricing the atmosphere as a resource within their jurisdictional boundaries. Tokyo's scheme is the most advanced, though Saitama, another Japanese city, is also participating. Similarly, a range of other subnational emissions trading schemes exist outside of Asia (Baietti et al. 2012). Trading of "credits" among these schemes is foreseen,

and both Asian Development Bank (ADB) and the World Bank are interested in promoting such a system. Trading of city credits among developed- and developing-country cities thus holds some promise.

Box 7.2 Indonesia's Citarum Scheme



Initially supported by an ADB Investment Program (which later led to leveraging of private sector and community investments), sustainable IWRM interventions have been realized for Indonesia's Citarum River Basin.

The Citarum River runs a total of 11.6 kilometers and has a total area of 13,000 square kilometers. This important body of water provides drinking water, hydropower, irrigation water, municipal water supply, and aquaculture opportunities to Jakarta and other urban centers in West Java. The Citarum River basin supports a population of more than 28 million people, and 20% of the country's industrial output. However, the basin's water resources have come under increased pressure over the past 20 years from urbanization and

industrial growth, causing severe water pollution, acute stress, and depletion of groundwater in several locations. Environmental degradation has reached levels that compromise public health and livelihoods, particularly for the poor.

For these reasons, the government adopted a concerted approach to improving land and water management in the basin. In this regard, it requested help from the Asian Development Bank in developing and funding a long-term development program for the Citarum River basin. This program was one component of a strategic plan for maintaining clean, healthy, and productive catchments and rivers. Under the program, the government and local communities worked together to achieve sustainable benefits for all inhabitants of the Citarum River basin.

The Integrated Citarum Water Resources Management Investment Program funded a range of interventions necessary for introducing integrated water resources management (IWRM) into the Citarum River Basin. These interventions included (i) institutions and planning for IWRM; (ii) water resource development and management; (iii) water sharing; (iv) environmental protection; (v) disaster management; (vi) community empowerment; (vii) data, information, and decision support; and (viii) program management.

The investment program was funded through a multitranche financing facility (MFF) that provided more than 15 years of water-related infrastructure and services across a number of IWRM key areas throughout the Citarum River basin. In essence, the MFF enabled

continued on next page

Box 7.2 continued

- flexibility in investment decisions and timing, based on needs and constraints;
- implementation based on the readiness of individual projects;
- development of a partnership for supporting the long-term vision of Citarum River basin stakeholders in a sustainable manner; and
- building capacity in IWRM.

Finally, the MFF facilitated funding from sources available to the central and regional governments, leveraged private sector and community investments, and facilitated effective financial planning with other funding institutions.

Source: ADB. 2008b. *Report and Recommendation of the President: Proposed Multitranche Financing Facility and Administration of Grant and Technical Assistance Grant, Republic of Indonesia: Integrated Citarum Water Resources Management Investment Program*. Manila.

Box 7.3 Emissions Trading in Tokyo

Emissions trading is a market-based approach to addressing air pollution problems. If designed and implemented well, emissions trading systems can be economically efficient in that they provide incentives for participants to reduce emissions of specific pollutants.

The Tokyo Metropolitan Government developed the Emissions Trading System (ETS), which is the world's first cap-and-trade program at the city level that targets energy-related carbon dioxide emissions. The ETS applies to approximately 1,340 large facilities including industrial factories, public facilities, educational facilities, as well as, uniquely, commercial buildings. The ETS took effect in April 2010.

During the first phase of the scheme which runs up to 2014, participating organizations will have to cut their carbon emissions by 6%. From 2011, those that fail to operate within their emission caps will be required to purchase emission allowances to cover any excess emissions, or alternatively, to invest in renewable energy certificates or offset credits issued by smaller businesses or branch offices. However, under the rules of the scheme, credits issued outside Tokyo cannot be equivalent to more than a third of the emission cuts required of participants.

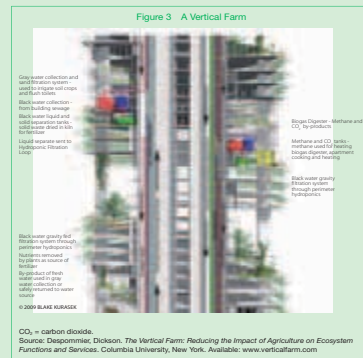
Firms that fail to comply with the new rules will face fines and will be ordered to cut emissions by 1.3 times the amount by which they failed to reduce emissions during the first phase of the scheme. In addition, offenders may be named and shamed by the government,

Sources: World Bank. 2010e. *Tokyo's Emissions Trading System: A Case Study*, Directions in Urban Development. Washington, DC; The Guardian. 2010. Tokyo kicks off carbon trading scheme. 8 April; *Green Futures Magazine*. 2010. Tokyo launches Asia's first ETS. 6 July.

Box 7.4 Financing Urban Agriculture

Analysis of 13 experiences with urban and peri-urban agriculture in Asia, Europe, and Latin America revealed that financing of urban agriculture has taken three forms: (i) mobilization of both financial and nonfinancial resources by urban farmers and their families, (ii) subsidies from both public sector and international agencies that are channeled through a variety of mechanisms, and (iii) provision of credit, generally in limited amounts, provided to individual borrowers rather than groups.

These mechanisms have been able to support three types of urban agriculture: (i) a *subsistence-economy type*, which is generally family-based, and does not generate a cash surplus, but provides food or medicinal plants that reduce the expenses of the family and improve diets and well-being; (ii) a *market-oriented type* that comprises production, agro-processing, and marketing of agricultural commodities; and (iii) a third type that is undertaken as part of *leisure and recreational activities* that relate to healthy practices by cities and citizens, raising awareness of environmental issues and allowing children to experience food production cycles.



Urban agriculture initiatives—such as the "vertical farm"—address the goal of increased food security in cities

Source: ADB. *Green Cities* (Brochure) 2011.

Subsidies, both from public sector and international sources, reduce the financial burden on small urban producers that engage in *subsistence-economy* urban agriculture. Such producers are typically unable to secure conventional banking guarantees for urban agriculture for two reasons. First, urban subsistence agriculture is not commercialized. Second, it is undertaken by the urban poor, who lack title to the land used and have no fixed employment or regular income. Such persons must thus mobilize their own resources, unless they are assisted by government agencies or nongovernment organizations.

The *market-oriented* type of urban agriculture appears to likewise have limited access to credit, but receives nonfinancial subsidies such as technical assistance or other inputs such as seeds, equipment, or tools.

Leisure and recreational-oriented urban agriculture enjoy significant public sector subsidies. For example, in St. Petersburg, such subsidies cover leases for trucks and tools, debt alleviation, microcredit for agro-processing or for agricultural production, seeds and animals, short-term loans (of less than 1-year duration) for acquisition of assets, and general microcredit (especially to women). In addition, conventional commercial loans are available to clients who are able to provide a high level of assurance to financiers. Nevertheless, own resources constitute a large part of financing to urban producers.

Source: C. Y. Cabanes. 2006. *Financing and Investment for Urban Agriculture in Cities Farming for the Future, Urban Agriculture for Green and Productive Cities*. Manila: Resource Centre on Urban Agriculture and Food Security Foundation, International Development Research Centre, and International Institute of Rural Reconstruction

Finally, food is an issue for city sustainability planning at the regional level. Despite what was just said about orange growers, policies should encourage agricultural investment in the city hinterland to supply food to the adjacent city. Urban agriculture is also important. Production of food in green spaces such as allotments, backyards, and balconies within the city can foster increased food security and reduce the environmental impact of transporting food from distant regions. Larger green spaces also provide “green lungs” that reduce the heat-island effect and lower the amount of energy required for cooling. In this regard, fuel pricing for transport is particularly important, since it is only financially viable to truck or fly food into urban areas from distant locales if fuel is cheap. Regional zoning discouraging monoculture on large areas also forces farmers to concentrate on high-value crops. In respect of urban agriculture, start-up costs can also be subsidized or, preferably, financed.

Incentives

The use of tax revenues and fees should be planned and implemented in a transparent manner. Again in principle, fees for service should be claimed by the enterprises providing the service, and any asset sales should provide capital for continuing improvement of the service in question. Yes, this is obvious, but parts of the highway network in the United States are being sold off to pay recurrent costs outside of the transport sector, and water enterprises in Indonesia have been “raided” by local government for their cash flows.

Tax revenue provides the basis for capital expenditure subsidies required for green investments that are not financially viable under any politically rational pricing system. Metro-level—and even city-region level—agencies that can achieve such financial management are notable by their absence in Asia, as well as many other countries. Effective planning, oversight, and enabling legislation are required at the provincial/state level for such entities to function effectively. In cases in which a city region or mega-region crosses provincial borders, national action may be required. New “green” cities may need even more support and special structures if they are to be made viable in the long run. For example, Masdar (Box 7.5) requires substantial national subsidies. Such support is potentially transparent and accountable, as Masdar is set up as a corporation that offers education and other environmental services. In this sense, Masdar is the ultimate “company town.”

At the level of the city and city neighborhood, the basis for green development is laid in planning. This is the case even for existing neighborhoods that are badly planned, poorly serviced, haphazardly developed, and badly maintained. Rehabilitation and retrofitting that allows the use of green technologies is possible, provided that actions are planned and executed in a coordinated manner. Examples include the Lower Lea

Valley in East London and the Pyrmont redevelopment in Sydney, where old warehouses and dilapidated housing have been replaced by high-quality urban development. These redevelopment projects required a local area agency with eminent domain powers and an ability to raise finance, as well as planning and zoning powers.

Box 7.5 Masdar City

Masdar is a planned city being built by the Abu Dhabi Future Energy Company, a subsidiary of Mubadala Development Company. The city is designed to be a hub for clean-tech companies. Masdar City aims to achieve its goals of zero net carbon impact by

- harnessing energy from several renewable sources;
- ventilation design that takes advantage of natural sea breezes and protection from the desert climate by a wall and wind towers;
- allowing at least 80% of its water to be recycled, with a low-energy desalinization plant providing the remainder;
- recycling or composting of solid waste; and
- personal rapid transit pods that run on magnetic tracks to reduce or replace the need for cars.

Currently, the Masdar City project relies heavily on investments initiated with start-up funding by the Abu Dhabi government. The project has invested in wind, solar, and other energy generation projects worldwide as a means of providing long-term funding. In fact, the Masdar Clean Tech Fund has raised \$265 million for investment and is looking to build a diversified venture capital and private equity portfolio that will include some of the world's most promising and pioneering clean-tech and renewable energy companies. The fund is made up of commitments from the Abu Dhabi Future Energy Company, the Consensus Business Group, Credit Suisse, and Siemens AG. In the future, it is likely that these investments will help Masdar become self-sufficient as a company.

Other Masdar-related partnerships include BASF, Bayer, Hansgrohe, and Siemens, each of which has agreed to locate a research and development center in the city, and use the partnership with Masdar Institute of Science and Technology (MIST) to help advance clean technology and test their products locally. Masdar cemented its importance on the world stage by securing the support of the International Renewable Energy Agency, which will move its headquarters to Masdar City as a show of support for the project.

Sources: Masdar City. Master Plan. <http://www.masdarcity.ae/en/>; *The Economist*. 2008. Masdar plan. 4 December. http://www.economist.com/node/12673433?story_id=12673433; M. Picow. 2010. Abu Dhabi's "Masdar Clean Tech Fund" Closes First Fund At \$265 Million. *Green Prophet*. 3 February. <http://www.greenprophet.com/2010/02/masdar-clean-tech-fund/>

Box 7.6 Pyrmont Redevelopment

Pyrmont, which lies to the west of Sydney's central business district, was historically a working-class suburb. As such, it mainly comprised industrial enterprises served by its docks, and working-class terraced housing. Pyrmont and adjoining Ultimo were the location of the city's wool storage, sugar refining, flour milling, and shipping industries for more than a century. In addition, much of the yellow block sandstone used in the construction of early Sydney buildings came from Pyrmont. But as industry moved out, both Pyrmont's population and the area in general fell into decline.

Government-owned property was particularly concentrated in Pyrmont-Ultimo. The asset realization potential of developing the government's land holdings, particularly for commercial development, and the potential for major urban consolidation, led the government to develop an urban strategy for the area, which was named the City West Urban Renewal Program. This program transformed Pyrmont into a lively inner-city urban community. Further, the old area was connected with the Darling Harbour redevelopment area and the central business district, thus further elevating its status in Sydney.

The New South Wales Government sold \$97 million worth of property in Pyrmont, thus making it available for private sector redevelopment, making Pyrmont one of the largest land sell-offs in Australia's history.

The City West Development Corporation was established to oversee Pyrmont's development, to administer government sites, and to ensure provision of major infrastructure. The corporation was significantly funded by the federal government's Building Better Cities program. The injection of more than \$240 million of Commonwealth and state funding, mainly for new services, roadways, and infrastructure, as well as a joint effort by the public and private sectors, have made Pyrmont what it is today—one of Sydney's most sought-after, livable, high-density districts.

Sources: City of Sydney. 2007. 2007 Local Action Plan City West. The villages of Pyrmont and Ultimo; G. Searle. 2007. Sydney's Urban Consolidation Experience: Power, Politics and Community. Urban Research Program. Research Paper 12. Brisbane: Griffith University.

Zoning is a delicate weapon in the planner's arsenal. To work at all, it must be enforced. That said, rigorous enforcement of inappropriate zoning is counterproductive in that it both provides a significant incentive for corruption and often runs counter to sustainability principles. For example, attempting to enforce residential-only zoning in a dense, mixed-use Asian city will not work. In addition, it will not only encourage bribery of enforcers but also run counter to a key tenant of urban sustainability, which is the principle of minimizing the need to travel, and thus to consume energy.

On the other hand, use of floor area ratios to encourage green development can be effective. Zoning of areas around public transport corridors and nodes to encourage high-density development is effective, but is often hated by established owners in leafy suburbs that surround a railway station. The NIMBY syndrome is alive and well in Sydney, and can influence politicians to blunt this effective tool that is at the disposal of planners. Site coverage ratios can encourage provision of green or open space, but unsubtle application of such rules sometimes results in sterile, cold plazas.

Other zoning regulations, combined with fees, can achieve positive environmental outcomes. Such zoning regulations applied in Sydney's central business district and Inner Frankfurt am Main do not provide for commuter parking spaces in new buildings. Similarly, on-street parking is not allowed. Likewise, developers are charged for cars they attract to the city, and the resulting revenue is used to build peripheral public parking that charges substantial amounts for the privilege of parking a car. This has the double benefit of raising public revenue and discouraging people from bringing their cars to the city.

Subsidies

Readers may note that much of this section deals with planning, not finance. This is important. The type, size, and use of a building are fundamental determinants of its economic value—in real estate terms, its “yield” as an investment. This value is the basis on which financing for construction can be obtained, but also the basis of revenue from which taxes may be taken to build and maintain infrastructure and services and to encourage green investment through subsidies.

Subsidies are another double-edged sword in the urban manager's arsenal. Inappropriately used and administered, they can be counterproductive and vehicles for corruption. Intelligently and transparently used, they can be effective indeed. Increasing floor-area ratios for green buildings is effectively a subsidy. However, the technique can also be applied to specific investments. Rebates (subsidies that refund part of the cost of an investment or activity *after* money has been spent) are easier to monitor and verify than are subsidies paid in advance of money being spent. As a result, they can and have been given for a wide range of green investments such as installing insulation in buildings, solar photovoltaic cells, water-saving appliances, and use of public transport. Subsidies can be, and sometimes should be, applied in ways other than rebates. In many cases, they should be targeted and set at levels that change behavior without creating a windfall profit. Arguably, Spanish and German subsidies for solar power fell into the latter category.

Box 7.7 Effective Subsidies: Water Supply to Manila's Low-Income Households

In the late 1990s, only 26% of Manila's populace had access to affordable and clean tap water. Others had to pay the high prices charged by water vendors, queue for hours at public faucets and community wells, or tap illegal connections. In some cases, informal settlers were unable to apply for regular water connections because they lacked proof of land ownership.

Between 2007 and 2009, 10,642 water connections were made using a Global Partnership on Output-Based Aid (GPOBA) connection subsidy funded by the World Bank. Manila Water, a private utility, designed the innovative *Tubig Para Sa Barangay (TPSB)* ("Water for the Community") program, which enabled marginalized households to connect to a piped-in water supply. Under this program, the World Bank provided funds to subsidize the cost-of-connection fees of customers who lived in low-income communities.



A woman inspecting household water meters. Low-income households now enjoy access to water supply through subsidies via output-based aid (OBA) schemes. Source: ADB.

The total connection charge per household was \$167, of which each household contributed \$36 in installments paid over 36 months. GPOBA contributed the remaining \$131. The GPOBA subsidy was paid directly to Manila Water Company as a single payment, on condition of independent verification of three months' satisfactory service delivery. In turn, Manila Water provided the water at reduced prices.

To accommodate the ill-defined streets and dense makeshift housing in the low-income settlements served by the TPSB program, an underground water pipe was brought to each settlement and connected to a cluster of meters. Inhabitants made their own household connections, and were given 36 months to pay the subsidized fee that covered the cost of the households' pipes and individual meters. Water costs were one-fifth of what they had paid previously. Further, the reduced contamination levels in the water provided under the program resulted in an 80% drop in the incidence of diarrhea.

To date, more than 1.6 million people have benefitted from the program in that they now enjoy water supplied right from individual taps 24 hours per day. By charging affluent customers proportionately more for the water they consumed, the TPSB program provided access to excellent quality drinking water to Filipinos who could not afford a full-service connection. This cross-subsidy was thus financed through water tariffs that provided 50% of Manila Water's total water-utility income from the 20% of the system's users who were more affluent.

Sources: Manila Water. 2009. Manila Water: Invests in the Future. http://www.manilawater.com/section.php?section_id=4&category_id=23&article_id=35; R. Simpson. 2012. Lessons Learned from PPIAF Activities: Pricing and Affordability in Essential Services. Technical Notes 4. Washington, DC: Public-Private Infrastructure Advisory Facility.

Subsidies can also be effectively used as a way to reduce the cost of a green investment that would otherwise not be undertaken. Such subsidies are called “viability gap subsidies” because they fill in the gap between the cost of an environment-friendly investment and the amount that community users can afford to pay for it.

Public transport subsidies are nearly ubiquitous since its provision is an expensive business. Even busways, which are relatively cheap, cost \$10 million per kilometer, depending on standards and capacity. Metro systems requiring ROW acquisition or expensive tunneling are typically 10 times more costly than are busways. Given that environment-conscious policy makers want to maximize the use of public transport, raising

Box 7.8 Land Value Capture for Investment in Copenhagen

Land value capture is particularly useful in relatively undeveloped areas that benefit greatly from provision of new infrastructure. Copenhagen’s metro, completed in 2007 and considered to be one of Scandinavia’s most ambitious transport infrastructure projects, provides an excellent example of land value capture. The Ørestad Development Corporation (ODC) was established with the dual goal of building the metro in Copenhagen and developing the Ørestad area. This area is jointly owned by the national government (45% share) and the municipality of Copenhagen (55% share).



Photos: AFP

Transport infrastructure investments such as the Copenhagen metro were made possible through land value capture.

The area developed is about 600 meters wide and 5 kilometers long, and is situated about 2 kilometers from the city center of Copenhagen. The project closely interconnects infrastructure, land-use development, and financing. The total cost of the project is estimated at 1.7 billion euros. By putting infrastructure in place, the sale of land to private investors was facilitated, and this in turn was important to the financing of the metro system.

continued on next page

Box 7.8 continued

ODC directly managed the Ørestad land. It likewise arranged loans on commercial terms that were a joint liability of the national government and the municipality. Furthermore, it designed, built, and initiated the new metro's operations in addition to planning and constructing other infrastructure projects, and then subsequently sold the land to developers and investors. The corporation uses the profits from these land sales to repay the loan, instead of using real estate tax revenues and profits from operation of the metro system.

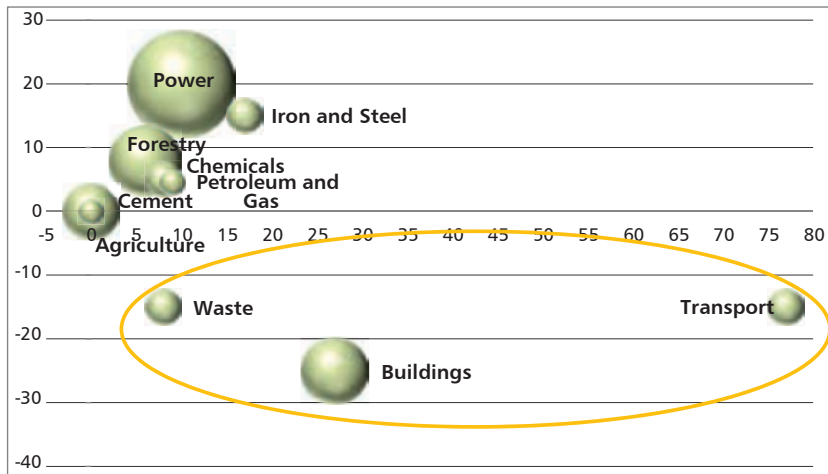
Source: OECD. 2007. *Infrastructure to 2030. Volume 2: Mapping Policy for Electricity, Water and Transport*. Paris.

fares to the point at which people do not want to use public transport is counterproductive. Thus, capital subsidies are often deployed to defray costs. This has the advantage of being a one-time, transparent subsidy. Other arrangements involving private sector provision that depend on subsidy are also possible (Box 7.8). In Hong Kong city (Hong Kong, China), public transport has run at a profit, but only by providing cross-subsidies (i.e., subsidies to a money-losing part of an operation provided from a profitable part). In the case of Hong Kong city's metro, profits from property development operations fund a substantial portion of the costs of running the trains, although this has recently been curtailed due to intense lobbying on the part of certain developers (T.E. 2011, Yeung 2008).

Catalyst Funding

Catalyst funding is supplied for the purpose of initiating an investment which, though financially viable in the long run, cannot, for a variety of reasons, obtain capital funding. Catalyst funding can take many forms and can be in any proportion to the total capital cost of the initiative concerned, depending on the sector funded and the capital market concerned. For example, reducing GHG emissions to the same level through investment in mitigation initiatives in various sectors requires widely differing amounts of funding, the greatest amount being required in the power sector (Figure 7.3). Given the long-dated investments involved and the cost per unit of GHG reduction in this sector, it is unlikely that GHG abatement would occur in the absence of significant increases in tariffs or subsidies. Due to the magnitude of the investment required, only cities such as Tokyo have sufficient resources to subsidize such investment, even with the support of the national government. Conversely, the investment required for GHG mitigation measures relating to buildings, waste management, and public transport is negative over the long term, indicating that the financial gains from increases in energy efficiency

Figure 7.3 Relative Magnitude of Investment to Reduce Greenhouse Gas Emissions



Source: ICLEI. 2010. *Cities in a Post-2012 Climate Policy Framework*. ICLEI Global Reports. Bonn.

brought about through these GHG mitigation measures ultimately outweigh the financial costs of undertaking such measures.

Examples of such investments include building energy-efficiency measures, fuel switching from gasoline to liquid natural gas, and investments in waste-to-energy plants. In such cases (e.g., those enclosed in the dotted line in Figure 7.3), the long-term profitability of the investment means that only small subsidies or financing windows are required, making them efficient investments for metro regions and cities. In the case of cities, sometimes only a small investment is required to induce significant changes in investment behavior. This is particularly true when such investments signal a long-term commitment to stimulating investment in green infrastructure, and even more so if such investments are supported by the national or regional government. California's Property Assessed Clean Energy (PACE) financing scheme is an excellent example of such innovative finance (Box 7.9).

Green investments that produce long-term net financial gains, such as those that appear within the dotted line in Figure 7.3, occur in developed and developing countries alike. Even in the People's Republic of China (PRC) where electricity is subsidized, the financial gains from undertaking such measures exceed the cost of undertaking them. Nevertheless, banks are reluctant to lend money for such investments in such a new and policy-dependent market. To demonstrate the viability of such investments, ADB provided a guarantee for the Pudong Development Bank's energy-efficiency facility (Box 7.10).

Box 7.9 California's Property Assessed Clean Energy initiative

More often than not, the costs of investing in solar photovoltaic systems, energy-efficient windows, and insulating a home will not be recovered when the home is to be sold. These up-front costs are considered to be one of the most significant barriers to solar and energy-efficiency retrofits.

In the United States, property owners can finance energy-efficiency and renewable-energy measures in homes and commercial buildings without the need for government subsidies. This is because the Property Assessed Clean Energy (PACE) initiative enables them to “mortgage” these improvements, and thus to pay only for the benefits they derive during the period they own the property in question.



The PACE financing program provides incentives to property owners to install solar panels and other energy efficiency retrofits.

Source: AFP.

Originally known as a “Special Energy Financing District” or “on-tax-bill solar and efficiency financing,” PACE was first proposed under the Monterey Bay Regional Energy Plan in 2005. However, the first PACE program was implemented in Berkeley, California to help achieve the San Francisco Bay Area’s climate-related goals. While California was the first state to pass legislation for PACE financing, the program has since covered more than 16 states. Such

legislation allows localities within the state concerned to establish PACE financing programs.

In jurisdictions where PACE legislation is applicable, local governments (through municipal financing districts or finance companies) offer a specific-purpose bonds to investors. The proceeds from the sale of such bonds are then lent to owners of both residential and commercial properties for the purpose of retrofitting these properties for energy efficiency. These loans are then repaid over the term specified (typically 15 or 20 years) through annual property-tax-bill assessments that are spread over approximately 20 years. However, the property owner benefits from the energy-cost savings from such improvements, which ultimately result in net financial gains.

Sources: Property Assessed Clean Energy Advocate. PACENow. Solar Financing for Residential Solar Panels.

Box 7.10 Asian Development Bank Support for Shanghai Pudong Development Bank Lending for Green Building

The Asian Development Bank (ADB) is providing partial credit guarantees to Shanghai Pudong Development Bank (SPD Bank) to support private sector financing of energy-efficient buildings across the People's Republic of China (PRC). SPD Bank is the first PRC partner in a program set up by ADB to encourage financial institutions to lend to companies seeking to retrofit old buildings so that they use less energy, or to construct "green" buildings that optimize energy and water efficiency. Retrofitting old buildings in this manner typically leads to energy savings of 20%–40%.



Photo: AFP

Shanghai Pudong Development (SPD) Bank provides a range of green credit solutions to the private sector.

Under its Energy Efficiency Multi-Project Financing Program, ADB is partnering with Johnson Controls, a private sector energy management company listed on the New York Stock Exchange. Johnson Controls identifies buildings with energy-savings potential, while ADB shares project credit risks with financial institutions.

The PRC government is keen to reduce the greenhouse gas emissions that have accompanied the country's rapid rise in energy consumption in recent years. Given the country's rapid rate of urbanization, improving the energy efficiency of buildings will significantly cut the emissions that contribute to climate change. However, companies have found it difficult to access finance for such purposes, given the little collateral they can offer to back loans. For their part, they themselves have little experience in financing energy-efficiency projects. Listed on the Shanghai Stock Exchange, SPD Bank was the first PRC domestic bank to offer a full range of green credit solutions to companies.

Source: ADB. 2011. Press release. Manila. 16 May.

Summary

Despite the obstacles they face in doing so, developing-country governments have committed themselves to moving toward long-term sustainability of the environment and natural resource base. That said, to date they have focused heavily on pollution abatement. This is in part because the economic costs of air and water pollution in many developing countries have constrained growth. For example, the annual cost of air and water pollution in Jakarta during the late 1990s has been estimated to exceed \$1 billion per year, the corresponding figure for Bangkok exceeding \$2 billion (ADB 2008a). More recent studies have estimated the annual economic costs of water pollution at \$1.5 billion for Indonesia, \$320 million for the Philippines, \$290 million for

Viet Nam, and \$150 million for Cambodia (World Bank 2008a). For the PRC, estimates of the annual cost of air pollution are in the range 3.5%–8% of gross domestic product (World Bank 2007a).

While the global environmental benefits of undertaking initiatives under the green agenda are widely acknowledged, the fact that they are dispersed among all of the world's countries means that they provide an insufficient incentive for undertaking such initiatives. However, the co-benefits of such initiatives (e.g., the health benefits of reducing fossil-fuel use and energy savings from using energy-efficient lighting or heating) justify undertaking mitigation initiatives at the national level. The same is true of the co-benefits that result from climate-change mitigation initiatives that allow the costs of saline intrusion, climate-related disasters, and food insecurity to be avoided.

Currently, schemes for promoting investment in environment-related initiatives in developing countries largely comprise legislation that specifies environmental standards. However, the fact that such standards are seldom enforced negates any value that their provision was intended to provide. An excellent example of this is the Philippines' Republic Act 9003 (the Ecological Solid Waste Law), which specifies waste collection and recycling standards that are even more stringent than those in effect in the OECD countries. Because of the mismatch between the stringency of such standards and the Philippines' corresponding enforcement capability, the efforts of activist lawyers who have been taking local governments to court for noncompliance provide the only exception to the country's citizenry completely ignoring them.

Even in cases in which enforcement of standards is constrained by availability of funding, positive incentives such as tax breaks can be effective, provided that the investor benefitting from the tax break concerned is in the formal sector and therefore actually pays the tax. In the informal sector where tax evasion is nearly ubiquitous, subsidies can provide effective positive incentives. However, such subsidies must avoid elite capture—or missing their target group entirely—if they are to be effective in bringing about the change in behavior desired. Effective use of subsidies in providing positive incentives for behavior change thus requires that all aspects of the market concerned be fully understood, so that appropriate types and levels of subsidy can be provided at the microeconomic level. For example, subsidies for encouraging installation of solar photovoltaic panels depend not only on the level of the direct subsidy itself but as well on the level of electricity tariffs in general and the relative level of any relevant feed-in tariffs.

This latter example suggests that fostering sound financing by public utility companies, as well as subnational-level government agencies that provide public services, is an important role of the national government. In this regard, distorted consumer behavior and significant waste of precious resources are the costs of pricing regimes that collectively fail to recover the

full cost of provision of such services. For example, not charging for energy used in providing district heating removes any incentive utility companies may have for installing thermostats in residences. In such cases, the preferred method of regulating indoor temperatures in subzero weather is to simply open windows. Experiments in market-based incentives are under way in some of ADB's developing member countries. The PRC's energy trading scheme provides an excellent example of such experiments.

Box 7.11 Establishing National Carbon Markets: The Cap-and-Trade Scheme in the People's Republic of China

The People's Republic of China is planning a trial energy cap-and-trade scheme that uses market forces to reduce fossil fuel consumption, as a means of lowering the country's carbon intensity to 40%–45% of 2005 levels by the year 2020. Pilot programs in 13 cities and provinces are planned that allow the trading of energy savings achieved through undertaking energy-efficiency initiatives. Under the scheme, the government will impose a hard limit on total energy use that would cap consumption from all sources at the equivalent of 4 billion tons of coal by 2015. The country's 5-year development plan for 2011–2015 also incorporates tax changes for encouraging greater energy efficiency.

Sources: National Development and Reform Commission, People's Republic of China; C. Buckley. 2011. [the People's Republic of] China to launch energy cap-and-trade trials in green push. *Reuters*.

Sources of Private Sector Financing Currently Available

The prospects for developing countries in attracting private sector funding for environment-related initiatives are examined in the following section, as are ways of ensuring that such resources are channeled into sustainable activities. To date, private sector investment in green initiatives has primarily occurred through three mechanisms: foreign direct investment, private equity/debt funds including socially responsible investing, and local retail finance.

Foreign Direct Investment

Foreign direct investment (FDI) is driven by short- and medium-term commercial interests, as well as the long-term plans of corporations (World Bank, UNEP, and IMF 2002). Because of their relatively low levels of capital utilization, investments in developing countries potentially offer higher rates of return overall as compared to investments in higher-income countries. Markets in numerous sectors in industrialized countries are increasingly

competitive. Thus, investment in such venues tends to deliver low and diminishing rates of return. Further, the OECD countries' aging populations suggest limited prospects for long-term growth, and thus a corresponding lack of prospects for investor rates of return driven by expanding demand for goods and services. Thus, in these latter markets, profits can only be maintained through cost cutting. This contrasts sharply with the relatively low wage rates and cost structures in developing countries that provide ample room for higher rates of return to investors, particularly in the face of rapidly increasing demand for goods and services driven by rapid growth in both population and per-capita income levels. Thus, developing countries are seen as key future markets in the long-term plans of most corporations, a fact that invariably piques the interest of investors.

The environmental impacts of FDI can be both positive and negative. The potential negative impacts of FDI include the following:

- Increased pollution levels and community dislocation, as FDI in some circles is thought to cause polluting activities to migrate from developed to developing countries where enforcement of social and environmental standards is relatively lax.
- Inefficient policy governing investment resulting from foreign investors manipulating policy making so as to gain an undue commercial advantage or special privilege that ultimately impacts the environment and natural resource base in a negative way.

The potential positive impacts of FDI include the following:

- Many multinational corporations adhere to more stringent standards regarding working conditions and environmental performance than do local corporations. Thus, many larger corporations now report on a triple-bottom-line basis that documents their environmental and social as well as their economic performance.
- Many companies that utilize FDI use capital equipment that embodies state-of-the-art technology, and thus more environmentally friendly and resource-efficient, improving environmental performance relative to other firms.
- The benefits from the above factors that accrue to the local population include higher living standards and, with this, education and awareness of the environment. Some companies even undertake environmentally positive corporate social responsibility activities in their host communities.

In assessing private sector investment opportunities in the developing world, political risk is often a primary consideration. In the case of urban infrastructure projects, for example, local authorities generally lack

international credit rating or performance record upon which the private sector can base a judgment of creditworthiness. Changing political leadership at the local-authority level and at the national level can create risks of breach of contract, currency inconvertibility, and expropriation. In the worst case, war or civil unrest can put the assets and the private sector's ability to operate at risk.

Innovative approaches combining FDI with official development assistance (ODA) could rebalance critical political risks in a manner that promotes private flows to a broader group of countries. There has recently occurred a significant shift in donor perception of the role of ODA, with many donor governments viewing the private sector as a potential partner in transferring both technology and skills. Donors have also developed a strong interest in new types of public-private partnerships (PPPs).

The development of new types of public-private partnerships creates a number of operational challenges for both aid agencies and private sector partners alike, which include

- balancing private sector interests with those of the community as well as aid agencies when awarding ODA;
- ensuring rigorous competitive assessment and full transparency in bidding processes, while avoiding bureaucratic delays; and
- dealing with programmatic conflicts of interest between individual companies and aid agencies.

The World Business Council for Sustainable Development has promoted this vision of an increased role for public-private partnerships in providing finance to developing countries, a vision that has likewise been endorsed by the Group of Twenty High-Level Panel on Infrastructure Provision. Some key actions are needed to make the vision a reality, such as

- supporting good governance through joint capacity-building programs to improve the understanding and skills of civil servants in relation to the enabling environment needed to attract sustainable investment and promote growth;
- improving institutional infrastructure by creating a better base for development of investment vehicles in developing countries, capacity-building in the identification and implementation of pilot projects for the Clean Development Mechanism and other post-Kyoto mechanisms; and
- supporting development of local finance for such initiatives, especially for small and medium-sized enterprises and households.

Private Investment and Equity/Debt Funds Including Socially Responsible Investment

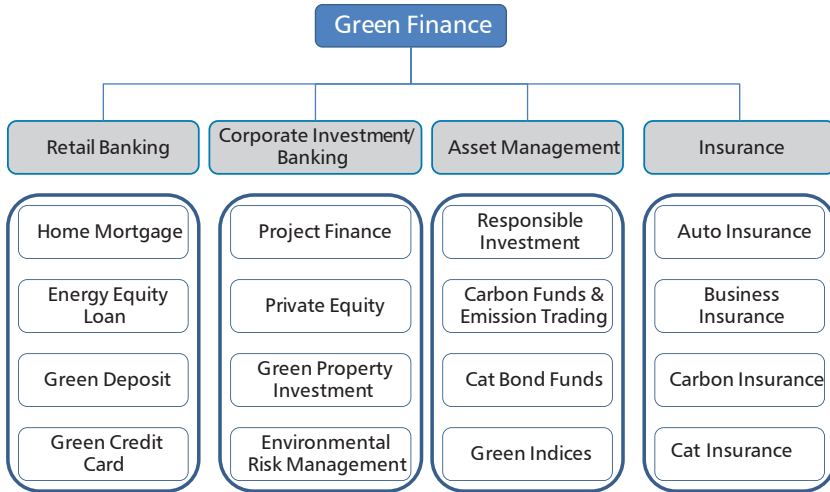
Financial institutions. Producers and consumers are increasingly willing to invest in, and to buy, “green” products. But often, because financiers see such investment as being unproven, they are reluctant to invest in the manufacture of such products. However, increasing numbers of private equity and debt funds are targeting green investments that range from wastewater treatment to solar energy. Central to upscaling such investment is a more supportive enabling framework within the global and national capital markets.

Green finance must influence all aspects of consumption and investment. To do that, green priorities must permeate the range of products offered by the financial system. This includes the banking system and the wholesale-funds markets that supply the longer-term financing needed for environmental investments. Tax deductibility of payments (applicable to either total payments or interest) in part or in full is the usual mechanism for governments promoting these priorities directly. The indirect method is to increase the price of “noncompliance” for consumers and industry, by increasing prices of non-green actions (e.g., through a carbon tax). Financing of green investments then becomes more attractive. The major areas of attention in this regard, together with examples of specific financial products, are depicted in Figure 7.4.

Figure 7.4 demonstrates that many areas of interest to financial markets influence the “greenness” of the economy. The four key areas in this regard are retail banking, corporate banking, asset management, and insurance. In retail banking, perhaps the most important area is mortgage finance. The purchase of a home is usually the most important investment a household makes. What is covered under the mortgage? Can additional “green” investment be undertaken at purchase? For example, will the mortgage cover installation of solar photovoltaic panels? This is important to environmental outcomes at a small scale, but systemic incremental change is likewise required. The legal form of a mortgage is likewise important. For example, does a particular mortgage allow repayment for green investments to be carried over to subsequent homeowners (as under the PACE scheme)? Allowing consumers to direct their savings or contributions to green purposes through Green Deposits and Green Credit Cards may become more effective in the longer run than at present, if such financial products become more popular. The Annex lists examples of green retail financial products.

Project finance through loans and private equity investment are the two core businesses of the corporate banking field. They are risk/return driven—

Figure 7.4 Major Areas of Interest of Green Finance



Source: Adapted from ICF Consulting Canada, Inc. 2007. *Green Financial products and Services: Current Trends and Future opportunities in North America*, Toronto.

even more so after the 2008 financial crisis and the subsequent regulatory changes of Basel 3 and other initiatives. While some private equity funds specifically target green investment (Annex), all require minimum risk/return ratios. The newness of many green investments to investors and the lack of performance record for such initiatives often mean that project finance and private equity managers feel that risks are greater for such projects, and that therefore the cost of capital should take account of these risks. Risk management and mitigation through insurance or other mechanisms thus become important, as discussed in the case of the Pudong Development Bank. Funding for green property is now facilitated by the rating of buildings under the Leadership in Energy and Environmental Design⁶ and other schemes. However, such investments can be highly profitable, particularly in light of the premiums charged for “green credentials” and the significant energy savings they yield relative to abatement costs. Similarly, cities can encourage such trends through their zoning and taxation powers.

Asset management involves deployment of institutional funds—usually pension funds and insurance funds—into debt and/or equity investment. The rise of “responsible investment” (Annex), which increasingly incorporates investment in “green” initiatives, has made a significant difference in the

⁶ <http://www.usgbc.org/DisplayPage.aspx?CategoryID=19>

funding of environment-based initiatives. However, deployment of capital into carbon trading will remain at a small scale until agreement can be reached on consistent regulation of carbon markets that are at present highly fragmented. Cat (catastrophe) Bond Funds provide funding for various forms of insurance. Cities could, in theory, benefit from such insurance, but to date it has proved difficult to structure packages appropriate to the diverse and complex institutional arrangements required for governing metropolitan areas, especially in Asia. Other forms of insurance products (Annex) can be “greened” by providing some incentive for consumer or business purchase of more energy- or materials-efficient products. Such incentives, usually involving a lower cost of cover, may result from analysis indicating lower net claims for such products or from tax deductibility of premiums.

Capital market systems. Green investments are often financially viable in the medium or long term. This is particularly true of energy-efficiency and mitigation actions. However, this viability depends on the tariff regime concerned, and the carbon benefits or subsidy they attract. These investments generally entail significant up-front costs, both in terms of capital and in terms of formulation and structuring of the investment. Because the expertise required for both formulating and structuring such investments typically exceeds that possessed by most developing-country enterprises, in such cases, the finance sector may be called upon not only to finance the investment but to structure it as well. In such circumstances, recovering the cost of undertaking these activities may occur through sharing the financial benefits of the initiative with the company concerned. Typically, developing-country capital markets have little experience with such investments. Asia’s capital markets are highly liquid, but mainly in the short term. The following points are important in this regard:

- Asia has high levels of saving. Thus, while banks and other financial institutions have access to money, short-term investments tend to predominate.
- Investment sectors may have no clear regulatory structure, a fact that causes transactions costs to be high compared with developed countries.
- Few mechanisms exist to encourage institutions holding long-term funds (e.g., pension funds and life insurance companies) to invest in infrastructure.
- There are few mechanisms for public sector debt finance and public/private special purpose vehicles.
- Inter-jurisdictional coordination issues make project formulation and structuring difficult.

Green bonds are the first level of intervention in addressing these issues. Issued by the World Bank and other institutions, these are often bonds these institutions would have issued anyway, but are bonds that are tied to green investments. Capital markets need more support in funding the required direct investments, such as ADB's funding of the Pudong Development Bank in support of energy-efficiency investments. A more ambitious activity in this regard involves the use of specialized project development and co-investment funds for leveraging private sector funds, as in ADB's Climate Public-Private Partnership Fund that was initiated jointly with the United Kingdom's Department for International Development.

```
graph TD
    Donors[Donors] --> ADB_FM[ADB, 3rd Party FM]
    Donors --> ADB_DfID[ADB, DfID, Other LPs]
    ADB_FM --> Risk_Mitigation[Risk Mitigation]
    Risk_Mitigation --> GP1[GP1]
    ADB_DfID --> Fund_Investments[Fund Investments]
    ADB_DfID --> Co_Investments[Co-Investments]
    GP1 --> Fund_Investments
    Fund_Investments --> PE_Fund[Private Equity Fund]
    Co_Investments --> PE_Fund
    PE_Fund --> P1((P1))
    PE_Fund --> P2((P2))
    PE_Fund --> P3((P3))
    Project_Development_Facility[Project Development Facility] -.-> GP1
    Project_Development_Facility -.-> P1
    Project_Development_Facility -.-> P2
    Project_Development_Facility -.-> P3
```

ADB = Asian Development Bank, DFID = Department for International Development of the United Kingdom, FM = fund manager, GP = general partner, LP = limited partner, P = project.

Source: World Economic Forum. 2011.

The diagram illustrates the structure of a Private Equity Fund. It shows the flow from Donors and ADB/3rd Party FM through GP1 to Fund Investments and Co-Investments, leading to the Private Equity Fund and its investments (P1, P2, P3).

```

graph TD
    Donors[Donors]
    ADB3P[ADB, 3rd Party FM]
    ADBDfID[ADB, DfID, Other LPs]
    RiskMit[Risk Mitigation]
    GP1_1[GP1]
    FundInv[Fund Investments]
    CoInv[Co-Investments]
    GP1_2[GP1]
    PEFund[Private Equity Fund]
    P1((P1))
    P2((P2))
    P3((P3))

    Donors -.-> PEFund
    ADB3P --> RiskMit
    ADB3P --> GP1_1
    RiskMit --> GP1_1
    ADBDfID --> FundInv
    ADBDfID --> CoInv
    GP1_1 --> FundInv
    GP1_1 --> CoInv
    FundInv --> PEFund
    CoInv --> PEFund
    GP1_2 -.-> PEFund
    PEFund --> P1
    PEFund --> P2
    PEFund --> P3
  
```

ADB = Asian Development Bank, DFID = Department for International Development of the United Kingdom, FM = fund manager, GP = general partner, LP = limited partner, P = project.
Source: World Economic Forum. 2011.

Responsible investment. Socially responsible investment (SRI) is based on the concept that investments—in this case, environment-related investments—can create positive and effective social change.⁷ In principle, such investment is sustainable, as it pays participants to continue (and perhaps extend or improve on) the change initiated by the investment. It combines attention to the rate of return with concern for social values. SRI is a potential mechanism for channeling additional funds to the developing world. SRI has grown rapidly in both Europe and North America, and the Japanese market is now emerging. The ethical investment market in the United Kingdom grew from \$6 billion at the end of 2001 to an estimated \$17.8 billion in 2011 (EIRIS 2011). At present, the United States is the world's largest SRI market, estimated at \$3.07 trillion under management (Social Investment Forum 2010). Despite its recent impressive growth, SRI faces numerous quantitative and qualitative challenges. Integrating social, environmental, and ethical criteria into the financial assessment of business is challenging.

Initially, SRI approaches focused largely on negative lists—the screening out of businesses involved in, for example, tobacco, alcohol, weapons, or animal-testing activities. Recent years have seen a definite movement to a greater appreciation of businesses that build value by integrating a sustainable development approach into their core business model and offering services or products specifically designed to meet the environmental and social, as well as economic, needs of clients. Furthermore, since 2008, markets have become somewhat more realistic regarding the returns expected—more in line with the potential earnings from viable environmental infrastructure projects.

A variety of market indexes have been developed to allow individual and institutional investors to track the developing SRI investment sector, and the whole SRI field is set to grow further. At present, SRI involvement in developing countries is embryonic at best. SRI approaches typically focus on publicly traded companies listed on stock markets. In the developing world, few companies are listed, thus limiting the applicability of SRI. Efforts to take the SRI approach into the developing world in a more systematic way are emerging.

SRI approaches could alleviate some of the concerns of foreign investors investing in developing countries. Companies that meet SRI criteria and have the knowledge and internal systems to enable them to effectively manage risk (whether social, financial, or environmental) will be in a stronger position to avoid potential pitfalls, to manage stakeholder relations and expectations effectively, and therefore to capture new markets and manage growth more efficiently. Social risks in particular are often intangible and harder to put a

⁷ Adapted from World Bank, UNEP, and IMF (2002).

financial valuation on; yet, they can have significant impact on the value and branding of a company, and thus on the viability of an investment, should they be mismanaged. Skills in assessing such risk are built up over time, and asset managers need to develop these skills if they are to manage risk systematically rather than subjectively, and to place indicative financial values on these risks in a way that makes sense to the market. Risk management including environmental risk is itself thus a critical component of SRI.

The Association for Sustainable and Responsible Investment in Asia (ASrIA) was formed in 2000 as a not-for-profit association dedicated to promoting SRI in Asian capital markets. ASrIA aims to increase momentum for sustainable investing by raising awareness and providing information; facilitating the provision of high-quality SRI products and services; driving the development of policies within both the financial and public sectors; and developing an outreach program to educate the Asian investment industry in SRI techniques and practices in South Africa. In 2001–2002, the African Institute of Corporate Citizenship explored the prospects for SRI in South Africa, and in June 2002, the Johannesburg Stock Exchange introduced an SRI index.

Retail Finance for Green Investments by Local Small and Medium-Sized Enterprises and Households

While multinationals and large corporations may have difficulty in accessing green finance for a variety of reasons, their ability to negotiate with financial institutions and the transaction costs in doing so are generally within their capacity. The same cannot be said for SMEs and private households in developing member countries (World Bank, UNEP, and IMF 2002). These enterprises and the households that own and work in them often comprise the majority of the economy and the bulk of total energy use. Thus, actions to help them finance environmental investments are of high priority. However, their special characteristics need to be taken into account when planning action. In this regard, the following points are of particular importance:

- SMEs often operate on thin profit margins that leave little room for even the bare minimum of investment. Undertaking investments that, for them, have high transactions costs, long payback periods (if at all), and require scarce managerial talent and time (all of which are characteristics of environment-related and energy-efficiency projects) is unfeasible. Yet, these are the companies that have, in aggregate, the greatest impact on the environment. Ways of reducing transaction costs, shortening payback periods or at least periods where net cash flow is marginal or negative, and building awareness and capacity are needed.

- The same is true of households, particularly low-income households. Their decisions regarding shelter, cooking, heating, cooling, and transport are driven by least-cost options. Any other strategy further constrains investment in a business, education, or health, all of which are essential for moving a family out of poverty. The same imperatives thus apply: reducing risk-adjusted cost and transactions costs, and simplicity.

Thus, in addition to technology which is affordable, financing solutions are needed that are

- 1) either low-cost or incremental (meaning small loans, perhaps even at higher interest rates) and appropriate to the volatile cash flows of many informal entrepreneurs and households; and
- 2) easily accessible both in physical terms (i.e., they are near the place of work or home or on mobile devices) and in terms of the bureaucratic requirements for access.

The e-trike project provides an example of how such constraints can be overcome (Box 7.12).

Successful alternative finance approaches (traditionally microfinance) can empower individuals and micro-, small, and medium-sized businesses to foster sustainable livelihoods in lower-income communities. Widespread deployment of capital through these approaches in developing countries could contribute significantly to a virtuous circle of investment, benefit, and reinvestment at the community level. Such finance has the ability to deliver the requisite capital, although care is needed to ensure that it is spent in ways that contribute to sustainable development.

Despite some recent setbacks, there is a growing body of evidence drawn from the microfinance experience of many countries that if programs are structured appropriately, borrowers that were previously thought uncreditworthy are not only able to pay for their microcredit but derive significant nonfinancial benefits as well. Once a dynamic cycle of sustainable livelihoods is created within a community, the collective ability to pay for clean water and secure electricity, among other basic necessities, is enhanced. Obvious benefits stemming from such a cycle include, among others, significant time savings and health from the provision of clean water, enabling greater economic opportunities and productivity, and educational benefits from the ability to study during evenings.

As the microfinance approach has spread into Africa, Latin America, and economies in transition, it has undergone a metamorphosis, resulting

Box 7.12 The e-Trike Project

The records of the Environmental Management Bureau of the Philippines' Department of Environment and Natural Resources (DENR) show that there are over 5 million motorcycle-taxi tricycles in the Philippines, of which 2.8 million are in Metro Manila. They create about 20 million cubic meters of pollution annually.

The Government of the Philippines and ADB have established a National Electric Vehicle Strategy to promote the use of alternative-fuel vehicles geared toward reduction of (i) fuel consumption by at least 2.8%; (ii) the carbon footprint of the transport sector in Metro Manila and other selected cities; and (iii) air and noise pollution from the tricycles that ply the streets of these selected areas.



The e-Trike exhibit during the 2011 ADB Asian Urban Forum. Project financing was made via an ADB loan while its distribution to tricycle drivers will be through lease-to-own arrangement by the local governments.

Source: ADB Urban Community of Practice. 2011.

Spearheaded by the Department of Energy (DOE) with an approved cost of P21.50 billion that will be partially funded by ADB and other official development assistance sources, the introduction of energy-efficient Electric Tricycle (E-Trike) Project aims to bolster the government's clean-air program. The project is intended to provide affordable financing for the acquisition of e-trikes that are powered by lithium ion batteries. This was the chosen power source over lead acid batteries, as lithium ion is 100% recyclable. Although the actual investment is profitable for small operators, finance is not readily available to them.

With a loan of \$400 million in the ADB pipeline, the project aims to provide 100,000 electricity-run tricycles to replace aging and two-stroke gasoline-fed units within 5 years, with an initial rollout of 20,000 units in the first 2–3 years. The e-trikes will be acquired by target local government units with financing from the Land Bank of the Philippines over the project's 5-year implementation period, and distributed to tricycle operators/ drivers through a lease-to-own arrangement by the local government. Initially pilot-tested in Puerto Princesa City in Palawan, the project has expanded to target the local governments of Metro Manila, Boracay in Aklan, Cabanatuan City in Nueva Ecija, and Davao City.

Sources: National Economic and Development Authority. 2012. ICC-Cabcom approved four ODA projects on road improvement, transportation. 21 February; Electric Tricycles. <http://www.electricticycle.net>; R. B. Bundang. 2012. Solon seeks inquiry into tax exemption and government subsidies provided in electric tricycle project of DOE-ADB. 2 April.

in a broader range of approaches tailored to regional circumstances. Although an increasing number of successful microfinance approaches are emerging worldwide, there is a clear need to scale up the overall impact of microfinance, building on the models that are commercially viable. To do so, a number of reforms are needed in the areas and for the following reasons:

- Capital requirements imposed by regulators are generally in excess of prudential requirements implied by credit histories, thus restricting upscaling potential.
- Management and systems need to be upgraded in many cases, which will result in lower costs.
- Many institutions need to increase their scale of operations and/or link to larger, more established institutions to spread high transaction costs more widely.

A variety of financing approaches could be applied to help local finance institutions achieve these objectives. For example, multilateral development banks can extend lines of credit or partial credit guarantees to local financial institutions. In addition, they, and other ODA providers, can provide additional equity capital—potentially also attracting private funds—or some form of transaction-cost recovery system such that the local finance institution still takes credit risk, but the incremental cost of making small loans is absorbed through some other budget, whether international or domestic. Initiatives for removing or lowering cost hurdles could include capacity-building programs that enable local finance institutions to “bundle” or securitize their loan books and take them to mainstream capital markets.

Multilateral and Bilateral Financing of Green Investments

Multilateral and bilateral financing that can be used for green investments, particularly climate change-related interventions, encompasses a broad spectrum of instruments.⁸ An overview is provided in Annex. It can include transfers of public funds in the form of loans or grants, either directly from one government to another (bilateral aid), or indirectly through nongovernment organizations or a multilateral agency (multilateral aid). At present, there are three primary, dedicated multilateral sources of international finance for city climate change interventions:

⁸ Adapted from Beltran (Unpublished).

- **Climate Investment Funds (CIFs).** Implemented through multilateral development banks, these funds bridge the financing and learning gap between the present and the upcoming international climate change agreement that will follow the Kyoto Protocol. CIFs comprise two distinct funds: the Clean Technology Fund and the Strategic Climate Fund, which are a set of trust funds with a capitalization of more than \$6 billion (Climate Investment Funds website). The Clean Technology Fund offers financing for improving fuel-economy standards, accelerating fuel-switching, and promoting modal shifts in public transport in large metropolitan areas. The Strategic Climate Fund is an overarching fund that supports targeted programs, with dedicated funding for the piloting of new approaches with the potential for scaled-up, transformational action that addresses specific climate change challenges or sectoral responses.
- **Global Environment Facility (GEF).** This is a partnership of 178 countries and international institutions that addresses climate change and technology-transfer issues. Since 1991, it has allocated \$2.5 billion and leveraged \$17 billion in cofinancing (World Bank 2010b).
- **Clean Development Mechanism (CDM)-based funds.** ADB (Future Carbon Fund) and the World Bank (Carbon Finance Unit Initiatives) have funds that pay part of the proceeds (usually 50%) from the CDM and post-Kyoto Protocol transfers up-front, rather than upon achievement of performance-based standards (World Bank 2010d).

The three instruments remain the largest and most commonly utilized sources of climate change financing for developing countries. However, other initiatives, some of which utilize new avenues and channels for funding, have recently emerged. The following are some of these initiatives:

Multilateral, bilateral, and export credit agencies. These agencies provide low-cost, long-term loans, cofinancing, and risk mitigation in funding infrastructure projects. Most development finance institutions have special funds and programs catering exclusively to climate change mitigation and adaptation. They also provide grants and technical assistance in project development and capacity development, as well as in sharing global best practices.

Bilateral cooperation. Bilateral cooperation and the sharing of technical capabilities are exemplified in the Sino–Singapore Tianjin Eco-City Project (SSTEC), in which private consortia⁹ of the People's Republic of China (PRC) and Singaporean companies provided technical assistance and commercial financing for the development of an eco-industrial park 40 kilometers from Tianjin City. SSTEC is intended to be a model eco-city that is energy- and resource-efficient with low greenhouse gas (GHG) emissions, while

⁹ Sino–Singapore Tianjin Eco-City, SSTEC Investment and Development Co. Ltd, and Keppel Corporation.

maintaining economic viability and social harmony. It is built on non-arable salt land. It thus converts land that is unsuitable for agricultural purposes into urban land with significant economic value. Singapore, through its private investors, has introduced global experience and knowledge into the design of this eco-city. The design of the SSTECH thus incorporates a mixed-land-use plan that reduces commuting requirements from outside SSTECH, and adopts energy-efficient building standards—more stringent than corresponding national standards—and as well promotes renewable energy use. The SSTECH is a pilot city that serves as a sustainable development model to be replicated in other PRC cities.

Official development assistance (ODA). Funds currently available for climate change interventions through ODA that are not limited to cities are estimated at \$9 billion per year (World Bank 2010a). This is a small percentage of total ODA. Developed countries have pledged fast-track resources of \$30 billion from 2010 to 2012, with a further target approaching \$100 billion per year by 2020. The Cancun Agreements mandate that fast-start funds have a “balanced allocation between adaptation and mitigation;” are “new and additional;” are “prioritized for the most vulnerable developing countries, such as the least developed countries, small-island developing States, and Africa;” and include “forestry and investments through international institutions.”

Several countries, including Japan and the United States, are channeling a considerable amount of their funds through export credit agencies and other public–private channels. The CIFs and the GEF are, at present, the primary multilateral institutions through which other funds are channeled. ADB will scale up its own financing for promoting low-carbon and climate-resilient growth, and will assist its developing member countries in accessing additional public concessional funds, thus ensuring that they make the most of private finance.

The major multilateral and bilateral climate funds sources are¹⁰

- Global Environment Facility
- Clean Technology Funds
- Carbon Partnership Facility
- Climate Change Program
- Climate Change Fund
- Carbon Market Initiative
- Clean Energy Financing Partnership Facility
- Global Climate Change Fund
- Indonesia Climate Change Trust Fund
- Special Climate Change Fund
- Nordic Environment Finance Corporation Carbon Fund
- Netherlands Fast-Start Facility
- Development and Climate Finance
- Hatoyama Initiative
- International Climate Initiative
- Renewable Energy and Energy Efficiency Partnership
- Australia–Indonesia Facility for Disaster Reduction

¹⁰ This list also includes several funds specifically targeted to Indonesia. For example, the PAKLIM program focuses on supporting climate change initiatives in Indonesia.

Cities can and should, be aware of the technical assistance facilities under these mechanisms that can be used in the preparation of investment projects to be financed under these same facilities. Operational understanding of the latter point can be quite a complex matter. However, project development facilities such as CDIA can act as intermediaries for the city concerned in accessing such funds.

Financing for Carbon Markets

The term **carbon finance** refers to investments in GHG emission-reduction initiatives and the creation of financial instruments that are tradable in carbon markets. For example, if carbon-emission reductions can be verified to have occurred as the result of an activity, then emission reduction credits relating to those reductions can be sold on the carbon market.

There are two types of carbon markets:

- **Compliance carbon market.** This market was created and is regulated by mandatory carbon reduction initiatives such as the Kyoto Protocol, of which the CDM is of relevance to developing countries.
- **Voluntary carbon market.** This market operates on the same principle as the compliance carbon market. However, it enables organizations, individuals, and governments to purchase carbon offsets voluntarily.

As of June 2011, 6,416 CDM projects have been registered with a total annual reduction of 850 million tons of carbon. Wind and hydropower projects accounted for 49% of all CDM projects. These were followed biomass energy (12%), methane avoidance (10%), energy-efficiency own-generation (7%), and landfill gas initiatives (5%) (IGES 2011). Due to their intensive capital requirements and relatively low-carbon revenues, transport initiatives accounted for a mere 0.6% of all CDM projects.

Unfortunately, city authorities have not been able to fully access markets for carbon credits. Less than 1% of projects registered with the CDM are credited to cities. There are several reasons:

- Climate-change interventions have historically been considered to be more of a priority for, and the responsibility of, national rather than local governments.
- Cities are generally more concerned with immediate development priorities, such as expanding access to urban services and slum upgrading.
- Administrative and transaction costs associated with the setting up of CDM projects in cities have been high as compared with their returns.

Of the various initiatives, projects that focus on methane avoidance and recovery, biomass energy, and energy efficiency have the highest chance of success in obtaining funding. These types of projects have technologies and CDM methodologies that are globally available, and that embody flexibility for establishing public–private partnerships. Most importantly, they fall within the administrative jurisdiction of cities.

Methane, biomass, and landfill projects can provide considerable carbon revenues to pay off investment costs. While wastewater and transport projects only contribute a miniscule amount of carbon revenues, they cover the operational costs of these capital-intensive sectors.

Emerging International Financing Mechanisms for Climate-Related Initiatives

In addition to multilateral and bilateral funds as well as carbon-market financing, there are a number of new and evolving international mechanisms for financing climate-related initiatives that are relevant to cities. These include

- Nationally appropriate mitigation actions (NAMAs)
- Green bonds,
- Responsible funds, and
- Post-Kyoto Clean Development Mechanisms.

Nationally appropriate mitigation actions (NAMAs) comprise a set of policies and actions by countries aimed at reducing or limiting GHG emissions as proposed to the United Nations Framework Convention on Climate Change (UNFCCC). NAMAs are expected to be the main vehicle for mitigation action in developing countries under a future climate agreement (Bockel, Gentien, and Tinlot 2011; Carpenter 2008).

During the 2007 UNFCCC, the Bali Action Plan recognized the need for developing countries to fully participate in efforts to reach global emission reduction goals through NAMAs. This concept was retained under the Copenhagen Accord during the Copenhagen Climate Conference in 2009, adding that NAMAs would be subject to international measurement, reporting, and verification. The 2010 Climate Conference in Cancun reinforced the role of NAMAs and recognized that developing countries are already contributing and will continue to contribute to global mitigation through agreements aimed at emission reductions, greater transparency, forest preservation, and the creation of a green fund for helping to mobilize much-needed investments throughout the world.

Green bonds. In November 2008, the World Bank offered its first green bonds to support climate change mitigation and adaptation projects in developing countries. Green bonds are a standard fixed-income product that offers investors the opportunity to participate in the financing of “green” projects that help mitigate climate change and help countries adapt to its impacts. These bonds have similar features as regular bonds’ by the issuing entity, including credit risk and size (Reichelt 2010).

Responsible funds. Ethical funds pool the money of hundreds of investors into a single fund, which in turn is invested in the stock market. A range of social, environmental, or other ethical factors influence the choice of investments.

Post-Kyoto Clean Development Mechanisms. The five major Post-Kyoto 2012 programs that will utilize the CDM protocols to fund green infrastructure include the Climate Investment Fund (World Bank), the Future Carbon Fund (Asian Development Bank), the European Union Emissions Trading System Climate and Energy Package, the Japan alternative CDM mechanism, and the Republic of Korea Emission Trading Scheme (Department of Energy and Climate Change website, Climate Investment Funds website, Future Carbon Fund website, Reuters Africa, 2010).

Experience of Current Global Funds

Current global systems, with the exception of the CDM under the Kyoto Protocol, are generally ad hoc and have no systemic impact. Many focus on emotionally pleasing, aesthetically appealing, and conscience-salving investments. However, from the systemic and technical impact perspective, these initiatives are nearly useless. The objective of international financial structures that finance green growth must be to foster a low-carbon economy, rather than to make an unsustainable economy pretty.

The CDM did have limited systemic impact. Operating on an objective basis (i.e., the amount of carbon saved from a particular investment), the CDM was market-based, although it applied to a limited and regulation-dependent market. The carbon price as set in Japanese and European markets has been sufficient to make a significant difference in the financial outcomes of certain types of projects. Methane-generating activities, and projects designed to reduce methane generated, are often lucrative under the CDM, and some useful investments in waste disposal resulted from this. CFC reduction investments were also highly attractive.

However, the impact of the CDM on economic structures was limited. This outcome mainly resulted from the following two factors:

- To justify the “additionality” of its investments, the CDM was highly regulated and required expensive consultants to set up the project, and to conduct the baseline studies and monitor the actual outcomes. Such transaction costs could not be borne by small projects and often, in developing countries, the technical and financial capacity to contract, deploy, and manage such consultants was not present in potential sponsor institutions, regardless of whether these were public or private. Arguably, concessions to reduce transaction costs were made. Further, some sources do exist within institutions such as ADB to finance the CDM for particular types of projects and particular countries. However, the impact of these measures is limited.
- The investments for which the CDM was available had to be clearly defined and were thus focused on particular technological improvements to processes, not on systemic shifts in policy. Although the “Programmatic CDM” was instituted toward the end of the protocol period, such projects were essentially the large-scale rollout of a particular technology (e.g., compact fluorescent lighting). This gave no room for policy-based mitigation impacts such as encouraging energy-efficient transit-oriented development where a high-efficiency public transport spine connects mixed use, high-density neighborhoods of energy-efficient buildings. Individual investments under such a policy regime (e.g., busways) derive only marginal benefit from the CDM as, individually, they do not have significant “additionality.” But their synergistic impact with complementary investments is potentially significant (CAI-Asia 2011). Similarly, while the CDM encouraged individual energy-efficient investments in industry such as new boilers, the overall materials and energy flows of an industry were essentially left undisturbed. The policy initiatives required to generate a reduce–reuse–recycle approach from industry, fostering industrial symbiosis, could not be funded. And yet, such initiatives would have a fundamental impact on the structure of an economy.

Other voluntary initiatives have had limited investment impact on urban areas, and no systemic impact.

How to Improve Performance in Green Finance

Barriers to Accessing International Climate Change–Related Finance Faced by Cities

The major barriers to accessing international climate change-related finance faced by cities include

- challenges in project development,
- political and regulatory barriers, and
- financial barriers.

Barriers at the Project Development Stage

- **Lack of knowledge regarding climate change intervention programming and prioritization.** City governments and their agencies lack the capacity to develop project proposals as required by international funding sources and by national ministries or agencies, which could then access climate funds from international climate change-related sources.
- **Poor project assessment and structuring.** International climate-funding sources often require counterpart funding from the city concerned. However, city government officials and their implementing agencies do not have the skills to assess project financing from domestic and, much more importantly, international financing sources.
- **Lack of equity and collateral in securing loans.** Cities have limited scope to raise public funds through tax increases and other revenue measures.
- **Cities have not realized the benefits of leveraging funding for public infrastructure from the private sector.** City budgets are increasingly being overwhelmed by recurrent expenditures (e.g., 75%–85% of the total budget of Indonesian cities).¹¹ Funding climate intervention projects, most of which comprise complex and capital-intensive infrastructure, will require collaboration with the private sector, which has the requisite project development expertise and financial resources.
- **Lack of commitment to sustainable development.** The priorities of cities might be biased toward poverty reduction and education rather than climate change. Short-term budgeting cycles of local governments also may conflict with the long-term project development periods of green infrastructure projects. Development finance institutions (multilateral and

¹¹ 2007 Specific Allocation Fund (DAK) allocations.

bilateral) now focus on and give emphasis to sustainable development goals and environment-friendly and low-carbon infrastructure projects in their selection of investments to fund.

Political and Regulatory Barriers

- **Weak institutional framework.** The overlapping roles of national and city governments and agencies result in tedious and difficult approval processes. Often, there is no clear demarcation of roles and responsibilities among the various government bodies. This leads to inadequate communication and consultation among these agencies, as well as to delays in implementation.
- **Risk of change of law, policy, and regulations.** Compared with the long-term development periods required by climate interventions, political decision makers usually have short-term mandates.
- **Perception of corruption and lack of fair procurement procedures.** Investors and funders are wary of city officials and agencies that have the reputation of hindering competitive bidding and of favoring business associates and cronies in the implementation of projects.

Financial Barriers

- **Financially weak projects.** Because of their inherent public service nature, some projects such as flood control initiatives do not provide financial returns acceptable to investors and commercial loan sources. Capital-intensive projects with limitations as to end-user charges will also be considered as financially weak projects. An example is bus rapid transit systems that require massive capital, but that restrict end-user charges. However, these mass transport systems reduce congestion and air pollution, and improve the urban quality of life.
- **Poor creditworthiness of cities.** A fundamental determinant of whether a project will be financed is the credit risk of the payment counterparty, that is, the city and its project partners. This has relevance to clean-energy infrastructure projects and energy-efficiency projects.

New technologies that reduce GHG emissions may have higher investment costs compared with conventional technologies. Development of new clean technologies under joint-venture structures will be one facet of a concerted effort to reduce carbon emissions and achieve long-term GHG stabilization levels. As new technologies are commercialized and new projects based on such technologies are commissioned, investors, lenders, and insurers will face challenges in creating project finance structures around projects that use these technologies that are acceptable to investors.

Actions that Support City-Level Access to International Climate-Related Finance

Interventions that address the barriers enumerated in the previous section are described in this section.

Strengthening Project Development

- **Building capacity and skills.** City governments need to conduct a detailed assessment of the skills required at each level. Nongovernment organizations, training institutes, and technical assistance funds need to be tapped for capacity development and technical assistance for project development. To attract international climate-related finance, city governments should clearly demonstrate the viability of projects from the perspective of the investor. This may be done by developing pre-feasibility studies with the assistance of well-reputed advisors.
- **Holding stakeholder consultations.** Consultations with financial institutions, project developers and contractors, end users, and related government agencies provide valuable insights into their perspectives regarding project restructuring.
- **Adopting sustainable development principles.** Leading multinational banks have adopted the Equator Principles which comprise a voluntary set of standards for determining, assessing, and managing social and environmental risk in project financing.¹² Equator Principles Financial Institutions commit to not providing loans to projects in which the borrower will not or is unable to comply with their respective social and environmental policies and procedures for implementing the equator principles.

Strengthening Regulatory and Institutional Settings

- **Standardizing procurement and strengthening bidding procedures.** City governments need to have a structured process using a standard set of criteria to evaluate procurement options for climate-change interventions, which may take varied forms. Major factors in the evaluation should consider the government's retention of its operational flexibility, reduction of risks, delivery within a given time frame, and provision of value for the city's investment.
- **Covering political risk with insurance.** For projects with a high uncertainty due to political risks, cities could tap multilateral and

¹² Equator Principles. <http://www.equator-principles.com/>

bilateral financial institutions for political risk insurance cover. One such institution is the Multilateral Investment Guarantee Agency.

- **Obtaining a favorable credit rating.** The potential to raise capital through bond issuances offers significant opportunities. In 2000–2007, bond issuances in Asia were a mere \$3.2 billion compared with \$333 billion in Europe during the same period (Platz 2009). For the issuance of municipal bonds, city governments need to obtain a favorable credit standing by curbing budget deficits, ascertaining cash inflows, and improving accounting practices. A city's municipal bond credit rating may be upgraded through credit enhancement mechanisms such as escrowing dedicated revenue streams, full guarantees of interest and principal, pledging of collateral, and pool financing.

Reducing Project Risks and Commercial Barriers

- **Pursuing private sector financing.** A significant funding gap exists between the infrastructure requirements of climate change projects required in Asian cities and the scarce resources available within the public sector. Compounding this gap is the inability of cities to raise funds from local taxes and domestic capital; chronic budget deficits; and their traditional reliance on fund transfers from the central government and its line agencies, the latter being disinclined to provide allocations for climate change projects. The public sector can collaborate with private sector partners and share its technical expertise, while leveraging the private sector's project implementation expertise and funding capabilities.
- **Pursuing national government support for financially weak projects.** Environmentally oriented projects may not be financially viable without government support. Through their leagues and associations, cities should submit proposals for viability gap funding, availability-based payments, shadow tolling, and tax exemptions and/or government guarantees on debt. The private sector may be completely dependent on this project support for its implementation of such projects. Ignoring this need may lead to the private sector's disinterest in city-level climate change interventions.
- **Utilizing the carbon market.** Additional revenues from carbon finance enhance the overall financial viability of low-carbon projects, and as performance-based payments, they create positive incentives for management and operational practices that sustain emission reductions over time (World Bank 2010c).
- **Leveraging existing assets.** Asset leverage, mainly in the form of land-based financing, has become an important source of urban infrastructure financing. As counterpart funding is often required by microfinance institutions, bilateral finance institutions, and private investors as an

assurance of the city's commitment to project implementation, land leases and land sales provide for significant up-front revenues for capital infusions. Over the past decade, Bogota, Colombia has cofinanced over 200 public works projects with international financial institutions through betterment levies from gains in land value (Peterson 2009).

- **Accessing special environmental programs and funds from national line agencies and ministries.** National governments have dedicated schemes for financing urban infrastructure that include climate change mitigation and adaptation projects. One example of this is the Jawaharlal Nehru National Urban Renewal Mission in India. As of December 2009, \$13 billion has been released to city-based projects that have implemented mandatory reforms such as environmental protection and the use of public-private partnership schemes.
- **City aggregations and regional proposals for environmental allocations.** Individually, a city submitting proposals for allocations for climate change measures to the national government or its agencies will be politically weak. Provincial and regional associations such as APEKSI (League of City Mayors in Indonesia) submitting project proposals for green infrastructure directly to line ministries will likely have more political clout than individual city proposals.

Examples of Effective Financing Structures

As discussed, the investment decisions of individual entrepreneurs and subsovereign agencies and governments collectively determine whether an economy moves on a low-carbon trajectory. These decisions, in turn, can be influenced by microeconomic measures that provide positive and negative incentives that determine the outcome of investment decisions.

The following are the basic principles of such interventions:

- When dealing with the informal sector, understand the risk profile, cash flow, and balance sheet of the informal entrepreneur concerned.
- When dealing with formal sector industry, understand the levers that can be applied to oligopolistic industries.
- When dealing with local governments and utilities, understand the cost structures they face, which are often mandated by political considerations, and the cost-recovery regime in place, which is again influenced by political considerations.
- When trying to foster public-private linkages, be aware of the transaction costs of each party and the appropriate allocation of risk.

Designing effective incentives under such circumstances is difficult. And it is of no help to say that the system is broken and needs to be fixed. The issue is, and will remain, what provides the incentives to fix broken systems?

An excellent example of effective administrative measures is the Department of the Interior and Local Government of the Philippines which provides matching grants for local governments undertaking sanitary landfills. This program is simple to administer, has transparent benefits to all sides, and is successful (Box 7.13).

Box 7.13 Performance-Based Funding through Matching Grants in the Philippines

In an effort to improve the performance of local government agencies, a performance-based incentive policy (PBIP) was established by the Department of the Interior and Local Government (DILG) of the Philippines. The purpose of the PBIP was to rationalize intergovernmental fiscal transfers made by the national government to local government units (LGUs) for the purpose of improving governance and delivery of basic services. The PBIP links incentive payments to performance targets and has thus appropriated P500 million to the Performance-Based Challenge Fund (PCF) for the purpose of financing subsidies to qualified LGUs.

Under the PCF, specific performance criteria were established in key areas of governance, including planning, fiscal management, transparency and accountability, and performance management. LGUs that fulfill these criteria can receive counterpart funding for local development projects. The PCF provides one-to-one matching funds for investments undertaken by eligible LGUs in the following areas:

- Attainment of Millennium Development Goals in a broad range of areas (e.g., school buildings, rural health units and health centers, birthing facilities, water and sanitation systems, farm-to-market roads, housing, and settlements).
- Local economic development (e.g., local roads and bridges, tourism facilities, irrigation systems, postharvest facilities, cold-storage facilities, ports and wharves, and other economic infrastructure and growth-enhancing projects such as markets, slaughterhouses, and water supply systems).
- Adaptation to climate change and preparedness for disasters (e.g., flood control, reforestation, solid waste management facilities, storm drainage, dikes and related flood protection measures, slope protection, evacuation centers, rainwater collectors, early warning devices, and rescue equipment).

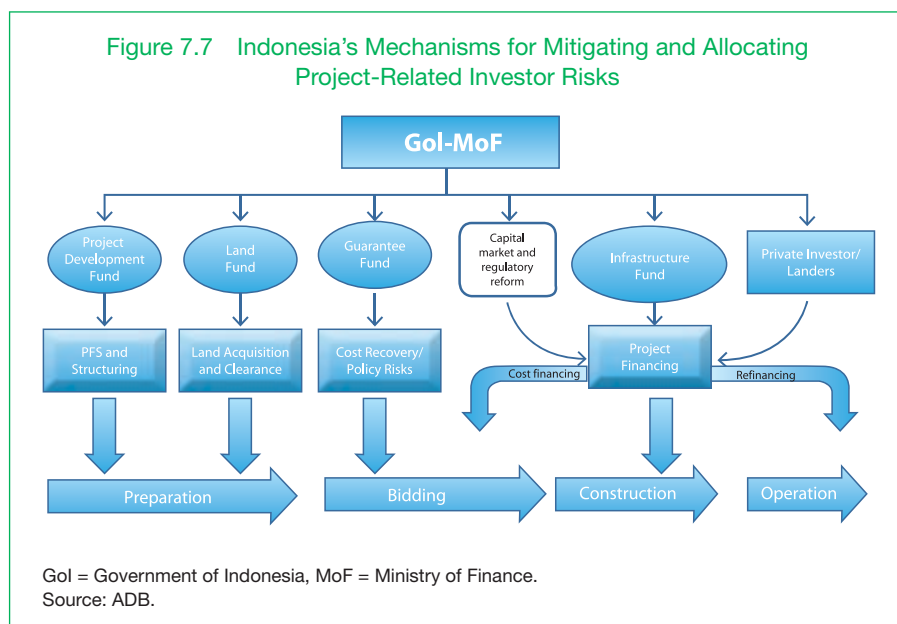
As of 2011, the PCF had funded 30 LGU projects in the following areas: educational facilities, health centers, potable water supply systems, farm-to-market roads, public markets, eco-tourism parks, public transport terminals, sea wall and flood-control systems, sanitary landfills, and solid waste management facilities.

Source: Department of the Interior and Local Government. <http://www.dilg.gov.ph>
DILG Memo Circular No. 2011-62 "Implementation Guidelines of the Performance Challenge Fund".

A good example of a system for addressing transaction costs and allocation of risk is that developed by the Government of Indonesia (Figure 7.7). This system addresses the following project-related risks:

- project development,
- land acquisition,
- credit risk (addressed through credit-enhancement and risk-mitigation structures sponsored both by commercial entities and government agencies, including participation by both international finance institutions and government for the purpose of providing a “halo effect”), and
- “greenfield investor” risk (mitigated through refinancing mechanisms that allow initial investors to exit such investments following a specified period) .

Figure 7.7 depicts the various mechanisms available to investors for addressing project-related risks associated with initiatives undertaken in Indonesia. While the structure is comprehensive, the details of such mechanisms in some cases mitigate against risk reduction, and some portions of enabling legislation and regulation necessary for operationalizing risk mitigation are not yet fully in place. This does not mean the system does not function. Instead, it means that additional resources are required, and that project preparation will likely require a longer period than would otherwise be the case. Ultimately, because of the advantages such programs offer, cities should be aware of the mechanisms available within their national contexts



that help them address project-related risks, and should seek assistance in formulating projects accordingly in cases in which they lack in-house capacity for appropriate project formulation and structuring.

Leveraging Private Sector Financing for Green Finance

New tools and approaches for attracting private sector financing. It is private sector financial institutions, such as those involved in banking, insurance, asset management, and venture capital, that have often been the source of financial innovation. If the sophisticated thinking that has seen the development of derivatives, hedge funds, exotic futures markets, and other risk-diluting products were applied with full force to the challenges of environmental sustainability, results on a scale currently unimaginable might be achieved.

The narrow spread of private flows to a limited number of developing countries leads to several questions. Is the current “tool kit” of the finance sector adequate in the way it views, quantifies, and prices risks and opportunities in developing countries? Are significant developing-country investment opportunities being missed because current methods of assessing risks and opportunities are too narrow? Are existing assessment methodologies so focused on areas in which high transaction volumes are required that any opportunities not fitting a mainstream profile are simply precluded at the outset? Are those financial institutions assessing opportunities in the developing world framing and pricing risk accurately, since only limited viable investment opportunities exist? If so, which public–private mechanisms might be developed to improve the risk–return profile of investment opportunities in developing countries? Fostering discussion that responds to these questions is important and should involve both the public and private sectors.

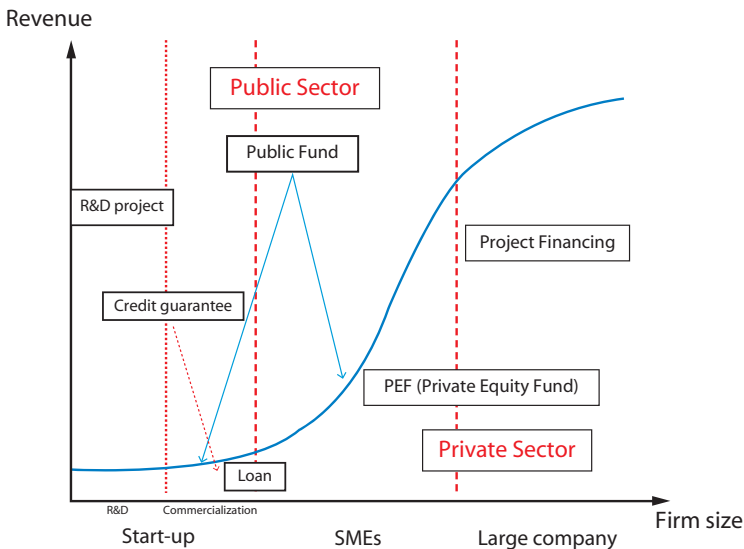
In summary, sustainability-focused projects in developing countries can appear unattractive for the following reasons: (i) they are subject to considerable political risk; (ii) they are perceived to offer low returns; and often, (iii) the policy environment remains unattractive for any form of private sector investment. Structures for addressing these issues are described in the section that immediately follows. These structures need to be differentiated according to the major types of involvement of the private sector in green investment:

- technology development,
- project sponsors and developers, and
- finance.

The private sector is often wary of “green” investments in developing countries due to their relatively low rates of return. In part, this results from the fact that it is difficult to get consumers to pay the full cost of provision of the services provided by such investments. For many environmental infrastructure projects, the health and amenity benefits to the community that the project delivers are not capitalized into the project’s financial rate of return (i.e., some project benefits are external—they do not accrue directly to the project’s beneficiaries, the latter thus understandably being unwilling to pay for such benefits). In such a context, there is scope for intervention by public sector agencies, either national or international, to support such investments by providing financial resources at a level that reflects the benefits provided by these investments that are external to beneficiary households. The discussion that follows addresses this issue in the context of each of the three aspects of “green” investments enumerated, and in particular defines the interventions that would likely be the most effective in this regard.

Technology development. Figure 7.8 depicts the phases of development of an environmentally beneficial technology such as transparent thin-film solar panels. Such films have the potential to be applied to every window in every

Figure 7.8 Funding the Developmental Phases of Environmentally Beneficial Technologies



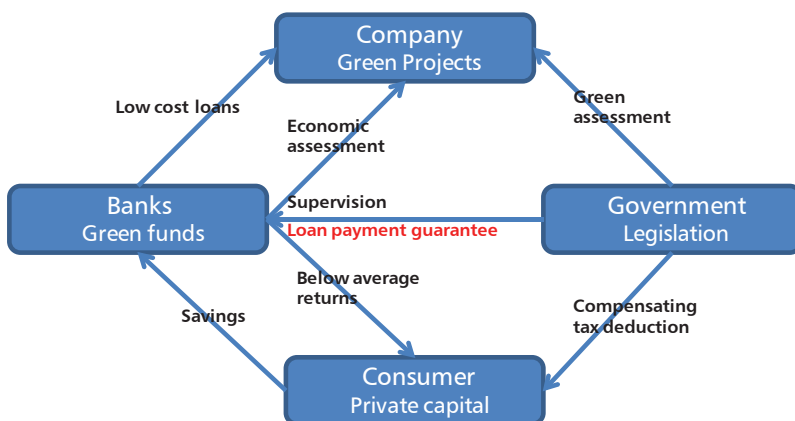
R&D = research and development, SMEs = small and medium-sized enterprises.

Source: D. Oh. 2011. Green Financing in [the Republic of] Korea. PhD Research Paper, Korea Corporate Governance Service.

building, thus transforming all buildings thus supplied into power stations in their own right. However, developing such a technology requires availability of research and development funding, financing of part of the initial start-up costs of the enterprise that produces such products, and bridging finance for transcending the cash flow problems inherent in upscaling production of such environmentally beneficial products.

Because of the positive externalities associated with development of environmentally beneficial technologies, it is economically efficient for the public sector to take an active role in ensuring that the costs associated with their development are financed. On the other hand, the statement should not be equated with a mandate for the environmental equivalent of stock-picking (i.e., a public sector agency attempting to select environmental projects with the highest rate of return from an entire universe of such projects), as this approach has proven to be ineffective. The principle that is critical to the public sector's efficiently subsidizing such projects is that of structuring publicly provided assistance in a way that works through—instead of disabling—market-based mechanisms. Under such a system (Figure 7.9), the government provides (partial) guarantees to banks for reducing the risks associated with funding such projects. This helps reduce the cost of providing such loans by banks and other financial institutions, and likewise reduces the level of risk as perceived by potential equity investors, thereby “crowding in” private capital. On the demand side, reductions in the level of government tax levied on products that use the environmentally beneficial technologies thus developed encourage consumers to buy such products. Bolstering demand in this manner also helps to secure financing for such initiatives.

Figure 7.9 Public Assistance to Environmentally Beneficial Projects Provided through Market-Based Mechanisms

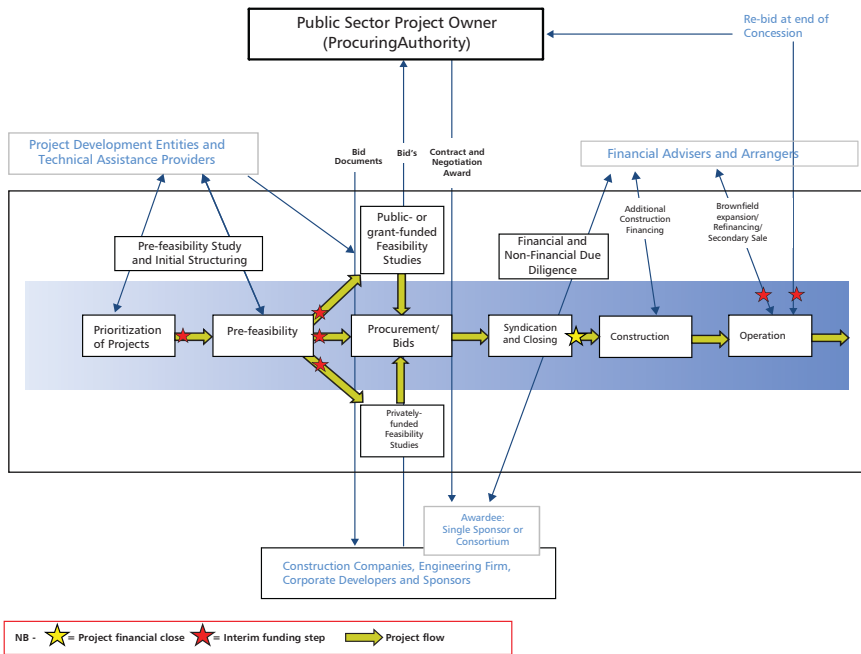


Source:: D. Oh. 2011. Green Financing in [the Republic of] Korea. PhD Research Paper, Korea Corporate Governance Service.

Project sponsors. Figure 7.10 depicts the required steps in funding a project over time and developers. A project moves from being a proposed investment to a priority project as it is developed, financial costs are attached to its specific components, and the financial returns accruing to the project are calculated. As a result, the project's implementation and funding structure needs to be determined at the pre-feasibility stage. Funding for pre-feasibility- and feasibility-related activities is often difficult for cities to access. However, this phase is perhaps the most crucial to successful funding, because it is at this stage that the basis for long-term viability and sustainability is laid. As the project is documented, and later requisite land is acquired, significant financial outlays are required. For a project hoping to attract private finance, this is a stage at which the government may need to carry the project forward, particularly in cases in which the relevant regulatory framework is not fully developed, and a record of performance in efficient, transparent procurement has yet to be established. In such cases, the project sponsor often requires revenue guarantees or credit enhancement of the special purpose vehicle for a project to achieve financial closure. Public entities may also be needed to co-invest in the project together with private financiers, thus adding a "halo effect" that reduces the level of project risk perceived by potential investors. Further public sector intervention may be required to improve the enabling environment in the relevant capital market for long-term projects, and to assist sponsors in refinancing the project through mechanisms such as infrastructure funds, covered bonds, or securitization windows.

As shown in Figure 7.10, numerous financing agencies are (potentially) involved over time in the development of a project. At the beginning of the project development process, financing for consultants for formulating the project will likely be required, particularly in the case of environmental projects. This may be accomplished by government or specialist companies (such as energy saving companies) that have developed ways of recovering costs from highly profitable projects. In addressing issues associated with limited funding for this phase, it may be advisable to avail of the services of the Cities Development Initiative for Asia (CDIA), an ADB-led consortium of donors that focuses on undertaking pre-feasibility studies and preliminary project structuring for urban environmental infrastructure projects in Asia. As the project is developed further, private sector actors are more likely to fund project development. When financing of the project is closed, there is sometimes a need for another set of public interventions, even for a commercially profitable project. To minimize the cost of project funding by private equity or debt providers, institutions such as ADB or their national counterparts may provide (i) co-investment through equity and/or debt, thus providing a "halo effect" for the project, and/or (ii) various types of credit enhancement mechanisms such as guarantees, or availability payments.

Figure 7.10 Procedural Steps Toward Mobilizing Financial Resources for a Project



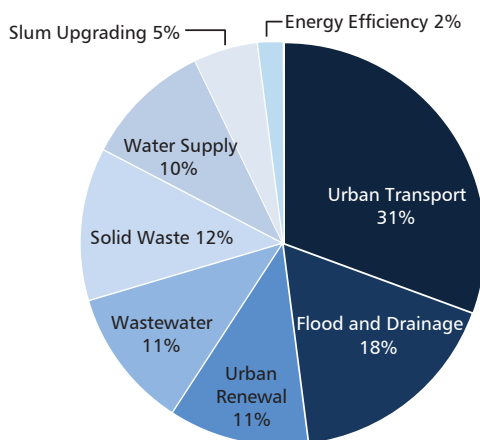
Source: ADB.

Finance, Cities Development Initiative for Asia. Cities Development Initiative for Asia (CDIA)'s long-term objective is that of promoting sustainable and pro-poor urban development as a means of improving both the environment and living conditions in all Asian cities. In pursuing this objective, CDIA bridges the gap between urban planning and policy making on the one hand, and concrete provision of basic urban services on the other. It does this by assisting city governments in pre-project preparation, and building institutional capacities for seeing such projects through to the end of their implementation. In recognition of the development objectives of its partners, CDIA support is underpinned by the following principles: (i) environmental sustainability, (ii) poverty reduction, and (iii) good governance. CDIA supports implementation of existing urban development strategies and plans that provide for socially, economically, and environmentally equitable and sustainable infrastructure and services.

CDIA has been directly engaged with 39 cities in 13 countries in performing 60 pre-feasibility studies. Urban transport accounts for more of CDIA's current portfolio than any other sector, followed by flood and drainage management, urban renewal, and wastewater management (Figure 7.11).

Figure 7.11 Sector Composition of Cities Development Initiative for Asia Engagement as of December 2011
(Percentage Shares in Total Dollar Value of CDIA Initiatives)

CDIA Engagement by Sectors (December 2011)



CDIA = Cities Development Initiative for Asia.

Source: Cities Development Initiative for Asia. 2012. Status Report to December 2011. Manila.

Conclusion

The types of mechanisms needed for enhancing provision of green finance and, once provided, for accessing such finance efficiently are known and, for the most part, are in pilot somewhere. The challenge is to foster the spread of such innovation. In sum, the principles of sound green finance correspond to the four levels of the international system for financing such investments that were laid out at the beginning of this chapter. These are briefly described once again.

- 1) Structures at the international scale for helping developing countries mitigate the impacts of climate change, or for overcoming the transaction costs of investing in climate-resilience and mitigation initiatives. Such initiatives are often financially and economically viable in the long run, but entail significant up-front costs in their implementation.
- 2) National fiscal structures that provide both positive and negative incentives for pollution reduction, energy efficiency, reduction of GHG emissions, and addressing climate change adaptation requirements.

- 3) Systems for regulating national and international capital markets, and for supporting their capacity in formulating, promoting, and deploying financial products for financing environmental sustainability. Systems are also required for ensuring access to, and affordability of, such financial products.
- 4) Microeconomic structures for encouraging and supporting the capacities of the private sector, government agencies, and subnational government bodies in formulating, structuring, and financing green investments.

Subnational governments and cities are emerging as large potential clients for ADB and other development finance institutions with regard to investments in environmental sustainability. These institutions are thus well positioned to provide leadership in closing the gaps identified above. Major areas of requisite support in this regard include (i) policy, regulatory, and institutional reforms that impact subnational finances and subnational creditworthiness; (ii) piloting of financial vehicles such as availability-payment loans and climate-finance mechanisms with which traditional banks are unfamiliar; and (iii) building the technical and financial management capacity of cities and their subordinate agencies in a way that facilitates their becoming financially credible, accountable, and capable of assessing and accessing green finance.

These entities can facilitate the greening of domestic capital markets by (i) providing risk-reducing and credit-enhancement support; and (ii) piloting municipal development fund-type institutions, and building their capacity to become intermediaries between cities and international and national finance agencies using, for example, covered bonds. Much experimentation is still required to determine the forms of risk-pricing and financial intermediation that can reliably close the viability gap in green infrastructure investment in most developing-country cities. Some of the most effective interventions could well be in more innovative, flexible, and responsive project development systems.

ADB and other development assistance agencies have the mandate and, potentially, the instruments necessary for supporting development of green finance in all of these areas. The remaining challenges are twofold: (i) effectively engaging developing member country governments in establishing the enabling framework for the effective operation of the needed mechanisms; and (2) adapting their own systems in a manner that allows their limited resources to be used most effectively in leveraging international private sector funds, as well as national public, private, and community funds. This chapter has set out some examples of appropriate financing that can be adopted and replicated in furtherance of this process.

Annex

Figure 7.12 Retail financial products and services that can be used in financing green initiatives

Product	Key Product Designs and Results/Potential	Bank	Region
Home Mortgage	Government-led “green” mortgage initiative. One percentage-point reduction in the interest rate for loans that meet environmental criteria.	Dutch banks	Europe
	Offers free home energy rating and offset carbon emissions for every year of loan. Will soon launch added features into portfolio.	CFS	Europe (UK)
	Green mortgages have only been announced by these banks, some of which are the largest mortgage providers in the country.	Abbey, HBOS, Halifax and others	Europe (UK)
	Generation Green™ Home Loan. Offered to both new and old homes, so those with existing mortgages can take advantage of discounted rates. All projects must exceed state requirements.	Bendigo Bank	Australia
	Green Power Oriented Mortgage. Provides an incentive for homeowners to use renewable power. Design focuses on sustainable behavior or customer, rather than on physical infrastructure of their residence.	N/A	N/A
	MyCommunityMortgage™ and Smart Commute Initiative Mortgage. Available to help borrowers buy energy-efficient homes and use public transportation. Product features a variety of options and flexible terms.	Fannie Mae (Citigroup)	US
	CMHC offers a 10% premium refund on its mortgage loan insurance premiums and extended amortization to a maximum of 35 years (subject to lender availability) to purchase energy-efficient homes or make energy-efficient renovations. Refund is a one-time payment.	CMHC (CIBC, BMO)	Canada

Table 7.12 *continued*

Product	Key Product Designs and Results/Potential	Bank	Region
Commercial Building Loan	Green Loans for new condos. Developer (Tridel®) repays loan with funds that would otherwise be spent on operating costs using conventional equipment and materials. Buildings must demonstrate +25% energy savings over conventional designs.	TAF/Tridel®	Canada
	Provides first mortgage loans for building and refinancing LEED-certified commercial buildings. Developers do not have to pay an initial premium for “green” commercial buildings, due to features such as lower operating costs and higher performance.	Wells Fargo	US
	Provides 1/8 of 1% discount on loans to green leadership projects in the commercial or multi-unit residential sectors.	NRB	US
Home Equity Loan	One-Step Solar Financing. Takes place over a 25-year term, equal to the same period of time as the solar panel warranty.	NRB	US
	Environmental Home Equity Program. For customers using line of Visa Access Credit, bank will donate to an environmental nongovernment organization.	Bank of America	US
	The bank signed a joint marketing agreement with Sharp Electronics Corporation to offer customers easily accessible and convenient financing options to purchase and install residential solar technologies. Enables users to take out a home equity loan or line of credit rather than accessing savings or taking out a general loan.	Citigroup	US
Auto Loan	Clean Air Auto Loan with preferential rates for hybrids. Product recently redesigned to cover all low-emissions vehicle types.	VanCity	Canada

continued on next page

Table 7.12 *continued*

Product	Key Product Designs and Results/Potential	Bank	Region
	goGreen® Auto Loan product has achieved worldwide recognition as a successful “green” product. Since its launch, the bank’s number of car loans has increased by 45%.	mecu	Australia
Fleet Loan	Small Business Administration Express Loans, with rapid approval process, no collateral, and flexible terms, are offered to truck companies for financing fuel-efficient technologies. Helps in purchasing Smartway Upgrade kits that can improve fuel efficiency by up to 15%.	Bank of America	US
Credit Card	Affinity Cards. The bank partners with ENGO, which accepts future royalties in exchange for the use of its name and logo. Annual percentage rate of 15%–22%, many with annual fees.	Various	Various
	Climate Card Bank. The bank will donate to World Wide Fund for Nature. The sum of donation depends on the energy intensity of the product or service purchased with the card.	Rabobank	Europe
	GreenCard Visa is the world’s first credit card to offer an emissions offset program. Cards will soon be made available in Germany and parts of Scandinavia. Product developers worked to bring this type of product to US customers in 2007.	Tendris Holding B.V,	Europe (NL)
	BarclayBreathe Card to include discounts and low borrowing rates to users when buying “green” products and services. 50% of card profits will go to fund emission-reduction projects worldwide.	Barclays	UK
	Existing cardholders can donate Visa WorldPoints rewards to organizations that invest in greenhouse gas reductions or redeem them for “green” merchandise.	Bank of America	US

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Table 7.12 *continued*

Product	Key Product Designs and Results/Potential	Bank	Region
	The bank donates £1.25 per £100 spent by personal (Co-op debit and credit cards) and business customers (Co-op Business Visa) to the bank's "Customers Who Care" Campaigns.	CFS	UK
Deposit	Landcare Term Deposit. Australia's first environmental deposit product. For every dollar spent, the bank lends the equivalent to support sustainable agriculture practices.	Westpac	Australia
	EcoDeposit®. Fully insured deposits earmarked for lending to local energy-efficient companies aiming to reduce waste/pollution, or conserve natural resources. EcoCash™ Checking Account allows for five free paper checks per month, with \$3 per-check charge applied. A portion of this fee goes to The Climate Trust.	Shorebank Pacific	US
Sales	Consumers can offset carbon dioxide emissions associated with air travel, with no funds being channeled to the bank. This new initiative is in partnership with offsetting organization Climate Care.	Barclays, HSBC	Europe

BMO = Bank of Montreal, CFS = Co-operative Financial Services, CMHC = Canada Mortgage Housing Corporation, HSBC = Hong Kong and Shanghai Banking Corporation, LEED = Leadership in Energy and Environmental Design, UK = United Kingdom, US = United States.

Source: Adapted from ICF Consulting Canada, Inc. 2007. Green Financial Products and Services: Current Trends and Future Opportunities in North America. Toronto.

Figure 7.13 Corporate and investment products and services relating to green investments

Product	Key Product Designs and Results/ Potential	Financial Institution(s)	Region
Project Finance	Specialized service divisions are dedicated to long-term financing of clean-energy projects. Some banks also specialize in one (or several) renewable technology types, and/or place a premium on working with states in which regulatory framework and government policy encourages early adoption of clean technologies.	BNP Paribas (wind) Rabobank, Barclays, Fortis, Standard Chartered Bank, WestLB (biofuels and wind)	Global
	Led the effort to raise \$1.5 billion of equity for the wind-power market in 2006, with approximately \$650 million allocated to its own portfolio. The firm's renewable energy portfolio now comprises approximately \$1 billion of equity investments in 26 wind farms since inception in 2003. The firm is also actively pursuing investments in biomass, geothermal, and solar power.	JPMorgan	US
	Portfolio financing technique. Combines the financing of a portfolio of renewable energy projects to the construction risks associated with project development.	Dexia (Wind)	US
	Lead arranger of energy-from-waste project financing that includes a 25-year loan supported by waste contracts with local authorities and corporate backing on noncontracted waste.	Bank of Ireland	Europe
Partial Credit Guarantee	Financial institution provides a bond issued by a municipality for financing environmental projects.	IFC	Global
Securitization	A risk-sharing arrangement for environmental projects. The financial institution represents a guarantor (or structuring investor) at the mezzanine level of risk, allowing the client to transfer risk to bank.	IFC	Global

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Table 7.13 *continued*

Product	Key Product Designs and Results/ Potential	Financial Institution(s)	Region
	Eco-Securitization scheme will test the feasibility of financing “natural infrastructure” by linking sustainable management of resources with the funding capacity and requirements of asset-backed securitization.	IFC and DFID	Global
	Green Mortgage-Backed Securities (proposed). Designed to package mortgages on buildings that meet specific energy-use and environmental benchmarks. Products would be rated higher and worth more as a result of the operational benefits associated with “green” buildings.	Not yet implemented	US
Bonds	Forest Bond designed to fund large-scale reforestation in Panama. Reinsurers underwrite a 25-year bond, while investors, who are frequent users of the Panama Canal, will purchase the bond.	Various	Latin America
	Cat bonds provide ancillary capital for risks from natural catastrophes. Can pay higher than average yield, while diversifying investor portfolios and improving industry reserves.	BNP Paribas, Goldman Sachs, Lehman Brothers	
Technology Leasing	Provides environment-friendly technologies at preferential rates.	Deutsche Bank, ABN AMRO, and ING Group	Europe
Private Equity	Private equity investments in wind, solar, and biofuels through Alternative Investments’ Sustainable Development Investment Program.	Citigroup	US
	Private equity focused on forest conservation and preserving biodiversity. Provides 100% financing, with a discounted rate on the loan, to a nonprofit organization for acquiring biologically sensitive land and implementation of sustainable forestry practices and management.	Bank of America	US

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Table 7.13 *continued*

Product	Key Product Designs and Results/ Potential	Financial Institution(s)	Region
Indices	Series of environmental private investor eco-market products. Includes a biofuels commodity basket, total returns solar energy index, clean renewable energy index, and total returns water index (e.g., enables interested parties to invest in water as a commodity).	ABN AMRO, JPMorgan	Europe, US
Carbon Finance and Emissions Trading	Banks provide equity, loans and/or up-front or upon-delivery payments for acquiring carbon credits from the Clean Development Mechanism and Joint Implementation projects. Most acquire carbon credits in order to serve their corporate clients' compliance needs, supply a tradable product to the banks' trading desks, or develop lending products backed by emission allowances and carbon credits.	Barclays, Capital, HSBC, Fortis, ABN AMRO, BNP Paribas, JPMorgan, Goldman Sachs, Citigroup, among others	Global (Mainly Europe)
	Allowance trading products can include, but are not limited to, discrete placement of physical orders, fixed-or-floating swaps, indexed sales or purchases, options, allowances repurchase structures, market-making for spot and forward trades, and price-hedging based on cross-commodities.	Various	Europe

DFID = Department for International Development of the United Kingdom, IFC = International Finance Corporation, US = United States.

Source: Adapted from ICF Consulting Canada, Inc. 2007. Green Financial Products and Services: Current Trends and Future Opportunities in North America. Toronto.

Figure 7.14 Asset management products and services relating to green investments

Product	Key Product Designs and Results/ Potential	Financial Institution(s)	Region
Fiscal Green Funds	By purchasing shares or investing in Dutch Green Funds, customers receive an income-tax discount, and thus accept a lower interest rate on investment. Banks can offer loans at lower cost to finance environmental projects relating to five eligible categories.	Dutch banks	Europe
Fund	UBS (Lux) Equity Fund – Eco Performance is the world’s largest “green” fund. 80% of assets are channeled toward eco- and social leaders, with 20% going to “eco-innovators.” The UBS (Lux) Equity Fund – Future Energy focuses on clean-energy-sector investments in four clean-energy-related business segments.	UBS	Europe
Cat Bond Fund	Leu Primate Cat Bond Fund. World’s first public fund for catastrophe bonds, a portion of which is aimed at climate-related natural disasters (or climate adaptation). Vehicle designed to hedge climate risks typically difficult to cover in the traditional insurance market.	Credit Suisse	Europe

Source: Adapted from ICF Consulting Canada, Inc. 2007. Green Financial Products and Services: Current Trends and Future Opportunities in North America. Toronto.

Figure 7.15 Insurance products and services relating to green investment

Product	Key Product Designs and Results/Potential	Bank	Region
Auto Insurance	Pay As You Drive™ Insurance. Mileage-based insurance.	Aviva, GMAC Insurance	Europe and North America
	10% discount for hybrid and fuel-efficient vehicles. The bank can also choose to offset vehicle's annual emissions (e.g., 20% emissions offset by CFS through Climate Care).	CFS, Aviva	Europe and North America
	Recycling Insurance. Customers pay up to 20% less for car insurance if recycled parts are used when vehicle is damaged and requires service.	Credit Suisse	Europe
Building/Home Insurance	Green Building Replacement and Upgrade Coverage. Product covers unique type of "green" risks relating to the sustainable building industry.	California's Firemen Fund	US
	"Climate-Neutral" Home Insurance Policy. First home insurance product to carry out greenhouse gas offsetting based on customer usage.	UK ETA	Europe
Business Insurance	Environmental Damage Insurance.	Rabobank	Europe
Carbon Insurance	Contingent Cap Forward for emissions-reduction tapes.	Swiss Re	Europe
	Carbon-emission credit guarantees.	AIG, Marsh	Europe

AIG = American International Group, CFS = Cooperative Financial Service, GMAC = General Motors Acceptance Corporation, UK = United Kingdom, US = United States.

Source: Adapted from ICF Consulting Canada, Inc. 2007. Green Financial Products and Services: Current Trends and Future Opportunities in North America. Toronto.

Figure 7.16 Selected Multilateral and Bilateral Climate-Finance Sources

Sectors Funded/Nature, Type and Level of Intervention	International Climate Finance Sources															
	Multilateral												Bilateral			
	Global Environment Fund	Clean Technology Fund	Carbon Partnership Facility	Climate Change Program Loan and Tranche	Climate Change Fund	Carbon Market Initiative	Clean Energy Financing Partnership Facility	Special Climate Change Fund	Netherlands Fast Start Finance	Global Carbon Partnership Facility	Adaptation Fund	NEPCO Carbon Finance and Funds	Indonesia Climate Change Trust Fund	Development and Climate Finance	Hayotama Initiative	German International Climate Initiative
Mitigation																
energy, efficiency	✓	✓	✓	✓	✓	✓	✓			✓	✓	✓	✓	✓	✓	✓
energy, renewable	✓	✓	✓	✓	✓	✓	✓		✓	✓		✓	✓	✓	✓	✓
solid waste			✓		✓	✓	✓		✓		✓	✓		✓		
sustainable transport	✓	✓			✓		✓				✓	✓		✓		
urban greening			✓								✓	✓		✓		✓
water	✓			✓	✓						✓	✓		✓		✓
wastewater			✓			✓	✓				✓	✓		✓		✓
Adaptation																
agriculture	✓	✓		✓		✓		✓				✓		✓	✓	✓
climate resilience	✓				✓	✓		✓			✓	✓	✓	✓	✓	✓
disaster risk management						✓		✓			✓	✓	✓	✓	✓	✓
land use and forestry	✓			✓	✓	✓		✓			✓	✓		✓		✓
public infrastructure	✓	✓				✓	✓	✓			✓	✓		✓		✓
Level of Intervention																
local	✓		✓		✓	✓	✓			✓	✓	✓	✓	✓		✓
national	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓
regional	✓	✓		✓			✓		✓		✓	✓		✓		
private sector	✓		✓	✓	✓	✓	✓		✓	✓			✓	✓	✓	
Nature of Support																
grant	✓	✓	✓		✓		✓	✓	✓		✓	✓	✓	✓	✓	✓
loan	✓	✓	✓	✓		✓	✓		✓	✓	✓		✓	✓	✓	✓
technical	✓	✓	✓	✓	✓	✓	✓	✓				✓	✓	✓	✓	✓
risk mitigation	✓	✓	✓				✓							✓		
equity	✓	✓		✓	✓	✓	✓						✓	✓	✓	
Type of Intervention																
capacity building	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓			✓
concept and plans	✓	✓	✓	✓	✓		✓	✓		✓	✓	✓	✓	✓		
infrastructure	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	
operations and management	✓	✓	✓		✓	✓	✓	✓			✓	✓		✓	✓	✓
technology transfer	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓

Source: ADB. 2012.

Figure 7.17 Cities Development Initiative for Asia Program Status Summary Table (December 2011)

Country/City	CDIA Funding (\$)	Counterpart co-financing (\$)	Intervention Sector							Development Impacts			Leverage Infrastructure Investment Value (\$ million)
			Urban Transport	Flood and Drainage	Urban Renewal	Water Waste	Solid Waste	Water Supply	Energy Efficiency	Poverty Reduction	Environment	Climate Change	
Bangladesh													
Khulna	483,000	90,000											31.3
Cambodia													
Battambang	424,600	90,000											14.0
PRC													
Guiyang	521,800	80,000											2,401.0
Handan	250,000	50,000											58.7
Yangzhou	241,000	45,000											122.6
India													
Chennai	423,000	84,700											260.0
Cochin	370,000	78,000											49.5
Rajkot	360,600	72,000											15.7
Indonesia													
Banda Aceh	327,500	44,000											22.6
Palembang	398,000	75,000											175.0
Surakarta	360,000	80,000											49.0
Yogyakarta	420,000	80,000											62.8
Lao PDR													
Pakse	439,000	80,000											34.2
Mongolia													
Ulaanbataar	196,000	42,300											10.0
Nepal													
Kathmandu	424,000	90,000											33.4
Pakistan													
Faisalabad	530,000	106,000											725.0
Philippines													
Iloilo	150,000	37,750											39.0
Thailand													
Thungsong	100,000	50,00											24.3
Viet Nam													
Thanh Hoa	37,100	87,500											38.9
Can Tho	200,000	40,000											34.0
Da Nang	410,000	75,700											29.0
TOTALS	7,399,500	1,477,950											4,230

CDIA = Cities Development Initiative for Asia, PRC = People's Republic of China, Lao PDR = Lao People's Democratic Republic.

Source: CDIA, 2012.

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CHAPTER 8

Smart Concepts for Greener Cities

by Alexandra Vogl

Introduction

The “smart” in “smart city” is more than just a simple adjective. It refers to an intelligent and attractive approach to building sustainable cities that combines infrastructure, technology, and local community involvement with a vision based on local conditions, capabilities, and resources.

The urban dimensions shown in Figure 8.1 represent different overlapping layers that are needed for creating a smart urban structure. Such a model for smart cities needs a systemic approach, encompassing different dimensions of “smartness” and stressing the importance of integration and interaction across many areas. In the process of becoming a smart city, utilization of technologies can—but not must—be an element. Much more important for smart cities is the ability of how to make use of locally available capabilities.

Can the notion of smart cities subsume economic competitiveness, inclusive growth, and environmental sustainability? Answering such a question requires clarifying the meaning of the term “smart city” itself. This phrase has become a catch-all reference to urban development that incorporates information and communication technology (ICT). But even this latter definition remains obtuse and fuzzy. Smart concepts are integrated into urban development to acknowledge the growing importance of ICT, but the social and environmental capital is required to create competitive cities as well. These latter two attributes—social and environmental capital—distinguish smart cities from their technology-laden counterparts such as “digital,” “intelligent,” or “virtual” cities.

The fact that the term “smart cities” underscores the role of social capital in sustained urban growth is important, since empirical evidence demonstrates that the cities that have achieved the most rapid sustained urban growth have in large measure relied on an educated labor force to accomplish this (Glaeser

and Berry 2006). Creating smart cities thus requires not just availability of ICT but capability on the part of urban inhabitants to use ICT to generate economic growth. This implies that the manner in which social capital is distributed among a city's inhabitants is likewise important. For example, if social inequality is so pervasive as to limit the human capability to use ICT to a small educated elite, then the economic growth rate of the city in question will inevitably suffer. Similarly, the degree to which this human capability is well distributed over the overall urban population will, in large measure, lead to a higher rate of economic growth for that particular city. This implies that reducing social inequality as it pertains to human capital can help to create smart cities that enjoy rapid, sustained economic growth.

Sustaining the current rapid rates of economic growth in the cities of Asia and the Pacific is one of the greatest challenges the region's urban policy makers face. Given the alarming rates of urbanization and population growth forecast for the region, creating smart cities is an important dimension of delivering sustained growth, since such cities tend to be far more nimble in responding to changing conditions than do cities that continue to follow the unsustainable urban development trajectories of the past century. A major focus of this chapter is thus how urban policy makers can use smart solutions to address the sustainability challenges of 21st-century urban development. The chapter is thus replete with numerous examples of how smart solutions have been used to address today's urban development challenges.

What Does It Mean to be a Smart City?

There is no official definition of the term "smart city," although many books have been written on that topic, and much has been said about it. Ultimately, creating smart cities that make intensive use of information technology is efficient in that it provides policy makers with more timely and complete information, thus enabling them to make decisions that lead to more rapid rates of economic advance than would occur in the absence of such intensive use of information technology. Further, intensive use of ICT enables efficient pricing of publicly provided goods. For example, scarce travel space in the urban core can be more efficiently allocated through the use of smart meters that sense a vehicle's entering a city's congested downtown urban core and charge for the privilege. Similarly, its use reduces the costs of provision of public goods, for example, through employing energy-efficient street lighting, and reducing the costs of revenue collection through e-governance infrastructure.

Such uses of ICT are often perceived to be costly interventions available only to cities in high-income countries. However, many smart solutions are available to urban areas in lower-income countries. Examples include allowing fees to be paid through cell phone communication networks, constructing multiuse buildings that serve both as schools and community

centers, establishing neighborhood support committees, providing mentors to troubled teenagers, and encouraging residents to expand green space through the use of gardens that improve local air quality. Furthermore, ICT solutions exist that help improve delivery of basic services to the urban poor who still lack access to clean water or improved sanitation facilities.

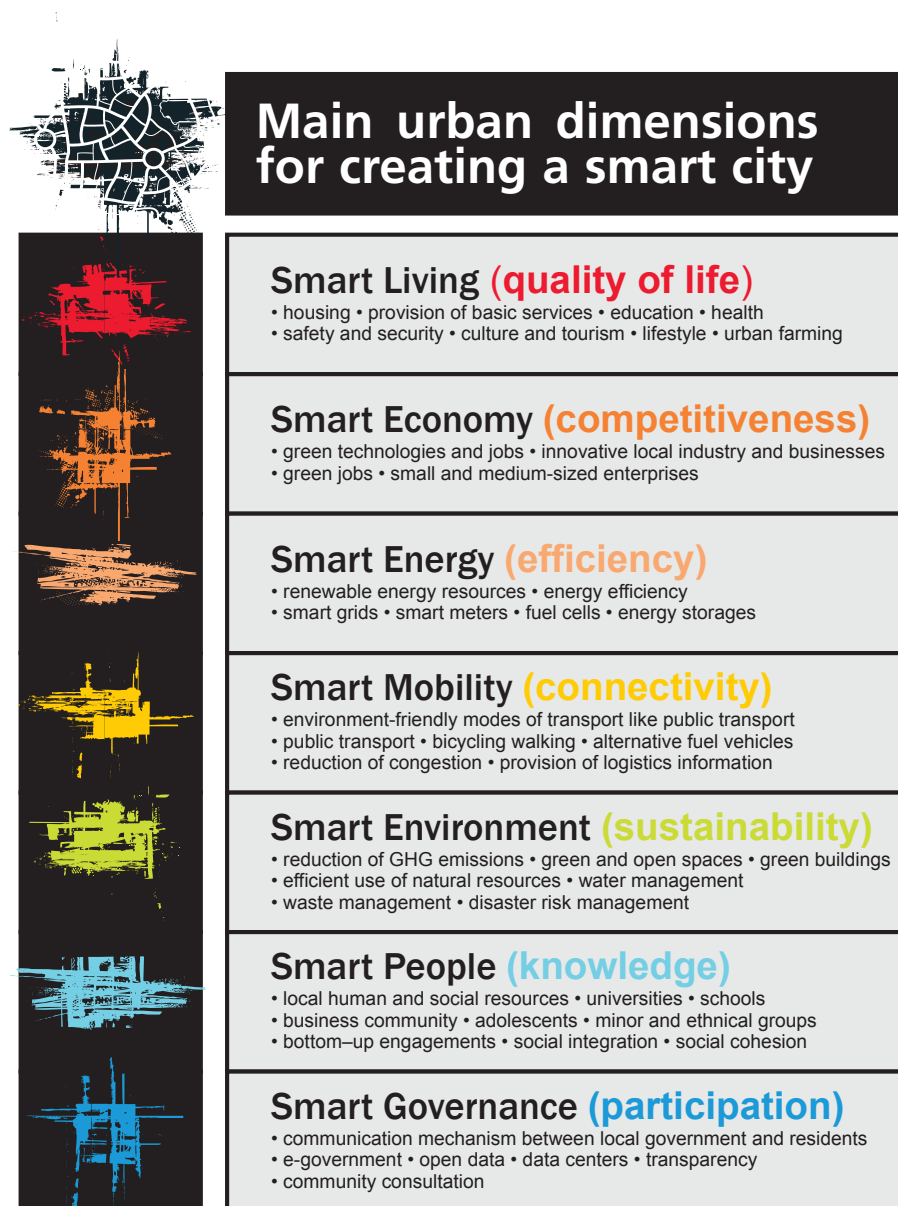
Building smart cities requires a top-down approach that is complemented by including the public at large in decision making. Thus, building smart cities requires not only a well-formulated vision of smart urban growth that is promoted among local-government decision makers but also inclusive implementation of that vision. At its core, a smart city is a welcoming, inclusive, open city that enjoys widespread participation by the entire community it comprises. It is administered with integrity in an accountable, fair, and honest manner. The administrations of such cities cooperate with other city administrations in order to learn from practical applications of urban development innovations elsewhere (Hoornweg 2011).

In sum, as used in this chapter, the term “smart city” incorporates ICT, social, and other dimensions of urban life in an intelligent way that improves the quality of life.¹ A smart city is thus a city that performs well in several urban dimensions, as well as in combinations of the latter.

Smart cities have to be underpinned with good basic service provision and constructed in a way that meets their residents’ needs. A network of reliable basic infrastructure and service provision for all is the base of smart cities (Hoornweg 2011). Nevertheless, the main focus and importance of realizing smart-city concepts is the participation and integration of local governance and citizens, assuring their acceptance, involvement, and sometimes also their change of behavior. Especially as urban development does not follow deterministic rules and there exists no “one-and-only” recipe for integrated urban development in general and for smart cities in particular, holistic development approaches focusing on local conditions including also knowledge about the mindsets of people are necessary to ensure that cities become smart, or even smarter. On the one hand, since cities are a kind of living organism, decisions are often based on human choice as much as on technical facts and figures. On the other hand, it might also be smarter to omit specific technologies for specific requirements. Making a city smart might also require urban leaders to stand for a vision that might not be the most popular at the beginning. Similarly, it is the responsibility of smart governments to communicate with local people and help them understand the cities’ needs and also participate in development processes. Development of smart cities is thus a journey, not an overnight transformation.

¹ In their study, Giffinger et al. (2007), define six main axes of smart cities that are used as the starting point for the following definition, which is amended based on the experiences and research results of the author. http://www.smart-cities.eu/download/smart_cities_final_report.pdf

Figure 8.1 Main Urban Dimensions for Creating a Smart City



GHG = greenhouse gas.

Source: A. Vogl.

“Smart cities make urbanization more inclusive, bringing together formal and informal sectors, connecting urban cores with peripheries, delivering services for the rich and the poor alike, and integrating the migrants and the poor into the city. Promoting smart cities is about rethinking cities as inclusive, integrated, and livable. [...] The concept of smart cities is really about good governance. It’s about giving basic services to our citizens. It’s about livability. It’s about how we are using our resources. It is how a city functions on a day-to-day basis. I think smartness is about doing more with less.” Abha Joshi-Ghani, World Bank

Source: R. Morier. 2012. *Who Needs Smart Cities for Sustainable Development*. 12 March. World Bank.

How Much Technology Does a Smart City Need?

Implicit in definitions of the term “smart city” is the ability to collect, analyze, and channel data in order to make better decisions at the municipal level through the greater use of technology, helping cities to become safer, cleaner, and more sustainable places to live. As many cities already collect large amounts of data, ICT applications could help to be used more efficiently and also to add real-time data to decision-making processes. The three main actors—local governments, businesses, and denizens—could use ICT tools for collecting and disseminating data to improve their cities. The private sector has particularly worked with local governments to create numerous amenities. Private initiatives, such as Cisco’s Smart+Connected Communities, General Electric’s Cities, IBM’s Smarter Cities, and Siemens’ Sustainable Cities, provide technologies and products that bring together municipal data sets from various sources to facilitate decision making by local governments. Nevertheless, such projects raise issues as to (i) whether cities and urban development could be captured in smart algorithms; and if so, (ii) whether local governments should contract private companies in fulfilling their responsibilities, and (iii) whether such partnerships would actually improve the quality of urban life.

Real-time data collection with networks of wireless intelligent sensor nodes can obviously support the measurement of various parameters for more efficient urban management, and as such can support the development of smart cities. For example, the concentration of pollution in each street can be monitored and automatic alarms activated when radiation levels exceed a certain limit. Car traffic can be monitored and the data thus generated can be used to improve the functioning of traffic lights in order to avoid congestion. Similarly, vehicle movement can be reduced by systems that detect where the nearest available parking slot is located. All such measures

can support cities in improving efficiency, optimizing the use of infrastructure facilities, saving energy, reducing air pollution, and improving the quality of life. Nevertheless, it has to be stressed that using ICT as an instrument for integrated urban development is beside collecting data; it is about the ability to provide efficient services, reduce waste, and empower residents to make more informed decisions about the resources they consume and to take a more proactive role in governing their urban units.

“The bias lurking behind every large-scale smart city is a belief that bottom-up complexity can be bottled and put to use for top-down ends—that a central agency, with the right computer program, could one day manage and even dictate the complex needs of an actual city. [...] the smartest cities are the ones that embrace openness, randomness and serendipity—everything that makes a city great. Accessible technology helps inform and empower people to shape and to lead their cities. Using ICTs to build the next generation of organized, informed and empowered leaders who will use their vision to shape cities—now that’s smart.”

Source: G. Lindsay. 2011. Not-So-Smart Cities. *The New York Times*. 24 September.

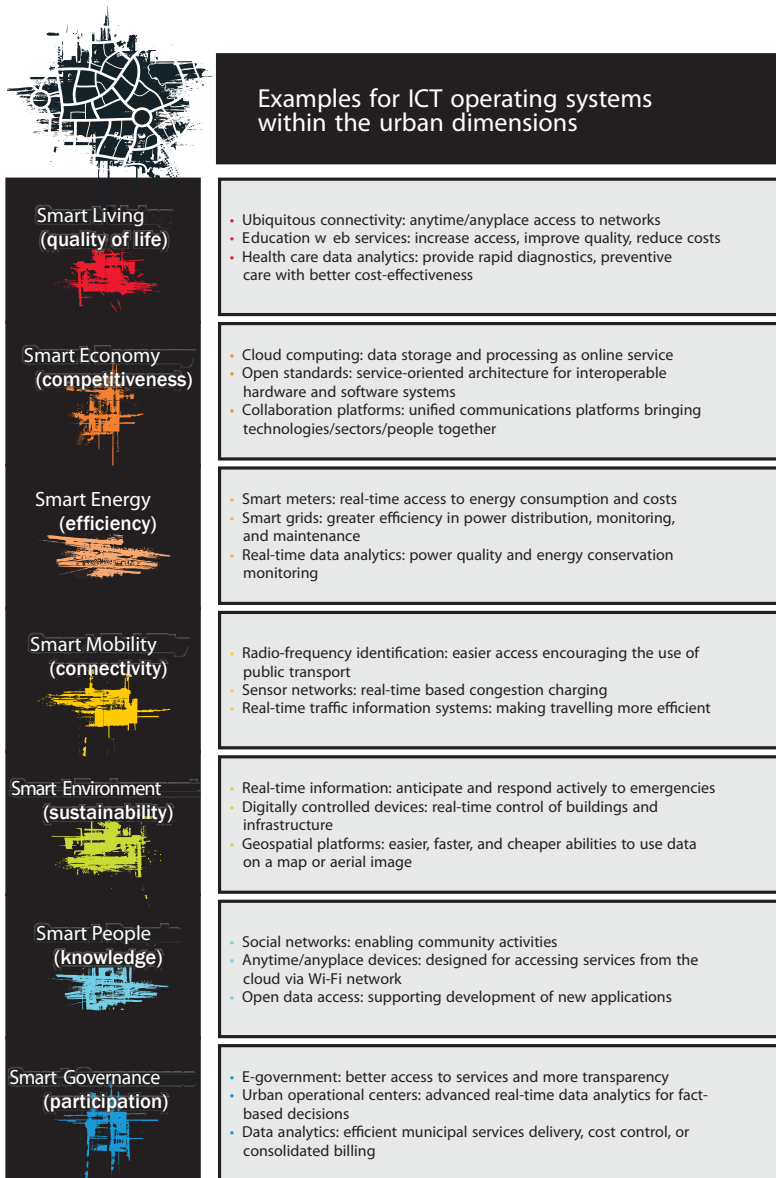
Must Smart Cities Provide Open-Data Access?

Research institutions and nongovernment organizations (NGOs) are working to showcase the fact that the smartness of cities is more on opening data for public use than on hiring consultants and buying ICT applications. They stress that open data can be used to create a variety of applications for improving urban life that follows people’s needs and makes governance easier for local officials. So at the technical level, smart cities are confronted with the need for open, standards-based platforms and data, as well as commercial and public-service models that allow easy integration. Nevertheless, becoming a smart city is more than simply arriving at a technical solution: “The real innovation that local planners need is not just new technology, but new ways of engaging the public in the direction and development of cities” (Lind 2012).

There are also many opportunities for using open data to focus on one or the other urban dimension (Figure 8.2), but surprisingly few of them are being taken advantage of. Application developments still focus on transport and governance. One reason for this might be that good sources of open environmental data (such as water losses and energy consumption) are often difficult to find. Official institutions either cannot or will not release information or data under the control of private companies. Concurrently, technology has enabled the public to create their own data, to use social media to voice people’s needs, and to enhance government data. As municipal budgets

are tight, having local people empowered to improve their own environment will be critical in developing smart cities. Nevertheless, there is the need to attempt real reforms. Otherwise, technologies risk becoming “nice to have” rather than “need to have.”

Figure 8.2 Examples for ICT Operating Systems within the Urban Dimensions



ICT = information and communication technology.

Source: A. Vogl.

Common Approaches to Smart Cities

Investments in building smart cities will be on the rise in the coming years. Pike Research estimates that during the period 2010–2020, more than \$100 billion will be spent worldwide on ICT to support smart city development, and that by 2020, annual expenditure will be almost \$16 billion (Bloom 2011). In summary of the approaches to smart cities that most frequently occur in discussions, the focus is on (i) upgrading and linking infrastructure, (ii) creating a competitive environment, (iii) ensuring inclusiveness, and (iv) securing environmental sustainability. Each of these approaches is discussed in turn.

Upgrading and linking infrastructure. This approach is about the “utilization of networked infrastructure to improve economic and political efficiency and enable social, cultural, and urban development” (Hollands 2008). The term “infrastructure” indicates basic services for business, housing, and leisure that are connected through ICT networks. One of the general ideas in this regard is to centralize the management of municipal services, thereby making them easier and less expensive to manage, especially as demand for those services grows (Bloom 2011). In the forefront of this idea is a wired city as the main development model and source of growth.

Creating a competitive environment. This approach allows a smart city to take advantage of the opportunities ICT offers to increase local prosperity and competitiveness, which implies integrated urban development based on multi-actor, multisector, and multilevel perspectives. This emphasizes economy-led urban development in creating business-friendly cities, and attracting, in particular, green industries. To this end, for example, cities may design business parks as smart cities.

Ensuring inclusiveness. This approach gives attention to the role of social and human capital in urban development. In this context, a smart city is a city whose community is able to use smart solutions to adapt or change behavior, and to learn and find innovative solutions for a higher quality of life. This can include a major focus on achieving social inclusion in public services and on emphasizing local participation, which is seen as a major strategic component of smart cities. A move toward this approach could, for example, include integration of participatory techniques such as online consultation, always bearing in mind that people need the requisite knowledge and ability to use such smart solutions. If social issues are not properly taken into account, social polarization may arise as a result. The debate regarding the possible class-inequality effects of policies oriented toward involving ICT solutions in creating smart cities has still not been resolved. However, it is exactly the question of how to ensure inclusiveness that can determine the very notion of a smart city in contrast to a digital, virtual, or intelligent city.

Securing environmental sustainability. This approach is a major driver of the smart-city movement worldwide. On a basic level, smart cities are usually part of large urban initiatives that integrate ICT components, such as smart meters, smart grid infrastructure, and renewable energy production facilities, which have an obvious role in curbing primary energy consumption and greenhouse gas (GHG) emissions. The focus here is on responsible and efficient use of natural resources, adaption and mitigation of climate change, and strengthening the use of renewable resources. For example, taking measurements to improve air quality, providing exact forecasts of hazards, and linking such kinds of information with other sectors might be part of the environmental sustainability component of smart cities. This is strongly linked to economy-led and socially inclusive development, because the balance of growth-enhancing measures and environmental protection is a cornerstone of sustainable urban development. In this context, smart-city concepts represent a move toward making environment-friendly cities more attractive to families, businesses, and industries, and maintaining a high quality of life over the long term (Bloom 2011).

In any case, developing smart cities is an approach that first needs a common vision. For example, all stakeholders should agree on particular goals, such as achieving CO₂ targets, saving a certain amount of energy or water, or limiting waste to a certain quantity. Becoming a smart city is a transformation; thus a clear vision and road map are necessities in formulating an action plan (van Beurden 2011).

Which Cities Are Today's Smartest?

Smart cities are developing around the globe. These cities mostly combine elements like zero-emission buildings, environment-friendly urban transport, renewable energy, and advanced water and sewage management to increase efficiency and reduce negative environmental impacts. New developments are especially criticized for being artificial creations that are cut off from surrounding societies.

Forbes magazine released a list of the World's Smartest Cities at the end of 2009. These cities were analyzed and ranked according to three key words: "environmental friendliness," "knowledge-based," and "self-sustainability." The outcome of this exercise was that "today's smart cities tend to be smaller, compact, and more efficient; in short, places like Amsterdam; Seattle; Singapore; Curitiba, Brazil; and Monterrey, Mexico" (Kotkin 2009).

Putting the smart city of the future aside for a moment, in 2012, a climate strategist from the United States put together a list of the world's 10

smartest cities based on previous city rankings in innovation, quality of life, sustainability, digital governance, and orientation toward becoming a digital community (Cohen 2012b).² Because this ranking was not based on a precise definition of the term “smart city,” it demonstrates the existing spectrum of smart cities, rather than defining particular rankings for particular cities. The heavy presence of European cities in the ranking might be due to the European Union’s efforts at devising a strategy for achieving urban growth in a smart sense for its metropolitan city-regions that follows its Strategic Energy Technology Plan (SET-Plan) launched in 2011, which has a heavy focus on energy savings and climate change, as buildings and transport are key in both its urban planning and energy-saving programs.

“Smart cities use information and communication technologies (ICT) to be more intelligent and efficient in the use of resources, resulting in cost and energy savings, improved service delivery and quality of life, and reduced environmental footprint—all supporting innovation and the low-carbon economy.” Boyd Cohen, PhD, LEED AP, climate strategist

Source: Cohen 2012b.

The “Top 10 Smart Cities on the Planet” and a brief description of the approaches they used in achieving that status follow directly below.

Vienna, Austria

Vienna is establishing bold smart-city targets and tracking the city’s progress in reaching them with programs such as Smart Energy Vision 2050, Roadmap 2020, and Action Plan 2012–2015. To achieve the targets it has set, Vienna is incorporating stakeholder consultation processes into formulating and executing changes in carbon-intensity, transport, and land-use planning in hopes of becoming a major European player in smart-city green technologies. The city is undertaking a broad range of projects within an integrated strategy for smart urban development. An example of various sectors working together is Vienna’s 14 drinking water hydropower plants within its water supply network reducing

14
drinking water
hydropower plants
GENERATE
electrical **ENERGY**

² Cohen (2012b) leveraged about a dozen global and regional rankings of smart-city components in order to develop a global ranking of smart cities.

pressure in their pipes, thus generating green energy, which is distributed to a local energy supplier. The 65 million kilowatt-hours of electricity per year thus generated fulfill the annual electricity needs of 50,000 inhabitants. The plants are financed through a public-private partnership (TINA VIENNA 2012).

Toronto, Canada

Toronto is moving toward a low-carbon economy by opening a Business Analytics Solutions Center and collaborating with the private sector in creating a Smart Commute Toronto initiative in hopes of increasing transit efficiency in the city's metro area. For example, they use natural gas from landfills to power the city's garbage trucks. The City of Toronto Fleet Services Division is responsible for managing the city's fleet of 5,200 corporate vehicles and pieces of equipment, more than 10% of which are smart vehicles. Use of these vehicles reduced CO₂ emissions by approximately 15,000 tons over the period 2008–2011 compared with using conventional vehicles. This equals an 11% reduction in fleet emissions.



Paris, France

Paris is well-known for its successful large-scale, self-service bicycle-sharing system called Vélib. This service consists of 20,000 bicycles that are available 24 hours a day. Its 1,800 bicycle stations, which are located every 300 meters, use electronic terminals and thus can be accessed by smart cards and phones. The concept underlying Vélib is to provide affordable access to bicycles for short-distance trips in an urban area as an alternative to motorized public transport or private vehicles, thereby reducing traffic congestion, noise, and air pollution. Since December 2011, Vélib has been complemented by an electric car-sharing scheme that operates on similar principles.



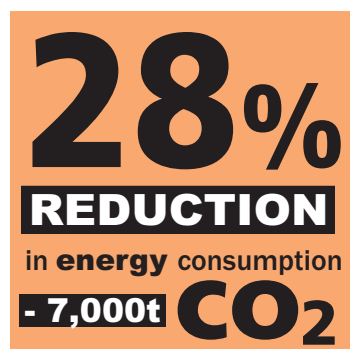
New York City, United States

Like Toronto, New York City partnered with the private sector to build an efficient technology platform under the city's ICT infrastructure modernization program. The goal of this initiative is to streamline delivery of city services by consolidating and updating ICT, thereby reducing energy consumption, strengthening security, and providing city workers with faster access to information. The new consolidated data center, which will bring together information from more than 40 government agencies to a modern cloud computing environment, is expected to save the city \$100 million over 5 years. Previously, the city operated dozens of separate data centers that lacked basic capabilities such as 24-hours-per-day support in fire suppression, emergency response, and security planning. The new center, which was created under the Citywide IT Infrastructure Services (CITIServ) Program, will enable New York to expand existing shared services; reduce costs; and provide modern, reliable, secure, and green-technology services (Hickey 2011).



London, United Kingdom

The city is well recognized for implementing a congestion tax and having a robust public transit system. But London has done much more in becoming a smart city. Concerning public access to data, London's Datastore encourages development of innovations with more than 5,000 public free-of-charge data sets relating to various issues. Furthermore, the city is partnering with private companies to launch the largest free Wi-Fi network in Europe. London also started RE:FIT, a public building retrofit program that reequips buildings with new insulation, low-carbon cooling and heating systems, and modern management technologies. Pilot projects under this program have been initiated for 42 public sector buildings across London. These projects resulted in energy savings measures over approximately 146,000 square meters of building space, and reduced CO₂ emissions by more than 7,000 tons, equivalent to an average 28% reduction in energy consumption. With



annual energy savings of more than \$1.5 million, the payback period for the expenditure of \$10.8 million under the program will be 7 years. In addition, a framework with standard contracts and tools that facilitated replication of these pilot projects was likewise developed under the initiative (Greater London Authority webpage).

Tokyo, Japan

Tokyo is known as a hub of innovation of digital-city approaches and smart-mobility solutions. In addition, Tokyo is creating new smart suburbs. Often driven by high-technology companies in cooperation with municipal bodies, such initiatives reduce carbon emissions through an intelligent network of electricity grids and homes fitted with high-tech equipment such as solar panels, storage batteries, light-emitting-diode applications, and devices that communicate with each other in order to maximize energy efficiency. Located 40 kilometers southwest of Tokyo, the smart-town project in Fujisawa city will build 1,000 houses that use smart grids and high-tech equipment (Tanikawa 2011).

1,000
new houses
using SMART GRIDS

The **Japan Eco-Town Project** was initiated by the government as early as 1997 to achieve a low-carbon, zero-emissions society. Twenty-six areas of this development have been approved, with the objective of promoting environmental industries. The initiative involves industry, the public sector, and consumers in creating a resource-recycling society that uses the reduce–reuse–recycle approach to creating an environment-friendly city. Japan’s Eco-Towns have a number of key features such as (i) legislation that encourages a material-recycling society, (ii) cooperation between national and local governments in bringing clusters of industry to the site, (iii) product research and development, (d) large and rapidly expanding eco-business market, both domestically and internationally, (iv) a heavy focus on environmental technologies and innovative solutions in addressing environmental challenges, and (v) a focus on energy conservation, material development, and integrated waste management. As of 2006, 26 areas in Japan have been approved by the government as Eco-Town projects.

Source: T. Fujita. 2011. Regional System Innovation from Eco-Model Cities in Japan and Their Contribution to Asian Cities and Regions. ISAP 2011 Low Carbon City Session in Yokohama. 27 July.

Berlin, Germany

Together with the private sector, the City of Berlin is testing smart meters for housing districts and retrofitting residential buildings with energy-saving measures. Today, Berlin is Germany's largest e-mobility laboratory. Together with the industrial and service sectors as well as research institutes and universities, the city is testing technologies for ensuring mobility in future years. Under its "Action Plan for Electromobility 2020," the city is pursuing e-mobility by constructing 550 recharging stations at a cost of 80 million euros. The city is also encouraging new electric vehicle-to-grid technologies and electric-vehicle car-sharing systems (Berlin Agency for Electromobility 2011).

550
recharging
stations
INSTALLED FOR
eCAR SHARING

Copenhagen, Denmark

Copenhagen has committed to carbon neutrality by 2025. In addition to widespread local commitment to this goal (e.g., 40% of the population regularly commutes via bicycle), there is also strong political support for stimulating the economy through "green" innovations. Copenhagen also hosts one of the largest global cleantech clusters. The Danish cleantech sector already accounts for 16% of total exports, with 40% of these companies enjoying annual growth rates of more than 25% (City of Copenhagen 2012).

16%
of total **DANISH**
EXPORTS
provided by
cleantech
sector

Hong Kong, China

Hong Kong, China has been a leading producer of radio-frequency identification (RFID) technology, particularly in the production of smart cards. The so-called "Octopus Card," which was introduced in 1997, is now used by millions of residents for services such as public transit, library access, building access, shopping, and parking. Today, more than 20 million cards

11 million
transactions
daily via
RFID
CARDS

are in circulation, which is nearly three times the number of its residents. The cards are used by 95% of the population of Hong Kong, China aged 16 to 65, generating over 11 million daily transactions worth HK\$100 million, or \$12.8 million (Octopus Cards Limited webpage). The city is also experimenting with RFID technology in its airport as well as throughout its agriculture supply chain.

Barcelona, Spain

As a pioneer in low-carbon solutions, Barcelona was among the first cities in the world to introduce a solar thermal ordinance in 2000 that required all new buildings over a certain size to generate hot water from solar thermal energy. In 2011, the city started an initiative that promoted the adoption of electric vehicles and charging infrastructure. In addition, Barcelona Wifi, a free city service, enables people to connect to the Internet through 430 Wi-Fi hotspots located in various municipal amenities and public-access points (Barcelona City webpage). Beside such general infrastructure, the city's "22@Barcelona" project transforms former industrial land into a living lab for urban, economic, and social innovation (22@Barcelona website).



It is obvious that there would be many other candidates for smart-city status that might also be included in the list, if one looked at initiatives aimed at transforming already-existing urban environments through approaches to smart design, construction, and operation of new cities. Because of their rapid rates of urbanization, cities in Asia and the Pacific will soon leapfrog into the future to follow the examples of their developed-country peers.

Making Already-Existing Cities Smarter

Existing cities are mainly facing the challenge of how to adapt to economic competitiveness and the expectation of residents for continuous improvement of basic services, while reducing GHG emissions and the overall urban ecological footprint. This is because improving a city's environment, its quality of life, and raising its profile as a high-tech and green investment center is one way of building an economic base for the coming decades. There exists a wealth of pilot programs that aim to develop more integrated transformation programs that are already under way worldwide.

Cities already in existence must develop models for urban renewal. Similarly, all smart cities hope that by becoming smart cities earlier than others, they will be in a position to provide top-quality infrastructure and services, and hence, a better quality of life in the coming decades.

Singapore

Singapore is promoting smart innovations in policy and infrastructure. At nearly 90%, the city-state has one of the highest home ownership rates in the world. Singapore's politicians are doing their best to keep vehicle ownership rates (and subsequent traffic and new road infrastructure expenditures) as low as possible. Singapore has an auction system just for obtaining the right to purchase a car. Depending on the type of



Photo: A. Vogl.

Marina Barrage: modern Infrastructure and green space

vehicle, auction values varied between \$50,000 and \$75,000 in 2011. The government also imposes massive taxes on the purchase of vehicles. On top of this, Singapore has implemented electronic road pricing, which varies depending on the hour, in an attempt to incentivize off-peak travel rather than peak-time travel. Cellphone data are used to map traffic and create alternative routes. Besides that, the city's robust metro system is reliable and modern. Stations are clean, and, as a result, the mass rapid transit system is very popular (Cohen 2012a). On the sustainability side, Singapore generally gets very high marks. The city-state has a high-level water management program that avoids dependence on water imports. The system consists of rainwater catchment, wastewater recycling, and desalination (Siemens 2011). The latter of course requires a lot of energy, but the government is working with the private sector to explore energy reduction technologies and strategies. There is also regular investment in ICT that ranges from ubiquitous security cameras to a plan to roll out a fiber network to every neighborhood, to sensors in public housing that detect earthquake tremors and send real-time texts to city engineers to request building inspections.

Portland, United States

The determination of Portland's residents to lead a more environmentally smart lifestyle dates back to the 1970s, when community-led protests forced a switch of public money from a new freeway to a light railway

system. In 1993, Portland became the first urban jurisdiction in the United States to adopt a plan for addressing climate change. In 2011, the city started an electric vehicle project and a program to transform 6,000 buildings by offering low-interest loans to owners wishing to improve energy efficiency (Morris 2012).

Rio de Janeiro, Brazil

In 2010, Rio de Janeiro opened an information management center that integrates information and processes from 30 different city agencies into a single operation center that provides a holistic view of how the city is functioning on a daily basis. The operation center serves as the “nerve center” of the city, applying analytical models to more effectively predict and coordinate responses to emergency incidents, and to manage movement of traffic and public transport and the efficiency of power and water supplies. In addition to using all information available for municipal management, data are shared with the population through mobile devices and social networks in order to empower people to contribute to an improved flow of city operations.



Two types of light rail vehicles in Portland

Source: <http://www.railway-technology.com/projects/portland/portland5.html>



In Rio de Janeiro, one operation center runs the city

Source: http://www.lastfm.de/group/Flagcounter/forum/94881/_/543479/186

Medellin, Colombia

Medellin's first cable cars started running in 2004, offering residents in the remote and mainly poor areas (barrios) a 7-minute ride to the metro system and the city center. Previously, this journey took 1 or 2 hours by minibus. Over the following 4 years, a second line was constructed, and libraries and community centers including nurseries have been built in and



Medellin Cable Car Station

<http://www.medellininfo.com/metro/metrocable11.JPG>

around the stations. This smart transport system integrates the poor into the community and economy, rather than sentencing them to life in its outskirts (Morris 2012). At the same time, Medellín stressed the social and economic benefits that public architecture and new public spaces can create for long-term, community-based policies that lead to urban renewal (Kimmelmann 2012).

Kibera, Kenya

Until 2009, the slum of Kibera was left off the official maps of Nairobi. Together with local people, researchers started a project that created their own interactive map, recording streets, buildings, and water pumps, as well as dangerous or well-lit areas. The result was not just a map for locals, but an international awareness of Kibera that caused the government to include the area in official maps. In turn, another media project was launched that allowed inhabitants to report emergencies or start conversations on politics via short message services (Map Kibera website).



Interactive map at the homepage of Voice of Kibera
Source: <http://voiceofkibera.org/main>

Building New Smart Cities

One of the great social changes of this century in developing countries is the evolution toward a predominantly urban society. One of the emerging questions is how smart the development of the new cities will be. According to the United Nations Human Settlements Programme worldwide, 510 new “small” cities, 132 new “intermediate” cities, and 52 new “big” cities emerged between 1990 and 2000, with a combined population of 254 million (UN-HABITAT 2008). If that figure is projected into the future and multiplied by a fairly conservative estimate of construction costs, and a relatively small percentage of that is taken for high-technology infrastructure, “it’s trillions of dollars.”³ This offers the potential for smart-city development, particularly in the context of Asia’s rapid urbanization, and in countries such as the People’s Republic of China (PRC) that expects 220 new cities with more than 1 million inhabitants to be built by 2025 (McKinsey Global Institute 2009).

³ Andrew Comer in an interview for the Global Urbanist (2011).

Some cities are being built from scratch that incorporate smart- and ICT-based sustainable technologies. Examples include Masdar City in the Middle East, which has become a notable center for smart-city development; and in Asia, Songdo (Republic of Korea), Tianjin Eco-City (PRC), Kochi (India), and Fujisawa (Japan). New smart-city development is also occurring in the developed world, though on a much smaller scale, and often on brownfield sites within or close to existing cities.

Masdar City, United Arab Emirates

Designed to be a carbon-free district for 40,000 residents, Abu Dhabi's multibillion-dollar investment in Masdar City is scientific in nature. Yet, the commercial side of Masdar City is a showcase of products from companies around the world. In short, it could be described as an urban laboratory. In Masdar City, advanced technologies measure, monitor, and thus produce information for handling basic urban infrastructure systems, meaning everything that flows in and out of the city, whether water or refuse. The upper part of Masdar City is built on a raised platform that gives access to pipes and is a showcase for a variety of green technologies like geothermal heating and cooling, electric cars, solar power, and advanced water systems (Sassen 2012).

Tianjin Eco-City, People's Republic of China

Experts anticipate that the PRC's urban population will double by 2040. New cities are literally springing up out of the ground. Developed by researchers in collaboration with private partners and Tongji University in Shanghai, the Eco-City model is a method of harmonizing urban growth requirements with environmental protection. Eco-City master plans are developed to help ensure that new satellite cities are self-sufficient, ecological, and, above all, pleasant to live in from the very beginning. The master plans include intelligent building systems and the use of renewable energy sources such as wind, solar, and hydropower, depending on the region. Efficient water treatment facilities and extensive public transit systems are also important parts of the Eco-City model (Siemens 2012).

One example of such development is the Tianjin Eco-City Central Business District, a joint project of the PRC and Singapore that is driven by private sector investment and development. The 30-square-kilometer Tianjin Eco-City is envisioned as a harmonious and sustainable community that will be a modern township where 350,000 residents can live, work, and play. By demonstrating that environmental protection and urbanization can progress in tandem with economic activity, the developers aspire to create an environment that will foster a "think green, act green, work green, and

live green” mindset. As a greenfield development, Tianjin Eco-City provides an opportunity to experience both hardware and software in areas such as green buildings, alternative transport solutions, connectivity, pollution, congestion, energy efficiency, eco-urban lifestyle, and economic vibrancy (Tianjin Eco-City website).

The Republic of Korea’s u-Cities: A Holistic Smart-City Vision?

Perhaps the most comprehensive approach to building smart cities is the Republic of Korea’s u(biquitous)-City initiative. The term “ubiquitous” refers to smart-city concepts in which ICT is used to address major urban challenges. Ubiquitous computing, meaning the technical integration of different urban elements, uses sensors in buildings, infrastructure, and artifacts to collect real-time information via wireless networks and to interact with surrounding physical spaces. Its goal is to integrate ICT into the urban space in order to provide inhabitants with access to any information they need from anywhere at any time, and to manage urban infrastructure through intelligent systems (Figure 8.3).

The first steps in building a u-City are (i) formulating an urban development strategy adapted to local conditions; (ii) drawing up an urban development plan which includes spatial arrangements, facilities, and planning for urban services; and (iii) establishing a master u-City plan for the application of ubiquitous technology. To implement u-City concepts, sensors are placed in all urban structures including roads, water supply systems, parks, schools, hospitals, buildings, and cars. The data collected from them are then transmitted over wired and wireless network to an urban integrated operation center. The real-time information thus provided is used for efficient urban management. For example, the center is interlinked with the city’s administration and emergency providers so that they can share information in real time. The system also makes it possible for public service agencies to rapidly inform city residents about issues of common interest, either through their own information broadcasting systems, or through information and telecommunications service providers or broadcasting networks (U-City World Forum 2011).

The Republic of Korea has selected several local governments for showcasing particular u-City models. These include Eunpyong-gu in Seoul (selected as a special u-City for disaster prevention); Busan (prevention of natural disasters such as radioactivity and tsunamis); Ansan in Gyeonggi-do province (self-sustaining “Smart Green u-Cities”); Naju in Jeollanam-do province (“Energyopia Cities” focusing on energy conservation and low

carbon emissions); Yeosu in Jeollanam-do province (u-City for international maritime tourism, leisure, and sports); and Pyeongchang, the host of the 2018 Olympic Winter Games (host of the “Smart Olympics”). Using this model, the Republic of Korea has implemented projects such as revitalization of Seoul’s old downtown, as well as various projects associated with construction of new cities (Kim 2012).

One of the Republic of Korea’s new u-City developments is Songdo International Business District. Built on a landfill, this new urban development, which will house a population of 300,000, is a noteworthy smart-city experiment because it combines technologically advanced measures with low-tech planning principles. Songdo is 40% green space, and there is a public transportation system that includes water taxis and bicycle lanes developed in a way that avoids the need for private car ownership. Regarding technical aspects, all buildings are built to rigorous environmental standards, incorporating special window glazing and ventilated double facades, a network of underground pneumatic pipes for removing solid waste and recycling of sewage for irrigation and use in cooling towers. Further, multitasking devices are able to operate the entire living environment of Songdo’s inhabitants including air conditioning and heating, lights that can be turned on and off via mobile phone or computer, video conference facilities available in every apartment, and “green meters” that allow residents to track their daily energy consumption (Hatzelhoff 2011). All of this can be done from one’s home or office, though the distinction between the two becomes increasingly fuzzy in a fully “sensored” city such as Songdo (Sassen 2012).

With the implementation of u-Cities, the Republic of Korea wants to achieve balanced land development to (i) give people a cleaner, safer, and happier life; (ii) improve business opportunities and research and development investments; and (iii) make city management more efficient by improving services and reducing costs. The u-City concept mainly utilizes a top-down approach with a heavy focus on ICT and data collection for improving specific local services. The concept is comprehensive in its approach to its core objectives of convenience, safety, cleanliness, and health (Figure 8.4). While the u-City concept includes most smart technologies, its top-led information-technology focus raises questions of data security and privacy, even as it makes community-level interactions more efficient. Addressing such questions might be important for more widespread acceptance of the u-City concept.


Figure 8.3 The Goal of the Republic of Korea's u-City Initiative Is to Provide u-Services in All Essential Areas of Urban Activity



Relative to the u-City model, the smart city is broader, and therefore more amenable to a holistic approach to green urban development.

Source: Concept of u-City. <http://www.ucta.or.kr/en/ucity/concept.php>

Figure 8.4 Potential “Smart” Extensions for u-City Concepts



	Examples for u-City applications	Potential “smart city” extension
Smart Living (quality of life)	<p>Technology-aided crime safety system</p> <p>Mobile device services: healthcare on real-time basis to make life more convenient</p>	<p>Strengthen solidarity among local community</p> <p>Enable innovations and development of mobile application by open data initiatives</p>
Smart Economy (competitiveness)	<p>u-employment/recruitment services</p> <p>R&D investments for new business possibilities</p>	<p>Strengthen innovation potential of local industry and business to create “green” jobs</p>
Smart Energy (efficiency)	<p>u-facility management for buildings</p> <p>Intelligent street lighting</p>	<p>Support the use of renewable energy resources, strengthen energy efficiency, and implement energy saving measures</p>
Smart Mobility (connectivity)	<p>Real-time information on roads, and up-to-date information such as transportation accidents to manage city transport more efficiently</p>	<p>Strengthen environment-friendly modes of transport like public transport, bicycling and walking, (alternative fuel) car-sharing concepts, etc.</p>
Smart Environment (sustainability)	<p>Real-time monitoring of pollution to create a clean environment</p> <p>Disaster response systems and emergency rescue systems to speed up assistance</p>	<p>Integrate land-use planning with green and open spaces</p> <p>Resilient infrastructure to avoid urban areas being affected by natural disasters</p>
Smart People (knowledge)	<p>Digital interactive media devices with touch-screen set up across the city, so people can conveniently access information</p>	<p>Beside consuming information, people actively provide content to information systems</p>
Smart Governance (participation)	<p>u-administration</p> <p>u-city management platform</p>	<p>Implement e-government, open data initiatives, public consultation and participation structures</p>

R&D = research and development.

Source: A. Vogl.

Smart-City Concepts for Making Cities Greener

In using smart-city concepts to create greener cities, it is important to have a common, holistic long-term vision, a midterm road map that also provides flexibility for innovations, and a short-term action plan for (coordinated) measures within various urban dimensions. The examples below all address smart urban technologies for creating smarter and more livable cities.

Smart living

Concerning the energy and housing sector, a climate-neutral building is nice to have, but is even better when solar panels on the roof feed back into the grid, when it uses the district heating and/or cooling from a nearby industrial zone or waste incineration plant, and when gray water is used for urban farming. The latter is becoming a new urban lifestyle trend. Activities range from simple balcony boxes to vertical farms supported by smart technologies that grow food inside environmentally controlled, multistory buildings that recycle organic, human, and animal waste and wastewater. Thinking even further ahead, smarter neighborhoods will evolve and buildings will be addressed collectively as regards the ecosystem in which they reside. This will drive measures for fresh air, reducing pollution and emissions, and built corridors that connect both horizontal and vertical surfaces within the city and its surroundings. Vertical farms could possibly produce food for a growing urban population, since one indoor acre is equivalent to 4–6 outdoor acres or more, depending upon the crop. For example, for strawberries, 1 indoor acre equals 30 outdoor acres (The Vertical Farm webpage).

**1 indoor
acre
vertical farm
is equivalent
4-6 outdoor
acres**

Smart economy

Masdar City, the Republic of Korea's u-Cities, and the Eco-Cities of Asia and the Pacific strongly focus on creating industry, business, and research clusters for "green technologies" that use cities as urban laboratories for creating new job opportunities. For example, Japan's Kitakyushu Eco-Town has created an extensive range of recycling and environmental industries that cover a large number of materials and

**100⁰ M
GREEN JOBS
worldwide
over the next
2 decades**

products from plastic, paper, and metal, to office equipment, vehicles, construction waste, and solvents. A smart economy also looks toward creating incubators for start-ups. For example, Sydney's ATP Innovations incubator—which is part of the Australian Technology Park—maintains a close working relationship with universities in assisting technology transfer, providing office and laboratory space for university spin-off companies alongside private entrepreneurs, and supporting start-ups in raising capital and selling products. The Sydney-based incubator facilitates growth of technology-based businesses in life sciences, engineering, and enterprise software (ATP Innovations website). A shift to a low-carbon, environment-friendly, and climate-resilient economy could allow cities in Asia and the Pacific to create new jobs and thus reduce social gaps. The projected number of green jobs that would be created over the next 2 decades could reach 100 million worldwide. This represents about 3% of the actual global workforce of over 3 billion (ILO 2008). Some of these green jobs will be newly created jobs, while others will substitute for existing jobs.

Smart energy

A major challenge in the energy sector's going green and smart is the current grid system, which is mainly not designed for two-way energy flow. There is thus a need to amend regulations so that consumers may supply (renewable) energy back to smart grids and receive a fair price for doing so. Smart-energy applications monitor, control, inform, and automate the delivery and use of energy, and help consumers by giving information that reduces energy consumption. Smart-

1.6^{mio}_{us} homes
retrofitted
SAVE 1
nuclear power plant

grid technology and infrastructure development in energy markets in Asia and the Pacific is a multibillion-dollar industry, which is forecast to grow by almost 35% over the next 5 years (Smart Grids – Smart Cities website). With the implementation of smart grids and smart meters, energy users may also be able to choose the source of energy (renewable or fossil, local or global) that they prefer, based on price and the time of use. In addition, smart-energy technologies include energy-efficiency measures like LED streetlights with sensors that detect movement and adjust illumination (Sant Cugat Smart City 2012), or the retrofitting of buildings for higher energy efficiency and reduction of GHG emissions. For less than half the cost of a new nuclear power plant, 1.6 million electrically heated homes in the United States could be retrofitted for energy efficiency, thus reducing the need for the same amount of energy that a new plant would produce. Doing so would also create 90 times more jobs than replacing an obsolete nuclear power plant (Energy Savvy 2011).

Smart mobility

If a city forces its residents to travel in private cars because there are no light-rail networks, metro trains, or bus transit options, it cannot even join a dialogue with green smart cities. Today, there are almost 1 billion cars on the road, and this number is expected to reach 2 billion before 2050. Virtually all of the expected growth in GHG emissions from the transport sector will come from private cars and trucks in emerging economies. The International Energy Agency has estimated that fuel consumption and emissions of CO₂ from the world's cars will roughly double between 2000 and 2050 (UNEP webpage). In order to support global reductions in CO₂ emissions from the transport sector, smart technological innovation will have to work hand in hand with smart policies. Especially for the urban transport sector, there are many possibilities for cities in becoming smarter and greener. With sensors, cities can implement congestion charges, applications for making transit easier, and data collection that can reveal patterns that encourage better transportation engineering. Real-time data can, for example, provide guidance to the best available parking spots or updates on public transport arrival times, making traveling more convenient, but also more efficient. Nevertheless, to move from a car-centered sprawling city to a dense, multimodal and green city, a change in people's behavior is needed in addition to more energy-efficient structures, technical solutions, and infrastructure for environment-friendly modes of urban transport. Therefore, the mutual interaction between the transport system and building construction must be considered in providing easy and reliable access to transport.

CARs
will **DOUBLE**
CO₂
BETWEEN 2000-2050

Smart environment

This dimension stands for how we address ecosystems and environment and natural resources. For example, in addition to effective water management and reduction of water losses, there also exist quite small but nevertheless smart projects that can help the most vulnerable in society achieve better access to basic services. An example to illustrate this is the NextDrop Initiative in India. In some regions of the country, water is only available a few hours a day, and people either spend time waiting for water or do without it all together. Based on the data provided by water utility providers, the NextDrop Initiative built a reliable mobile network that notifies people by text messages when the water has been turned on (Next Drop website). More

complex and high-tech-based concepts in this regard include waste-to-energy (WTE) concepts that encompass thermal and biological conversion technologies. WTE can extract valuable energy contained in waste and use it for the production of electricity, as well as for district heating and cooling. WTE facilities can prevent the use of landfills (globally some 73% of all municipal solid waste is either landfilled or dumped in open pits) and offer an attractive option for promoting low-carbon growth in the renewable energy sector. Asia and the Pacific—and the PRC in particular, accounting for 14% of global WTE facilities—are expanding installed WTE capacity by at least 250% over the coming decade. This expansion will shift the center of the “WTE universe” away from Europe to Asia and the Pacific (Lawrence 2012).

WASTE-TO-ENERGY
will **EXPAND** at least
250%
the next decade in
Asia and the Pacific

Smart people

While technology is an enabler, smart people are the change agents that make use of smarter and greener neighborhoods and cities. The bottom-up engagement of local inhabitants, universities, and businesses in urban development is one dimension of smart cities that will be of growing importance, especially in times of tight public budgets. The “internet of things,” meaning the online representation of real-time data, will arm people with instantaneous information, thus proliferating new smart applications and enabling smarter decision making. In this context, experiments like Urban Prototyping Weekends are using “from the ground up” innovation to improve urban environments through the use of technology and open data by giving stakeholders like residents, entrepreneurs, government employees, and researchers an opportunity to develop and prototype innovative solutions that make cities smarter (UP Singapore webpage). The same is true of social media platforms developed by local communities like nexthamburg.de (Germany), fixmystreet.com (e.g., in Canada, India, the Republic of Korea, and the United Kingdom), and seeclickfix.com (United States) that engage citizens in dialogue regarding urban needs. These allow people to voice problems, make proposals for neighborhood development, and contact local government agencies through

215,000
FixMyStreet
REPORTS
since
February 2007

the internet. In the United Kingdom alone, more than 215,000 reports have been sent through FixMyStreet since its launch in February 2007. This is an average of 100 messages concerning potholes, broken streetlights, and other problems that are communicated to local authorities each day. Those reports are the work of over 87,000 people, 52% of whom had never before reported an issue to a council. FixMyStreet is built on open code, so that it can be replicated by anyone with appropriate technical knowledge (FixMyStreet 2012).

Smart Governance

In addition to comprehensive urban operation centers like Rio de Janeiro's, to become smarter, cities need to bring in all their stakeholders from the beginning—including also the private sector—since collaboration is what makes a city smart. Smart governance often builds on information technology infrastructure investments made by the public sector. Back-office systems help to improve efficiency and integration of services, and front-office systems support multichannel communication with citizens and transactional service areas such as energy, transport, and waste management, particularly in relation to the goal of transitioning to environmental sustainability. The use of ICT also makes it possible to locate public-service facilities that are located close to clients, whether through a government-agency kiosk, or through a personal computer. For example, Tirunelveli in Tamil Nadu (India) employs a number of e-governance initiatives including systems that track the condition of streetlights and the status of garbage collection; that monitor town planning, and also address complaints or collect taxes and fees. Another example is Ho Chi Minh City (Viet Nam) that is simplifying administrative procedures faced by businesses as a way of promoting investment. The city has established an online “one-stop shop” for business license applications, which has also enabled administrative reforms and has inspired simplification of administrative procedures. Citizens benefit by spending less time waiting and traveling, and having better information provided to them (Wescott 2003). Similarly, in Hong Kong, China, the internet is the preferred channel for contacting the city government in that it accounts for 55% of all public access to government services (Yeo 2011).



55%
of all access
to government
SERVICES via
INTERNET

Conclusion

In the 21st century, science and technology will assume increasing importance in society, and new inventions capable of making our cities greener will be developed. But smart-city approaches are much more than technologies. Smart cities are about synergies and partnerships. Technologies within and across services can generate much greater benefits than can individual technological “fixes.” For example, the combined development of a high-capacity public transport system together with adjacent high-density, high-amenity, and energy-efficient urban development will have a greater greenhouse gas reduction impact than the sum of individual transport and urban-development investments.

Smart cities need partnerships among national and local governments, administration, businesses, and residents to deliver smart solutions for reducing infrastructure and service costs, while at the same time improving the quality of life. Today’s cities have new options for integrating technologies into existing infrastructure and services. However, to enable inclusive and green outcomes, they will also need to choose between how much they want to manage and control infrastructure, and how much they want to control their relationships with their residents. The smart-city concept offers potential solutions to issues such as finding a balance in environmental concerns, economic development, and the need to provide a higher quality of life for Asia’s urban population. These smart-city approaches must be flexible enough to respond to local social and economic circumstances.

“A smart city is responsive to the needs and hope of its residents. It offers accessible, affordable, and quality education and healthcare systems, [and] sustainable, innovative, and safe transport for all. It creates conditions to provide adequate housing and basic services and strives to improve the housing conditions of the urban poor. The city promotes the growth, preservation, and development of recreation services, parks, and green spaces to enrich the leisure needs of its inhabitants, with pedestrian walkways and bicycling lanes.”

Anna Kajumulo Tibaijuka, Under-Secretary-General and Executive Director, UN-HABITAT

Source: Inaugural Address at the UN Pavilion Lecture Series at the Shanghai World Expo 2010.

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Conclusion: Green Cities Will Become a Reality

by Michael Lindfield and Florian Steinberg

The preceding chapters have described numerous initiatives that can be undertaken to make Green Cities a reality. They have likewise described the dynamism of the cities that are currently undertaking such initiatives. A review of the group of intervention described in this book that cities may undertake to move toward environmental sustainability shows that the cities that *do* undertake these interventions all share several characteristics. First, policy makers in these cities are innovative in that they are determined to build on cross-sectoral synergies that have historically either been ignored or were thought to not exist at all. Second, these cities all tend to use integrated planning and management as policy vehicles for taking full advantage of these synergies, this naturally leading to integrated implementation of the investments undertaken. Both integrated planning and management of initiatives take advantage of the now-obvious fact that implementing such measures in a piecemeal fashion produces significantly fewer—and more scattered—positive development impacts than if synergies are exploited through integrated planning and management.

Third, exploiting these synergies to their fullest extent requires not only the support and cooperation of all stakeholders concerned but also an understanding on their part of how these synergies interplay to build momentum toward environmental sustainability. This requires influencing the attitudes and behaviors of all stakeholders, which is best done by providing timely, complete information that is delivered in a transparent fashion. Providing both positive and negative incentives for behavior change likewise accelerates shifts in attitudes and behaviors, as well as acceptance to change itself. Finally, widespread understanding of the importance of finance to fund successful implementation is necessary for all potential synergies to be fully exploited. The following sections elaborate on these four key characteristics of successful integrated implementation.

Stakeholders. While changing the attitudes and behaviors of stakeholders always requires more effort than does pursuing status-quo approaches, it is precisely this effort that will in the end ensure that Green Cities will

become a reality. Currently, some are skeptical about the financial viability and feasibility of Green Cities for Asia and the Pacific in that they believe that the region cannot “afford” the transition to Green Cities. However, the basic assumption underlying such a view is that environmental degradation is an inconvenience that can easily be financed through economic advance. This assumption unfortunately ignores the fact that continuing degradation of the natural resource base—that is the very source of economic advance itself—has been shown in this book to lead to *ever-increasing* costs. Thus in the end, transitioning to Green Cities will ultimately be seen as the *least-cost* approach to sustaining the region’s current rate of economic advance. For this and other reasons, we are convinced that the greening of cities and support for environmental sustainability will assume ever-increasing importance in the international development agenda over the coming decades, this ultimately being linked to widespread momentum toward the greening of entire economies.

Innovation and Synergies

Innovations. It is obvious from most of the chapters in this book that there increasingly exists an inspiring range of technological and systems innovations in many sectors that will positively impact the cities of the future. Furthermore, these innovations are occurring in all sectors, including construction and building technology, urban transport, energy, water and sanitation, waste management, and smart technologies, all of these potentially resulting in life-changing modifications of the urban metabolism.

Synergies born of innovation. The pace of innovation has accelerated considerably over the past decade, and will likely accelerate further in coming years. Further, synergies among innovations appear to be likewise multiplying, as the concept of Green Cities itself revolutionizes the way we think about urban life issues such as mobility, enclosing space for commercial or domestic purposes, controlling temperature, or communicating. These new ways of thinking have created now-obvious synergies in sectors previously thought to be unrelated. For example, synergies in the public transport and land management sectors can facilitate the creation of cities that are cleaner and more compact, and that are low-carbon or even zero-carbon energy users. Innovations such as emissions-free automobiles powered by fuel cells, and the phasing out of obsolete and polluting 20th-century production technologies will likewise greatly reduce the ecological footprint of cities, as will widespread application of solar power that vastly alters the energy balance of buildings and even entire urban areas. Cross-sectoral synergies among such innovations abound, simply because they impact the totality of urban life.

Need for Integrated Planning and Implementation

Planning. To transform the archetypical chaotic, polluted, inequitable Asian city into a competitive, equitable, and environmentally sustainable urban area—in short, a livable city—will require a new approach to urban development, as well as support from the Asian Development Bank (ADB) for that development (ADB 2008). Central to this transformation will be a renewed emphasis on integrated planning in the provision of environmental infrastructure, basic services, and other public goods. Through its urban operations, ADB will support a planning approach that treats urban areas as systems instead of supporting ad hoc, individual interventions on a piecemeal basis. Planning of this type is both holistic and specific in that it initially considers urban development from an overall perspective, and then selectively pursues specific investments that are consistent with this overall view. Perhaps nowhere is this balance between an overall urban development plan and the underwriting of specific initiatives more important than in the sequencing and timing of specific initiatives, as well as in the engagement with development partners in this regard. Such an approach is consistent with the fact that development of livable cities is a long-term process that can be optimized only through integrated planning and implementation of the specific investments undertaken.

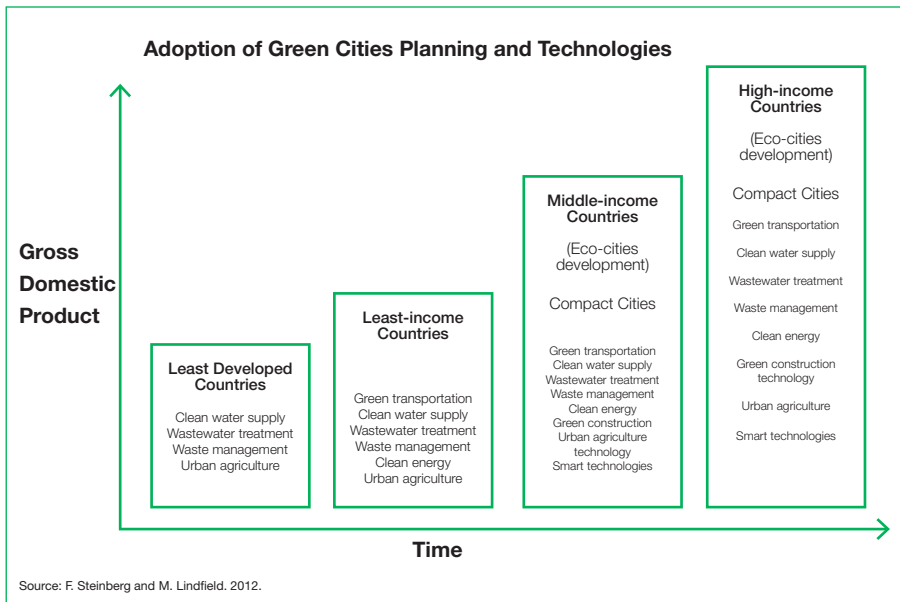
Implementation. Even given integrated planning, many potential benefits of individual interventions may be lost if implementation is not likewise integrated. Exploiting the synergies referred to at the beginning of this chapter in large part depends on the sequencing of investments rather than simply on their physical provision. Construction of high-density housing that lacks public transport connections will undoubtedly generate additional car trips, and thus lead to additional congestion and pollution, both of which lower the quality of urban life. However, if public transport facilities are provided in advance of high-density housing being occupied, these negative impacts can be avoided. In addition to appropriate sequencing of interventions, integrated planning takes account of the particular level of national per-capita income in the urban area concerned, as this impacts affordability and hence financing.

Benchmarking and indexes. Benchmarking of cost and implementation performance as well as outcomes are likewise important components of integrated implementation in that implementation of initiatives proceeds more smoothly if urban policy makers are aware of how implementation is proceeding relative to performance criteria laid out in their own urban plans, and likewise relative to the implementation performance of other cities. For this purpose, ADB is developing a National Infrastructure Information System that is used to benchmark individual projects. Likewise, Green City

Indexes already exist that allow urban policy makers to address shortfalls in the “green” performance of particular cities (Siemens AG 2011).

Attitudes and Behavior

The role of the middle class. Some innovations such as green building technologies, the greening of neighborhoods, electric bicycles, and low-carbon cars and home appliances are likely to initially be driven by middle-class consumption patterns. That said, the preferences of the middle class over time tend to spread to society overall, thus leading to wide acceptance of technological innovations. As “going green” becomes fashionable in middle-class circles, the demand for “green” products will likely expand, thus enabling economies of scale that reduce the costs of such products, in turn allowing lower-income groups to mime the preferences of the middle class in purchasing them. This is likely to ultimately lead to acceptance of both green products and urban technologies on a mass scale. The fact that the middle class is growing rapidly in both absolute size and percentage share of the national population in nearly all of the region’s countries suggests that consumer acceptance of green products and technologies is likely to grow over time. Similarly, as government revenues expand in tandem with per-capita income growth, public sector uptake of green technologies on a national scale is likely to accelerate.



The fact that the technologies envisioned by the ecologists of the 1970s, such as green and clean buildings, roof-top greening, and (vertical) urban agriculture, are components of today's technological development stream suggests that the demand for such innovations will be a likely response to rising prices of fossil fuels and conventional construction practices.

Inclusiveness. There is no point in planning a Green City if social and income barriers mitigate against its implementation. For example, rivers can never be cleaned if they comprise the only cost-effective waste disposal option for low-income communities living along their banks. Thus to become a reality, Green Cities must support provision of basic infrastructure at the community level and connection of such infrastructure to city main systems. In this regard, ADB coordinates with both the governments concerned and other development partners in addressing such requirements, as these are prerequisites to making Green Cities a reality. Assistance in building the implementation and administration capacity of neighborhood organizations, civil society, and governments in support of inclusive development will likewise be required for Green Cities.

The All-Important Issue of Finance

How can transforming investments be financed? In recent years, many institutions including ADB have begun to finance interventions in energy efficiency and low-carbon transport. Due to ADB's long-standing commitment to energy efficiency, this trend will likely continue in coming decades. However, the cost of a full transition to Green City status for any of the region's existing cities is likely to be beyond the means of both official development assistance and government finance. This implies that ensuring the continued flow of finance for transforming investments will require new private sector financial instruments. Given Asia's relatively high savings rates, as well as the considerable investible resources of pension and insurance funds in higher-income countries, the costs of transforming investment can be financed, given appropriate private sector financial instruments.

Consumer loans made through private sector entities may well be another vehicle for financing the transition to Green Cities. For example, the cement producer *Holcim* has successfully extended consumer financing to its customers in Mexico and Indonesia, a practice that may be replicated on a large scale in financing numerous construction-related activities that transition consumers will undertake to green practices and lifestyles.

Incentives. Given expanding private sector financial flows to transforming investment, the role of the public sector will likely increasingly be that of a motivator and intermediary of private sector engagement and investment

in Green Cities. The scenario by which this might occur includes national banks becoming significant lenders in support of local innovation by private investors, with the role of multilateral finance institutions increasingly being that of supporting these national financing institutions through loans or guarantees. Financial instruments that incorporate results-based lending will likely be used to underwrite technological innovation.

There is considerable scope for urban policy makers to support the transition to Green Cities through urban planning and management. For example, both can be increasingly used to promote construction of green buildings, water conservation, waste recycling and reuse, and adoption of green technologies, as well as green practices in energy generation. Numerous instruments can be used for incentivizing adoption of all of the above. Increasing the ratio of a building's floor space to the total area of the plot on which it is constructed for persons or entities that invest in green technology innovation provides but one example. Such a policy intervention could trigger not only accelerated application of energy-efficient and green technologies but also higher urban densities and urban efficiencies.

ADB pipeline. Under ADB's Urban Operational Plan (2012), a number of innovative financial products are proposed in support of the transition to Green Cities. These include (i) guarantees for green investments to be used by national public or private financing institutions; and (ii) preferential public sector lending in support of clean energy, green transport, and green buildings.

Conclusion

Will there be Green Cities for all? Currently, the notion of Green Cities exists in the real world in the form of individual experiments with Green City technologies that are more or less equally distributed across the world's regions. This bodes well for the scaling-up of such technologies, particularly in rapidly urbanizing Asia. The fact that the region's population densities are expected to grow substantially over the coming decades suggests that scale economies could significantly reduce the costs of transitioning to green technologies, thus incentivizing their uptake on a large scale.

How long will it take? Transformation of today's cities will not occur overnight. Global-scale application of green technologies is thus likely to be an evolution rather than a revolution. But as the rapid spread of communications-based products has demonstrated, new technologies can spread very quickly, particularly when costs fall rapidly, thus enabling scale economies in production, and hence decrease in price to levels that make such products affordable on a mass scale. Furthermore, as the continuing

transformation of the older industrial urban areas of Europe and the United States has demonstrated, industrial blight and dilapidated buildings can be replaced within a few decades. This suggests a similar trajectory of transition to green city status for Asia's urban areas, once affordable green technologies come to market and consumer preferences turn toward products based on such technologies as a result of their quality, low cost, and inherent environmental benefits.

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Green Cities

Asia shares a vision of making all its cities livable one day. The knowledge and financial resources needed to realize that vision exist. But if the challenges of climate change and pollution are to be met, we must reduce energy demand in cities and the undesirable environmental impact associated with energy production and consumption. We must also address the pollution of watersheds and the air. To achieve this, we must manage urbanization process, city form and design, urban density, transport systems and logistics systems more efficiently and effectively.

About the Asian Development Bank

ADB's vision is an Asia and Pacific region free of poverty. Its mission is to help its developing member countries reduce poverty and improve the quality of life of their people. Despite the region's many successes, it remains home to two-thirds of the world's poor: 1.7 billion people who live on less than \$2 a day, with 828 million struggling on less than \$1.25 a day. ADB is committed to reducing poverty through inclusive economic growth, environmentally sustainable growth, and regional integration.

Based in Manila, ADB is owned by 67 members, including 48 from the region. Its main instruments for helping its developing member countries are policy dialogue, loans, equity investments, guarantees, grants, and technical assistance.

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