Eco^2 Cities

Ecological Cities as Economic Cities

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SELECTED ABBREVIATIONS

BRT	Bus Rapid Transit
CAGECE	Companhia de Água e Esgoto do Ceara
CAPEX	capital expenditure
CBD	central business district
CDM	Carbon Development Mechanism
CHP	combined heat and power
CO_2	Carbon dioxide
DSM	Demand Side Management
DSS	Decision Support System
ELP	Environmental Load Profile
ESCO	energy service company
FAR	floor-area ratio
FY	fiscal year
GDP	gross domestic product
GEF	Global Environment Facility
GHG	greenhouse Gas
GIS	Geographic Information Systems
IBRD	International Bank for Reconstruction and Development
IDA	International Development Association
IFC	International Finance Corporation
IPPUC	Institute for Research and Urban Planning of Curitiba
LCA	life cycle assessment
LCC	life cycle costing
LED	light-emitting diode
LFG	landfill gas
LNG	liquefied natural gas
LPG	liquefied petroleum gas
MDB	Multilateral Development Bank
MFA	material flow analysis
MIGA	Multilateral Investment Guarantee Agency
NGO	nongovernmental organization
NMT	non-motorized transport
NPO	nonprofit organization
NPV	net present value
O_2	oxygen
OECD	Organisation for Economic Co-operation and Development
OPEX	operation expenditure
PPP	public private partnership
PSP	private sector participation
PT	public transport
R&D	research and development
SEK	Sweden Krona
SO_2	sulfur dioxide
TDM	travel demand management
TDR	transfer of development rights
TOD	transit oriented development

Foreword

Urbanization in developing countries is a defining feature of the 21st century. Some 90 percent of global urban growth now takes place in developing countries—and between the years 2000 and 2030, developing countries are projected to triple their entire built-up urban areas. Urbanization has enabled economic growth and innovation across all regions—currently accounting for three quarters of global economic production. At the same time, urbanization has also contributed to environmental and socio-economic challenges, including climate change, pollution, congestion, and the rapid growth of slums.

Global urban expansion poses cities, nations and the international development community with a fundamental challenge and opportunity. It sets forth before us a once in a lifetime opportunity to plan, develop, build and manage cities that are simultaneously more ecologically and economically sustainable. We have a short time horizon within which to impact the trajectory of urbanization in a lasting and powerful way. The decisions we make together today, can lock-in systemic benefits for current and future generations.

The Eco^2 Cities Program presents itself at a critical historic juncture in relation to this challenge and opportunity. This book, which marks the launch of the Eco^2 Cities Program, sends a positive message. The knowledge and expertise to resolve these challenges exist, and forward-thinking cities in developed and developing countries have already applied this knowledge to make the most of opportunities. Importantly, many cities have shown that cost is not a major barrier to accomplishing urban sustainability.

The Eco^2 Cities Program is an integral part of the World Bank's new Urban Strategy which is currently being developed in consultation with stakeholders. The Eco^2 Cities Program is also complementary to the ongoing efforts the World Bank and its development partners are making in sustainable development and climate change.

Cities are now on the frontlines of managing change and leading the global development agenda. It is only through cities that poverty reduction, economic growth, environmental sustainability, and climate change challenges can be addressed together. Sustainable city planning, development, and management, can unite these objectives and link them to activities at local, regional, national, and global levels. We believe the Eco² Cities Program will further enable cities to make the most of their opportunities in effective, creative, and holistic ways, thereby ensuring a more meaningful and sustainable future.

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Preface

This book provides an overview of the 'Eco² Cities: Ecological Cities as Economic Cities' Program. The objective of the Eco² Cities Program is to help cities in developing countries achieve greater ecological and economic sustainability.

What do we mean by Ecological Cities?

Ecological cities enhance the wellbeing of citizens and society through integrated urban planning and management that fully harnesses the benefits of ecological systems, and protects and nurtures these assets for future generations.

Ecological cities value their own ecological assets as well as the regional and global ecologies they depend on. Through their leadership, planning, policies and regulations, institutional measures, strategic collaborations, urban design, and holistic long-term investment strategies, they drastically reduce the net damage to the local and global environment—while simultaneously improving the overall wellbeing of their citizens and the local economy. Ecological cities also learn from and incorporate management and design solutions from the efficient self-organizing strategies used by ecosystems.

What do we mean by Economic Cities?

Economic cities create value and opportunities for citizens, businesses, and society by efficiently utilizing all tangible and intangible assets, and enabling productive, inclusive, and sustainable economic activity.

Often, when people talk about economic cities, they are referring to a narrower definition of 'productive' cities, driven by a singular emphasis placed on the indicator of GDP. While productivity is certainly a fundamental attribute of economic cities, it is not the only one, and often the short term and excessive pursuit of productivity or profit displaces fundamental social and cultural considerations, and might undermine longer term economic resilience. In some cases, productivity overshadows our basic value systems, and exposes us to substantial risk—as is evidenced in the causes and consequences of the current global economic crisis. In the Eco² Cities program, we propose a more balanced notion of economic cities—where the emphasis falls on sustainable, innovative, inclusive, and resilient economic activity, within the context of a larger cultural and value system.

So what do we mean by an Eco² City?

As the name implies, an Eco² City builds on the synergy and interdependence of ecological and economic sustainability and their fundamental ability to reinforce and strengthen each other in the urban context.

Innovative cities have demonstrated that with the appropriate strategic approach they can greatly enhance their resource efficiency by realizing the same value from a much smaller and renewable resource base—while simultaneously decreasing harmful pollution and unnecessary waste. By doing so, they have improved the quality of life of their citizens, enhanced their economic competitiveness and resilience, strengthened their fiscal capacity, and created an enduring 'culture' of sustainability. At the same time, many of their interventions have also provided significant benefits to the poor. Urban sustainability of this kind is a powerful and enduring investment that will pay compounding dividends. In a fast-paced and uncertain global economy, such cities are most likely to survive shocks, attract businesses, manage costs, and prosper.

It is with the purpose of enabling cities in developing countries to realize this value, and to take on a more rewarding and sustainable growth trajectory while the window of opportunity is still open to them, that the Eco² Cities Program has been developed.

How does the Eco² Cities Program work?

The World Bank's Eco² City program is a broad platform that will provide practical and scalable, analytical and operational support for cities in developing countries to achieve ecological and economic sustainability.

The issuing of this book marks the completion of the first phase of the Eco² Cities Program—the development of the analytical and operational framework. This framework can be adapted by cities in developing countries to systematically work toward and accomplish the positive results mentioned above. The analytical and operational framework is rooted in four key principles. These are 1) 'A City Based Approach,' which enables local governments to lead a development process that takes into account their specific circumstances, including their local ecology; 2) 'An Expanded Platform for Collaborative Design and Decision Making,' that accomplishes sustained synergy by coordinating and aligning the actions of key stakeholders; 3) 'A One System Approach,' that enables cities to realize the benefits of integration by planning, designing, and managing the whole urban system; and 4) 'An Investment Framework that Values Sustainability and Resiliency,' by incorporating and accounting for life cycle analysis, the value of all capital assets (manufactured, natural, human, and social), and a broader scope of risk assessments in decision making.

Through these principles are derived a set of core elements. Using the analytical and operational framework, each city can operationalize the core elements into a series of concrete action items or 'stepping stones,' that should take into account local conditions, in a logical sequence. Together these stepping stones enable a city to develop its own unique Eco² action plan, called an Eco² Pathway.

In this context, an Eco² City is a city which formally accepts the four key principles, applies the analytical and operational framework to its particular context, and by doing so develops and begins to implement its own Eco² Pathway.

Clearly, taking on all the core elements simultaneously may not always be possible for all cities. Many cities will probably need to take an incremental or phased approach. Often, cities may begin by engaging in capacity building and by targeting their most critical priority through the development and implementation of an Eco² Catalyst project. Unlike stand alone projects in resource efficiency, what will distinguish an Eco² Catalyst project is its explicit objective and ability (beyond its immediate project scope and objectives) to drive the city forward on its Eco² Pathway by catalyzing a process of change.

How will the Eco² Cities Program Evolve?

The second phase of the Eco² program has begun with the release of this book, and will focus on the application of this framework in specific pilot cities.

Application in the real world will initially require strong efforts and commitment. It will require political will, leadership, capacity building, collaboration, institutional reform, and even a new process for creative design and decision-making. However, the successful application of such a program will leave behind a legacy—as it has already done in the inspiring cases you will encounter through this book. The Eco² Program is intended to provide the support that cities will need to make their own transition. It brings together a network of partners and practitioners, who share in the Eco² philosophy, and who can all contribute to the process in their own capacities.

It will be important that the first set of pilot Eco² Cities demonstrate strong political will and city leadership. A fundamental issue in the second phase is to ensure that the first set of pilot cities provides a genuine and strong opportunity to mainstream Eco², and to effectively implement changes. Diversity between the conditions and contexts of the first set of pilot cities (city size, geographic conditions, socio-economic conditions, institutional framework, fiscal capacity, etc.) will also be important. This will provide a broader and richer platform on which to apply the Eco² framework, and thereby enable the program to learn from and assess its value-added in different circumstances.

It is evident that a city-by-city approach will be important as we pilot Eco², and learn from the ground level experiences of each case. However, given the magnitude and rate of ongoing urbanization, we will not be able to achieve the desired global impact within the window of opportunity that currently presents itself, if we limit ourselves to a city-by-city approach. Accordingly, the third phase of Eco² will aim at mainstreaming and scaling up the Eco² Cities Program through institutionalized national programs.

As we continue to work towards our common objectives, the Eco² Cities Program will evolve and grow as new knowledge, methods, tools, and resources become available. As we forge new partnerships and work with more cities, new possibilities and innovative ideas will continue to present themselves. The Eco² Cities Program will constantly work to incorporate these in an inclusive, iterative, and purposeful way.

The Structure of this Book

This book is divided into three parts.

Part One is the framework for Eco². It describes the approach, beginning with the background and rationale. Key challenges are described, and lessons are drawn from cities which have managed to turn these challenges into opportunities. A set of four key principles are introduced. The program is then developed around these four principles. Each of the principles is addressed in separate chapters that describe the core elements of the program, and the stepping stones that each city can follow as they develop their own unique Eco² 'pathway.' Part One concludes with an overview of some of the ways in which cities can draw on the resources of various development partners as they embark on their Eco² pathways.

Part Two of the book is a City-based Decision Support System that introduces a set of core methods and tools to help cities as they develop their own Eco² pathway, and work towards applying some of the core elements and stepping stones outlined in Part One. Part Two looks into methods for collaborative design and decision-making, and methods to create an effective long-term framework that can align policies and actions of stakeholders. Part Two then looks into material flow analysis, as well as the use of layered maps to facilitate a more integrated approach to urban infrastructure and spatial planning. Techniques for life cycle costing are described, and specific tools are referenced. Finally, Part Two introduces methods for forecasting workshops and resiliency planning. It is expected that as the Eco² program grows, there will be greater depth of information generated to enrich the City-based Decision Support System.

Part Three of the book is a 'Field Reference Guide' that contains background literature designed to support cities in developing more of an in-depth insight and fluency with the issues at two levels. This section provides a city-by-city and sector-by-sector lens on urban infrastructure. It begins with a section on a series of case studies from best practice cities around the world. Each city offers the program a very different example of how various elements of the Eco² approach can be applied. Most of these cities have already agreed to be a partner in the Eco² Cities Program. The next section comprises of a series of Sector Notes, each of which explores sector specific issues as they pertain to urban development. The sectors include: energy, water, transport and solid waste. This section also includes a note on the management of the spatial structure of cities. Together, these sector notes provide insight on how each sector functions, and on how they currently interrelate with each other. As we view these issues from a city-by-city and sector-by-sector lens, a bigger picture starts to emerge. Part Three also includes a final section on some of the specific financial instruments of the World Bank.

While the first two parts of this book address the Eco² Cities Program directly, the Field Reference Guide provides the background on current best practices, and a full scope of policies, specific measures, and institutional structures which need to be considered. Together, these three parts provide cities with an up-to-date survey of the terrain ahead, and guidance on how to move forward on an Eco² pathway. This book is a conference edition that lays out the scope of Eco², and should be viewed as an evolving document, particularly Parts Two and Three. We will soon be launching the Eco² Cities program website at www.worldbank.org/eco2, which will provide detailed and updated information on a regular basis.

Executive Summary

Challenges and Opportunities

Urbanization in developing countries may be the single greatest change in our century. It is projected that developing countries will have tripled their entire built-up urban area between 2000 and 2030—from 200,000 square kilometres to 600,000 square kilometres.[1] These 400,000 square kilometres of new urban built up area, which are being constructed within just 30 years, equals the entire world's total built up urban area as of 2000.[2] One could say we are building a 'whole new world' at about 10 times the speed, in countries with severe resource constraints (natural, fiscal, administrative, and technical). We are doing so in an increasingly globalized context with many new, constantly fluctuating, interlinked, and uncontrollable variables.

So what is driving the massive rates of urbanization described above? Historically, and across most regions, urbanization has propelled the growth of national economies. On average about 75 percent of global economic production takes place in cities, and in developing countries this share is now rapidly increasing.[3] In many developing countries, urban shares of GDP already surpass 60 percent.[4] In most regions of the world, the opportunities provided by urbanization, have enabled large segments of the population to lift themselves out of poverty.

However, urbanization at this rate and scale is certain to be accompanied by unprecedented consumption and loss of natural resources. Calculations already show that if developing countries urbanize and consume resources as developed countries have, an ecological resource base as large as 4 planet earths would be needed to support their growth.[5] But, of course, we have only one Earth. As the underlying resource base required to sustain such a transition does not exist, cities in developing countries, as well as ones in developed countries, must find more efficient ways to meet the needs of their populations.

It is clear that if we are to absorb and sustain this powerful wave of urbanization, while continuing to manage the existing built stock, we will need a paradigm shift. Fundamental questions to be addressed are: How can cities continue to effectively harness the opportunities for economic growth and poverty reduction offered by urbanization, while also mitigating its negative impacts? How can cities do so given the speed and the scale at which this urbanization is progressing, and given their own capacity constraints? How can ecological and economic considerations be dovetailed, so that they result in cumulative and lasting advantages for cities? How do we go from 'Eco vs. Eco' to 'Eco^2 Cities'?

Innovative cities have demonstrated that with the appropriate strategic approach they can greatly enhance their resource efficiency by realizing the same value from a much smaller and renewable resource base—while simultaneously decreasing harmful pollution and unnecessary waste. By doing so, they have improved the quality of life of their citizens, enhanced their economic competitiveness and resilience, strengthened their fiscal capacity, and created an enduring 'culture' of sustainability. At the same time, many of their interventions have provided significant benefits to the poor. Urban sustainability of this kind is a powerful and enduring investment that will pay compounding dividends. In a fast-paced and uncertain global economy, such cities are most likely to survive shocks, attract businesses, manage costs, and prosper.

What is most encouraging about the efforts made by these innovative cities is that many of the solutions are affordable—even when budgets are limited—and they generate returns, including direct and indirect benefits for the poor. At the same time, much of the success can be achieved using existing and well proven methods and technologies, and by focusing on home-grown localized solutions.

The challenge that lies ahead is to take full advantage of the many opportunities created by the rapid rates of change and by successful innovations. Inappropriate institutional structures and mindsets are commonly cited as the single greatest challenge when cities try to implement such opportunities. Best practices do exist for long term planning and regional growth management, and an emergence of new tools for systems analysis and mapping offer potential for more integrated, practical, and rigorous analysis and planning. Methods for collaborative design and decision-making among key stakeholders have also proven effective. Realizing that successful cities are often fundamental to successful nations, higher levels of government are increasingly key partners in helping cities take initiative.

There is also growing concern and commitment at the international level for supporting cities and for financing longer-term investments within cities. New funding opportunities have emerged for cities in developing countries that are willing to implement actions to achieve sustainable urban development—particularly measures promoting energy and resource efficiency that lead to GHG emission reductions. New accounting methods for estimating the full costs and benefits of various policy, planning, and investment options are also being used (e.g., Life Cycle Costing). At the same time, accounting for all capital assets (manufactured, natural, social, and human) and the services they provide, offers a more holistic and complete incentive framework to cities. Channelling these opportunities toward the massive scale and accelerating pace of urban development creates the potential for tremendous positive impact.

It is with the purpose of enabling cities in developing countries to benefit from the promise of a more rewarding and sustainable growth trajectory while the window of opportunity is still open to them, that the Eco^2 Cities Program has been developed.

The Analytical and Operation Framework

The Eco^2 analytical and operational framework is rooted in four key principles. Cities will face challenges when trying to adopt a new approach. These challenges have been carefully anticipated in the framework, and together with the valuable ground level lessons from best practice cities they help to frame our strategic response: the key principles that will define the Eco² Cities Program. Each of these has been elevated to status of principle, because it is widely applicable, critical to success, and frequently ignored or under-appreciated.

These four principles are 1) 'A City Based Approach,' which enables local governments to lead a development process that takes into account their specific circumstances, including their local ecology; 2) 'An Expanded Platform for Collaborative Design and Decision Making' that accomplishes sustained synergy by coordinating and aligning the actions of key stakeholders; 3) 'A One System Approach' that enables cities to realize the benefits of integration by planning, designing, and managing the whole urban system; and 4) 'An Investment Framework that Values Sustainability and Resiliency' by incorporating and accounting for life cycle analysis, the value of all capital assets (manufactured, natural, human, and social), and a broader scope of risk assessments in decision making.

The four principles are interrelated and mutually supportive. For example, without a strong city-based approach, it is very difficult to fully engage key stakeholders through an expanded platform for collaborative design and decision-making. And without this expanded platform, it is difficult to explore creative new approaches to the design and management of integrated systems, and to coordinate policies to implement through the one system approach. Prioritization, sequencing, and effectiveness of investments in sustainability and resiliency will be greatly enhanced by appreciating the city as 'one system' and expanding the platform of collaboration.

Through these four key principles are derived a set of core elements that further define the Eco² Framework. Cities are encouraged to operationalize the core elements into a series of concrete action items or 'stepping stones,' that take into account local conditions, and follow a logical sequence. Together, these stepping stones enable a city to develop its own unique Eco² action plan, called an Eco² Pathway. The Eco² Cities program also introduces cities to methods and tools that will lead to more effective decision-making through powerful diagnostics and scenario planning. These methods and tools can also be used to operationalize the core elements and to implement the stepping stones.

In this context, an Eco² City is a city which formally accepts the four key principles, applies the Analytical and Operational Framework to its particular context, and by doing so develops and begins to implement its own Eco² Pathway.

PRINCIPLE 1: A City-Based Approach

A city-based approach is the first principle, and it carries two complementary messages. Firstly, it recognizes that cities are now at the front lines of managing change and leading an integrated approach. Not only do cities now embody the engines of economy and the homes of citizens, they also are responsible for a majority of resource and energy consumption, and harmful emissions. Only at the city level is it possible to integrate the many layers of site specific information, and to work closely and rapidly with the many stakeholders whose input can impact the effectiveness of an Eco² Pathway, and who have a stake in its successful implementation. In addition, fiscal and administrative decentralisation has brought important decision making and management responsibility to local governments. Cities can exercise proactive leadership, and thereby trigger a process of change.

Secondly, a city based approach serves to emphasize the importance of incorporating within any development program the unique aspects of place—especially ecological systems. In this sense, a city-based approach responds to opportunities and constraints of local ecologies. How might development fit into the topography of the area so that water is provided by gravity, and so that drainage is provided by natural systems (reducing the need for expensive infrastructure investments and related operation costs)? How might a city protect its water recharge areas and wetlands, so that water capacity and quality are sustained? How do we distribute populations and design cities so that local or regional renewable energy—windy sites, forests, solar access—is sufficient to meet basic needs? These types of questions may ultimately provide urban professionals with their most exciting design challenge: how to fit cities into the landscape in ways that respect and complement the natural capital, and ensure ecological services are available for present and future generations.

A city-based approach is thus very place specific, with a focus on enabling local leadership, local ecologies, and the broader local context. In fact, one of the first stepping stones of a city will be to review and adapt the Eco² framework to the local context.

PRINCIPLE 2: An Expanded Platform for Collaborative Design and Decision-making

Cities are increasingly experiencing a splintering of infrastructure responsibilities, the overlapping and intersection of jurisdictions, and an increase in private sector ownership of key assets. If cities are to lead the process of urban development, especially in the context of rapid urbanization, it is important to get ahead of this curve.

A city can lead a collaborative process on at least three tiers of an expanded platform. At the first tier, projects may be completely within the realm of control of the city administration itself, and will entail a city getting its own house in order—for example, by supporting an energy efficiency upgrade for all municipally-owned buildings, or a ride-share program for employees, or energy and transport peak load management by adjusting working hours. At the second tier, projects will involve the city in its capacity as a provider of services and include its formal planning, regulatory, and decision making powers—this can include water provision, land use planning, or transit development. At this level, greater collaboration is warranted with other stakeholders (including the private sector and consumers) who can influence, and who might be impacted by, the outcomes. The third tier of the expanded platform will entail collaboration at the scale of the entire urban area or region—this can pertain to issues like the development of new land or metropolitan management—and may necessarily involve senior governments, key private sector partners, and civil society.

A core element of the triple tier platform for collaboration is a shared long-term planning framework for aligning and strengthening the policies of both the city administration and key stakeholders, and for guiding future work on Eco² projects. In this way, triple tier collaboration can get everyone rowing in the same direction.

PRINCIPLE 3: A One-System Approach

The One System Approach is about taking full advantage of all opportunities for integration by learning to view the city and the urban environment as a complete system. Once we see the city and the urban environment as a system, it is easier to design the elements to work well together. This can mean enhancing the efficiency of resource 'flows' in an urban area through integrated infrastructure system design and management. For example, the looping and cascading of energy or water through a hierarchy of uses can satisfy many demands with the same unit of supply.

The One System Approach also includes integrating urban 'form' with urban 'flows' by coordinating spatial development (land use, urban design, and density) with the planning of infrastructure systems. For instance, new development can be directed to those locations with a surplus of water, energy, and transit. Urban form and spatial development also establish the location, concentration, distribution, and nature of demand nodes that impact the design of infrastructure system networks. By doing so, urban form establishes the physical and economic constraints and parameters for infrastructure system design, capacity thresholds, technology choices, and the economic viability of different options. This has tremendous implications for resource use efficiency.

It is a challenge, and a huge opportunity, for any city to integrate the planning of flows and forms, and operationalize initiatives. The One System Approach also focuses on how to implement projects using a more integrated implementation approach. This means sequencing investments so that the city sets the correct foundation by addressing the long-lasting, cross cutting issues first. This also means creating a policy environment that enables an integrated approach, co-ordinating a full range of policy tools, collaborating with stakeholders to align key policies, and targeting new policies to reflect the different circumstances between urbanization in new areas and improving existing urban areas.

Integration can apply to the elements within a sector, or across sectors. It can apply to implementation policies, collaboration of stakeholders and their plans, sequencing of financing mechanisms, and all of these in combination! In every case, the integration of elements tends to reveal opportunities for greater efficiency, synergy, and increased utility from a given investment, with corresponding improvements in ecological and economic performance.

By applying the One System Approach, cities, and their surrounding natural and rural areas, can strive to coalesce into a functional system that works well as a new whole.

PRINCIPLE 4: An Investment Framework that Values Sustainability and Resiliency

The simple concept of investing in sustainability and resiliency for cities has become extremely difficult to put into action. Policies, plans, and projects tend to be assessed on their short term financial returns, or on an economic valuation based upon narrowly structured cost benefit analysis, from the perspective of a single stakeholder or project objective. Investments are valued in monetary terms, and what cannot be monetarised is either ignored, or addressed on the side as 'externalities.' Decisions are dominated by immediate capital costs, despite the fact that often over 90 percent of lifecycle costs for typical infrastructure are expended during operational maintenance and rehabilitation.

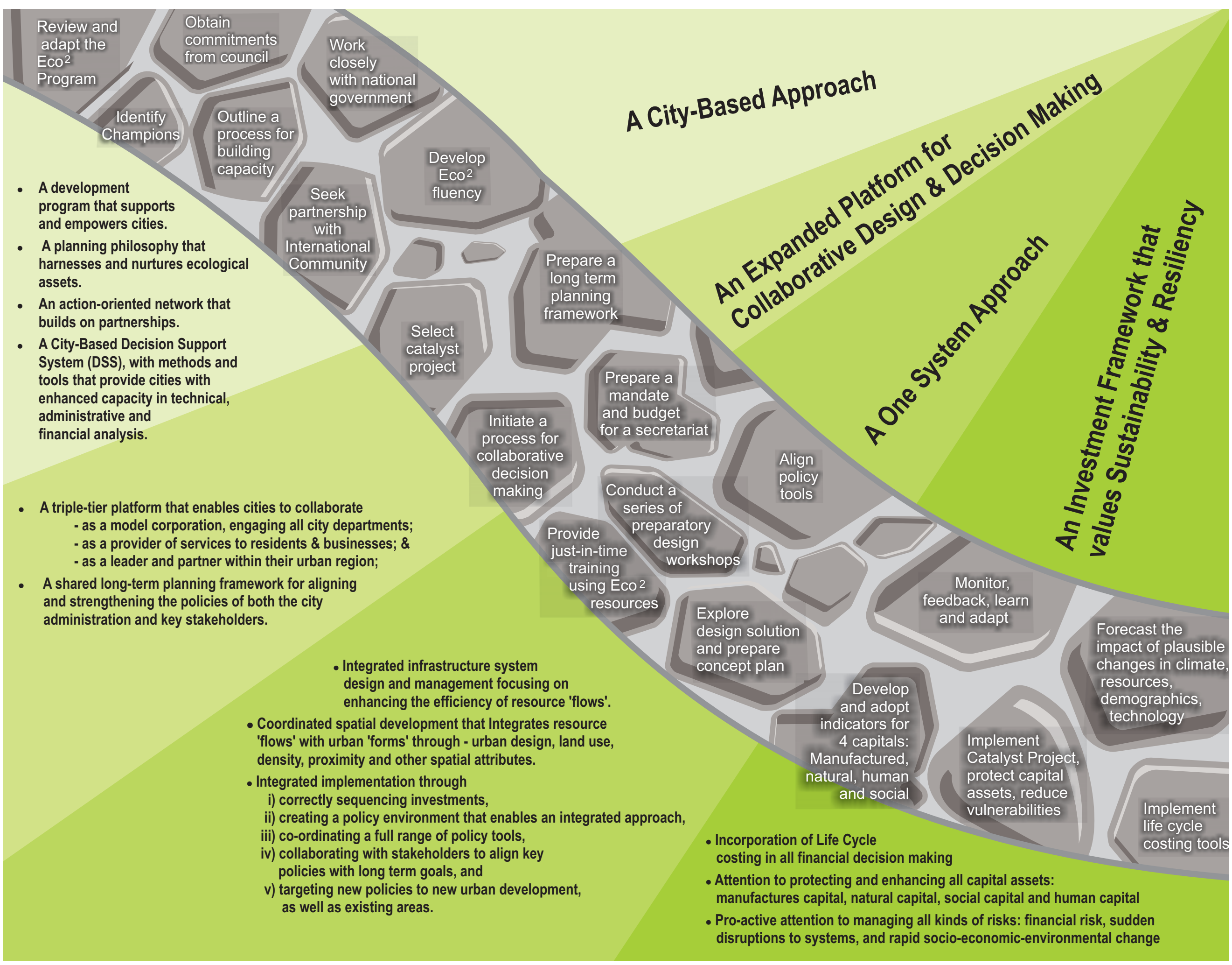
Few cities worldwide have a real knowledge of the impact of new development on their long-term fiscal condition. Lifecycle costs are often back-loaded, which means that future generations will have a massive infrastructure deficit, as they face costs for repair and replacement of infrastructure without any prior capitalisation.

At the same time, ecological assets, the services they provide, and the economic and social consequences of their depletion and destruction are not accounted for in most government budgets. Since these assets are not measured, they are treated as zero value—and their services go unaccounted for. Principle 4 requires that cities adopt a new framework for making policy and investment decisions.

The framework has multiple elements. A new range of indicators and benchmarks must be adopted for assessing and rewarding performance of all stakeholders. The family of indicators must address the needs of different categories of decision-makers (e.g., strategy evaluation vs. operational). Longer time horizons are needed, and life-cycle cost-benefit analysis must be applied to understand full implications of policies and investment options. All four categories of capital assets (manufactured, natural, human, and social) and the services they provide must be appropriately valued or priced—and monitored through indicators. The combination of indicators should be viewed as a whole so that the qualitative dimensions of city life (cultural, historic, and aesthetic) cannot be ignored when assessing costs and benefits.

At the same time, investing in sustainability and resiliency will entail broadening our scope of risk assessment and management to include managing the many indirect, difficult to measure risks that nonetheless threaten the viability of an investment or even the city as a whole.

These principles described above underlie the Eco² approach. Using the Analytical and Operational Framework, a city can apply the principles through a set of core elements, and use these elements to create a phased, incremental Eco² Pathway. The Eco² Pathway of each city will be designed in consideration of its own needs, priorities, and capacities. While the Analytical and Operational Framework enables a city to chart out its Eco² Pathway, the City-Based Decision Support System (DSS) introduces the methods and tools that provide cities with the capacity to undertake more integrated development—and better navigate this pathway.



A City-Based Decision Support System

The City-Based Decision Support System introduced in Part Two of this book, is part of the Eco^2 Program, and enables cities to better develop their capacity to operationalize some of the core elements of the Eco^2 Program. It comprises a few core methods that together provide cities with a greater ability to implement the core elements of the four principles listed above.

The fundamental purpose of these methods is to simplify the process of analysis, assessment, and decision-making. They provide practical ways for cities to take leadership, collaborate, and analyze and asses various ideas for Eco^2 projects. All methods are proven approaches to getting the work done. They are expected to remain relevant for many years.

The chosen methods support the typical planning process at different times and in different ways. Some methods can be used repeatedly. For example, meta-diagrams that summarize resource flows can be used firstly as a way to baseline how a location is currently performing, and then later to help with diagnosing, target setting, scenario development, and also cost assessment.

As an illustration, 'Methods for Analyzing Flows and Forms' reveal the important relationships between spatial attributes of cities (forms) and their physical resource consumption and emissions (flows). The combination of these analytical methods helps cities to develop a 'transdisciplinary' platform to analyze current situations as well as forecast scenarios.

One of the first Stepping Stones on the Eco^2 Pathway is to plan a process for capacity building. Reviewing the DSS is a good place to begin. It sets out the scope of skills and knowledge that are an essential part of Eco^2. While this book simply introduces the core methods, the capacity building plans of a city can include obtaining more information, acquiring specific tools, obtaining outside technical support, and applying the methods to a catalyst project.

A Field Reference Guide

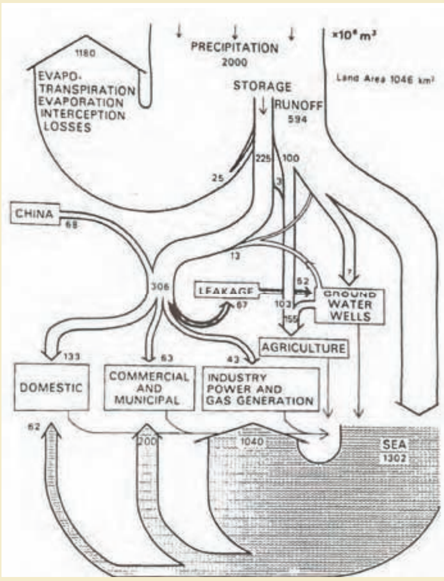
The Eco^2 Field Reference Guide provided as Part Three of this book, is a technical resource specially tailored to building ground level and technical knowledge. It contains background literature designed to support cities in developing more in-depth insight and fluency with the issues at two levels. It provides a city-by-city and sector-by-sector lens on urban infrastructure. It begins by exploring a series of case studies from best practice cities around the world. Each city offers the program a very different example of how various elements of the Eco^2 approach can be applied. Some of these cities have already agreed to be a partner in the Eco^2 Cities Program, and to assist cities in developing countries with their specific challenges.

The field reference guide also provides a series of Sector Notes, each of which explores sector specific issues as they pertain to urban development. As cities develop their Eco^2 Pathways, it helps to survey issues through the lens of each urban infrastructure sector. Ideally, this leads to a kaleidoscopic view of the city, where each perspective can be turned to the next, as we interrelate *energy, water, transport,* and *solid waste* with each other and with the built form of the city.

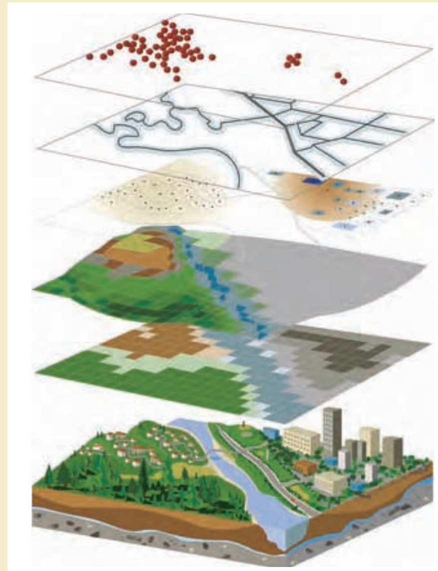
It becomes clear as we study these sectors that many of their operational and jurisdictional lines impede innovation and creativity in achieving better outcomes. What is also clear is that investments made in one sector can result in savings in another sector (for example, investments in water efficiency usually result in large energy cost savings), and that pooling scarce resources to invest in multifunctional and multipurpose common elements can benefit everyone (for instance, through single purpose underground infrastructure corridors).

The Sector Notes shed light on critical sector-specific issues that have an impact on city sustainability, but are not under direct

Combining Flows and Forms to create a Transdisciplinary Platform



This flow diagram summarizes all the water flow through Hong Kong, and is one of the first illustrations of an urban metabolism.[a]



FLOWS: Materials Flow Analysis and Sankey Diagrams

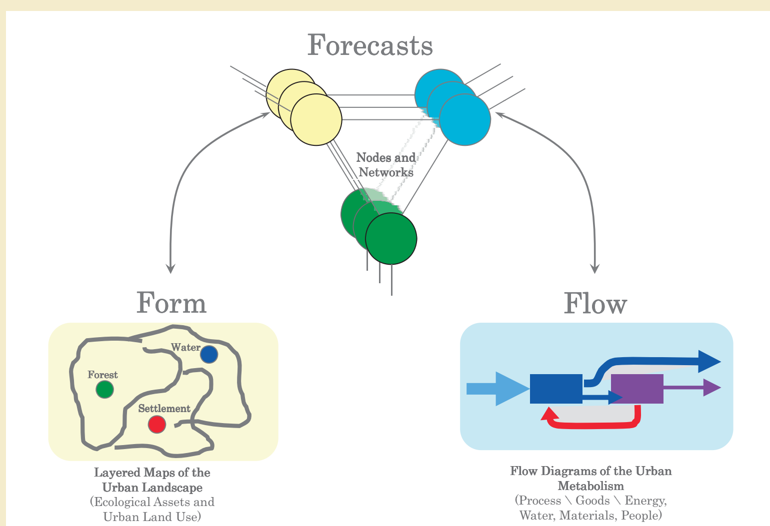
This is a method for calculating and illustrating the flow of resources through any size of urban area. Inputs and outputs are determined as a resource is extracted from nature, processed by infrastructure, consumed by home and businesses, treated by infrastructure, and finally returned for re-use, or delivered back to nature as waste. Colourful and simple diagrams are used to educate everyone on the resource flows, and how effectively they are used, all on a single page.

FORMS: Layering of Information on Maps

Maps are especially useful in collaboration, since they speak so well to so many: a picture is worth a thousand words. The layers of information make it possible to immediately interrelate the different features and qualities of the landscape, and also to easily quantify important spatial relationships. Layering is an old technique that has become more powerful as a result of computer technology and satellite imagery.

INTEGRATING FORMS AND FLOWS: A Transdisciplinary Platform

Because diagrams and maps can be easily understood and shared by a broad range of professionals and decision-makers, they help to bring stakeholders and experts together, facilitating a common understanding of integrated approaches to design and decision-making. Both forms and flows should be analyzed and understood for current and future scenarios. The methods in combination form a 'transdisciplinary' platform for understanding both the spatial dynamics of a city and its physical resource flows—elements that are interdependent but difficult to integrate because they involve such different skill sets and stakeholders.



A platform is needed to integrate the design concepts for urban form with the corresponding resource flows.

Source: Redrawn and Adapted from Baccini P, & Oswald F 1998: Netzstadt, Transdisziplinare Methoden zum Umbau urbaner Systeme. Zurich, Switzerland: vdf Hochschulverlag Zurich control of city authorities. These issues may need to be addressed on a sector by sector basis—in collaboration with key stakeholders, particularly higher levels of government. Identifying critical pressure points beyond the direct control of city authorities is also important to devising an expanded platform for collaboration.

The guide also provides a strategy for managing the spatial structure of cities, and important lessons on how spatial planning and land use regulations can powerfully impact mobility and affordability.

Moving Forward Together

As forward-looking cities in developing countries develop and implement their own Eco^2 pathways, support may be available from best practice cities worldwide, the international community, including development agencies, and academia. Cities are encouraged to tap into the unique resources of each of these partners. In this context, the World Bank Group[6] together with other development partners is in a position to provide Technical Assistance and Capacity Building and Financial Support to cities that demonstrate strong political will and commitment to implement the Eco^2 program.

PART 1

The Framework

Opportunities and Challenges, Principles and Pathways

CHAPTER 1

Ecological Cities as Economic Cities

Challenges and Opportunities

This chapter outlines the key issues driving the urgent need for a new approach to urban planning, development, and management. While all of the transformations occurring can be seen as threats, they also can be perceived as opportunities for rapid and widespread adoption of a new approach to design, decision-making, and investment. By reviewing a few case studies, this chapter demonstrates the tangible benefits of cost effective approaches that have led to greater ecological and economic sustainability in cities. It also clarifies some commonly held misconceptions about urban sustainability, and concludes that cities should invest in and capitalize on opportunities. As you will see, if acted upon correctly, the changes now underway offer new opportunities to achieve the sustainability and resiliency of urban development for generations to come.

The Scale and Rate of Urbanization is Unprecedented

Urbanization in developing countries may be the single greatest change in our century. It is projected that developing countries will have tripled their entire built-up urban area between 2000 and 2030 from 200,000 square kilometres to 600,000 square kilometres.[7] These 400,000 square kilometres of new urban built up area, which are being constructed within just 30 years, equals the entire world's total built up urban area as of 2000.[8] One could say we are building a 'whole new world' at about 10 times the speed, in countries with severe resource constraints (natural, fiscal, administrative, and technical). We are doing so in an increasingly globalized context with many new, constantly fluctuating, interlinked, and uncontrollable variables.

For the first time in history, more than half of the world's population, or 3.3 billion people, reside in urban areas. This is expected to grow to almost 5 billion by 2030.[9] Over 90 percent of this urban growth is taking place in developing countries. By the middle of the century, Asia alone will host 63 percent of the global urban population, or 3.3 billion people.[10] Cities in East Asia housed about 739 million people in 2005.[11] They will need to accommodate another 500 million by 2030.[12]

The growth of the urban population is accompanied by an increase in the number and size of cities. There were about 120 cities with over one million inhabitants in 2000. This figure is projected to increase to more than 160 by 2015.[13] The World will have 26 mega cities—cities with populations of more than 10 million—by 2025. Developing countries in Asia will host twelve of them.[14] An important issue characterizing this growth is that 50 percent of all urban growth is occurring in medium and smaller sized cities of less than 500,000 people. Over the next decade, half of the increase in urban population in East Asia is projected to be absorbed by these cities.[15]

These population statistics imply a massive investment in manufactured capital, including building stock, urban infrastructure, and land development. The implications of the strategic urban approaches chosen and the infrastructure decisions made within the next few years will no doubt have consequences for generations to come. While a more integrated approach does represent a challenge, it also represents an opportunity for much improved efficiency of urban systems that will last for generations.

Cites are Engines of Economic Growth

So what is driving the massive rates of urbanization described above? Historically, and across most regions, urbanization has propelled the growth of national economies. On average about 75 percent of global economic production takes place in cities, and in developing countries this share is now rapidly increasing.[16] In many developing countries, urban shares of GDP are already surpassing 60 percent.[17]

The competitiveness of cities is determined by a variety of factors, including geography, national policies, city leadership, market forces, and capital inflows. Historically, nature and geography (altitude, topography, and climate, as well as proximity to coasts, rivers, borders, and natural resources) have often been the triggering factor in the development of cities. National policies also play an important role in determining and facilitating the growth of cities by deciding on the location, quality, and connectivity of key infrastructure investments, which in turn further influence the investment and location decisions of private capital. These together enable and generate a range of economic activity and diversification which leads to population increases through rural-urban migration and productivity gains. In the context of increased globalization, the roles of trade and foreign investment are increasingly recognized as other factors driving the growth of the cities. It has also been observed that as cities transition swiftly to a high value, knowledge based economy, their critical and competitive advantage is their ability to attract, retain, and invest in human capital.[18] Under these circumstances, a city's ability to provide a business enabling environment (such as good infrastructure, favourable policies which reduce the cost of doing business, and connectivity to external markets), a good quality of life, and an environment that attracts and retains human capital (by providing strong social infrastructure and a clean, affordable and liveable environment) has become a critical determinant of the growth of cities.

As organizational systems, urban agglomerations provide unique opportunities due to scale—both economic and spatial. The supply of critical infrastructural services (physical and social), as well as the institutional and administrative organization upon which much economic development and social welfare are predicated, become financially viable and reach economies of scale in cities. At the same time, geographic proximity reduces transaction costs and achieves economic efficiencies by creating concentrated markets of labour, capital, and goods. This encourages growth, diversification and innovation in the provision a wide range of goods and services, and the spill over of knowledge and skills critical to the creation of new ideas. Cities also serve as concentrated markets for the agricultural output of their rural hinterlands.

It is not simply the concentration of activities that makes cities attractive: it is also the diversification and intensification of activities which eventually make cities resilient, competitive, and dynamic. Besides, in addition to the spatial dimension, cities have a temporal dimension. To remain relevant and competitive, successful cities continue to evolve. The waterfront manufacturing land uses of many older industrial cities have now been converted into high-end residential and financial sector real estate. Through the vastly improved global telecommunications and internet infrastructure, it is now possible for large segments of the service sector (whose products and services can be transferred across the globe at the speed of light) to access consumer and labour markets at the click of a button. This will pose interesting new possibilities for human settlement and employment patterns. Although global economies based upon cities have occurred at various times throughout history, never before has a global economy achieved anything like the current reach: almost no city today operates outside of the global economic system, and every city finds a place in the network of cities.

It is because of the transformative forces of agglomeration economies that countries in East Asia are also undergoing a major shift in economic activities and employment patterns from agriculture to industry and services, accompanied by a diversification of the economy within sectors. Concentration of economic production in urban areas is particularly significant in East Asia. The more dynamic coastal regions of China produce more than half of the country's GDP with less than one fifth of its land area.[19] Concentration of GDP is not proportional to that of population. For instance, Bangkok accounts for 40 percent of national GDP but only 12 percent of Thailand's population. Such imbalances are commonly observed in other major Asian cities—for instance, Manila (31 percent of national GDP but 13 percent of national population), Ho Chi Minh City (29 percent and 6 percent) and Shanghai (11 percent and 1 percent).[20]

Poverty Within and Around Cities is a Challenge

In most regions, the opportunities provided by urbanization have enabled large segments of the population to lift themselves out of poverty. The United Nations Population Fund has examined this relationship in 25 countries and concluded that urbanization has contributed significantly to poverty reduction. For instance, 28.3 percent of Bolivia's poverty reduction between 1999 and 2005 was attributable to urbanization.[21] It is no wonder the poor have continued and will continue to migrate to urban areas in search of better lives. However, while urbanization has led to economic growth and helped to reduce poverty, urbanization alone has not been able to eradicate poverty. Urban poverty and inequality exist despite the concentration of income in cities.

Slums represent the worst of urban poverty. Individuals and communities living in slums face severe inadequacies in the most basic human requirements, such as shelter, land, water, safe cooking fuel and electricity, heating, sanitation, garbage collection, drainage, paved roads, footpaths, street lighting, etc. Largely because of inadequate supply of serviced land at affordable prices, often caused by unrealistic regulatory standards imposed on land (and chronic administrative deficiencies), poor households are unable to access land and housing through legal channels. The poor are thereby forced to live in ramshackle and flimsy settlements on environmentally sensitive areas (slopes, low-lying areas), along railway lines and roads, close to hazardous industrial facilities, and often close to the city's ecological resources. At the same time, since basic urban services are not provided, slum dwellers often live in the worst conditions, and they often have no choice but to pollute the land and water resources where they live. Industries often pollute freely and dangerously in slum areas, since the disenfranchised residents have little access to legal, financial, or political recourse. In many cases, these living conditions are life threatening; slums are significantly more susceptible to floods, landslides, diseases, exposure to toxic industrial waste, indoor air-pollution, fires, etc.

Slums increased substantially in the 1990s when urban population in developing countries grew faster than the capacity of cities to support them. More than 810 million people, or more than one-third of the developing countries' urban population, lived in slums in 2005.[22] About 64 percent of them, or 516 million people, live in Asia.[23] UN-Habitat projected that if no firm and concrete actions are taken, slum dwellers will increase to about two billion in the next 25 years.[24]

Besides being inequitable and unconscionable, slums also threaten the wellbeing of other residents in a city by destroying collective ecological assets and by increasing the risks of water borne and infectious diseases. Slums are also a visible symbol of social exclusion.

While cities have had a significant impact on economic productivity, they can do more to address the very crucial issue of urban poverty, particularly the problem of slums. Migration to urban areas is increasing, driven by the promise of a better future.

The flip side of urban migration is the loss of population in many rural areas and hinterland communities. While people are 'pulled' from the countryside by the promise of wealth, they are also 'pushed' from their traditional communities due to uncontained urban growth and an almost complete absence of effective, complementary rural planning. Thus the slum problems and excessive pace of urban growth are to some degree also a symptom of poor rural planning and inadequate investment in rural development. The solution is to adopt a more integrated approach spatially, engaging rural areas in a long-term collaborative exercise for rural-urban linkages and urban growth management.

Continued Urbanization is Impossible Using Standard Practices

Urbanization at the rate and at the scale described earlier is certain to be accompanied by an unprecedented consumption and loss of natural resources. Calculations already show that if developing countries urbanize and consume resources as developed countries have, it will take a resource base as large as 4 planet earths to support the growth.[25] Even more surface area would be required if farmers were required to fallow their fields and regenerate soils, and if biodiversity was to be sustained. But of course we only have one Earth. The underlying resource base required to sustain the transition going on in developing countries does not exist, unless these cities, and developed cities as well, find more efficient ways to meet the needs of their population.

In addition to resource inefficiency, 'business as usual' urbanization and economic growth

Source of Earth Photos: NASA

generate enormous quantities of waste and pollution which impose heavy environmental, social and (eventually) economic costs at the local and global scale. Much of this cost is localized and realized within the city itself: through significantly diminished human health and wellbeing caused by pollution (of air, water and land), the destruction of ecological assets, a growing fiscal burden, and reduced long term economic competitiveness. It is often the poor who suffer most from localized pollution and unhealthy living conditions, as they cannot access safe places to live. Such issues are of immediate concern to city leaders, who wish to improve the wellbeing of all their citizens, provide a stable and attractive environment for businesses, protect and capitalize on their ecological assets, and enhance their own fiscal strength.

Poor management of wastewater and inadequate solid waste management have become major environmental and health hazards in cites of many developing countries. In addition the World Health Organization estimates that more than one billion people in Asia are exposed to outdoor air pollutant levels that exceed WHO guidelines. For instance, a recent joint study of the Chinese Government and the World Bank estimated that the cost of ambient air pollution in China's urban areas amounted to about US$63 billion in 2003, equivalent of 3.8 percent of China's GDP in 2003.[26]

There is also a substantial globalized cost of 'business as usual' urbanization. It is estimated that cities consume about 67 percent of global energy, and account for well over 70 percent of GHG emissions: the main contributor to climate change.[27] Heating and lighting in residential and commercial buildings generate nearly 25 percent of GHG emissions globally. This amount is as large as the amount generated through all agriculture and industrial activities combined. Transport contributes 13.5 percent of the global GHG emissions with road transport attributing 10 percent.[28] These emissions cause irreversible climate change, which seriously affects global ecosystems and the global economy as a whole, particularly disadvantaging poorer nations.

> A few forward-looking cities are now taking the issue of climate change very seriously. For instance, the City of Brisbane in Australia is comprehensively addressing this issue through its CitySmart program. Brisbane officials hope their experiences can pave the way for other cities (see Part Three to read more about Brisbane's initiatives).

According to the Stern report on consequences of climate change, business as usual scenarios could lead to a 5 to 10 percent loss in global GDP, with poor countries experiencing a loss of more than 10 percent of GDP. Taking the analysis a step further (beyond measures of losses in income and productivity like GDP), and looking into the costs of climate change (factoring direct health and environmental impacts, and amplifying/reinforcing feedbacks of such impacts and their outcomes) the business as usual assessment of the costs of the impacts and outcomes of climate change could reduce welfare by an amount equivalent to a reduction in consumption per head of between 5 and 20 percent. An accurate estimate is likely to be in the upper part of this range.[29] The report clearly states that "the impacts of climate change will not be evenly distributed; the poorest countries and people will suffer the most."

In essence, the economic, social and environmental externalities of 'business as usual' urbanization are unsustainable.

A Twin Challenge: The Existing as well as The New

It is clear that if we are to absorb and sustain the powerful wave of urbanization in developing countries, while continuing to manage the existing built stock, we will need a paradigm shift. Fundamental questions to be addressed are: How can cities continue to effectively harness the opportunities for economic growth and poverty reduction offered by urbanization, while also mitigating for its negative impacts? How can cities do so given the speed and the scale at which this urbanization is progressing, and given their own capacity constraints? How can ecological and economic considerations be dovetailed, so that they result in a cumulative and lasting advantage for cities? How do we go from 'Eco vs. Eco' to 'Eco² Cities'?

In general cities are confronting a twin challenge—that which is posed by their existing urban areas, and that which is posed by rapid new urban expansion.

In dealing with existing urban areas cities can use a range of measures to enable the existing built form to perform much more effectively. Examples of retrofitting measures include implementing end use efficiency in the energy and water sector, reducing reusing and recycling waste, and adapting existing transport infrastructure (roads) to be used more efficiently (for instance, by designating routes for bus rapid transit and lanes for bicycles). At the same time, cities can explore cost effective ways of re-modeling the distribution, density, and use of the existing built form by increasing the floor area ratio, allowing the transfer of development rights (TDR), implementing land readjustment programs, re-zoning and changing land use patterns, and, importantly, by revising and enforcing building codes and standards. Redevelopment projects at a larger scale for certain areas/districts of a city have also been successful in enhancing the sustainability of existing areas. Both retrofitting measures and redevelopment projects require holistic planning and coordination across sectors.

At the same time, cities are facing unprecedented rates of urban expansion, and are in danger of being locked into patterns of inefficient and unsustainable urban growth from which there is no easy return. In urban development, initial conditions form the bedrock for development at every scale, and impose powerful constraints on what might be accomplished as the city matures. Such initial conditions include the spatial development pattern, the built urban form and most related trunk infrastructure investments, which due to their size and permanence provide powerful constraints on many future options. This is typically referred to as Path Dependency. Such path dependency is also evident in the institutional architecture that evolves to support large complex infrastructure systems—this institutional architecture can then further reinforce and perpetuate growth of a particular kind. It is a tremendous prospect to be able to influence new urbanization and the growth of cities—getting things correct to begin with is much more cost effective than dealing with the situation later on. Being proactive can provide compounded economic, social, and ecological returns. Action taken at this critical phase in the growth of these cities can provide a defining opportunity to leap-frog into built-in systemic advantages in efficiency and sustainability. Timing and sequencing are crucial to ensure the lasting impact of coordinated interventions, maximize benefits and reduce long term externalities. There is an enormous opportunity cost to not acting at the correct time—and the correct time is now.

It is in the urgent interest of helping cities systematically capture this value, while the window of opportunity is still open to them, that the World Bank is proposing the Eco² City program.

Innovations in Urban Sustainability and their Benefits

It has been concretely demonstrated by some innovative cities that ecological sustainability and economical sustainability can significantly reinforce each other and benefit a range of stakeholders. One role of the Eco² Cities Program is to reflect on these examples, and find ways to transfer the lessons and successes to cities elsewhere. To begin the process, let us quickly review three different case studies. Each of these cases is presented in much more detail in Part Three of this book. The first is a case of implementing a successful integrated waste management program accomplished through systematic engagement with stakeholders—which has led to significant environmental and economic gains. The second is a case of integrated utility and resource planning and management through systematic stakeholder collaboration which leads to significantly greater life cycle benefits. The third is a case of well coordinated and comprehensive urban development as well as social and environmental programs. The last case demonstrates that cost is not a major barrier to ecological and economic urban planning, development, and management—and is an illustration of successful path dependency (spatial, institutional and cultural) in urban development.

Yokohama accomplishes large environmental and economic benefits through stakeholder engagement in integrated waste-management.

Yokohama, the second largest city in Japan, initiated an Action Plan called G30 in 2003 (G = garbage; 30 = 30 percent reduction in waste generation by FY 2010). The G30 Action Plan clearly identifies the responsibilities of households, businesses, and the government to achieve waste reduction by the '3R' (reduce, reuse, and recycle) method, and provides a mechanism for an integrated approach to waste reduction.[30] Environmental education and various promotional activities related to waste reduction were provided to enhance awareness and knowledge of people and business.

Yokohama had reduced waste generation by 38.7 percent from about 1.6 million tons in FY 2001 to 1 million tons in FY 2007[31] while its population increased by 166,000 during the same period.[32] This significant waste reduction allowed Yokohama to save US$1.1 billion of capital costs otherwise required for renewal of two incinerators. This also led to net savings of annual operation and maintenance costs of about US$6 million (US$30 million O&M costs of two incinerators minus US$24 million O&M costs of waste recycling operations).[33] Yokohama has two landfill sites. When the G30 was planned in 2003, it was anticipated that the residual landfill capacity of these two sites would be 100,000 m^3 by 2007. However, thanks to the waste reduction, the two sites still retained a capacity of 700,000 m^3 in 2007. The value of the saved 600,000 m^3 disposal capacities of two landfills is estimated to be US$83 million.[34]

It is calculated that this waste reduction between FY 2001 and FY 2007 resulted in about 840,000 tons of CO_2 emission reduction. This is equivalent to the amount that 60 million Japanese cedar trees can absorb annually. Approximately 600 km^2 (an area 1.4 times larger than the City) is needed to plant 60 million of Japanese cedar trees.[35] At the same time, if these emission reductions were certified and sold, they could provide an additional ongoing revenue stream through carbon finance.

Stockholm demonstrates that integrated planning and management through systematic stakeholder collaboration can lead to significantly greater life cycle benefits

In the ongoing redevelopment project of Hammarby Sjöstad (a southern city district in Stockholm), the city council of Stockholm had set out to be 2 times more sustainable than Swedish best-practice in 1995 (the environmental program was adopted in 1995) on a range of indicators—most notably energy efficiency per meter squared. In Sweden the average annual rate of energy use in some regular new developments is 200kWh/m^2, cutting edge practice produces an efficiency of 120kWh/m^2 [36], and the current project is aiming for 100kWh/m^2.Other targets set for the project include: water conservation, waste reduction and reuse, emissions reduction, reduced use of hazardous materials in construction, use of renewable sources of ener-

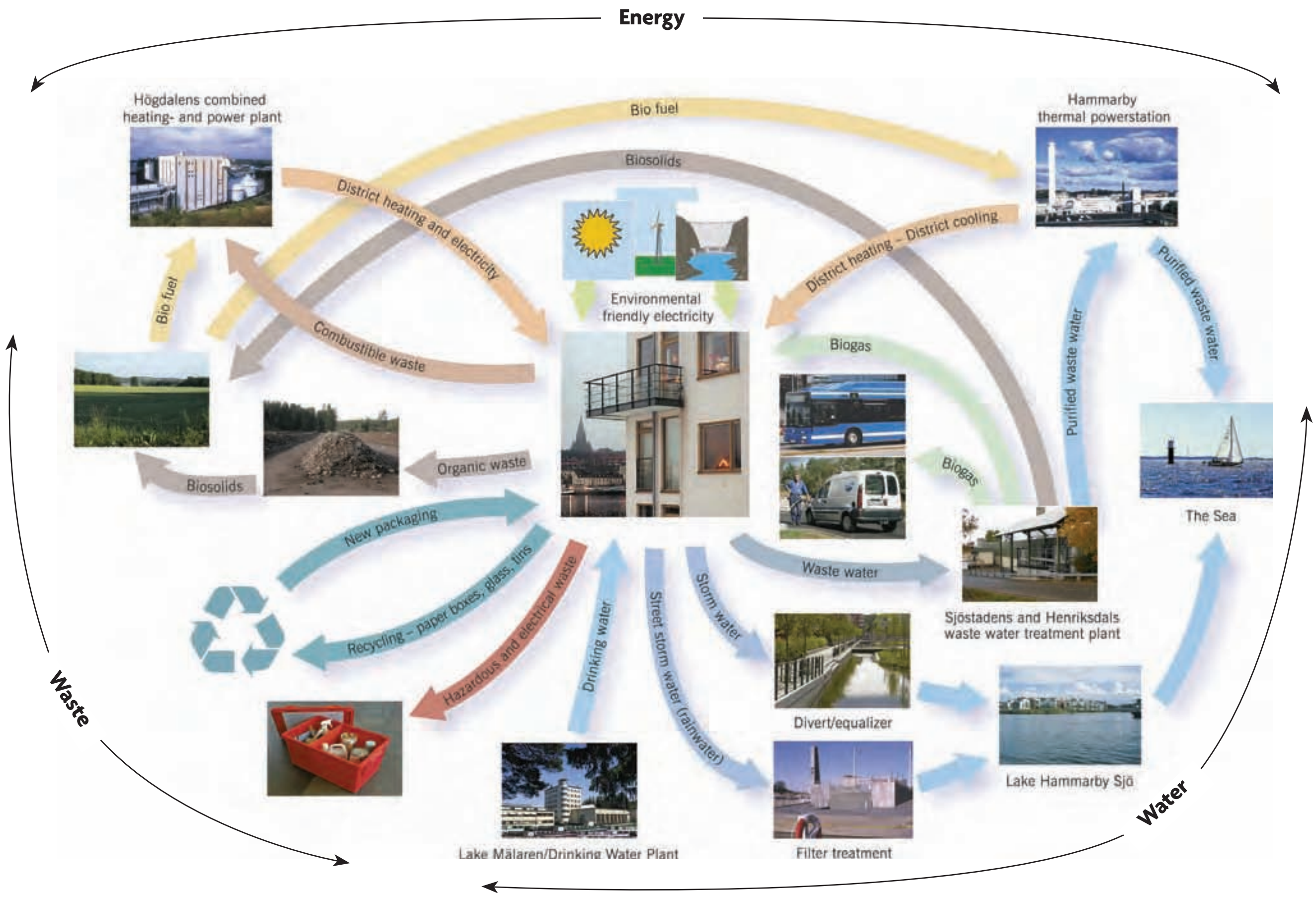


Figure 1.1. The Hammarby Model, Stockholm: An Example of Integrated Planning and Management[37]

gy, integrated transportation solutions, etc. Stockholm is already a sustainable city and the city council intended for this project to be a path breaking demonstration of sustainable methods of urban redevelopment. Hammarby Sjöstad is one among 3 'ecocycle' districts in Stockholm.

To accomplish the objectives set out by the city council, the three city departments of waste, energy, and water & sewage, collaboratively came up with the 'Hammarby Model.' The Hammarby Model is an attempt to turn the linear urban metabolism (consume resources on the inflow and discard waste through outflow) into a cyclic one, optimizing the use of resources and minimizing 'waste.' This model streamlines various systems of infrastructure and urban service delivery, and provides the foundation and blueprint for achieving the sustainability objectives outlined above.

Initial findings from the preliminary evaluations of the first phase of development 'Sikla Ude' (SU) as compared to a reference scenario (Ref), can be seen in Figure 1.2: a 30 percent reduction in non-renewable energy use (NRE), a 41 percent reduction in water use, a 29 percent reduction in global warming potential (GWP), a 41 percent reduction in photochemical ozone creation production (POCP), a 36 percent reduction in acidification potential (AP), a 68 percent reduction in eutrophication potential (EP), and a 33 percent reduction in radioactive waste (RW).

Success in a project like Hammarby Sjöstad depends on coordination between key stakeholders. To channel all efforts in a single direc-

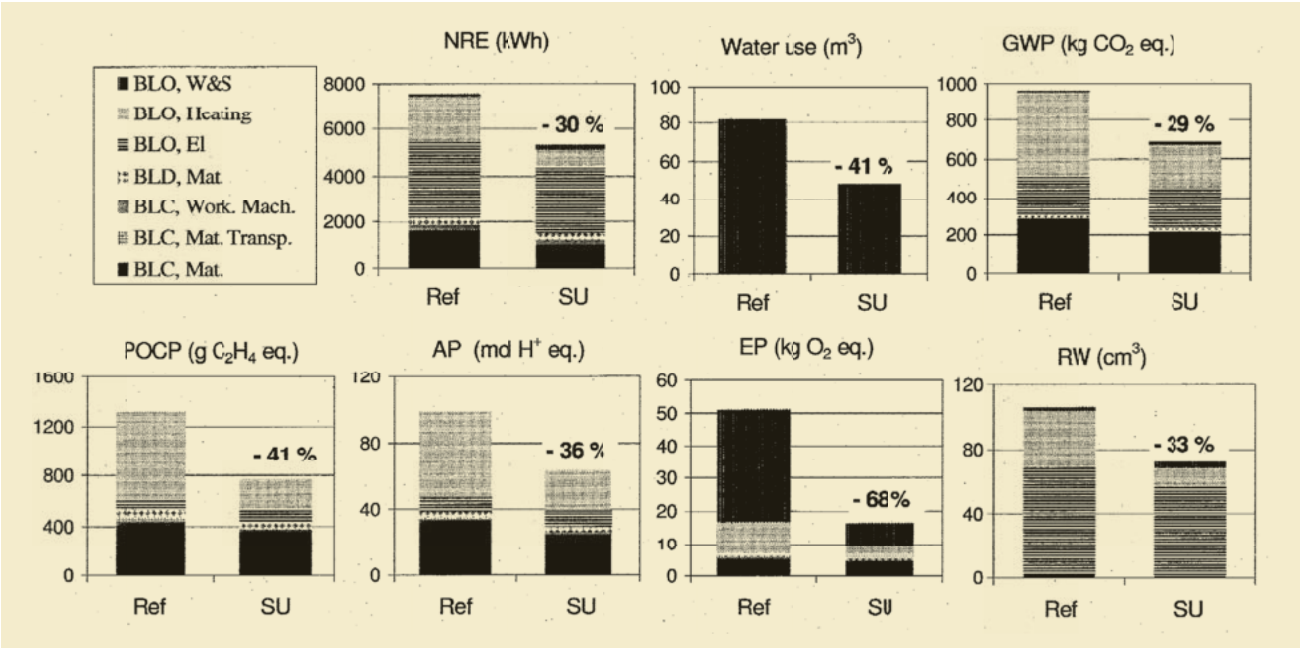


Figure 1.2. Initial First Phase Results of Hammarby Sjöstad by the Environmental Load Profile Life Cycle Analysis Tool[38]

tion, the city appointed a Project Team in 1997. In 1998, the Project Team was incorporated into the City's Department of Roads and Real Estate (now called the Development Department).[39] This move had several positive ramifications. First, by being housed in the city's Department of Roads and Real Estate, the Project Team had greater access to and control over public funds.[40] In addition, the Project Team was in a much stronger position to leverage and negotiate with private interests.[41] The structuring of the team itself was established as follows: the lead was taken by a project manager and an environmental officer, while representatives from the city departments of planning, roads and real estate, water and sewage, waste, and energy were also members of the team.[42] The various departments of the city were integrated into a single fabric led by a project manager and environmental officer who were charged by the city with the responsibility to "guide and influence all stakeholders, public as well as private, to realize the environmental objectives of the project."[43]

Curitiba's case demonstrates that cost is not a major barrier to ecological and economic urban planning, development and management—and is an illustration of successful path dependency (spatial, institutional and cultural) in urban development

Sustainable urban development has been successfully undertaken by forward-looking cities in developing countries, with relatively limited fiscal resources, too. Consider the case of Curitiba, Capital of Parana State of Brazil. Through its innovative approaches in urban planning, city management, and transport planning since the 1960s, Curitiba has been able to sustainably absorb a population increase from 361,000 (in 1960) to 1,797,000 (in 2007) on what was initially a very limited budget. It has provided critical urban services with a wider coverage and smaller ecological footprint than many cities with much greater fiscal resources at their disposal. At the same time by doing so, Curitiba has expanded its own fiscal capacity and economic base—and has gained an identity as one of the best examples of ecological and economic urban development.

The most significant planning decision made by Curitiba was to grow from the city core in a radial linear-branching pattern, opening up the city, while still preserving its density and protecting green areas. This was in contrast to the typical concentric, ad-hoc development. In order to encourage effective linear urban growth along major structural axes (rather than extensive sprawl), Curitiba pursued incremental development of an integrated bus system. Land use and zoning simultaneously encouraged higher density commercial and residential development along each structural axis. The colour-coded bus system is designed for various scales and levels of service (inter-district, feeder, inter-municipal, etc.), and is integrated as a whole system with the land use plan.

As a consequence, Curitiba has the highest rate of public transport rider-ship in Brazil (45 percent). This resulted in Curitiba having one of Brazil's lowest rates of urban air pollution. Fuel loss due to traffic congestion in 2002 was US$930,000, compared to US$13.4 million in Rio de Janeiro. By contrast, in 2000, congestion in 75 metropolitan areas in the United States caused fuel and time losses valued at US$67.5 billion.[45] If these areas were planned and developed more efficiently, a major portion of this annual recurring loss and harmful emissions could be avoided.

In the 1950s and 1960s, Curitiba suffered from persistent flooding as construction and development was proceeding at a fast pace. Additional drainage canals would be required at an enormous cost. However, by setting aside land for drainage and putting low-lying areas off limits for development, the city managed to tackle the costly flooding problem—and avoided huge capital costs for flood control and drainage.[46] The city turned these areas into parks planted with many trees, and created artificial lakes to hold floodwaters. Buses and bicycle paths integrated the parks into the city's transportation network.[47] This is an excellent example of how ecological assets and green infrastructure can be integrated into urban design. The cost of this strategy, including the relocation costs of slum dwellers, is estimated to be five times less than building concrete canals. Also, as a result, the property values of neighbouring areas appreciated, as did tax revenues.

A 'Transfer of Development Rights,' which allowed developers to transfer their rights to develop land from locations the city desired to pre-

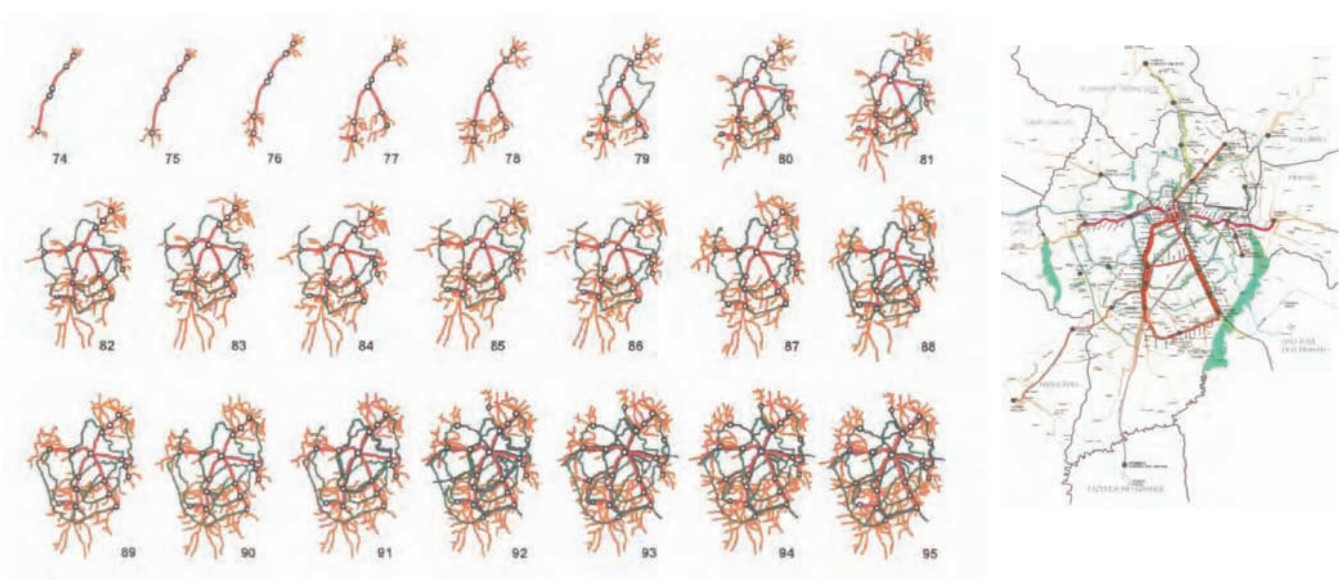


Figure 1.3. The Integrated Transport Network in the 1970s to 1990s, and Today.[44]

serve to locations which the city desired to develop, provided incentives and tax breaks for preserving green areas as well as historic and cultural heritage sites. At the same time, Curitiba preserved its vibrant urban density along the axes of growth: population density increased from 1,410 persons/km^2 to 4,161 persons/km^2 between 1970 and 2007, as the green area per person increased from 1 km^2 to 51.5 km^2 .

Much of the success of Curitiba can be attributed to its Institute for Research and Urban Planning of Curitiba, also known as IPPUC. Founded in 1965, IPPUC is a powerful 'Municipal Independent Public Authority,' and serves as the research, planning, implementation, and supervision agency in Curitiba. The IPPUC enabled coordination of different elements of urban development and was the most important factor in ensuring continuity and consistency in the planning process through successive city administrations. Its imaginative and integrated urban planning, development, and management solutions significantly reduced the inefficiencies associated with piecemeal development.

Jaime Lerner, who contributed to drafting the 1966 Master Plan and worked as President of the IPPUC in 1969 and 1970, was elected mayor of Curitiba three times (1971–75, 1979–83, and 1989–92). He is widely known as one of the most popular, creative, and successful mayors in Brazil, whose influence has spread globally. He has won many awards (from the UNEP, UNICEF, International Institute for Energy Conservation, Prince Claus Awards of Netherlands, and so on).

The current administration has also achieved wide-ranging success by taking on innovative new projects with a sustained focus on social, environment, and urban planning issues through substantive consultation with public audiences. Mayor Carlos Richa, who began his administration in 2004, enjoys very high popularity, as can be seen by his 77.27 percent approval rating when he was reelected Mayor of Curitiba in October 2008.

Powerful Lessons from Best Practice Cities

One of the most powerful lessons derived from stories like Yokohama, Stockholm, and Curitiba is that many of the prevalent misconceptions about urban sustainability efforts have no sound basis in fact.

Many solutions are affordable—even when budgets are limited—and they generate returns

Often one of the biggest and most prevalent misconceptions is that such measures are not affordable, and that they do not generate significant returns. As concretely demonstrated by Yokohama and Curitiba, this is certainly not the case. Many creative, practical and cost effective solutions can simultaneously achieve greater benefits than the business as usual scenarios. Another example might further help to underscore this lesson. The municipality of Emfuleni (South Africa) initiated an energy and water savings project and achieved savings of some 7 billion litres of water and 14 million kWh per year. At a cost of only US$1.8 million, the project saved over US$4 million each year, giving the project a payback period under 6 months. Since the contract was financed and implemented by an energy service company (ESCO), the municipality not only saved large sums of money because of reduced water losses and pumping costs, but also did not have to pay for the investment upfront. The ESCO, on the other hand, recouped its investment quickly by sharing in part of the cost savings.[48]

Ample evidence like this demonstrates that actions to improve energy and resource efficiencies can bring about strong fiscal and economic gains. At the same time, solid waste management in many medium sized cities can account for 40 to 50 percent of the total municipal budget.[49] Programs like the one in Yokohama can be powerful illustrations of the significant returns that can be achieved and the capital costs that can be avoided. For cities and utilities looking for ways to meet budget shortfalls or save municipal expenditures for worthy social pursuits (such as extending tap water services, waste collection and treatment or street lighting coverage to slums), there is no better place to look for new funds than cost savings from resource use efficiency.

At the same time, good and well coordinated urban planning, land policies, and an appropriate spatial layout can provide strong and sustained long term and compounding economic, social, and ecological returns. Effective urban planning and land policies can help integrate the urban poor into the economic, social, and physical fabric of the city—proving economically beneficial to cities, national governments, and the urban poor. The financial costs required for good planning are not significant. However, sustained commitment and investments in maintaining strong technical, administrative, and institutional capacity are required.

When designed and implemented appropriately, policy and regulatory measures can also generate environmental, fiscal, and economic gains. Households and businesses are major determinants of energy and resource consumption and the levels of waste generation, and their savings can be translated into economic and fiscal gains for a city as a whole. Since the mid-1970s, California's energy efficiency policies, consisting of standards, research and development, and utility improvement programs, have held per capita electricity use constant while the Unites States as a whole has increased per capita electricity use by nearly 80 percent. This has generated substantial savings from consumers, households, and businesses in California.[50] Over the past three decades, California consumers have saved more than US$50 billion from appliance and building efficiency policies alone. Educational programs and awareness campaigns can also influence consumption patterns without spending a lot of resources.

Significant success can be achieved using existing, well proven technologies, and appropriate new technologies

Best practices suggest that success is not so much about new technologies as it is about appropriate technologies. Expensive hydrogen fuelled cars are less relevant to most cities than increasing the length of bicycle and pedestrian-friendly pathways. Simple technology solutions like insulation of homes or water saving faucets can often generate much more cost effective savings than many 'new' technologies.[51] That said, many of the new technology options are often mistakenly considered commercially unviable because: 1) the true cost-benefit analysis from a lifecycle point of view has not been carried out; and 2) sometimes new technologies have to compete with embedded subsidies that their competitors are benefitting from. (An example of this is the high implied subsidy to automobiles by way of free and cheap parking on public lands, and extensive highway construction). The simple solution is sometimes to embrace appropriate new technologies through: 1) bulk procurement by city and partners; or 2) incubating them through phased subsidy schemes until economies of scale bring down local prices; and/or 3) public awareness campaigns. In cases where local production can fill the need, the impact on Local Economic Development can be a significant valued added. Manufacture and installation of efficient technologies helps to circulate money within the community—generating and retaining new local employment instead of exporting money to purchase water or energy commodities. Countries like Sweden and Denmark have invested in incubating new technologies and are now reaping the rewards. There is now a growing international demand for much of their technological expertise.

Developing countries should take pride in developing home-made solutions

In many cases, cities in developing countries perform significantly better on sustainability indicators than their counterparts in 'developed' countries. It is important to remember that most energy and resources are consumed, and waste generated, in developed countries. Cities throughout the West are locked-in to development patterns—such as existing building heights and set-backs, parking allocations, street widths, road patterns, and so on— that cannot easily be changed. Usually the best approach for a developing country is to learn from these mistakes, rather than repeat them. In fact, many 'developed' countries have a lot to learn from cities like Curitiba. As cities in developing countries grow in size and affluence, they should first look at successful examples of cities like Curitiba. Then they should learn from best practice examples of developed country cities, while being sure to learn from their failures as well. For instance, European cities consume much less energy, and are significantly more ecological and well planned when compared to North American cites—even though the level of development of the two regions is similar. This is partly the result of the environment-friendly city-level and national or EU policies that promote clean energy and energy efficiency. Also, Europeans have higher energy prices, and have historical and cultural preferences for compact urban form and high quality public transport. This is a result of regulations requiring automakers in Europe and Japan to produce cars that are much more fuel efficient than those in the United States. By thoroughly selecting and combining actions suitable to their capacity and needs, cities can best achieve their objectives with home grown solutions.

> "A case study from Dhaka illustrates the potential for improving conditions for urban poor through interventions in urban environment. Waste Concern, an NPO, works with the city government and succeeded in reducing emissions in Dhaka by composting solid waste instead of burning or flaring, and then selling it to fertilizer companies. It is helping to reduce 52 percent of generated solid waste that remains uncollected in Dhaka. The city provides public land for community composting. Waste Concern facilitates with the city to collect house-to-house solid waste in rickshaw bicycles, and bring it to processing plants. Organic waste is separated from other rubbish. Waste is composted into enriched bio-fertilizers. Waste Concern arranges for fertilizer companies to purchase and nationally markets the compost-based fertilizer. This can create 16,000 new jobs for the poor of Dhaka, and 90,000 new jobs for the poor across Bangladesh.

Many solutions can benefit the poor indirectly and directly

Fiscal gains for cities and utilities can free up room for social investments and thus indirectly benefit the poorest segments of the urban population. Furthermore, because poor people are so dependent upon land policies and urban services, many planning measures taken by cities can offer direct and substantial benefits. For example, regulatory reform, effective urban planning, and land use policies have a powerful direct impact on improving the situation of the poor by reducing the prices for land and housing. The poor may also benefit directly from more public transportation, pedestrian access and bicycle paths; improved water access, sanitation and electricity connections; provision of safe cooking fuels; and energy efficient light emitting diodes (LED) lights in slums. Better environmental standards for industrial pollution will strongly enhance the living conditions of the poor. Innovative programs like the Orangi Pilot Program in Karachi, Pakistan, which involved the poor directly in a community based sanitation construction project, offered jobs to families and achieved extremely cost effective construction of local sanitation networks which link to the trunk lines of the city. The money and the services both contribute to Local Economic Development, generating local employment and income, improving local environmental conditions, increasing local home values, and creating local ownership in neighbourhoods.

Capitalizing on the Opportunities

The challenge that lies ahead is to take full advantage of the many opportunities created by rapid rates of change and by successful innovations. Best practices do exist for strategic long-term planning and regional growth management, and an emergence of new tools for systems analysis and mapping offer potential for more integrated, practical, and rigorous analysis. Realizing that successful cities are often fundamental to successful nations, higher levels of government are key partners in helping cities take initiative. There is also growing concern and commitment at the international level for supporting cities and for financing investments enabling ecological and economic sustainability within cities. New funding opportunities have emerged for cities in developing countries that are willing to implement actions to achieve sustainable urban development—particularly measures promoting energy and resource efficiency that leads to GHG emission reductions. New accounting methods for estimating the full costs and benefits of various policy, planning, and investment options are also being used (e.g. Life Cycle Costing). Channelling these opportunities toward a massive scale and accelerating pace of urban development create potential for tremendous impact.

An increasing number of cities have initiated actions to achieve greater ecological and economic sustainability according to their own visions, needs, and capacities. Limited resources or capacities do not discourage these cities. Some cities demonstrate strong leadership in pioneering new approaches, some use well established approaches and excel in the implementation of these approaches, and some work with the international community to learn from best practices and invest in technical, institutional and administrative capacity.

It is with the purpose of enabling cities in developing countries to benefit from the promise of a more rewarding and sustainable growth trajectory while the window of opportunity is still open to them, that the Eco^2 Cities Program has been developed. The Chapters ahead provide a detailed framework that can be adapted by cities in developing countries to systematically work towards and accomplish many of the positive results discussed so far.

CHAPTER 2

Eco² Cities: Principles and Pathways

The previous chapter explored the many opportunities offered to cities as a consequence of change. It also used examples of best practice drawn from cities worldwide to illustrate the potential environmental and economic benefits associated with the innovative approaches. If the knowledge and means exist to design and implement such measures, and if practical and powerful solutions have been demonstrated even for cities with very limited budgets, then why are other cities not taking advantage of these opportunities? Why are these examples so rare?

This chapter will begin with a brief overview of the many challenges that cities face when trying to adopt a more integrated approach. Most readers will be familiar with these challenges—they are unfortunately very common—and a detailed accounting is unnecessary. However the challenges are worth highlighting at this time because together with the valuable ground level lessons from best practice cities, they help to frame our strategic response: the key strategies and principles that will define the Eco² City Program.

After reviewing challenges, this chapter describes a set of four overarching principles that provide the scope and direction for all elements of the Eco² Program. Adopting these principles represents the first step towards the Eco² approach. Basically, the principles are proven strategies that can help cities seize new opportunities, overcome challenges, and transfer best practices to every new project

At the end of this chapter a summary table is provided of the Eco² approach. The principles are translated into a number of core program elements, and an example is provided for how any city might operationalize the program in a step by step fashion, and create its own unique Eco² Pathway.

Cites are Challenged on Many Fronts

Limited Resources

In general, cities in developing countries face significant capacity constraints—administrative, technical and financial. Cities are further challenged by the rapid pace of new urbanization. For such reasons, city staff tend to focus their attention on chronic problems, and on the day to day and sector to sector problems that are piled on the front counter. Ask any city administrator, and you hear the same story: no time exists to take on long-term plans or cross-cutting agendas like Eco².

Misinformation

Another reason for lack of initiative is that the lessons described in Chapter One have not been widely shared or understood. Instead, many local decision-makers operate under a series of myths and false assumptions. Solutions like Eco² are perceived as demonstration projects, rather than a permanent, alternative approach to planning, developing, and managing cities. They are assumed to be costly, dependent upon advanced and complex technology, and practical only for wealthy neighbourhoods and well-resourced city administrations. This attitude is exacerbated by the all-too-common assumption that the most advanced approach to city building is to import the styles and technologies used by a majority of western cities—rather than building on local culture and ecology.

Correcting misconceptions may need to be one of the first 'stepping stones' in a city's Eco² Pathway.

Institutional barriers

Inappropriate institutional structures and mindsets are commonly cited as the greatest challenges when cities are considering implementing integrated solutions. Some of the most obvious examples include:

- *Fragmentation of responsibilities;* Separate budgets, timelines and goals; piecemeal solutions that serve individual interests well, but that—in combination—are precisely wrong.
- *Excessive specialization* and overwhelming complexity; silos of expertise; incomplete perspectives on urban resource use and associated costs.
- *Single purpose funding mechanisms* that fail to address cities directly, or that fail to address the urban system as a whole, or that fail to link program objectives to priority issues in a city.
- *Lengthy and challenging political processes* for allocating funding at all scales.
- *Short–term and narrow accounting formats* that ignore indirect costs and benefits, separate capital costs from operating and maintenance costs, fail to capitalize the replacement of systems, do not take into account all capital assets (manufactured, ecological, human and social) and risks, and mislead investors as well as citizens.

'Locked-in' relationships among networks of public and private institutions and existing technologies

Some dimensions of urban planning reflect a complex set of entrenched relationships between many different organizations, public and private. Because some groups benefit from the status quo, they actively promote more of the same, and create obstacles to investment in alternatives.

A well-know example is the 'highway lobby' which represents everyone who makes money from roads, and which has been accused of promoting massive investments in road building regardless of societal costs and alternative technologies.

Cities commonly become locked-in to certain technologies as a result of their past capital investments in facilities and the on-

> "Techno-Institutional Complex(TIC) arises because large technological systems, like electricity generation, distribution and end use, cannot be fully understood as a set of discrete technological artefacts, but have to be seen as complex systems of technologies embedded in a powerful conditioning social context of public and private institutions.
>
> TICs develop through a path-dependent, co-evolutionary process involving positive feedbacks among technological infrastructures and the organizations and institutions that create, diffuse and employ them. Once locked-in, TIC are difficult to displace and can lock-out alternative technologies for extended periods, even when the alternatives demonstrate improvements upon the established TIC."
>
> **Gregory Unhur, Understanding Carbon Lock-in, 2000**

going need to recover sunk costs and realize a return. If someone proposes to invest in demand side management, or to meet the need for services in other ways, the effect is to reduce the flow of revenues below what was projected; as a consequence, the existing facilities remain over-sized and may become economically unviable. This can happen whenever cities or their financial partners invest in new energy plants, water factories, waste-water treatment plants, solid waste transfer stations, and incinerators. Under such circumstances, it is common for cities to use policy to prevent innovative approaches. Public private partnerships, if not developed properly, are another common example of how cities can become locked-in to technologies by entering into contracts that guarantee a long-term demand for services of one type.

Human inertia

A new planning process that involves many planners and designers will certainly challenge the natural tendency of people—and professionals in particular—to resist change of any kind. Without a focused effort to manage change, human inertia will invariably reproduce the same patterns of land development, and exactly the same infrastructure, in city after city, all in accordance with 'standard practice.' It is difficult to change the mould. If conservative engineers are hired to consider a type of system they have never previously designed, they will invariably condemn the idea. While conservative engineers are in most respects the best kind to have, the process of preliminary engineering, or concept design, requires a much more open and innovative mindset—something that is difficult to find without engaging specialty firms, at added expense and risk.

The Continuing Dominance of 19th Century Models

Part of the difficulty with adopting a program like Eco² is that current design and planning practices for cities are rooted in patterns established in the 19th century, when an abundance of coal, combined with new manufacturing technologies, brought unprecedented increases in wealth and improvements in quality of life. By the beginning of the last century, millions of families in Europe and North America suddenly had access to clean water, sewage treatment, space heating, lighting, clean streets and public transit. This wave of societal progress and modernism was achieved through single-purpose, centralized, supply-oriented utilities that operated in silos, and capitalized on economies of scale, abundant resources, and open access to public goods like water and the atmosphere.

Hugely successful in their time, the 19th century models are no longer the best solution, and in fact have become part of the problem. The world is more crowded and complex, and requires much more efficient, longer-term solutions for servicing urban areas. Nevertheless, the 19th century models are integral to our professional training and institutional structures. A program that encourages a more integrated approach must overcome the inertia of past practice, and the natural resistance to change within established institutions and groups of practicing professionals.

A Principled Approach can Overcome the Challenges

The Eco² Program is designed on the premise that the many opportunities and challenges described so far can best be addressed through adopting a new set of four principles that can be used to guide the process of design, implementation, and financing of urban development. The principles function as 'super' strategies for cities in transition. The four Eco² Principles are: 1) 'A City Based Approach,' which enables local governments to lead a development process that takes into account their specific circumstances, including their local ecology; 2) 'An Expanded Platform for Collaborative Design and Decision Making' that accomplishes sustained synergy by coordinating and aligning the actions of key stakeholders; 3) 'A One System Approach' that enables cities to realize the benefits of integration by planning, designing, and managing the whole urban system; and 4) 'An Investment Framework that Values Sustainability and Resiliency' by incorporating and accounting for life cycle analysis, the value of all capital assets (manufactured, natural, human, and social), and a broader scope of risk assessments in decision-making.

Each of these strategies has been elevated to status of super strategy, or Principle, because it is:

- universally applicable;
- crucial to success (based upon the experience of best practice cities); and
- frequently ignored or under appreciated.

The four principles are interrelated and mutually supportive. For example, without a strong city-based approach, it is very difficult to fully engage key stakeholders through an expanded platform for collaborative design and decision-making. And, without this expanded platform, it is difficult to explore creative new approaches to the design and management of integrated systems, and to coordinate policies for implementing the one system approach. Prioritization, sequencing, and effectiveness of investments in sustainability and resiliency will be greatly enhanced by appreciating the city as 'one system' and through an expanded platform of collaboration.

The synergy between the principles will become much more apparent as we move into later chapters of this book. For now, let's explore each of the Eco² Principles, one at a time.

PRINCIPLE 1: A City-Based Approach

A city based approach is the first principle, and it carries two complementary messages. Firstly, it recognizes that cities are now at the front lines for managing change and leading an integrated approach. Only at the city level is it possible to integrate the many layers of site specific information and work closely and rapidly with the many stakeholders who need input into an integrated solution. In addition, fiscal and administrative decentralisation has brought important decision making and management responsibility to local governments. Secondly, it serves to emphasize the importance of incorporating within any development program the unique aspects of place, especially the ecological assets. Increasingly, cities depend upon their natural landscapes to provide food and recreation, capture and store water and energy, absorb wastes and satisfy many other needs. Protecting and enhancing ecological assets—the natural capital—is a priority when directing (and constraining) urban growth. A city based approach is thus very place specific, with a focus on enabling local leadership and local ecologies. Let's look at each of these in turn.

Depending upon size, cities are the most influential institutions within the modern state. Not only do they represent the engines of the economy and provide homes for a majority of the population, they also are responsible for a majority of resource and energy consumption and harmful emissions. Thus a city that works with its key sectors and stakeholders is especially well placed to explore Eco² solutions. Cities also have some critical instruments at their disposal, (zoning, permits, approvals, taxes, fees), and have been further empowered through fiscal and policy decentralization in many countries. It is not surprising, therefore, that almost all the case studies of Eco² solutions have occurred in cities that have taken leadership, and applied a city-based approach.

When a city takes leadership in setting priorities and implementing solutions, two factors appear to be critical: its level of commitment and its capacity to act. Decision-makers need to be convinced of the value of an Eco² approach, and they need to mobilize political support within their constituency. A city's success will depend upon how effectively and creatively it uses and develops the levers of influence within its control: these can range from its human & technical capacity and its knowledge of local realities, to its formal urban planning tools and municipal finance strategies. Often, in order to act effectively, a city may need technical, administrative and financial support, including knowledge, skills and tools.

A city's capacity to act will also depend on the levers of influence beyond its realm of control. Often its legislative, administrative, and fiscal powers are circumscribed by national or state level governments whose cooperation is crucial. At the same time, given the growing predominance of metropolitan areas which span the jurisdiction of more than a single city, it is often the case that coordination is required at the metropolitan level for optimal interventions within and across all sectors. Thus leadership by cities needs to occur at many levels, including the region.

> "The living city is not an island: its metabolism is interlinked to surrounding ecosystems and its people and culture networked to other viable urban cells to form a living and developing tissue, a net primary producer, not a parasitic system."
>
> **India-Goa 2100 Plan, 2003**

The city based approach is not only political, it is fundamentally ecological. Cities are centers of resource consumption, and ultimately resource efficiency will depend greatly on how well the city is integrated into the local and regional ecologies. City planning is firstly about protecting and regenerating the irreplaceable natural capital, especially the natural assets and ecological services throughout the urban region in which the city is located. All cities need to be fully integrated into a viable local ecology. The integration of cities into local ecologies can happen at all scales, from food gardens and nature-scaping to planning containment boundaries that effectively separate urban areas from natural areas.

Ideally the ecological elements mix and intersect within the city, and stretch throughout the city as a natural blue/green web, providing multiple services to the local economy. Ecologies and open green spaces serve as a kind of 'green infrastructure.' They might pollinate crops and orchards on behalf of the agri-food systems, or recharge aquifers on behalf of the water supply system, or channel wind toward open hilltops or water basins on behalf of the local energy utility. Green infrastructure may also serve to enhance the larger ecological systems.

PRINCIPLE 2: An Expanded Platform for Collaborative Design and Decision-making

As we have seen, one of the characteristics of resource efficient and well planned cities is their ability to capture synergies from integrated approaches, and to coordinate actions among multiple stakeholders over the long-term. An integrated approach and an alignment of policies is not something that is likely to emerge by default. The process requires a platform that is suitable for the expanded scope of activity.

Cities are dynamic phenomena. They emerge from the overlapping actions of many different groups of stakeholders—public sector, the private sector, civil society groups and citizens—each of which has influence over how elements of the city are designed and managed. Although none has the mandate or capacity to address the performance of the city as a system, they all stand to benefit when the elements are well integrated. However without a proactive effort to bring these stakeholders together, and to integrate plans and policies, the likelihood exists that some policies and actions will conflict, and that the costs of conflict will be borne by the economy and the environment. Even without direct conflict, the tendency for all stakeholders to act in their own immediate interests ignores the potential for positive synergies, and optimum solutions.

Cities are increasingly experiencing a splintering of infrastructure responsibilities, the overlapping and intersection of jurisdictions, and an increase in private sector ownership of key assets. An additional constraint is the election cycle, which can limit the capacity of cities—on their own—to execute policies over the long-term. The typical four-year election cycles for local governments essentially undermine sustainable decision-making, since the change in leadership frequently means a loss in continuity. If cities are to lead the process of urban development, especially in the context of rapid urbanization, it is important to get ahead of this curve.

A city can lead a collaborative process on at least three tiers of an expanded platform. At the first tier, projects may be completely within the realm of control of the city administration itself, and will entail a city getting its own house in order—for example, an energy efficiency upgrade for all municipally-owned buildings, or a ride-share program for employees, or energy and transport peak load management through the adjustment of working hours. At the second tier, projects will entail the city in its capacity as a provider of services and include its formal planning, regulatory, and decision-making powers—this can include water provision, land use planning, or transit development. At this level, greater collaboration is warranted with other stakeholders who can influence, and who might be impacted by, the outcomes.

The third tier of the expanded platform will entail collaboration at the scale of the entire urban area or region. This can pertain to issues like the development of new land, or metropolitan management, and may necessarily involve senior governments, key private sector partners and civil society. When collaborating at the scale of the entire urban area, the city itself may lack the authority to coordinate actions of many stakeholders. Senior governments, utilities, landowners, and private sector groups all have their own plans and agendas. At this level, it is often an appropriate process to develop an overarching planning framework, including a growth management strategy, which sets the context for all other plans in the urban area by all other stakeholders. At each of these scales, very different levels of collaboration are necessary and different working groups are required, all participating in a city-led collaborative process.

As a city embarks on its Eco² pathway, many different projects could occur over a single year in which different players from the private sector, public sector, civil sector and other sectors may wish to participate, or may have valuable information or assistance to offer at various levels. For this reason, it is important for a city to initiate a process where participants develop a shared long-term planning framework to guide all projects and efforts, and which creates the opportunity and vehicle for groups to align their policies and programs around a common set of long term goals and strategies. The framework can also set the context for specific projects. In many cases a primary collaborative working group can generate sub groups that meet as needed and that can also benefit from professional facilitation, research, and other support. The planning framework can be a powerful platform for collaborative design and decision-making and can enable the city to steer the efforts of all stakeholders toward a commonly agreed upon vision. Because Eco² focuses on integrated design solutions, as well as integrated implementation policies, projects may invariably expand to include multiple stakeholders and require a highly diverse pool of expertise.

Once the formal collaborative process is in place, it also offers the opportunity for much more intensive participation on particular projects amongst stakeholders in design and implementation. For example an integrated approach to neighbourhood revitalization can often benefit from iterative series of design workshops that engage a variety of experts from different groups in creative design exercises. Regular participation in such creative design workshops is much easier to arrange and approve if the groups who need to be involved are already participating in a formal collaborative process at the most senior level. The same is true when it comes to implementing the preferred design solutions. Essentially, an expanded platform for collaboration at different scales creates a mechanism that can be used repeatedly to bring stakeholders together, and to expedite the intensive, and interdisciplinary process of design and implementation of Eco² projects.

Finally, the expanded platform for collaboration, in combination with a long-term planning framework, is likely to increase the commitment by local governments to its longer-term policies. It is much more difficult for a new council or mayor to reverse decisions if many other stakeholders have participated in the decisions, and are cooperating through their own policy instruments. In the case of Curitiba, for example, the creation of a separate planning institute—the IPPUC—provided a particularly strong basis for on-going collaboration in long-term planning. This approach has now been followed in many other countries in Latin America. By extending the platform for decision-making to include planning institutes, and by encouraging alignment amongst all stakeholders, the governance of a city becomes less vulnerable to the inevitable disruptions created by elections, political incidents, and the manipulation of policy by special interest groups and swing voters at election time. An expanded platform for collaboration compensates for the inherent short-termism of the democratic process.

PRINCIPLE 3: A 'One-System' Approach

Chapter One offered a number of specific examples of system integration within cities—all of which led to sizable and lasting benefits. An integrated approach to planning and management in Stockholm helped to significantly improve resource efficiency in a large urban redevelopment project. In Yokohama, an integrated approach to waste reduction, reuse and recycling saved over a billion dollars for the city, with just as impressive environmental gains. In Curitiba, an integrated and holistic approach to urban planning, transportation planning, and socio-economic vitalization has enabled the city to achieve tremendous results across all sectors and for many stakeholder groups.

There are many more examples that you will encounter in this book. What distinguishes these cities from others is that they broadened their perspective to adopt a One System Approach, which they pursued largely through strategies of integration.

A One System Approach enables cities to plan, design, and manage the whole urban system by integrating and/or optimizing its key subsystems. In doing so, it provides the opportunity for cities to realize many benefits through synergy.

The One Systems Approach is about taking full advantage of all the opportunities for integration. Integration can apply to hard infrastructure systems and land use planning. One can integrate elements within a sector or across sectors. Integration can be applied to policies, stakeholders and plans, sequencing of financing mechanisms, and all of these in combination! In each case, the integration opportunities tend to provide greater efficiency and increased utility for a given investment, and improve ecological and economic performance. By applying the One System Approach to every project, entire cities, and their surrounding natural and rural areas, can coalesce into a functional system that works well as a new whole.

The benefits of integration are especially attractive because the efficiency gains tend to be substantial, and because the opportunities tend to be missed. The greatest success in best practice cities has been achieved: 1) in joint land-use, spatial, and transport planning and coordinated policies; 2) through positive synergies across infrastructure sectors—such as increased water system efficiency positively impacting energy efficiency by reducing the need for electricity to pump water; 3) in integrated utility management systems (for instance, the reuse of sludge and organic waste as biogas (methane) and fertilizer); 4) through technology solutions, such as combined heat and power plants; and 5) through synchronization of policy, investment planning, and regulations.

Integration is a powerful concept for cities, as we shall see in Chapter Five. So where does the concept come from, and where might it take us in the long run?

Integration is used here as it relates to the application of systems theory: seeing the full scope of elements that make up the city, how these different elements are connected, and how changes in one element can affect the others. This systems perspective is a way of seeing the world that has emerged from studying ecological systems, and in the end it can help us design and manage cities so that they can become very efficient, and very adaptive—just like natural ecologies.

Ecological systems are characterised by a multi-functionality of elements and the looping and cascading of resources through interlinked and nested subsystems, which greatly enhance productive utility. They also demonstrate powerful strategies for managing change; strategies like succession and evolution, self-organization, and adaptive management. All of these strategies are part of what we mean by the integrated or One-System Approach. The strategies serve two purposes: they improve the efficiency of the system as a whole—maximizing assets and information quality over time; and they help the system adapt to change at least cost, and recover quickly and fully from shocks. Many of these ideas are being applied by innovative cities which grasp the potential

> "Systems thinking can be defined as the art of simplifying complexity, managing interdependency, and understanding choices. Once we understand something—once we see it as one system—we no longer see it as chaotic or complex.
>
> "Contrary to widely held belief, the popular notion of a multidisciplinary approach is not a systems approach. The ability to synthesize separate findings into a coherent whole seems far more critical than the ability to generate information from different perspectives."
>
> ***Systems Thinking,* Garajedaghi 2006**

of these opportunities for system wide sustainability and resilience.

A One System Approach has many dimensions, but it is not complicated. The whole idea of systems thinking is to reduce complexity by understanding how parts fit into the whole. The challenging part is overcoming the institutional structures and inherited attitudes that prevent city leaders, investors, designers, users, suppliers, and managers from working as a team. Adopting the One System Approach as a principle for all projects is a good way to bring the team together.

PRINCIPLE 4: An Investment Framework that Values Sustainability and Resiliency

Despite a rising interest in sustainability in many locations, and a demonstrated capacity for urban design solutions, cities today are having difficulty investing in systems that are long-term and ecological. Although many exceptions exist, our time horizons for investments generally appear to be shrinking. Perhaps the fast-paced and deregulated global economy makes it especially difficult for corporations and political leaders to take a long view.

Whatever the explanation, the simple concept of investing in sustainability and resiliency has become extremely difficult for cities to put into action. Policies, plans, and projects are assessed on their abilities to provide short term financial returns, or economic valuations based upon narrowly structured cost benefit analyses from the perspectives of single stakeholders. Investments are valued in monetary terms, and what cannot be monetarised is either ignored, or addressed on the side as 'externalities.' Decisions are dominated by immediate capital costs, despite the fact that often over 90 percent of lifecycle costs for typical infrastructure are expended during operational maintenance and rehabilitation.

Most cities worldwide have no real knowledge of the long-term impacts on fiscal health of new development. Lifecycle costs are back-loaded, which means that future generations will have huge costs for repair and replacement of infrastructure without any capitalisation. In many developed country cities, that future has already arrived by creating a massive infrastructure deficit that can only be addressed through subsidies and/or more debt financing.

At the same time, ecological assets, the services they provide, and the economic consequences of their depletion and destruction are not accounted for in most government budgets. Since these resources are not measured, they are treated as zero value assets—and their services go unaccounted for.

For instance, green areas in a city are usually thought of as simply providing some sort of soft aesthetic value. But, in fact, green areas are ecological assets that provide valuable services and economic benefits in several ways: 1) they provide natural drainage (results in avoided infrastructure capital and maintenance costs, and reduces seasonal losses related to flooding); 2) they can reduce the average temperature in cities (this reduces peak load demand on electricity, which can result in avoided capital costs for installed power power as well as related operation and maintenance cost); 3) they absorb carbon dioxide and release oxygen, are natural air cleaners, and support overall citizen health; 4) they can be integrated into the public transport system as a network of bike paths and pedestrian walkways to enhance utility; and 5) they have generally been shown to increase physical and mental wellbeing, while creating a sense of community and reducing crime. If all of these services were truly valued, and understood in the long-term, then decisions in many cities might be made in a way similar to Curitiba.[52]

To achieve ecological and economic sustainability, decision-making needs to be clearly guided by a holistic perspective. What this entails is a new accounting and assessment framework that allows every city to adopt a lifecycle perspective and make investments that are fair to all stakeholders, effective at preserving all assets (manufactures, natural, human and social), and good for our long-term fiscal health.

This will entail adopting a new range of indicators and benchmarks for assessing and rewarding the performance of all stakeholders. Longer time horizons and life-cycle analysis on the implications of policies and investment options and strategies among multiple stakeholders will need to be carried out to reflect a truer, more inclusive, and more complete picture. All capital assets (manufactured, natural, human and social) and the services they provide should be appropriately valued or priced—and monitored by indicators. The combination of indicators should be viewed as a whole, so that the qualitative dimensions of city life (cultural, historic, and aesthetic) cannot be ignored when assessing costs and benefits. The basis and implications of policy decisions, regulatory actions, and legislation will need to be assessed in the broader context of Eco².

At the same time, investing in sustainability and resiliency will entail broadening our scope of risk assessment and management to include managing the many indirect, difficult to measure risks that threaten the viability of an investment or even the city as a whole. In reality, cities today face multiple hazards that are largely external to financial calculations. These include sudden disruptions to systems, such as epidemics, natural disasters, and socio-economic changes. By proactively adopting the concepts of resilience and adaptive capacity, cities will be better positioned to absorb and respond to shocks and protect their investments.

It is clearly understandable that introducing new methodologies and a broader scope of accounting in many countries will be difficult and complex. But, while the actual use of complex methodologies will take time to be established, at least the principle behind such methods should be clearly understood and considered by decision-makers. Curitiba did not do a detailed accounting and valuation exercise before following its development agenda. But by appreciating the broader and longer term perspective, it managed to focus on critical interventions which continue to pay lasting and compounded benefits.

Moving from Principles to Core Elements to a Unique Eco² Pathway

The four principles define the scope of each city's unique Eco² pathway. In other words, every aspect of a city's pathway follows directly from one or more of the principles. The connections to principles are reinforced in all aspects of the pathway. Since they lie at the core of the program, if things become complicated or confused, we can always 'fall back' on our principles.

The Analytical and Operational Framework emerges from the principles. For starters, we derive a set of Core Elements from each principle.

The Core Elements serve to operationalize the principles. They provide specific information on new concepts, and on the roles and responsibilities of Eco² Cities and their partners. Each core element is an arena of activity and learning that will be addressed in detail in later Chapters of this book.

Each city will translate the Core Elements into a series of action items or 'stepping stones' that adapt the Elements to local conditions in a logical, step-by-step sequence. The Framework below summarizes how each principle leads to a set of core elements and Stepping Stones.

Together, the Stepping Stones for a particular city constitute a unique Eco² Pathway. The Pathway should include all the essential actions needed to take leadership, collaborate, and design Eco² projects, and invest in the preferred solutions.

Table 1.1 on the following pages provides only a summary of the core elements and stepping stones. Each item is described in much more detail in subsequent chapters. However, it is clear from the summary that developing an Eco² Pathway is not a simple exercise, nor is it likely to be quick and easy. For this reason, this book also includes a number of methods and tools, such as the city-based DSS, that is designed to save time and guide decisions. The methods and tools provide practical ways for cities to take leadership and collaborate, and analyze and assess ideas for Eco² projects. The methods also address all aspects of project implementation, including the use of an expanded accounting process and a strategic approach to financing.[53]

In the final analysis, all cities want to benefit from good urban and spatial planning. It is up to city leaders to determine whether the Eco² Program is the kind of pathway they are seeking. The following chapters describe the step by step processes.

Table 1.1 The Eco² Cities Principles and Pathways

PRINCIPLES	CORE ELEMENTS	STEPPING STONES
A City-based Approach	A **development program** that supports cities in making good decisions, and implementing those decisions using all their levers of influence and control. **A planning philosophy** that recognizes the fundamental role played by local ecological assets in the health and wealth of cities and their surrounding rural communities. **An action-oriented network** that provides city leaders with the full support of national governments as well as the international development community (including the World Bank), and global best practice cities. **An Eco² Decision Support System (DSS)** with methods and tools that adapt to varying levels of knowledge and skill, and that provide cities with the technical, administrative, and financial capacity to develop an Eco² Pathway.	**Review the Eco² Program** and adapt the Eco² Principles to the local context, especially the current issues of concern and the local political constraints; **Identify champion(s)** and the specific groups or individuals who are vital to success; **Obtain commitments from city council** and influential groups and people; **Work closely with the national government,** and where possible, dovetail the Eco² elements so they clearly fit within the National Priorities; **Seek a partnership** with the international development community (including the World Bank), best practice cities, and Eco² program partners; **Outline a process for building capacity,** enhancing skills and knowledge of local professional staff with help from the Eco² DSS; **Develop Eco² fluency** among local decision-makers, using case studies and concepts from this book and other materials from the Eco² program.
An Expanded Platform for Collaborative Design and Decision-making	**A triple-tier platform** that enables a city to collaborate (1) as a model corporation, engaging all city departments; (2) as a provider of services; engaging residents, businesses, and contractors; and (3) as a leader and partner within its urban region, engaging senior governments, utilities, rural settlements, private sector stakeholders, NGOs, and academia. **A shared long-term planning framework** for aligning and strengthening the policies of both the city administration and key stakeholders, and for guiding future work on Eco² projects.	**Initiate a process for collaborative decision-making** and integrated design to develop Eco² approach as a corporation; as a provider of services; and as a leader within the larger urban area; **Prepare a mandate and budget for a *secretariat*** that can support collaborative committees through background research on cross-cutting issues, facilitation of regular meetings, communications products, and event planning; **Prepare a long-term planning framework** in collaboration with others, and seek consensus on common goals and indicators of performance, an over-arching growth management strategy, and an adaptive management approach; **Select a 'Catalyst' Project** suitable for demonstrating the Eco² Principles, aligned with goals and strategies identified in the long-term planning framework.

Table 1, *continued*

PRINCIPLES	CORE ELEMENTS	STEPPING STONES
A One-System Approach	**Integrated infrastructure system design and management** focusing on enhancing the efficiency of resource 'flows' in an urban area. **Coordinated spatial development** that Integrates urban 'forms' with urban 'flows,' combining land use, urban design, density, and other spatial attributes with infrastructure scenarios. **Integrated implementation** through 1) correctly sequencing investments, 2) creating a policy environment that enables an integrated approach, 3) coordinating a full range of policy tools, iv) collaborating with stakeholders to align key policies with long term goals, v) targeting new policies to reflect the different circumstances between urbanization in new areas and improving existing urban areas.	**Provide 'just-in-time' training and capacity building on Eco²;** arrange for multiple opportunities for local professionals to become comfortable with the One System Approach, and make the best use of the Eco² support network and the technical resources in Part Two and Part Three; **Conduct a series of integrated design workshops** Integrated design workshops create important opportunities for planners, designers, and engineers to come together and use new methods and information. A series of short workshops can clarify goals and set targets. The Long-Term Planning Framework can guide, design, and stimulate creative solutions ; **Explore Design Solutions and Prepare a Concept Plan for Review.** An integrated design process should be used to generate alternative proposals for how to design, construct, and manage the project. An intensive, multi-day Urban Systems Design Charrette (described in Part Two) is a tool that can facilitate the integrated design process. The integrated design process should culminate with a recommended Concept Plan for implementation, including any policy reforms. **Align a full set of policy tools to ensure successful implementation** in collaboration with stakeholders to sequence and enable a One-System Approach, and to coordinate actions across various sectors. A Strategic Action Plan can be prepared to clarify who is responsible for what tasks, and to show how policies interact.
An Investment Framework that Values Sustainability and Resiliency	**Incorporation of lifecycle costing** (LCC) in all financial decision-making. **Equal attention to protecting and enhancing all capital assets:** manufactured capital, natural capital, social capital, and human capital. **Proactive attention to managing all kinds of risk:** financial risk, sudden disruptions to systems, and rapid socio-economic-environmental change.	**Use a LCC tool to better understand the life cycle costs and cash flows;** **Develop and adopt indicators for assessing the four capitals, and for benchmarking performance;** **Forecast the impacts of plausible changes** in climate, markets, resource availability, demographics and technology by hosting a forecast workshop; **Implement an Eco² Catalyst Project in ways that protect and enhance capital assets, and reduce vulnerabilities.** The best way to learn the Eco² accounting methods is in practice, on an Eco² catalyst project. A base case scenario can be developed as a benchmark for comparing alternative approaches; **Monitor, feedback results, learn, and adapt to improve performance.**

CHAPTER 3

A City-based Approach

The first step towards a city-based approach is to appreciate and apply the philosophy at all levels, from local councils to national governments to the international community. It needs to be recognized that local governments, working in collaboration with stakeholders, are now on the frontlines in dealing with some of the most pressing development challenges, and that most often they hold the key to solutions. It is this philosophy that underlines the Eco² Program. The core elements and stepping stones of a City-based Approach are designed to enable local governments to lead a development process that accounts for their specific circumstances, including local ecology.

The Core Elements of a City-based Approach

A development program that supports cities

Cities have a wide range of powers that they can use to influence their development trajectories. In addition, many countries are now forwarding processes of fiscal and administrative decentralisation. This has further brought important decision making and management responsibility to local governments. Often the impact of initiatives will depend on how effectively and creatively city leadership cultivates and uses these powers. A development program that supports cities in their decision-making process, and more critically in the implementation of decisions, is strongly needed to better enable cities to use their powers to exercise meaningful proactive leadership.

> After assessing 25 successful cases of sustainable urbanization in different European cities, Timothy Beatley concludes that the role of city leadership is crucial to success—"Government in these cities is not seen as laissez-faire or caretaking in nature, but as an entity exercising important proactive leadership; it is a pacesetter, not a follower or spectator."
>
> **Timothy Beatley, Green Urbanization, 2000**

A planning philosophy that recognizes the fundamental role of local ecological assets

Local ecological assets provide all kinds of services to cities, from sand and gravel for concrete, to renewable sources of energy, to supplies of drinking water, to assimilation of waste products, to pollination of market gardens, to pleasant views and recreational environments. The list of services for a typical city is very long. Increasingly, these services are critical to the viability of the local economy and the health, safety, and quality of life for residents. Because we lack a systems perspective and comprehensive accounting methods, the real quantity and value of such assets are rarely recognized. New accounting methods should help. So will a new philosophy of planning that gives priority to these assets when making decisions about urban form and land use.

A city-based approach alters the mindset of the urban planner and civil engineer. Urban development moves from 'big architecture' industrial engineering, and environmental management (coping with externalities), to the stewardship of landscapes and integration of both social and ecological values into land use planning and infrastructure design and management. This is a change from the traditional city-centric view where natural systems are valued only as economic inputs or amenities, and where the rural and natural fringe of lands surrounding a city is most often ignored, or treated as an 'urban reserve' for future expansion.

The Eco² approach to planning begins with understanding the opportunities and constraints of local ecologies. How do we fit into the topography of the area so that water is provided by gravity? How do we protect the water recharge areas, and the wetlands, so that water capacity and quality is sustained? How do we distribute populations so that local renewable energy –windy sites, forests, solar access—is sufficient to meet our basic needs? These type of questions are the first place to start, and may ultimately provide urban professionals with their most exciting design challenge: how to fit cities into the landscape in ways that respect and complement the natural capital and ensure ecological services are available for present and future generations. In theory, all the constructed elements that make up a city can contribute to—and benefit from—the health and productivity of local ecologies and natural resources.

An action-oriented network

The Eco² approach is a team effort. If cities are in the driver's seat, then they need plenty of passengers to help with navigation and problem solving. The composition of the team will vary from place to place. Often, it is the national governments that must play a key role as their cities look for support and guidance in a fast-changing and competitive global marketplace. National governments need to provide new channels for delivering resources to their cities. However, few countries have the resources to introduce all cities to new paradigms like Eco². Nor can national governments provide cities with the on-going technical, administrative, and financial resources that are needed to adopt best practices. It is for this reason that the Eco² program is not an association of only cities, but rather a broad network of senior governments, international agencies and organizations, best practice cities, academic institutes, and private corporations—all of whom embrace Eco² Principles and are willing to support those cities that assume leadership. The network allows each group to offer its special expertise and resources to cities in a coordinated or complementary fashion. Only through such multi-lateral and multi-level support will it be practical to achieve significant widespread changes to urban development in growing cities.

A City-based Decision Support System (DSS)

The Eco² approach requires that cities enhance their technical and administrative capacity, particularly with respect to leading collaborative processes and exploring integrated design solutions. Capacity-building means adopting methods and tools that help to simplify what would otherwise be very complex decisions. This is the role of the City-based Decision Support System (DSS). The City-based DSS is an evolving set of methods and tools that is designed primarily to help cities take leadership and make the best choices.

Coping with complexity is one of the greatest challenges for Eco². Cities represent the longest-lasting, most valuable, and most complex artefact created by humanity. Even under the best of circumstances, urban planning is a complex task, and the challenge increases when attempting to implement integrated solutions, which can be complex in themselves. Of course, the task becomes that much more challenging for developing countries where resources are limited and everything seems to be happening at once. Further challenges for developing countries include their lack of experience with using computer-based planning tools, and the often inadequate performance of existing infrastructure. For all these reasons the City-based DSS is an essential element in the Eco² Program.

One of the most difficult tasks faced by anyone trying to apply an integrated approach to infrastructure systems is the dynamic relationship that exists between physical flows and spatial form. Physical flows are more often addressed through modeling and calculation, and involve individuals with engineering and technical backgrounds. Spatial issues are usually addressed through mapping techniques, and involve individuals with a planning or design background. Integrated design solutions need to incorporate both spatial and physical flows and understand interrelationships. The City-based DSS can help to create a 'transdisciplinary' platform for this purpose. Physical and spatial effects are communicated by using graphical tools, sharing common data, and using terms and images that can easily be understood by a multidisciplinary group. These and other aspects of the Eco² City-based DSS are described in much more detail in Part Two.

Stepping Stones for Taking a City-Based Approach

Review and adapt the Eco² Program

Change management is most successful when the new ideas are clothed in familiar patterns and sensitive to local concerns and capabilities. An assessment of local strengths and weaknesses can help to tailor the Eco² program to local conditions and experiences. This can include a number of different ways to 'customise' Eco²:

- **Travelling Back to the Future:** begin by reviewing the history of the city and region, focusing on examples of where city leadership has achieved positive outcomes, or where a more integrated approach to design, or a process of collaboration, has already helped to provide multiple benefits. Use these historical examples to help explain the strengths of Eco². To obtain broad support within the city, the program is best introduced as a return to what has worked previously—a reaffirmation of traditional values and institutions. The history of most cities is replete with stories that can be used for this purpose.

- **Talking to the Trigger Issues:** identify which of the current political issues within the community are most likely to be improved by an Eco² approach. All politicians want to resolve these issues, and the media wants to speak to these issues and not a program or philosophy. These are the trigger issues which will build support for the Eco² approach.

- **Learning to lever influence, stand firm and say No:** The levers of influence and control vary considerably from one location to another, and this obviously affects the potential for an Eco² approach. For example, in some countries the national government controls the finances for urban infrastructure; in other countries, the ability of cities to invest in local renewable energy systems is prohibited by law. Cities that lack control over financing or lack the authority to develop new policy obviously face a greater challenge. But often the biggest difficulty is to use what levers exist to influence decisions—zoning, development approvals, hook-up requirements for infrastructure, and so on. An assessment of local strengths should clarify the full extent of influence and power available to local government. Almost always, cities have more authority than they realise, and the real challenge is learning to say no to the short-term vested interests that drive so much land development.

Identify local champion(s)

The successful introduction of Eco² principles usually requires a strong champion who can help to motivate the many groups that need to be involved, sustain the commitment over time, and provide confidence and leadership. Local champions can help put forward key ideas in ways that are acceptable to various stakeholders, and thereby broker solutions that are widely accepted. Local champions can also attract other influential individuals, by virtue of their reputation and influence.

The Eco² champion can be drawn from any place—everyone has the potential to take leadership. However the task is easier if the champion is someone with recognised authority or influence, such as a well-liked retired statesperson, the city mayor, the chief administrator, or the chair of a development committee. Sometimes, leadership can emerge from an advisory group of senior statespersons or 'elders' who are widely respected and support the Eco² concept.

Wherever the champion is located, a support group of committed and knowledgeable individuals is also necessary. All champions depend upon a support group, or their 'change agents' to develop their networks and their knowledge base. In an Eco² city, support can come from a small group of hard-working staff, or from an ad hoc group of experts and community activists. Ideally, the support group should be capable of providing its champion with both administrative and technical support. In some cases, a national body can be part of the support group. For example, support from national governments may include an office for providing cities with both technical and financial assistance.

Obtain a commitment from the city council

Much of the land in a city, and a majority of the infrastructure as well, may be owned by private sector groups or by senior levels of government. Nevertheless, democratically elected local councils have a high degree of legitimacy when it comes to land-use planning, especially in making strategic choices that can affect the long-term health of the community. These councils are often seen as the appropriate leaders for bringing together regional stakeholders, and promoting collaborative decision-making and integrated design. Whenever a local council is fully engaged, others come to the table. It is thus critical that support is received from the council and individual councillors with special interests in development issues. The council needs to be engaged in the Eco² program from the start.

When involving a council in Eco² planning, it helps if the Eco² Pathway is presented as a way to address issues of greatest concern to councillors. This is not usually a problem. The integrated approach adds strength to any specific issue by providing multiple benefits, and expanding the base of support for positive change. For example, affordable housing can be designed to treat wastewater for the neighbourhood, or to simultaneously increase the available space for small shops and business. The multi-purpose nature of Eco² projects, and their more thorough analysis of impacts on the whole economy and ecology, make these projects easier to broker.

Obtaining an informed commitment from the council, and sustaining this commitment, can be difficult and time-consuming. It is especially important to emphasize the long-term and collaborative elements, and to use both these features as a means to dissociate Eco² from any one political party or power group.

Work closely with the national government

National governments can play a number of complementary roles in the Eco² program. They can function as an important center of expertise and networking on best practices in urban design and planning. National governments can share best practices from one city to another, and develop new policies in support of a city-based approach. They can choose to work with cities on a locally specific planning framework (e.g., a regional growth management strategy), and contribute expertise on a project by project basis.

Although the limited resources available to national government departments can constrain their ability to participate directly with cities on new initiatives, these departments should still find ways to participate to some degree in any regional-scale collaborative working groups.

Another interesting and highly influential role for national governments is to establish a national Eco² Fund Program, which can serve as a conduit for financing programs and disseminating knowledge on global best practices. Both Sweden and Canada have used similar mechanisms to support cities. The Swedish Local Investment Program (LIP) which lasted from 1998 to 2002, allocated SEK 6.2 billion (671 million Euros) to 211 local investment programs in 161 municipalities, involving 1,814 projects.[c] This national investment leveraged from municipalities, businesses and other organizations SEK 27.3 billion (2.95 billion Euros), of which SEK 21 billion (2.27 billion Euros) were investments directly related to sustainability and the environment.[d] 20,000 full time temporary or permanent jobs were estimated to be created.[e] For more details on this program, please refer to Part Three, the Field Reference Guide.

Figure 1.4 illustrates one possible model of a National Eco² Fund Program. The national government would adapt the Eco² Program to local circumstances, working in partnership with the World Bank, other international agencies, development organizations, and the private sector. It would allocate resources among cities, and administer funds.

Whatever the involvement of national government in the program, it is important for local governments to adapt their Eco² pathway to current priorities established at the national level. This means finding points of commonality, and adopting terms and language similar to those used by the national government. In this way, the national government automatically becomes an ally, and a potential partner.

Engage the International Community, Best Practice Cities, and the World Bank's Eco² Program

Engaging the World Bank and other partners directly in the Eco² Pathway is an option for every city. The Eco² Program can offer cities a variety of literature, including guidelines and technical reports, to support every stage of the Eco² Pathway. On a case-by-case basis, the World Bank, in concert with national governments and Eco² global partners, may be in a position to assist with financing Eco² integrated solutions. For example, the World Bank can help cities integrate and consolidate a variety of financial mechanisms, as Eco² projects tend to need different types of financing at each stage, and may qualify for multiple types of funding. The World Bank's various financial instruments are introduced in in Chapter 7 of Part One, and in Part Three.

Eco²'s global partners are willing to provide support to cities in cases where special exper-

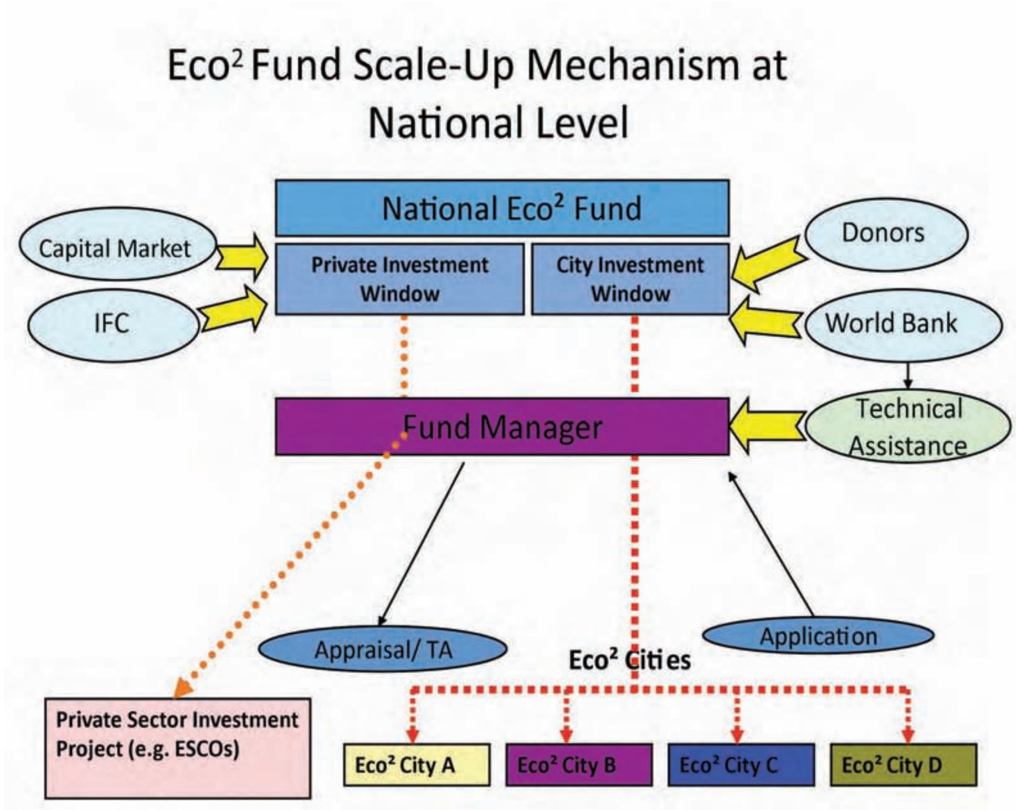


Figure 1.4. A Possible Role for National Governments: Administering a National Eco² Fund to Support All Participating Cities

tise is needed and resources can be found to cover costs. Best practice cities, for example, are continually sharing information with the Eco² program, and may provide additional assistance and support to cities.

Outline a process for building capacity

Capacity building involves the familiar process of professional development and demonstration projects. The DSS, described in this chapter as well as in Part Two, should be a key element in any capacity building plans. The City-based DSS includes methods and tools without which it is almost impossible to adopt an integrated approach to design and policy. Most methods and tools within the City-based DSS are well supported by tool developers, and may be accompanied by useful handbooks, guides, and tutorials.

As cities outline a process for capacity building, it is important to recognize that the Eco² Program represents a significant departure from standard urban planning, development, and management. The examples of integrated infrastructure cited in Chapter One are not yet commonplace. The large majority of growing cities—including those located in the developed world—is still unable or unwilling to contain urban sprawl, optimize land use and infrastructure, adopt life-cycle costing, or apply many alternative designs and policies used in best practice cities. For these reasons, an Eco² Pathway must incorporate a carefully planned change management process, with special attention given to adopting new ideas for leadership, visioning, collaboration, and analysis.

Develop Eco² fluency

Another challenge with any change in standard practice is familiarizing the city leadership group with the key concepts, and helping officials to understand what is truly different about the new approach and why it can be especially beneficial. Individuals need quiet time to absorb new ideas. The Eco² Cities program provides resources—including this book—that can help introduce key concepts and terms. Case studies are an excellent place to start. Talking with best practice cities or viewing video testimonials from other experienced decision makers can also be helpful in providing leaders with the confidence to adopt and promote a new approach.

Developing Eco² fluency might require special sessions for local politicians and executives that allow these officials to explore new concepts and practice defending new approaches. Within the Eco² program, for example, the concept of collaboration involves consensus decision-making at different tiers, and a formal commitment by stakeholders to attend regular meetings and align their policies in cases where consensus exists. These distinctions need to be made clear and acceptable, since they expand upon traditional views of best practice in governance.

Another example where Eco² fluency is important entails the concepts of ecological design. The 'looping and cascading' of resource flows within a city can be explained using graphical case studies. It may be helpful to gather key decision-makers together for several hours in a comfortable environment to discuss the case studies and key lessons learned, or even participate in mock workshops and design exercises. The Eco² fluency campaign is about making decision-makers comfortable using a new language for design and investment.

CHAPTER 4

An Expanded Platform for Collaborative Design and Decision-Making

This principle speaks to the importance of adopting a design and decision-making process that is more integrated, adaptable, and lasting. If we want to improve economic and ecological performance through integrated, fine-scaled, flexible and long-lasting solutions, we must also pursue shifts in the institutional arrangements that enable design and decision-making. In many ways, the constructed environment is mirror of the way we think and relate.

The solution is two-fold: 1) engage stakeholders at all scales in a collaborative process as part of every major project; and 2) develop an over-arching planning framework for sustainability and resiliency, which includes goals, targets, and strategies. Each of these elements is discussed in this chapter. The elements are mutually supporting. The collaboration at all scales generates the skills, goodwill, and creative interchange needed to adopt new business models. The shared planning framework provides the context for integrated project design, and also aligns everyone's plans and policies with a common set of community goals.

Collaboration is also a new form of governance. By engaging stakeholders at all scales, the city creates a planning forum that is more appropriate to mixed economies, where private sector groups often control a majority of infrastructure systems. And because the process is driven by long-term goals and strategies, it can help cities compensate for the impacts of fre-

> "...the future seems to lead quite clearly to a consensus-led approach where everything is discussed and the participation of all interested groups spans all phases of the development plan process."
>
> **Towards Sustainable Urban Infrastructure: Assessment, Tools and Good Practice**
> European Union, COST Action 8 2006

quent election cycles, which tend to focus attention on short-term agendas and crisis issues.

The single greatest difficulty in adopting collaborative arrangements is the lack of any institutional champion to lead and guide the process. Almost by definition, no department, group, or government has the mandate, funds, or independence to undertake such a broad, cross-cutting process. Without a sponsor or host, the process never gets started. This is one reason why so few collaborative models exist at the city scale. It is also a key reason why the Eco² Cities program proposes that cities assume leadership in creating a platform for on-going collaboration. Methods and tools to help cities organize an expanded platform for collaboration, and to use this platform to develop effective planning frameworks, including regional growth strategies, are included in the City-based DSS (Part Two).

The Core Elements of a Platform for Collaboration

A triple-tier platform

The City can lead a collaborative process on at least three levels or tiers. Each tier affects the others, and in an ideal world, every city should lead a collaborative working group at every tier. In practice, the process may be incremental, or periodic. However, it is still important to differentiate the options. The tiers reflect the varying levels of control and influence.

Inner Tier—House in Order (Corporate Operations)

The first and most fundamental tier is the collaboration that can occur within and between departments of the city. At this inmost tier, the city has a great measure of control. It is here that city government can address how well it functions as a corporation and works as a team to put its 'house in order.'

Various departments can routinely collaborate to make decisions that are more integrated and more effective. Cross-cutting goals and targets can be adopted and incorporated into the strategic plan. A reporting and monitoring process can be implemented that informs the wider community of how well the city is looking after its various assets including publically owned buildings, employees, equipment, capital, and so on. Special internal programs may be warranted. For example, the city might reduce transportation costs for employees by means of ride sharing, bicycle storage, new parking policy, purchase of efficient vehicles, tele-work, and so on. Such a project might require changes to building facilities and employee benefits—changes that may only be possible through a collaborative process involving many city departments. Other internal initiatives might include improving the efficiency of building operations, procurement processes, waste management systems, and energy use.

Whatever the program or project, this inner tier collaboration provides the city with an immediate opportunity to learn how to lead an effective process, such as an Eco² project, and demonstrate its benefits. The city can use the collaborative process to become a model for all types of efficient and sustainable corporate operations. In almost every sector worldwide, the leaders of sustainability not only provide sustainable products and services, they also take pride in corporate performance, such as, for example, their 'green' head office. The same logic applies to cities. There is no excuse for failing to collaborate internally, since the city can initiate the process unilaterally. And the benefits extend well beyond internal operations. It is always easier for cities to lead a collaboration process externally—with stakeholders and partners—when the city has already succeeded internally.

Middle Tier—The City as a Provider of Services

The middle tier of the collaborative platform can be focused on municipal services—the various public services delivered by city government to residents and businesses within city boundaries. Although the services and associated investments may be largely or completely within the control of the city, they nevertheless affect many other stakeholders, at all scales. Collaboration at this tier can help with policy development in many areas. For example, the choice of transit system may be a city responsibility, but has major long-term impacts on land values and development potential, the competitiveness of local businesses, local job creation, street safety and livability, and the development of neighbourhoods. Ideally, a local transit system needs to be integrated with land use planning , parking policies, energy supply systems, street profiles, neighbourhood planning , regional transportation connections, and much more. Without a well-structured collaborative process, it is difficult for any city to understand the full implications of alternative policies. Moreover, the impacts of new investments may be uneven, and may become necessary to manage the political agenda. Rather than debates and autocratic 'predict and provide' models, a meaningful dialogue is required on the best long-term strategies. All complex system design can benefit from a process that encourages creative solutions and allows for consensus decision -making by key stakeholders.

Collaboration at the middle tier is necessarily a more complex process than what occurs at the inner tier. A larger number of groups must commit to the process and share information with other stakeholders, (such as businesses and households), and also with their respective constituencies. Larger financial investments may be required to launch city-wide programs and to implement capital projects, and this may require collaboration with the financial community.

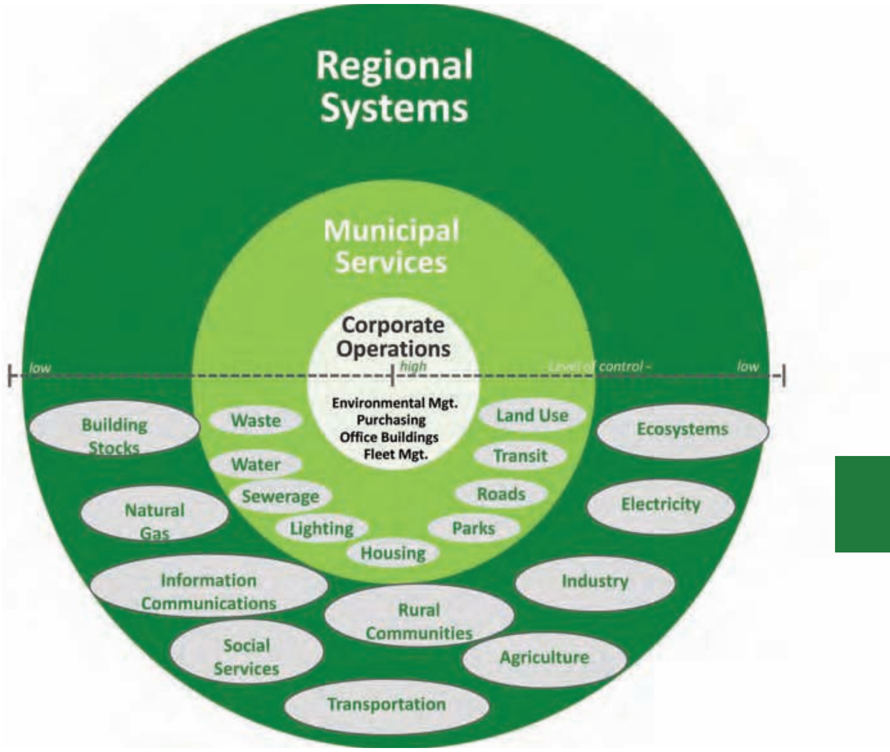


Figure 1.5. Cities' Collaborative Working Group at Three Tiers: Corporate, Municipal and Regional

Moving from the inner to the outer tier increases the number of stakeholders, and the complexity and scope of potential benefits

Outer Tier—the urban region

The outer tier of collaboration focuses on the urban region. In a metropolitan area, this may mean focusing on the 'city of cities.' In almost all locations, it means expanding beyond the strict boundaries of the municipality to include adjacent towns and cities as well as the rural lands and natural areas that are part of the economic region and the bioregion. This scale is the most challenging for cities, but potentially the most rewarding. At the outer tier, the city is just one player among many. It is not immediately clear why or how the city becomes a leader. It is also difficult to find (except in the case of island states) any one definition of boundaries for a region, since the ideal boundaries will change with each issue. The urban region is always a fuzzy concept. However, many examples now exist of cities that have risen to the challenge and, in so doing, greatly enhanced the capacity of their

The Danger of Predict and Provide Models

In the middle of the 20th century "a new 'scientific' and professional endeavor was born through the transport planning and traffic engineering disciplines. The basic philosophy of the urban transport planning process was to plan for infrastructure supply to meet projected traffic growth—a 'predict and provide' approach. This approach became characterized by self-fulfilling prophecies of spiralling traffic growth, congestion and road building. This method of transport planning has proven damaging to cities around the world. Freeways have been punched through neighborhoods, demolishing large section of urban fabric, severing communities and destroying natural environments and food-producing areas. Roads have been built and widened to accommodate more traffic, reduce congestion, save fuel and reduce emissions, despite evidence that this approach fails. Public transport, and particularly non-motororzied modes, have been big losers in a planning process optimized for the automobile."

J. Kenworthy *"The Eco-City: Ten key transport and planning dimensions for sustainable city development"* in Environment and Urbanization, Volume 18, No. 1, April 2006

communities to articulate and achieve economic and ecological goals. To a large extent, the sustainability of a city depends upon its capacity to provide leadership and collaborate at the scale of the urban region in which it is immersed.

Stakeholders at the outer tier may resist attempts to develop a formal platform for collaboration. For an electrical utility, for example, its service territory may form a logical planning unit, not a particular urban region. For adjacent towns and cities, the habitual mode may be competition for land rents and tax base or access to development funding. The focus of collaboration needs to be long-term to find common purposes. Absent a collaborative process, the regional stakeholders will almost certainly be working at cross purposes. Collaboration provides an unusual and important opportunity for such groups to meet, develop personal relationships, agree on long-term directions, and discuss current plans. For example, electricity companies might meet with natural gas companies, and begin a conversation about the best long-term uses for these scarce energy resources within the city. Or the owners of buildings might discuss with the city departments the appropriate level of investment to be made to upgrade existing building stock for resource efficiency. These are crucial issues for Eco² cities, and they can only be resolved through a continuous, well-managed dialogue and collaborative decision-making.

The outer tier collaborative platform needs a very strong structure. It may include senior statespersons at the core, team leaders from private firms, knowledge institutions and public bodies, and experts and champions from a variety of sectors. The structure can build upon existing partnerships and committees if these exist, and if they are consistent with the collaborative process. A collaborative working group does not need to be time limited. Ad hoc sub-groups can be formed to meet regularly on specific issues as appropriate. Part Two provides much more detail on the potential make-up and activities of collaborative working groups.

From 2003 to 2009, the urban region of Auckland New Zealand undertook a collaborative process, including the preparation of a shared long-term (100-year) planning framework. The process of developing a framework was highly inclusive, with many conversations feeding into the framework and emerging responses. The Regional Growth Strategy, for example, facilitated region-wide discussions and a councillors' reference group to provide direction and support. Similarly, local authorities and the central government formed a working group to ensure representative influence, enable shared responsibility for funding the Auckland Sustainability Framework, and ensure that staff would be actively involved. The process was neither linear nor predictable and its 'messiness' can be seen as an inherent quality of a positive outcome. A key collaborative element was the relationship between central and local governments aligned with common governance elements, including a joint commitment to developing a shared long-term view of a sustainable Auckland. Part Three includes a full case study of the Auckland collaborative process and the sustainability framework this city created.

A new approach to governance, and perhaps a new way of living together

Collaboration is a process that can evolve from a simple working group for interdepartmental planning, to a new forum for governance for the urban region as a whole, to a new culture of cooperation and flexible teamwork that is adopted as a matter of course. Whatever the scale of collaboration, the capacity to lead a collaborative process can greatly improve potential for integrated design and policy, and for sustainable development. The first step towards success is to fully understand how a city can organise and support a collaborative process. Much more detail is provided in the City-based DSS (Part Two).

A shared long-term planning framework for the urban region

A second step towards creating an expanded platform for collaboration is to adopt a shared long-term planning framework. The framework ensures that all public decisions—including capital investments—are supported by a logical, transparent rationale. An Eco² framework needs to combine two perspectives on the future: 1) achieving goals for sustainability, and 2) managing risk for greater resiliency. Box 1.1 summarizes how these two perspectives become integrated into a strategic plan for the region. The framework needs to be developed through a collaborative process if it is to be influential across the region. Once in place, the framework becomes a tool that supports further collaborative efforts at all scales.

Not everyone will immediately see the point of developing a broad framework that transcends the urgent issues of the day, and transcends the authority of any one group. To in-

The Emergence of the Regional City as a Crucial Scale for Long-term Planning

Peter Calthorpe describes the resurgence of a regional approach to city building. He argues that the economic, social, and ecological patterns of cities now seem to be best understood and planned at the regional scale. As cities mature, the traditional combination of urban sprawl and satellite or edge cities transforms into a structure that is better described as 'polycentric'—looking more like a bunch of grapes than a single fruit with a dense core. The polycentric forms are complex, instead of the focus on a single centre we see layers of networks—economic, open space, resources, connections—with many more centres or nodes nested within other nodes. The challenge is to fit these complex forms into the landscape in ways that fit the ecology of the region and its resource base, and also to contain the nodes so they are human scale and walkable. "The regional city must be viewed as a cohesive unit—economically, ecologically and socially—made up of coherent neighbourhoods and communities, all of which play a vital role in creating the metropolitan region as a whole."

Calthorpe P. The Regional City, 2001

"Coordination and collaboration between national, provincial and local authorities can achieve harmonious regional and urban development, provided they share a common vision and demonstrate sufficient political will…local authorities, working with regional authorities, need to develop clear visions and strategies that articulate short and medium-term responses to enhance economic and social condition in their cities."

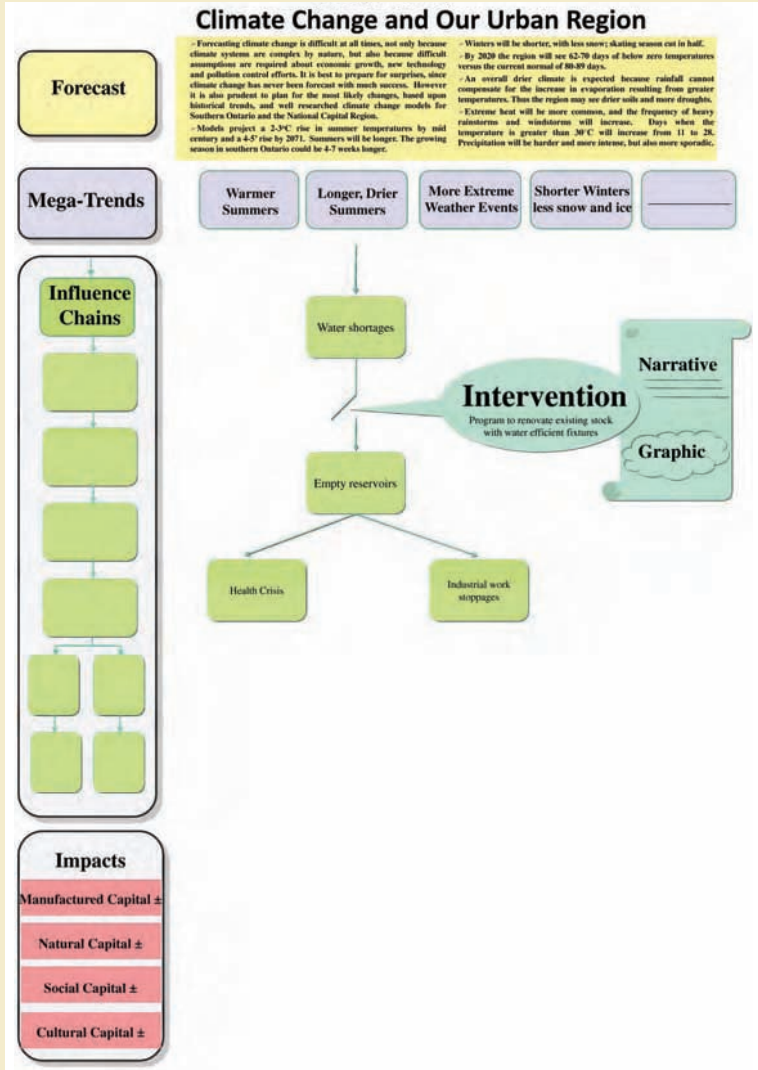
State of the World's Cities2008/09
Harmonious Cities UNHabitat

BOX 1.1

Combining Forecasts and Backcasts to achieve Resiliency and Sustainability

FORECASTS: Projecting Impacts of Forces and Planning for Mitigation and Adaptation;

Forecasts (or narratives) explore the likely impacts on infrastructure of changes in population, climate, economics, and technology. The impacts can be presented visually using cause and effect chains, which help to tell stories about the future of complex systems. Forecasting with diagrams can sensitise all design teams and decision-makers to the different types of futures that may be encountered by the city, and its systems. The forecasts can also be used as a mind-map or decision tree—helping groups to brainstorm the most appropriate interventions to mitigate threats or adapt to change. The Climate Change Primer for Cites, a book produced by the World Bank, provides many examples of how climate change might impact different parts of a city, and how the community can respond. Similar kinds of exercises are needed to address other external forces, like technological and population changes.

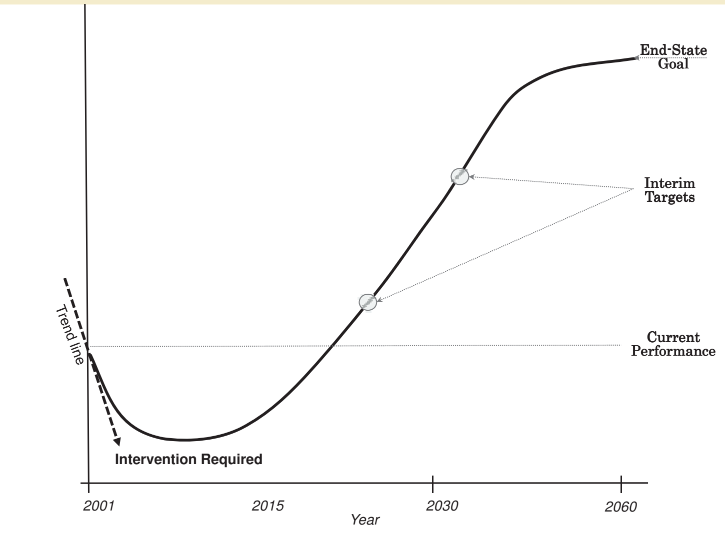


troduce the concept, it can help to take a moment and explore just how frameworks function.

A framework is a structure for connecting visions to actions—a kind of mental map or way-finding system that provides us with a sense of how elements fit together and relate to each other. All of us use some kind of framework to help us make decisions. Most frameworks rely on a hierarchical structure to reduce complexity, moving from the big ideas or categories to the details and specifics. The Aalborg Charter, adopted by 2,500 European communities, is an example of a comprehensive framework for long-term planning by cities. The outline of planning steps in the Aalborg Charter helps each city address the key steps in the planning process, from problem identification and visioning, to implementation and monitoring. The framework also provides a common language and a standard sequence for planning.

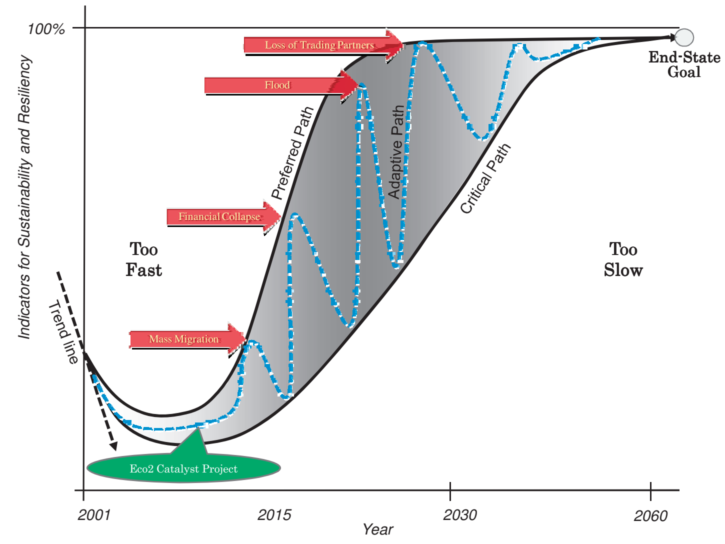
BACKCASTS: Managing the Transition to Endstate Goals

Backcasts are about making changes in those areas where a city has real influence and control. The term backcast refers to the process of working backwards from where you want to be at a future point in time, to the current situation, creating a kind of 'critical pathway' for managing change. Interim targets can help to set the pace of change to better fit the ambitions and priorities of the city. Moving too fast can be just as destructive as moving too slow. The biggest problem for backcasting is when trends are taking the city in the wrong direction altogether. Use of automobiles for commuting is on the increase in most cities, for example, and is not sustainable. Such a trend must be counteracted through interventions that can accelerate and leverage preferred alternatives.



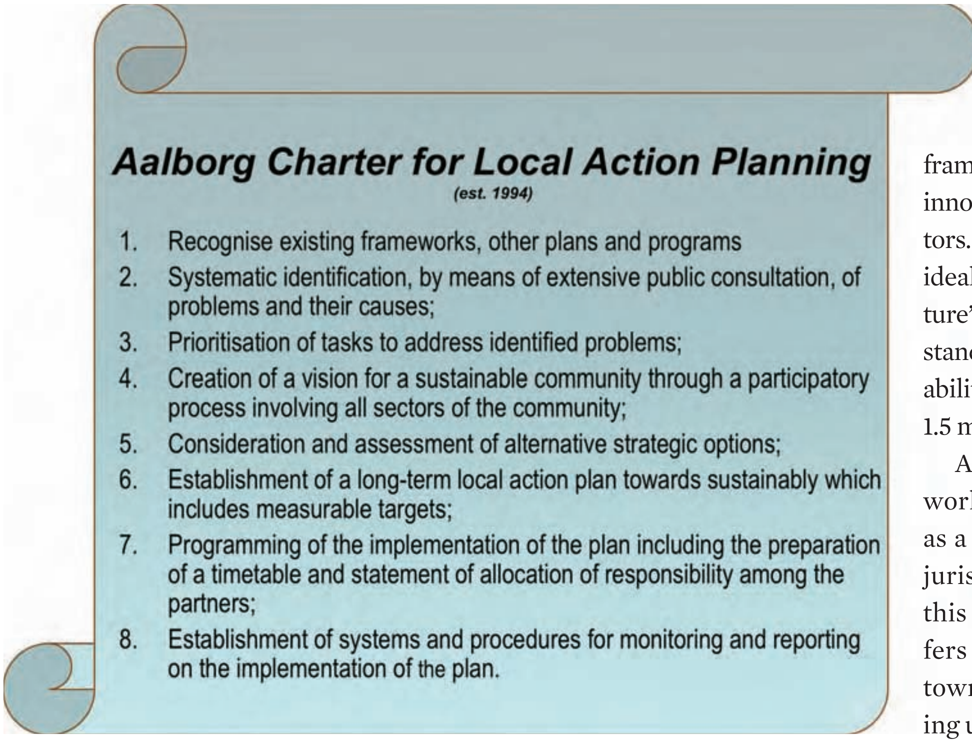
INTEGRATION: A Proactive Strategy that Addresses both Sustainability and Resiliency

By responding to forces outside of your control, and by managing the things you can control, the potential is created for managing the transition to a more resilient and sustainable city. A city must define a 'solution space' that avoids moving too fast or too slow, and that provides the space required to recover from the inevitable shocks and surprises that will be encountered over the next few decades. When the trend is in the wrong direction, an Eco[2] Catalyst Project can help to redirect. By mitigating threats and adapting to changes, the number of 'surprises' or dislocations is reduced. In this way, we can sustain a managed transition to end-state goals.



A shared framework is useful for all aspects of planning and design. Local governments can use the framework to organize and align their Strategic Plans, Master Plans, Concept Plans, Transportation Plans, and Economic Development Plans. Integrated design teams can use the framework to direct each stage of their designs, and to remind designers about the full scope of community goals and priorities. At every stage, a shared framework helps us communicate and work together in a coordinated fashion. Because everyone shares the framework, it is clear how each activity fits into the whole, and there is less need to micro-manage the myriad city departments and stakeholders who might be involved in project planning and implementation.

As cities undertake a more integrated approach to system design, and develop an extended platform for collaboration, the shared framework can help to solve the problem of organizing and communicating complexities. It


Aalborg Charter for Local Action Planning

(est. 1994)

1. Recognise existing frameworks, other plans and programs
2. Systematic identification, by means of extensive public consultation, of problems and their causes;
3. Prioritisation of tasks to address identified problems;
4. Creation of a vision for a sustainable community through a participatory process involving all sectors of the community;
5. Consideration and assessment of alternative strategic options;
6. Establishment of a long-term local action plan towards sustainably which includes measurable targets;
7. Programming of the implementation of the plan including the preparation of a timetable and statement of allocation of responsibility among the partners;
8. Establishment of systems and procedures for monitoring and reporting on the implementation of the plan.

Figure 1.6. Aalborg Charter
This charter describes a long-term planning framework that has been adopted by 2,500 communities in Europe.

puts first things first and cross-links every concept and action into an easily understood argument. This creates an easy-to-follow mental map for setting and justifying specific recommendations. Everyone involved in the planning can follow the transparent, logical connections between, on the one hand, intended goals and overall vision, and, on the other, detailed actions and results. It allows every agency and stakeholder to understand how their work fits inside, and contributes to, the long-term vision and goals. Ideally, the framework serves to align the various initiatives a city may undertake.

Over time, the collaboration around goals and strategies can begin to develop a common frame of reference throughout a city. The framework is a triggering factor, leading to innovation and compliance across all sectors. Such positive spill-over effects are the ideal result—creating a powerful local 'culture' of sustainability. In Curitiba, for instance, the overarching vision of sustainability inspired citizens to voluntarily plant 1.5 million trees along the streets.

A shared long-term planning framework is best focused at the urban region as a whole, even if this area exceeds the jurisdictional boundaries of the city. In this context, the term 'urban region' refers not only to the city or group of towns and cities that make up the existing urban areas, but also to the combination of rural and natural areas immediately surrounding the city. A lot of city planning is city-centric, and treats areas outside city limits as simply the responsibility of another jurisdiction. However, without regional planning, it is impossible to address long-term goals and to benefit from an ecological and economic perspective—the Eco^2 approach.

Part of the reason why a regional context is important is the unregulated and unplanned urban expansion that is occurring worldwide—in some cases even where populations are shrinking—and this threatens the long-term health and prosperity of both cities and countries. Increasingly, cities depend upon the rural and natural areas in which they are immersed. These

> "Automobiles are often tagged as the villains responsible for the ills of cities. But the destructive effects of automobiles are much less a cause than a symptom of our incompetence at city building."
>
> **Jane Jacobs,** *The Death and Life of Great American Cities,* 1961

> "In many cases, the decline—and possible renewal—of cities cannot be divorced from their wider regional contexts. Declining cities are almost always concentrated in declining regions."
>
> **State of the World's Cities 2008/09**
> **Pg. 44, Harmonious Cities UNHabitat**

areas provide ecological functions: capturing and cleaning water, cooling, slowing and filtering air, growing fresh produce for food security and public health, and providing energy resources that are renewable and secure. A shared regional strategy becomes an umbrella plan that defines how to direct city growth in ways that protect and enhance many ecological functions. This type of umbrella plan is sometimes referred to as a Regional Growth Strategy.

The urban region is also a vital scale for economic planning. Almost all economic patterns are formed at the regional scale, and efforts to intervene and control economic development must also be executed at this critical scale.

Defining the boundaries of an urban region can be difficult. In fact the actual dimensions of a region can be kept deliberately flexible, so that borders can adapt to reflect concerns of stakeholders. For example, the regional boundaries used for growth strategies might need to include watershed planning, commuter sheds, air sheds, utility service territories, market gardens, local energy generation, ecological systems, and economic development planning—each of which requires a different delineation. Regardless of the label and scope, a regional strategic plan must help everyone to understand how the city will fit into its ecological surroundings, and how the pace and direction of growth will be consistent with near term targets and long-term goals. The City-based DSS in Part Two has detailed information on: 1) Long-term Planning Frameworks, and 2) Creating a Regional Growth Strategy.

Stepping Stones for an Expanded Platform for Collaboration

Initiate a process for collaborative decision-making

The process of creating collaborative committees begins with an invitation to key stakeholders to discuss the collaborative process, and to consider the benefits of participating in an Eco² Pathway. It is usually necessary for the Eco² champion to meet individually with key stakeholders, and to establish a common basis of good will and interest prior to a group meeting. Each stakeholder needs to see the benefits of participation from its position. For example, land developers have a chance to affect the regulations under which they must work, and ultimately to improve business by influencing policy. Utilities and land owners can become more informed about opportunities for new business and improved customer relations. For second and third tier committees, it is especially important to clarify the role of the city as initiator and secretariat, and NOT as a group in control of decisions. Sometimes it is necessary for the city to explain to everyone that the integrated approach means it must temporarily remove its 'regulator' hat, and join with others in the search for integrated solutions.

Prepare a mandate and budget for a secretariat

A secretariat needs to support the collaborative committee, which means that it needs to be distinct from other city departments, even if it shares city offices to reduce costs. The size of the secretariat can adjust to fit the pace and scope of collaborative processes. If only one person is involved, this person must have skills in communications (facilitation, writing), research, and data collection. Finding a budget for a secretariat can be challenging as collaborative committees are not normally budget items. One option is to include collaboration in strategic planning costs. Regardless of the funding source, the secretariat needs at least three years of secure budget to prove its worth.

Prepare a long-term planning framework for sustainability and resiliency

Part Two provides the detailed methods and tools that can assist with preparing a framework. If time or money is limited, a rapid process is possible, using pre-defined goals and strategies from appropriate best practice cities. In this context, the Case Study reports are helpful in providing examples of goals and strategies. Software tools are available on the web which can help to develop a framework that connects visions and goals to specific strategies and projects, and that allow the public and other stakeholders to explore the content of the framework. The framework also needs a locally specific set of external forces (e.g., climate changes in your location, demographics for each city's population). An extensive collaborative effort may be required to complete the framework, supported by such tools as visioning workshops and foresight workshops (Part Two).

Select a catalyst project

A catalyst project is a key part of managing change. Catalyst projects should be projects that offer substantial benefits to the most influential stakeholders and that can be completed relatively quickly, at low risk to the city. With luck, the catalyst project will contribute to a rising spiral of goodwill and acceptability for an Eco² Pathway. Choose carefully—first impressions count for a lot. The creation of positive expectations among the participating stakeholders and the public is crucially important to successful change management.

CHAPTER 5

A One System Approach

A One System approach enables cities to plan, design, and manage the whole urban system by integrating and/or optimizing its key subsystems. In doing so, it provides opportunities for cities to realize many benefits through synergy.

As we explore the possibilities for a One System approach we will first address enhancing the efficiency of resource 'flows' in an urban area through integrated infrastructure system design and management. These approaches apply to most urban infrastructure sectors, like transport, energy, water, and waste management—and may be applicable within each sector and across sectors.

We then look at possibilities for applying a One System approach to integrate urban 'form' with urban 'flows.' We will consider spatial planning, land use, density, connectivity, proximity, and other attributes of urban form, and see how a large extent of the overall system efficiency depends on integrating and coordinating these attributes with infrastructure systems. There is a fundamental relationship between a city's infrastructure systems and its urban form. Urban form and spatial development establish the location, concentration, distribution, and nature of demand nodes for the design of infrastructure system networks. By doing so, urban form establishes the physical and economic constraints and parameters for infrastructure system designs, their capacity thresholds, technology choices, and the economic viabilities of different options. These have tremendous implications for resource use efficiency. At the same time, infrastructure system investments (transport, water, energy, etc.) will typically enable and induce particular spatial patterns on the basis of a market response to these investments.

The final section of this chapter looks at how to implement projects using a more integrated implementation approach. This means sequencing investments so that the city sets the correct foundation by addressing the long-lasting, cross cutting issues first. This also means creating a policy environment that enables an integrated approach, coordinating a full range of policy tools, collaborating with stakeholders to align key policies, and targeting new policies to reflect the very different circumstances between urbanization in new areas, and improving existing urban areas.

As cities strive for greater ecological and economic sustainability, it is critical for them to adopt a One System approach. By reviewing this chapter, a more complete picture of opportunities and the possibilities for new development paths starts to emerge.

Eco² Methods and Tools facilitate a One System Approach

Planners, engineers, and designers will need to adopt new methods and tools if they wish to develop a systems perspective and apply the One System approach. Methods and tools can help everyone visualize the system dynamics, model the system-wide impacts of different design and policy options at varying scales, and generally think outside of the silos created by professional training, institutional structures and historical practice. Part Two provides a full description of the Eco² methods and tools that make a One-System Approach possible. As outlined in Box 1.2, this will include the use of Material Flow Analysis and the Layering of Information on Maps to create a 'transdisciplinary platform' for integrated design.

The Core Elements of a One System Approach

Integrating Flows: Infrastructure System Design and Management

We will first address the issue of enhancing the efficiency of resource 'flows' in an urban area through integrated infrastructure system design and management. These approaches apply to most urban infrastructure sectors like transport, energy, water, and waste management—and may be applicable within each sector and across sectors.

Integrating Demand and Supply

—ADDRESSING EFFICIENCY AND CONSERVATION BEFORE SUPPLY SIDE INVESTMENTS

An integration of supply and demand always must begin by asking: Why bother with new infrastructure if investments in demand reduction and more efficient use of existing infrastructure are more economic and beneficial? Integration of supply and demand is a strategic approach that needs to be supported by careful investment planning. For any given investment in services, an optimum balance exists between investments in system-wide and end-use efficiency, and investments in new supply systems. In an ideal scenario, supply side and demand side investments are considered on a level playing field, and money is placed where the returns to society, economy, and environment are greatest. In most utilities, proper tariff structures based on full cost recovery principles together with progressive block tariffs (for targeted social considerations) are an effective mechanism to reduce demand. This is because tariffs that do not reflect the true economic cost can send the wrong signal to consumers

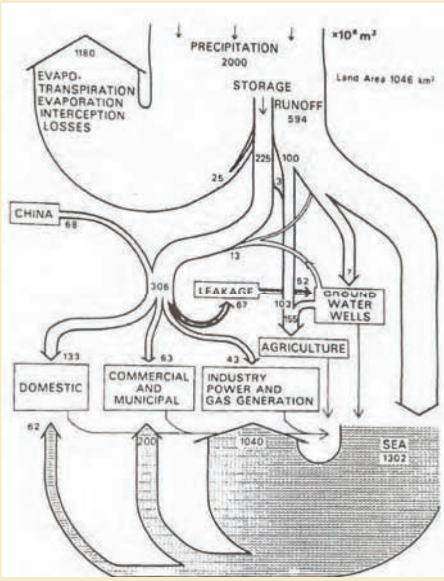
Demand vs Supply Approach

Urban infrastructure projects are predominately of a supply nature, that is, they are focused on the supply of the service rather than reducing the demand for the service. This can encourage the excessive use rather than efficient use of services, which is counter to sustainable development: for example, building more roads encourages a greater volume of traffic. The future approach to sustainable development should therefore be to reduce demand and then provide efficient and effective supply.

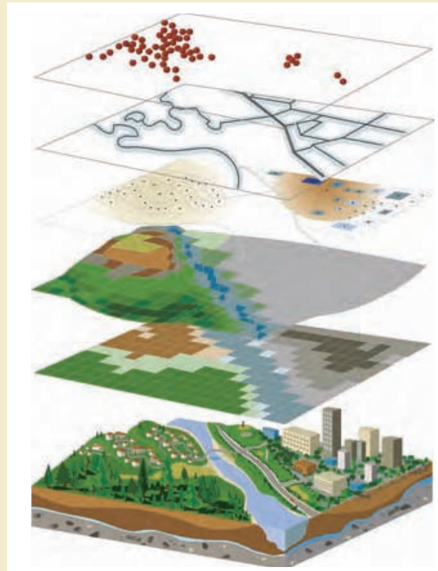
Towards Sustainable Urban Infrastructure: Assessment, Tools and Good Practice, Results of COST Action 8, (Europe)

BOX 1.2

Combining Flows and Forms to Create a Transdisciplinary Platform



This flow diagram summarizes all the water flow through Hong Kong, and is one of the first illustrations of an urban metabolism.[a]



FLOWS: Materials Flow Analysis and Sankey Diagrams

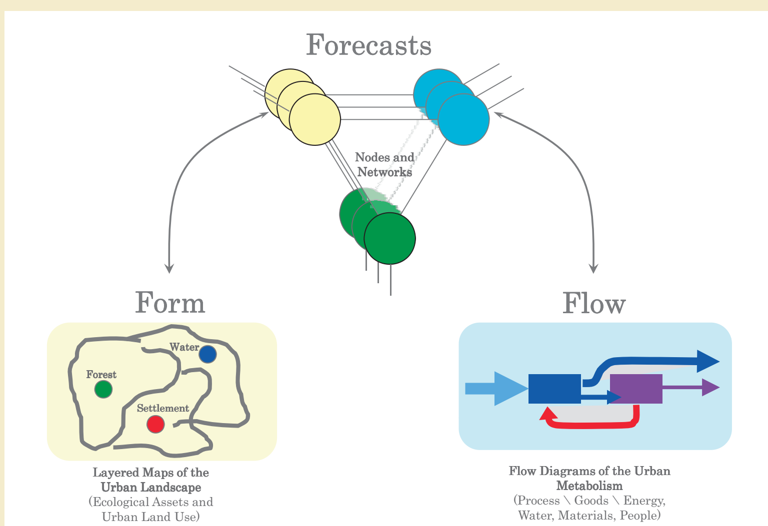
This is a method for calculating and illustrating the flow of resources through any size of urban area. Inputs and outputs are determined as a resource is extracted from nature, processed by infrastructure, consumed by home and businesses, treated by infrastructure, and finally returned for re-use, or delivered back to nature as waste. Colourful and simple diagrams are used to educate everyone on the resource flows, and how effectively they are used, all on a single page.

FORMS: Layering of Information on Maps

Maps are especially useful in collaboration, since they speak so well to so many: a picture is worth a thousand words. The layers of information make it possible to immediately interrelate the different features and qualities of the landscape, and also to easily quantify important spatial relationships. Layering is an old technique that has become more powerful as a result of computer technology and satellite imagery;

INTEGRATING FORMS AND FLOWS: A Transdisciplinary Platform

Because diagrams and maps can be easily understood and shared by a broad range of professionals and decision-makers, they help to bring stakeholders and experts together, facilitating a common understanding of integrated approaches to design and decision-making. Both forms and flows should be analyzed and understood for current and future scenarios. The methods in combination form a 'transdisciplinary' platform for understanding both the spatial dynamics of a city and its physical resource flows—elements that are interdependent but difficult to integrate because they involve such different skill sets and stakeholders.



A platform is needed to integrate the design concepts for urban form with the corresponding resource flows.

Source: Redrawn and Adapted from Baccini P, & Oswald F 1998: Netzstadt, Transdisziplinare Methoden zum Umbau urbaner Systeme. Zurich, Switzerland: vdf Hochschulverlag Zurich and lead to waste or overuse of resources. Historically, it is widely recognized that too much has been invested, too quickly, in supply solutions as opposed to investing in reducing demand through resource efficiency standards, building retrofits and substituting lighting, fixtures, vehicles, and appliances. In every sector, there are significant gains realized by demand side management (DSM); we have seen the cases of Yokohama in the waste sector (avoided capital expenditure of US$1.1 billion) and of Emfuleni in the energy and water sector (where singular investments of US$1.8 million led to annual savings of US$4.0 million). Not only do the net economic returns tend to be higher for DSM, but so too do the many indirect benefits for a city, including improved living environments, and reduced vulnerability to future price fluctuations or interruptions in resource supply.

While in some cases DSM can be easy to implement and very quick to pay dividends, in others it is difficult to implement due to the incentives of various stakeholders. Consider the case of housing and commercial buildings: on one hand, they represent a tremendous potential for DSM, as most buildings have not been constructed to energy or water efficiency standards and can generate high returns quickly for relatively small investments. On the other hand, changes to existing buildings require collaboration among decision-makers, and benefits do not always accrue to those who must make the investments, thereby fracturing the incentive structure. For instance, if owners cannot capture the benefits of energy efficiency savings, they will not invest in retrofitting—and renters who have a short time horizon also have no incentive to investing in retrofitting. In addition, the standards for products, including building codes, are often established by senior governments, and are therefore difficult to align with local goals and strategies. For all these reasons, a well planned collaborative process is necessary to capture the benefits of integrating supply and demand.

DSM measures can apply to all sectors and can include investments in more efficient technology. Typical examples include energy retrofits of building envelopes, resource efficient lighting and appliances, low flow water fixtures, waste reduction, reuse and recycling, and using Bus Rapid Transit instead of cars on the same roads (thereby avoiding the need to construct more roads). It can also imply a culture of doing more with less, and living lightly on the earth, by voluntarily limiting consumption and waste. DSM also can be achieved by improving designs at multiple scales, and through regular audits, commissioning, process enhancement, and improved training for personnel who install, operate, and manage systems. The proliferation of the ESCO sector is evidence of the growing and still untapped potential of the energy efficiency market.

Often, DSM in one sector can lead to benefits in another sector. For this reason, integrated approaches across sectors are critical. For instance, the significant urban energy benefits of the water sector's DSM led to a program launched by the Alliance to Save Energy called 'Watergy.' The Alliance has achieved significant benefits in developing-country cities in increasing access to clean water while reducing energy costs and water losses.

In Fortaleza (northeast Brazil), the Alliance worked with the local utility, the Companhia de Água e Esgoto do Ceara (CAGECE), to develop and implement measures to improve the distribution of water and the access to sanitation services, while reducing operational costs and environmental impacts. CAGECE invested about US$1.1 million, including in the installation of an automatic control system, and has saved US$2.5 million over four years. The efficiency gains were so high that 88,000 new households were connected to the water system, without the need to increase supply!

DSM can even apply to spatial systems. For example, the demand for land can be reduced by reviewing regulations (including adjusting minimum lot sizes, increasing floor area ratios, revising zoning, and adjusting land subdivision parameters), layering functions, or reducing parking spaces. Further analysis on managing the spatial structure of cities can be found in Part Three. In all cases, the demand and supply relationship needs to be replaced with an approach that enables and encourages demand management as a preferred approach.

Peak Load Management

—MANAGING THE DEMAND FOR SERVICES TO MINIMIZE THE REQUIREMENTS FOR PEAK CAPACITY

Energy, water, and transportation systems all tend to suffer from daily and seasonal peak loads that force utilities to oversize systems to meet peak demand at a particular time or period. This can be very inefficient from an economic and resource point of view. Peak loads also force utilities to supplement supply with back-up or imported resources and services that are especially costly. Even spatial systems suffer from highly uneven demand for spaces dedicated to such uses as parking, roads, and restaurants.

Reducing the need for overall system capacity through the management of daily and seasonal peak loads is peak load management. The object of peak load management is to even out the demands throughout the system, and to distribute demand across time to avoid investment in new permanent capacity. In some cases, peak load management can also help to avoid paying high costs for topping-up capacity when the primary system has reached its maximum output.

By delaying or avoiding costly capital investments and costly back-up strategies, peak load management can be extremely economic. It can also reduce resource consumption requirements, and can end up making more optimal use of existing capacity. However, it requires a systems perspective to recognize the best locations to intervene at each stage in the system.

For instance, in Europe, the heat demand varies significantly during the heating season. To deliver all district heating through a Combined Heat and Power (CHP) plant would require the utility to size a plant in accordance with the maximum heat load, which would require higher investments. Therefore, a strategy sometimes used is that only the base load is supplied by a CHP plant, and the peak load by a simple boiler plant.

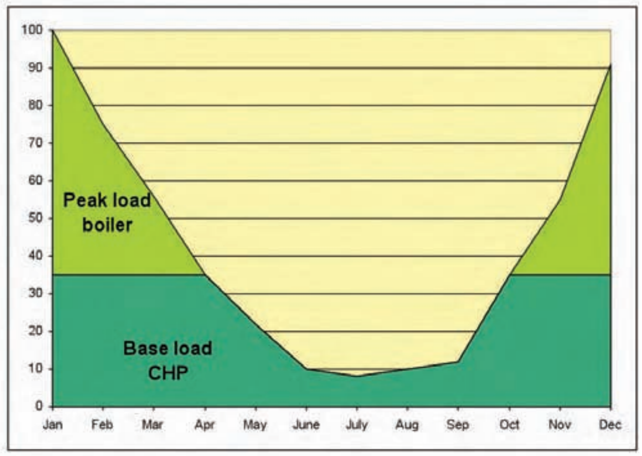


Figure 1.7. Load Curve of a District Heating System[h]

The system is designed for 35 units of base load instead of 100 units of peak load—representing significant savings.

Peak load management is often applied to the public transport system and highway system to reduce overcrowding or congestion during rush hour. In Japan, most commuter railway systems adopt an Off-Peak-Hour Tariff (lower tariff) to induce passengers to take trains during off peak hours. The Tokyo Metropolitan Highway Authority also uses an Off-Peak-Hour Tariff for the highway toll. The Highway Authority adjusts tariff levels among different highway routes to divert traffic from one route to another to reduce congestion.

Peak load management may also benefit from a more collaborative approach, since demand profiles are influenced by many factors that are sometimes difficult for cities to control unilaterally: land uses, time-of-day pricing structures; metering technology; control technology; business and school operating hours; daylight savings time; and the sizing of the distribution and storage facilities at each scale. At the same time, simple alterations to business and school operating hours can have a significant impact on transportation peak loads.

Cascading Resource Use

—MATCHING RESOURCE QUALITY TO THE REQUIREMENTS OF EACH USER

Cascading resource use is another option for integrating flow pathways. Cascading is achieved by matching the quality of a resource to the requirements of the end user. As the quality deteriorates, the resource is directed to uses with lower quality requirements. In this way, water, energy, and materials can achieve two or more functions in sequence. Figure 1.8 illustrates the transition from a once-through flow water supply system to an integrated system that matches quality to needs: its cascades water flows from drinking and cooking and sanitation to toilet flushing and sub-soil irrigation of gardens. The chief benefit of cascading is efficiency gains (satisfying many demands with the same unit of supply); however, an added advantage is the capacity to direct scarce resources to essential needs during difficult times. Resources can cascade through multiple uses and then, through processing, can be looped back to their original point of use.

The city of Singapore, considered a water-scarce city-state, adopted an integrated water-resource management strategy that includes many of the integration strategies, including the cascading and looping of water resources. This approach successfully lowered the annual water demand in the city from 454 million tons in 2000 to 440 million tons in 2004, while its population and GDP per capita grew from 3.4 percent to 10.3 percent, respectively. Cascading and looping caused a welcome departure from conventional supply driven investment approaches (often based on business as usual scenarios) to a new resource management approach, including effective demand management control.

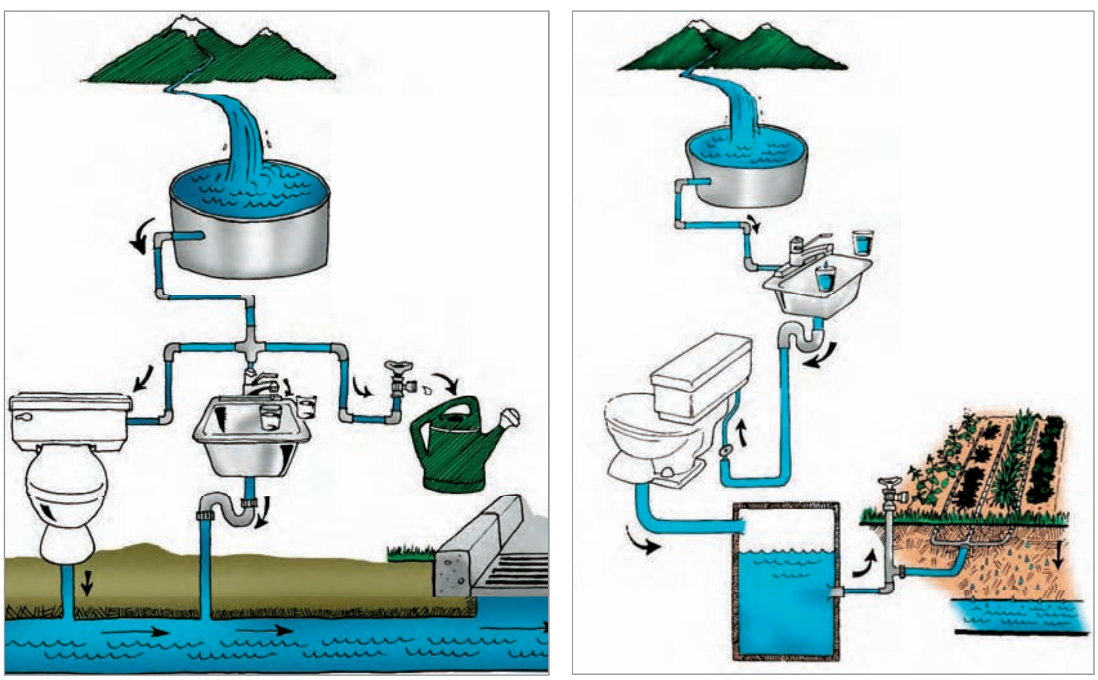


Figure 1.8. Cascading Water Use

If the quality of resource flows is matched to the needs of end users, the system becomes integrated as flows cascade from one user to another.

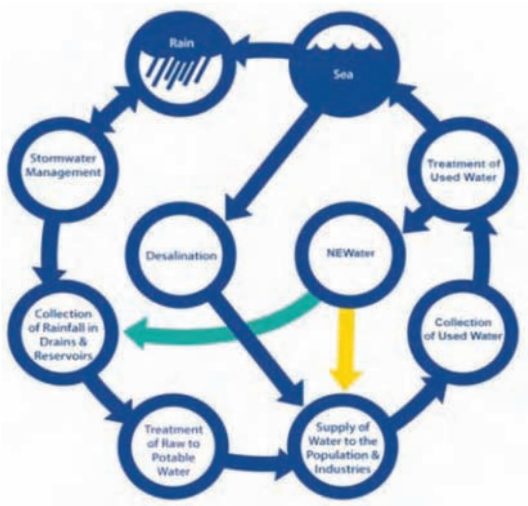


Figure 1.9. Cascading and Looping Water in Sinagpore[54]

The City's Life Support Systems

"The overall aims of environmental technologies are to maximise the possibility that cities can meet their needs from the natural capital of their own bio-regions in a renewable way and to move to closed loop infrastructure systems that recycle and re-use their own wastes, so that the absorptive capacities of natural systems are not overwhelmed with the waste loads from urban areas."

The Eco-city: ten key transport and planning dimensions for sustainable development, by Jeffrey R. Kenworthy

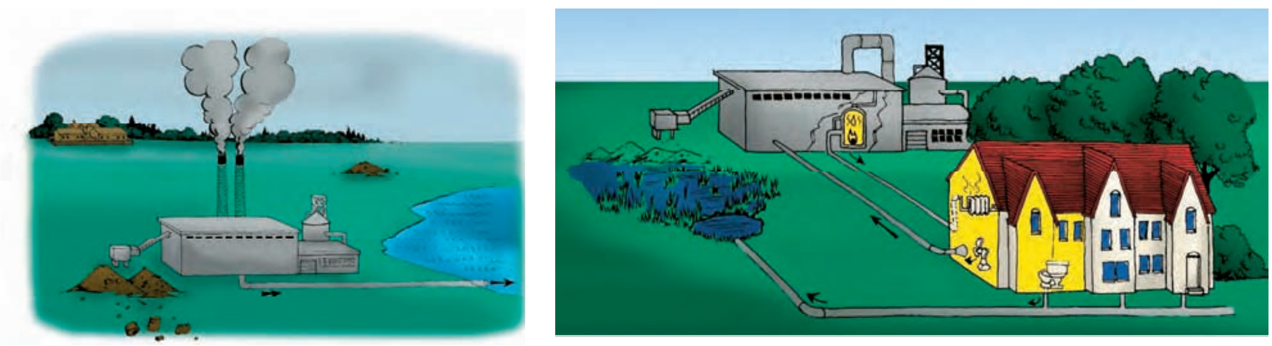


Figure 1.10. Looping Resources

In the example on the left, a factory consumes resources and generates waste. On the right, an urban ecology has emerged, where the waste heat, water, and material are reused by other land uses, looping within the city to save costs and reduce negative impacts on the environment.

Looping Resource Use

—RECLAIMING THE SECONDARY RESOURCE VALUES

Looping refers to the closed loop systems that ultimately return water and materials to their point of origin. Returnable drink containers are an obvious example, but the same concept can apply to the much larger flows of organic material and water that are carried within drinking containers.

Looping is a common in natural ecologies, where it manifests in the water cycle, carbon cycle, and nitrogen cycle. City infrastructure is most successful when loops are closed. This might mean recharging aquifers during rainy periods, or converting organic waste into soil supplements for local parks, gardens, and farms. Looping close to home is especially effective, since it reduces transport costs and creates many potential benefits such as jobs close to home and local stewardship.

An example of cascading and looping across infrastructure sectors is exemplified in the case of Hammarby Sjöstad in Stockholm. Energy, water, and waste are looped many times to enhance and optimize the utility derived from resources. (see the case study on Stockholm in Part Three).

Looping also provides an opportunity to invest strategically in the weakest link. Once the connections in the loop are understood, it is possible to retrofit existing infrastructure based on greater knowledge of the most effective investments in each sector. For example, for water, wastewater, and gas distribution systems, leakage reduction in existing pipelines is a very effective investment for improving water and energy use efficiency.

Distributed Systems for Omni-Directional Flows

—GREATER FUNCTIONALITY FOR NODES AND NETWORKS

Integration of nodes and networks is achieved through more distributed systems. In a traditional supply-oriented approach, the number of nodes is few—a single supply facility might be the only supply node, for example, and the distribution network may be a simple one-way hierarchy from a big facility node directly to users. A fully distributed system actually works in both directions and enables omni-dirrectional flows. The supply system can begin at or near the home, office, or shop where demand for services originates. Local and renewable options can be explored for on-site supply, storage, or treatment—roof-mounted technology can capture and store water, for example, or capture and convert sunshine. It is conceivable that public utilities may still own and manage technologies, but they are located on-site. If on-site facilities are not practical, sufficient, or economic, the next choice is to examine options for the cluster, block, or neighbourhood.

Economically, it is often viable to locate a significant capacity of supply and treatment facilities at the neighbourhood or district scale, or at the centre of small clusters of mixed use buildings, so that equipment can be well managed and used continuously. Combined heat and power plants in Europe often operate at this scale providing both power as well as district heating at a city district scale. Another example might be septic tanks attached to buildings, which may be interconnected to a small in-ground waste water treatment facility at the local park, or to a high-rate composting vessel at the nearest recycling depot or community garden. Distributed systems make greater use of networking. Local networks for capturing water or generating power may allow nearby sites to share surpluses with others, creating a two-way micro network. Surplus energy (for instance) generated by a cluster of users can be stored for later use or sold back to a smart grid. Local networks can be nested within larger networks. In this way, the pattern changes to a system with many nodes serving clusters of users,

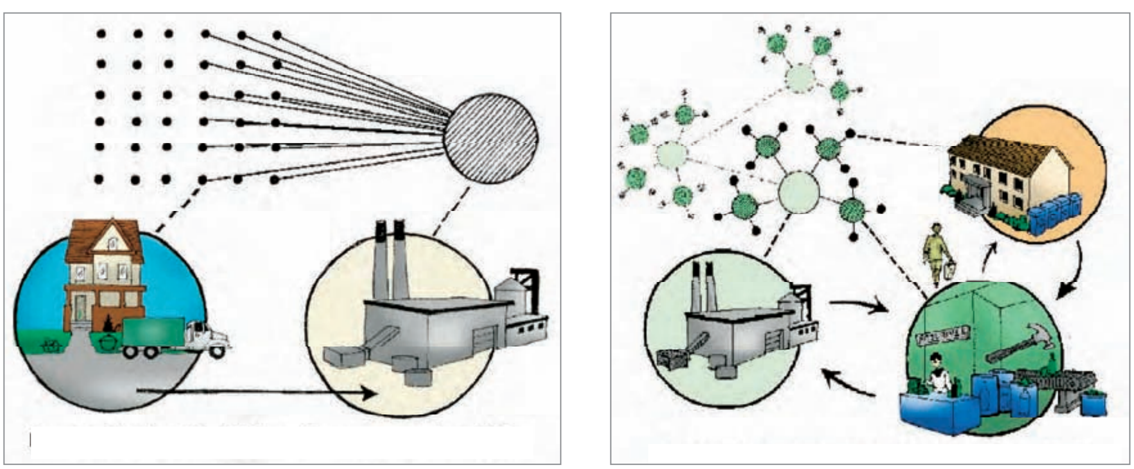


Figure 1.11. Cluster Management of Waste.

The scenario shown on the left is the common supply model, where solid waste is collected from many sources by a centralised trucking system, and then processed at a large, remote facility. On the right, a two-way network evolves to eliminate waste within the cluster.

connected by a complex network with omnidirectional flows. Distributed systems may cover large areas of the city, but the nodes are more numerous, and the networks more adaptable.

The Rocky Mountain Institute's path breaking and comprehensive work on the viability of distributed energy systems ("Small is Profitable," Rocky Mountain Institute 2002, by Lovins, et.al.) catalogues over 200 benefits—the most significant of which relate to the systems' modularity, which contributes to a reduction of economic and financial risk by several orders of magnitude. Other potential benefits from integrating nodes and networks might include reduced costs for land dedications, and well as the characteristically large transmission and conversion losses. For many cities, a growing proportion of utility resources are being used in unproductive generation and distribution, especially as DSM has reduced demand for services at each node. Not only does a distributed system help to avoid these costs, it can also offload the costs of new facilities from taxpayers to developers, and give developers a long-term interest in the efficiency of neighbourhoods. Other benefits from more distributed systems include a more incremental pace of investments shaped by demand, better matching of capacity to existing load, and less vulnerability to whole system collapses. As infrastructure facilities move close to buildings, so do their jobs, and the city becomes more efficient and walkable. Proximity of facilities also increases the potential of almost all other types of integration (e.g., recycling and looping of resource flows, multi-use and culturally distinct structures).

As demonstrated by the City of Rizhao in the Shandong Province of China, distributed solar water heating systems can be effective urban energy solutions while also helping to address social equity issues.

Spatial planning can also benefit from distributed systems that make nodes of population more self-reliant. This is the philosophy behind smart land uses—mixed use walkable communities that provide easy access to transit, services, shops, and parks, rather than forcing everyone to travel to the city centre or mall with the attendant costs of time, energy, and emissions.

Multi-functionality

—SERVING DIFFERENT ENDS USING COMMON SPACES AND STRUCTURES

Integration of infrastructure facilities across sectors is achieved through multipurpose elements that serve different sectors simultaneously or at different times. A common example is the integration of energy and water systems. In many towns and cities, the largest single energy account in the community is for pumping municipal water from wells or water bodies. Sewage digesters also require large motors and energy expenses. Thus saving water automatically means saving energy required for water supply and sewage treatment. An integrated approach is the logical option.

Solar Energy Systems in Rizhao

Rizhao, a city of about 350,000 people in northern China, is using solar energy to provide water heating and lighting. Starting in the early 1990s under a municipal government retrofit program, the city made it mandatory for all buildings to install solar water heaters. After fifteen years of efforts, 99 percent of households in the central district obtained solar water heaters. Solar water heating is now common sense. In total, the city has over a half-million square meters of solar water heating panels, the equivalent of about 0.5 megawatts of electric water heaters. Most traffic signals and street and park lights are powered by solar cells, reducing the city's carbon emissions and local pollution. Using a solar water heater for 15 years costs about US $1,934(15,000 Yuan), less than running a conventional electric heater, which equates to saving US$120 USD per year per household in an area where per capita incomes are lower than the national average. This achievement is the result of a convergence of four key factors: a regional government policy that promotes and financially supports research, development and deployment of solar water heating technologies, a new industry that takes the opportunity in strides, and city leadership that not only has a vision, but also leads in action and brings along other stakeholders.

Source: Worldwatch Institute, *State of the World 2007*, www.worldwatch.org.[i]

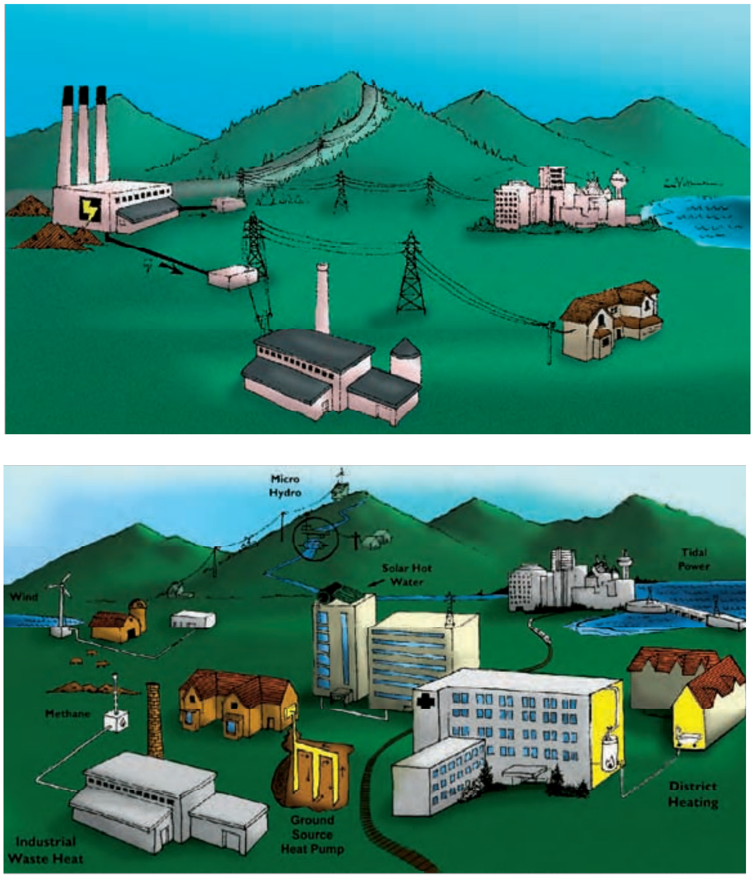


Figure 1.12. Distributed Systems.
Centralized, remote facilities with one-way networks can be transformed to distributed systems as shown in these two extreme examples of energy systems. In the centralized example, a remote facility services all end users in a one-way distribution network. In the distributed case, all buildings within a 5 km radius are connected to a local heating /cooling plant, using low temperature water to move heat or cooling from one location to another. Excess heat can be captured from local industrial processes, or sewage, or large buildings like the hospital, and then shared at low cost. Local power generation is an option—creating a mini electrical utility that offers its 'waste heat' to buildings or to operate a cooling system. Typically, such a combined system can raise overall efficiencies from 55 to 80 percent. The on-site power can be used for local transit year round. Flexibility is also enhanced, since energy sources can be mixed to take advantage of market rates, local waste products, weather, new technology, and so on. Any excess electricity from the local utility can be offered to the regional grid, and used for better load management and back-up.

Integration of energy and water can involve more than just shared efficiency gains. The water system for Vancouver's new Olympic village, for example, is closely integrated with the energy supply systems in the city. As the water travels down from the city's mountain reservoirs, it turns a turbine within the pipes. The turbine creates electricity. After the water is used in the village, a heat pump draws thermal energy from the sewage, and returns this heat to buildings that require space and water heating. When the sewage is eventually treated, the methane gas that is released is used to power the treatment facility. Is this a water system? A hydro electric system? A gas-fired electrical system? A district heating system? A sewage treatment system? Answer: all of the above.

The picture below describes the integration of a trail system with other forms of infrastructure. Many possibilities exist for such multipurpose facilities and amenities. At some point, the integration of systems is most successful when it is in fact difficult to isolate any particular system on its own. Functional components of urban services are tightly woven into the fabric of the community at the most local scale.

Integrating Flows with Forms: Spatial Planning and Urban Design

We now look at the possibilities for the application of a One System approach in integrating urban 'form' with urban 'flows.' We will consider land use, density, connectivity, proximity, green infrastructure, and other attributes of urban form, and see how a large extent of the overall system efficiency depends on integrating and coordinating these with infrastructure systems.

Urban Form, Land Use Mix, Density, Connectivity, and Proximity

Integration of spatial planning with infrastructure system design represents the most significant opportunity to enhance overall system performance. Urban form, land use mix, density, connectivity, and proximity all have effects on infrastructure performance. Yet, few land use plans are evaluated from this perspective. Planners and engineers sit at different tables, at different times, asking different questions. Seldom do infrastructure concerns influence land use plans or vice versa. Despite this disconnect, the best time to consider ways to minimize in-

Figure 1.13. Uses of a Pedestrian Pathway.
This pleasant pedestrian pathway is serving the transportation needs of a walkable community, providing a quiet, safe, and cool option for moving around. At the same time, it also functions as an element in other infrastructure systems. The garden strip on both sides of the pathway is growing plants and flowers that help to keep the city cool, reducing air conditioning energy requirements. The pathway is bordered with a gentle swale (or depression in the earth), which functions as an infiltration trench, intercepting and slowing storm water flows. The soil in the trench is enriched with composted organic waste, avoiding the need to truck such waste out of the community. The enriched organic soil is highly absorbent, and thus needs little irrigation to stay green, helping to reduce the city water budget. The sub-base for the pathway is composed of ground glass and rubble from returned bottles and from industrial waste. In essence, the pedestrian pathway is a transportation facility that also serves to manage and treat storm water flows, recycle organic and inorganic waste, cool the city, and provide a water-efficient garden amenity.

Source: Rutherford, S. WCEL 2007[i]

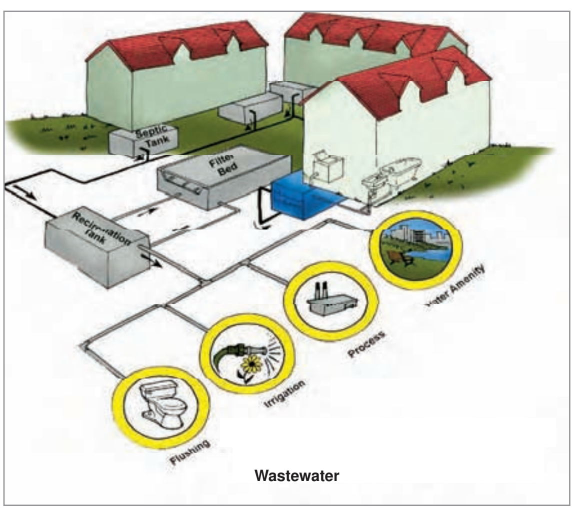


Figure 1.14. Distributed System for Wastewater Treatment.
In this example, a distributed system for waste water treatment incorporates low flow fixtures in buildings, primary treatment in septic tanks attached to each building, and an advanced secondary treatment system in a courtyard to serve a cluster of nearby buildings. The water is decanted from septic tanks and sprayed over a gravel bed in the recirculation tank. The reclaimed water exiting the tank is safe for all uses other than drinking. This water can be used for flushing toilets in a two-pipe system or for irrigating and fertilising gardens. It can also be used as an input into local industrial processes, or to augment water in streams, fire prevention reservoirs, and fish ponds.

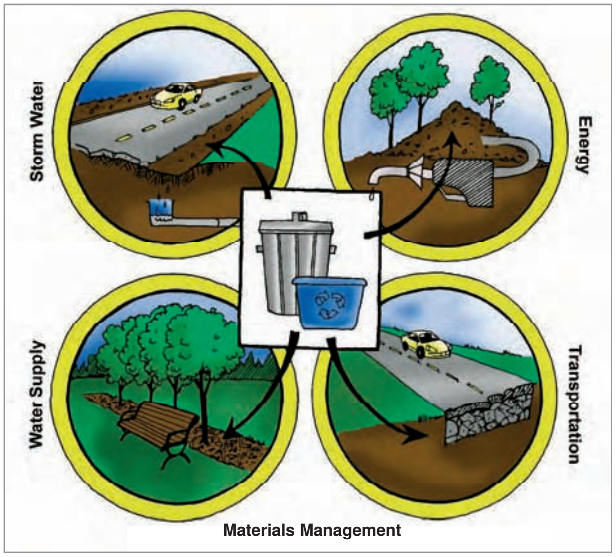


Figure 1.15. Integrated Materials and Waste Management.
In this simple illustration, we can see how the solid waste stream from a city neighbourhood (centre) is diverted into other sectors: crushed glass provides a base for roads; composted organics provide nutrients; compost provides soil additives to parks and public green space; and coarse organics are used to create French drains next to highways that capture and clean storm water flows and run-off water from the road. Finally, a facility converts organic matter to biogas for use in generating heat and power.

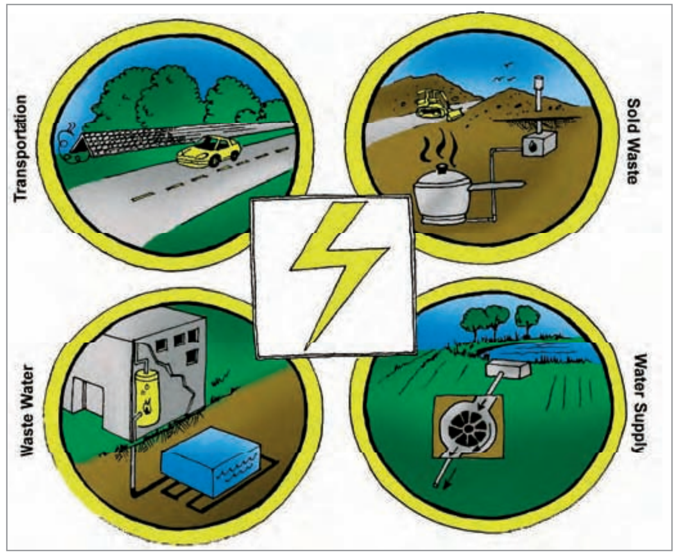


Figure 1.16. Innovative Energy Infrastructure.
Energy systems can take advantage of flows from other sectors: for example, a sound barrier along the highway has photovoltaic panels that generate electricity reused for domestic hot water; a small turbine in the water supply system harnesses excess water pressure to generate electricity; methane from composting facilities is used to generate heat and power.

Figure 1.17. Integrated Stormwater Management.
Storm water management systems can realize synergies with other urban systems: a cycle path doubles as an infiltration trench; shady trees and green roofs reduce energy use and also keep precipitation away from drainage systems and slow rainwater flows; roof rainwater catchment and storage systems provide water for gardens and lawns; finally, storm water is directed into finishing ponds for reclaimed wastewater, helping to treat sewage and maintain amenities.

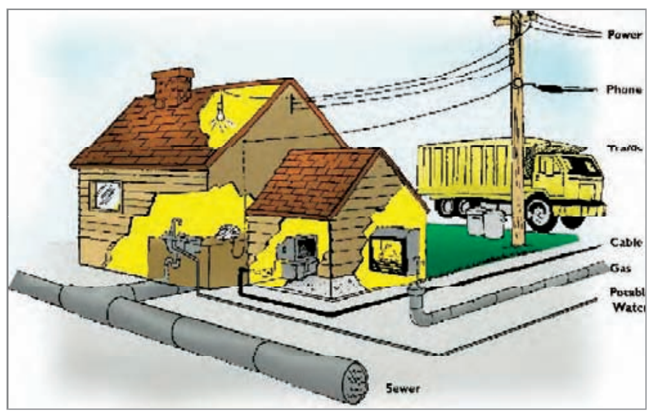


Figure 1.18. Traditional Dwelling Supply Systems
This dwelling has high demands that are satisfied by disconnected, infrastructure supply systems.

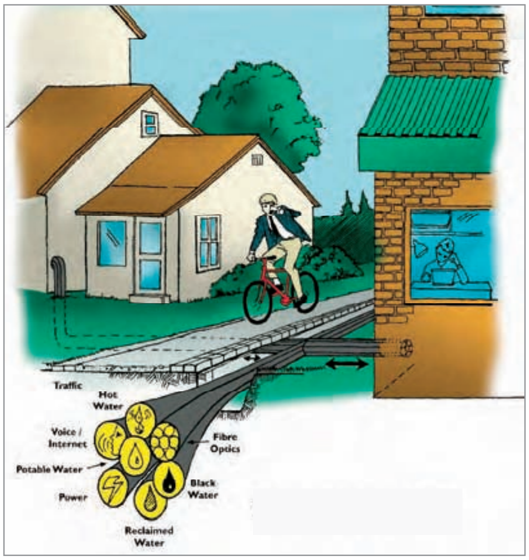


Figure 1.19. Combined Trenching for Infrastructure Systems

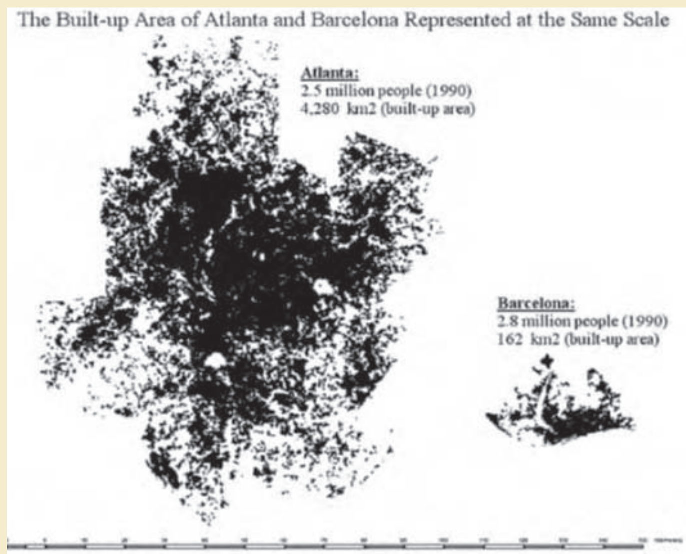
This dwelling is much more resource efficient by design; infrastructure application combines trenching and more varied flows to facilitate sharing and cascading of resources within the housing cluster

BOX 1.3

Form and Flows

The sustainability of infrastructure systems depends upon the path chosen for spatial development. To appreciate impacts, compare the spatial layout at the same scale of Atlanta and Barcelona.

The comparison between these spatial distributions of population illustrates differences in urban spatial structure and consequences for the operation of transit and other infrastructure. Imagine the differences in capital costs to service these similarly sized populations. Remember that distribution network cost is a large share of the total cost—for example, pipes account for about 70 percent of the cost of a water supply system. Also, imagine the differences for these cities in the operation and maintenance of their water systems (pumping of water, collection and treatment of waste) and their transportation system. Keep in mind that about 30 percent of urban energy bills is often for pumping water and wastewater.



Source: Bertaud, A., and T. Pode, Jr., Density in Atlanta: Implications for Traffic and Transit (Los Angeles: Reason Foundation, 2007).

frastructure costs is during the early . Despite this disconnect, the best time to consider ways to minimize infrastructure costs is during the early stages in land development processes.

In principle, spatial planning can contribute to lower infrastructure costs by increasing density and compactness, and by locating development sites in close proximity to key facilities. The amount of linear infrastructure required for low density, single family housing can be 17 times greater than what is required for multi-unit dwellings in dense urban developments.[k] The capital cost saving are roughly proportional to the average length of the system per serviced unit. In low-density, single-use developments, local governments often generate less in development fees and property taxes than they spend in services and infrastructure costs,like roads, water mains, and sewers. An analysis found for every US dollar raised in development fees and property taxes in Southwestern Ontario, $1.40 need to be spent on services. The rest of the city subsidises lower density development.

The urban form and density locks-in some of the most significant physical and economic parameters for supply side infrastructure investments. Public transportation and district heating and cooling are examples of efficient technologies that become financially viable only at certain threshold urban densities.

As cities sprawl and splinter, the energy consumption for transporting people can increase by a full order of magnitude, and cities can decisively exclude pedestrians, as shown in the following photographs of Houston. Houston has a population of 2.2 million, and its area is 1,600 km^2.

Figure 1.20. Houston Texas: Broad View of City Center
The expanded view shows a parcel of land that is theoretically within walkigng disacnce of ticy center.

The following graph illustrates this relationship across a range of cities, underscoring that urban form and density significantly impact energy consumption for transportation.

Proximity and connectivity to key facilities are other factors, since scattered pockets of development are likely to be for from supply and processing systems, and require relatively greater investments in trunk lines, major roads, pumping stations, and so on. The additional capital costs for remote connections are typically shared by all users, and translate into cost premiums. If higher density, transit-oriented developments are instead located downstream from water reservoirs and close to existing mains, the capital costs of development will be much lower, and the city can avoid otherwise significant costs (often 30 percent or more of total energy bills) associated with pumping water to new households and businesses.

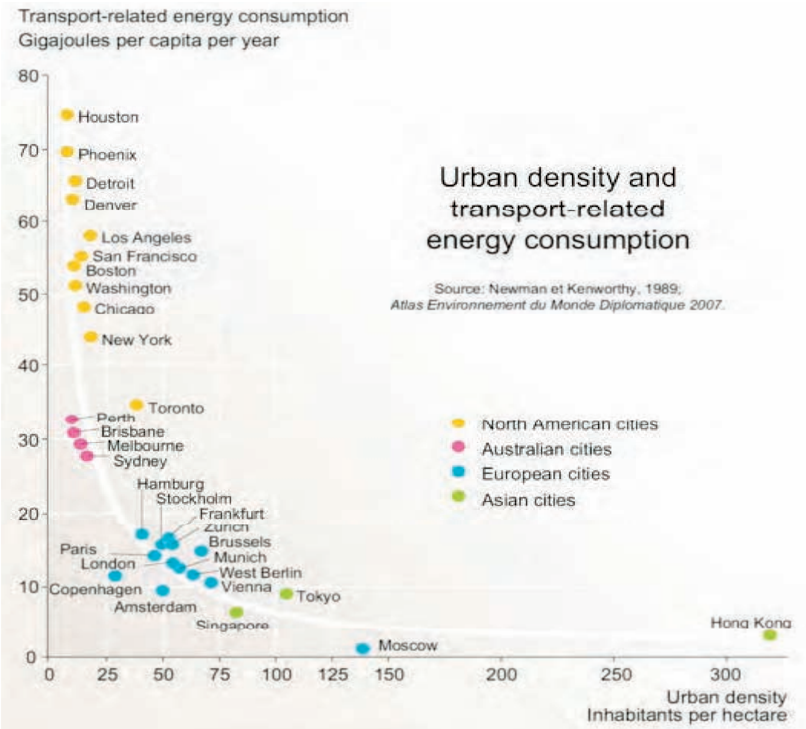


Figure 1.21. Urban Density and Transport-related Energy Consumption
Source: Adapted from Kick the Habit: A UN Guide to Climate Neutrality

Because resource efficiency and emissions are influenced directly and permanently by urban form and density, intelligent spatial planning is the first proactive step towards 'demand side' management for infrastructure. The mixing of land uses at the neighbourhood scale can further reduce system costs by evening demand for services, and reducing peak loads that directly affect the design capacity and capital costs of infrastructure systems.

Land use plans also need to consider existing and planned infrastructure capacity, and direct growth plans accordingly. Certain locations within a city may be especially suitable for infill or new development, precisely because they have excess capacity for power, roads, and water. In other locations, capacity may be non-existent, and further land development may require major new investment for one or more systems. Ideally, infrastructure capacity needs to be analysed and mapped on a fine scale, and included in the overlay analysis that guides land use planning.

At the same time, spatial development (and its coordination with broader investment strategies and plans) has significant implications for economic competitiveness, and it impacts land and real estate markets. Spatial development and infrastructure investments set in place and shape the contours of these larger economic dynamics. Spatial development is also influenced by these dynamics. For more detailed information on how spatial form and land use regulations impact mobility and affordability, please see Part Three.

Poor spatial planning can fragment labour markets and make cities unaffordable to those who cannot buy cars, and vulnerable to fluctuations in oil prices. For instance, the spike in gasoline prices in the US in the spring of 2008 resulted in a 6 percent drop in vehicle kilometres travelled in 4 months. By moving people out of cars and onto public transit, the area required for roads and parking can be drastically reduced, as suggested by the photographs of Houston! Cheap or free parking subsidizes car use, as do massive land investments in roads. In cities, parking should be market priced and compete for real estate.

Policies that affect the viability of transit also affect the cost and performance of transportation infrastructure. For example, densities of around 50 people/ha are required to provide convenient alternatives to the car. These two issues are impossible to separate. Thus, a key strategy for improving overall system performance is to organize land use, densities, connectivity and access to ensure viable public transit and other infrastructure.

Green Infrastructure

INTEGRATING NATURAL SYSTEMS WITH BUILT SYSTEMS

Integration of natural systems with infrastructure is possible through 'green infrastructure' and ecological engineering. Green infrastructure refers to the city's 'naturescape'—the mix of trees, shrubs, hedgerows, gardens, green roofs, lawns, parkland, and waterways. These natural elements can be very effective at providing a variety of services for other sectors. For example, when the mayor of Los Angeles was facing brown outs and severe energy shortages in 2004, his response was to invest in planting thousands of street trees. Urban forests save energy by reducing temperatures, shading buildings, cooling the air, and reflecting sunshine. Los Angeles' trees are part of the city's energy infrastructure.

The most common examples of green infrastructure are the ribbons of green riparian areas along streams and rivers. These green strips act as filters, preventing silt and nutrients from entering streams. Storm water permeates the soil, or is retained on leaves or captured by roots, and the result is less damage to aquatic environments or reduced requirements for investing in treatment systems.

Such natural systems can be more or less engineered to suit the city's needs. For instance, being surrounded by rivers such as the Iguaçu, flooding has been a big problem in Curitiba. Instead of controlling water flow by concrete structures, Curitiba created natural drainage systems. Riverbanks were converted to parks where flooding water can be contained in the soil, and lakes were constructed to contain floodwaters. River and rainwater that lead to flooding can be contained naturally in the lakes and parks surrounding the lakes. The ecosystem is preserved in a natural way. As flood water to the park area is released from ground to the river naturally, (rather than being drained at high speeds through straight concrete-made drains), flooding downstream can be avoided. People are less exposed to environmental hazards and diseases caused by flooding. The costs of building parks, including the relocation costs for slum dwellers, are estimated to be five times more economical than building concrete canals.

Land use plans can also be used to incorporate green infrastructure most effectively when they include policies that control demand for services. In Freiburg, Germany, for example, land use plans address storm water run-off by taxing land differently based upon the permeability of the surfaces. As a consequence, developers are careful to minimize hard

Figure 1.22. A Different Paradigm for Urban Design

Big roads, lengthy pipes, big wires, and larger pumps are replaced by a mixed use, compact, pedestrian friendly design where public funds are used for parks and social and local services surfaces over parcels, using crushed stone for pathways, paving stones for parking, and so on. The result is less cost for taxpayers, as the city avoids investment in infrastructure for capturing, transporting, and treating storm water.

Layering

—INTEGRATING DIFFERENT USES FOR A COMMON SPACE OVER TIME

Layering of uses can also occur over time. A school and its playgrounds might serve to educate children during the day. However, these areas might become sites for after-school programs in the afternoon, schools for adults in the evening, and, on weekends, serve as cafés, theatres, or open-air craft and farmers markets. The schoolyard might also be an overflow flood control basin in monsoon season. Smart cities don't build schools; they build multi-purpose civic facilities that change their use by the hour, day, weekend, and season. It is the community, not the school board, that controls usage, and the building continues forever as a community asset, even if the need for schooling decreases.

The multiple functioning of elements in a system creates a 'layered' approach to design, where each location serves many purposes. This is part of a slow evolution away from the highly segregated land use patterns that are typical for many modern cities. More attention to design helps to mitigate or eliminate the negative impacts of diverse uses on surrounding parcels. Industries are not necessarily dirty affairs that need to be isolated from the homes of workers. In fact, their processed wastes and emissions are now recognised as valuable resources, providing feedstock for new industry. Mixing shops into residential areas enhances livability and sustainability, and creates jobs close to home.

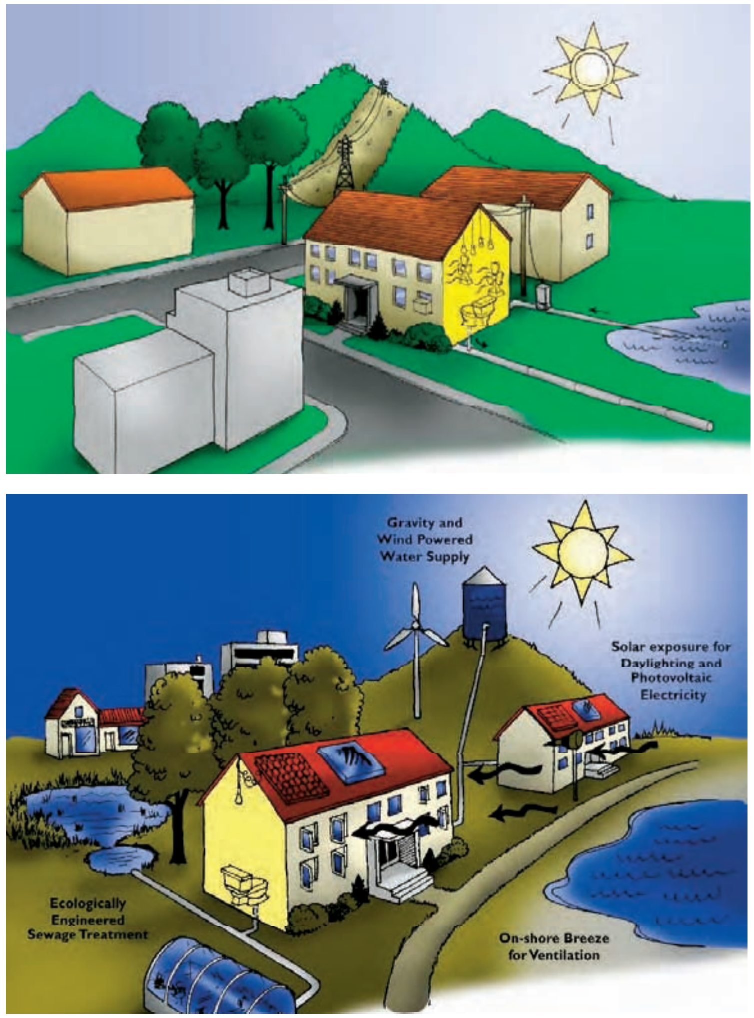


Figure 1.23. Integrating the Benefits of Natural Systems in Communities
This settlement on the top is not blended into its surrounding ecological systems; it neither benefits from nor uses these systems efficiently. By contrast, this settlement on the bottom harnesses ecological attributes, including wind, elevation, sunlight, ecological sewage treatment options, to its advantage. This reduces the settlement's footprint and ongoing costs.

Figure 1.24. Multiple Uses of a Public School.
A public school functions as an adult education centre in evenings, a farmers market in summer, community craft market on weekends, theatre on weekend nights, cafe in evenings, and a community centre all of the time.

Co-location

—ADVANTAGEOUS SITING AND PLACEMENT OF NEW STRUCTURES AND RIGHTS-OF-WAY

More efficient and use and facilities can be achieved through strategic and cooperative siting and placement of new structures and rights-of-way. One common example is the mounting of photo voltaic and solar water heating panels on rooftops where they can take advantage of unobstructed sunshine (and possibly provide useful shading for buildings). Rights of way can be shared by many different services. A wet waste composting facility might be co-located with community gardens to facilitate easier looping and to better manage the noise, odor, and activity impacts. Although the relevant structures and activities may be planned by different groups, their integration can benefit everybody.

Place-making

—CREATING SOCIAL AMENITIES AS INTRINSIC ATTRIBUTES

Hard infrastructure facilities can be designed in ways that contribute to the community in many social and aesthetic ways. It is no longer necessary to hide wastewater reclamation plants if the treatment basins can become pleasant nature ponds with quiet trails and landscaped shorelines. The reclamation system in Irvine California is frequently used by residents as a park area because the connected water bodies and trails provide a unique and enjoyable experience. Water storage tanks can become sculptures and way-finding landmarks. Recycling depots can become community gathering locations. The opportunities are really unlimited if the mandate for design is integration.

Integrated Implementation

We now look at how to implement projects using a more integrated approach. This means sequencing investments so that the city sets the correct foundation and addresses long-lasting, cross cutting issues first. This also means creating a policy environment that enables an integrated approach, coordinating a full range of policy tools, collaborating with stakeholders to align key policies, and targeting new policies to reflect the different circumstances between urbanization in new areas and existing areas.

Sequencing

—THE PHASING OF INVESTMENTS TO CAPTURE WHOLE-SYSTEM SYNERGIES

Sequencing refers to the ordering of integration strategies so that decisions in one sector don't preclude integration in another. For instance, a city's location and its route of growth are primary factors determining its spatial advantages and constraints. Location determines the physical and environmental conditions of the city: al-

Sanitary and Energy Systems Integration in Shanghai

As part of an environment program for Shanghai funded by the World Bank, the Shanghai Municipal Sewage Company (SMSC) plans to construct a large scale incineration plant for sludge drying. The SMSC is planning to use the steam generated by a nearby thermal power station for drying. The use of the steam generated by this power station will improve the incineration plant's efficiency and safety, while reducing the need to burn imported oils, leading to GHG emissions.

> "Sense of place increases when structural and infrastructure systems integrate with ecological and human systems and dynamics. ...When this integration occurs, structural and infrastructure systems make resources available for human use, while communicating an integration of people and place."
>
> **Landscape Design, Motloch 2001**

titude, topography, and climate. Location has implications for a city's urban form and density, its infrastructure systems (demand and supply), and its built environment requirements and possibilities. Location also determines access and proximity to natural resources (such as renewable energy resources), as well as access and links to the economic geography of a region.

Cities, like people, work best when they have good bones—strong structural elements that can provide the right context for the shorter lived elements. Within an urban region, the sequence typically progresses from slow-moving elements like local ecologies and natural assets, land use patterns (including rights-of-way), and building stocks, to the faster moving elements like management policies and consumer behaviour.

The longer lasting elements are given priority since they are slow and costly to change, and will for constrain what is possible in other sectors. When the long-lasting integration opportunities are missed, it can take a very long time to get things right.

Figure 1.26 provides a rough guide for sequencing integration opportunities during the diagnostics stage of a project. Moving from the outside in, we see how specific integration opportunities tend to line up. Harmonizing infrastructure with the surrounding ecology and resource base is a good first step. Integration with urban form and land use is next. Demand reduction is next. All of this is common sense. As mentioned earlier, there is no point in investing in large remote supply or processing systems, if a similar investment in local ecologies, or smart growth or demand reduction, can provide a much more sustainable solution.

Enabling

DEVELOP POLICIES THAT ENABLE THE DIFFERENT TYPES OF INTEGRATION STRATEGIES

Despite the best intentions, cities often get in their own way when trying to implement more sustainable infrastructure and land use. Out-

Sustainable Urban Design, Goa

"The urban design flowed seamlessly from the ecosystem and landscape design, integrating natural systems, heritage elements and the existing settlement fabric of Goa into a new condensed structure. Instead of settlements colonizing the landscape, settlements become compact islands in a sea of biodiversity. The settlements themselves are also planned on these principles, guided by slope and contour, water flow lines, and linkages to water and transport networks. They are interwoven with surrounding agriculture, horticulture and forestry areas, with green fingers penetrating in to the settlements."

From Goa 2100: the transition to a sustainable Urban design, by A. Revi et al, in Environment and Urbanization, Volume 18, No. 1, April 2006

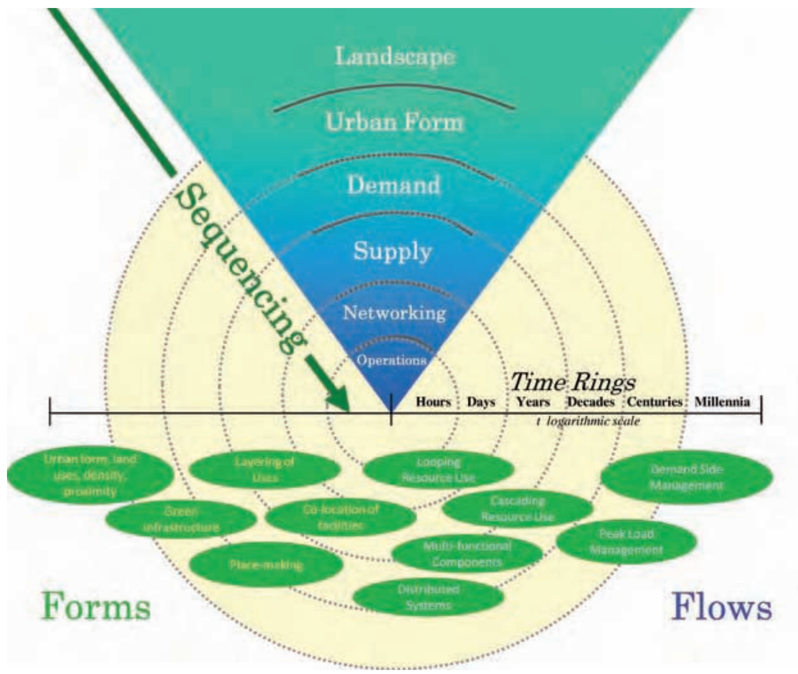


Figure 1.25. Time Rings.

Time rings help to sequence investments for optimum returns. A strategic approach to infrastructure planning examines all opportunities for integration, but moves in sequence, from the slowest changing elements such as integration of infrastructure with natural systems and land use plans, to the fastest, like integrating management systems, providing incentives for consumers, or monitoring and adaptation.

dated polices prevent new approaches, and artificially freeze the technology. Policies developed for one reason inadvertently impact design solutions in unforeseen areas. Any developer who has tried to apply ecological design will have plenty of such stories. For example, consider a proposal for a new underground advance on-site sewage treatment system for Dockside in Victoria—Canada's premier example of sustainable mixed use development. Although the system was eventually built and is now working well, the developer first had to deal with months of difficult negotiations. The city didn't like the idea of on-site sewage treatment, despite the fact that the whole city was dumping its sewage untreated into the ocean. The developer's plans were rejected initially because the city had regulations against treatment plants in residential areas. Other regulations from the health department forbade any use of reclaimed water for toilet flushing and gardening– making the advanced technology at Dockside much less ecological. How could they benefit from reusing wastewater? Yet another obstacle was the city's property tax structure which forced the residents in the new Dockside neighbourhood to pay a share of the city's upcoming sewage system, despite the fact that they will not be using it.

The reality is that every city will have many policies that conflict with a new One System planning framework, and with the ecological design and management of new projects. It is important to recognize that one of the most important outcomes from an Eco² Catalyst project is that such policy conflicts will be exposed, and—hopefully—resolved. A collaborative framework can help to quickly resolve such issues for catalyst projects, and develop new policy in the process.

In general, enabling policies go well beyond conflict resolution. Ideally, the policy environment that evolves in a city reinforces the goal and objective oriented framework, and stipulates performance requirements rather than prescribing specific solutions. While the city needs to articulate clearly the constraints and targets for the community as a whole, the most creative design solutions are most likely to be achieved at the most local scale—at the building or parcel or neighbourhood. In other words, primary responsibility needs to rest with the local actors and decision-makers. It is they who first explore design options, and thus have the greatest freedom to innovate. What is passed on to the scale above are only those service or performance requirements that cannot be successfully satisfied locally (due to technical, economic, or other practical reasons). At the regional scale, there may be less need for policy or investment in infrastructure, except for what is required for regional integration such as region-wide transport systems. From this ideal perspective, implementation policies for the city can begin to emulate the self-organising and self-reliant properties of natural ecologies.

Coordinating

OFFER INSTRUMENTS IN AT LEAST FIVE FULL FLAVORS

Local governments have many policy tools that can be used to implement a One System approach. Too often, the focus is exclusively on legislation and enforcement. An Integrated approach to implementation requires that cities take full advantage of all instruments available to the city, and to stakeholders who collaborate with the city. Every Eco² project can benefit from integrating at least five different categories of instruments. **Financial instruments** can include incentives, subsidies, pricing, taxing policies, fee structures, market reforms, purchasing policies, and much more. **Special planning initiatives** can include new plans, new institutions, institutional restructuring, special reporting, and special events. **Research and demonstration** can focus on innovative technology applications, tours, fact-finding missions, surveys and assessments, conferences and think tanks, as well as forecasting. **Education and inspiration** can include professional training, visioning exercises, co-training, communities of practice, curriculum reform, special publications and communications, social networking, and investments in social capital. **Legislation and enforcement** can include a wide variety of regulations, codes and standards, as well as specific fines and policing policies.

In some cases, the capacity of a city to apply particular policies will be restricted by national governments and by statute. However, by working with senior governments and stakeholders, through a collaborative working group, such limitations are overcome. The best approach to implementation is always to use the full set of instruments in concert, at time and resources allow.

For instance, if a city wants to reduce water consumption at lowest cost, it could work collaboratively to explore an integrated approach. This might involve: 1) a public awareness and education campaign targeting households and businesses to convince them of the need and benefits of water savings, and to seek their support in designing tariff increases (stakeholder engagement); 2) adjusting the structure of water tariffs fees/pricing (a policy and regulatory issue and demand management); 3) promoting the use of water saving faucets and toilets (a regulation and building code issue and public awareness); 4) designing guidelines and standards for new residences and businesses to encourage investments in the best performing water saving faucets and toilets, and procurement policies for private sector suppliers so that the best technology is supplied at high volume market prices (engagement with private sector stakeholders); 5) incentives for capturing rainwater and reusing treated wastewater (resource management and market reform); 6) reducing the peak load demand, by creating incentives for distributing use across time or by integrating storage of water into the delivery system in areas where capacity is at peak; and 7) reducing water leakage by upgrading the system.

All these measures will reduce water consumption, energy requirements for pumping, and the load-bearing requirements (and therefore design specifications) of the pipes and pumps, and a major component of water system costs. On the supply side, if water systems investments are being planned, then the design and layout of the pipes and distribution network, as well as the location of the treatment plant should be made in consideration of spatial efficiency (for instance, topography and its relation to the demand location are often considered for the efficient use of gravity in water/wastewater networks)—and energy efficiency.

Collaborating

SYNCHRONIZE POLICIES AMONG ALL THE STAKEHOLDERS

The best approach is to get everyone rowing in the same direction. All stakeholders or project partners bring a unique combination of policy tools based on their mandates, skills and resources. Part of the challenge for cities implementing new projects is ensuring that all stakeholders have aligned their existing policies and programs, and are using their particular strengths to support project goals and strategies. By collaborating with senior levels of government, local utilities, private-sector corporations, and NGOs, the potential is created for a broad and diverse suite of policy tools. A collaborative process can even identify potential actions for the public at large, and for individuals with special talents or interests.

Aligning

DEVELOP POLICIES THAT ARE CONSISTENT AND ALIGNED WITH THE GOALS AND STRATEGIES IN THE PLANNING FRAMEWORK

All new policy should begin with the relevant goals and strategies from the long term planning framework, using these as a rationale. The references can be included directly in the policy document, if this helps. Sometimes the changes to policies must occur within the natural rhythm of policy review, and this can result in delays. However, the proposed changes can be worked out immediately, and placed in queue in the review process. In the meantime, the application of new policy on an Eco² project can be a pilot or a preview from which to learn. Most catalyst projects end up as combinations of new technology and new policy. Institutional reform may also be necessary—especially when patterns of development are locked-in to networks of public and private groups, as discussed in Chapter Two.

We have seen that the shape of urban spatial form matters significantly. The interaction of government action (transport investments, land and tenure regulations, and taxation) together with market forces is complex, and this interaction in turn results in shaping cities spatially. The table below is an attempt to summarize in a simplified manner the complex interaction between government action and city shape. Of course, much depends on the specifics of a particular case, and the summary below might not be applicable in all cases. For instance, preservation of sensitive areas through urban growth boundaries can be designed to work in a particular context.

However, what is most important to understand from the One System perspective is that

Table 1.2. Impacts of Government Actions on Land Markets, the Size of the Informal Sector, and the Spatial Structure of Cities

Government Action	Market reaction				Impact on size of informal sector	Spatial impact			
sector	Land supply		Land price			Dispersion		Concentration	
	center	suburbs	center	suburbs		Population	Jobs	Population	Jobs
1- Transport infrastrucure									
Improving or/and building radial roads		(+)	(+)	(-)	(-)			(+)	(+)
Building ring roads		(+ +)	(-)	(-)	(-)	(+)	(+)		
Building transit in radial pattern		(+)	(+ +)	(-)	(-)			(+)	(+ +)
Building transit in grid pattern		(+)	(-)	(-)	(-)	(+)	(+)		
2 - Land use Regulations									
Low Floor area ratio			(+ +)	(+ +)	(+ +)	(+)	(+)		
High minimum plot area		(-)		(+)	(+ +)	(+)			
high standard of land development		(-)		(+)	(+ +)	(+)			
Long approval process for building permits	(-)	(- -)	(+ +)	(+ +)	(+ +)			(+)	(+)
Restrictive zoning practices	(-)	(- -)		(+ +)	(+ + +)				
Setting up an urban growth boundary (UGB)		(- -)		(+ +)	(+ +)	(?)		(?)	
3 - Land tenure									
Large government land holding	(- -)	(- -)	(+ +)	(+ +)	(+ +)	(+)	(+)		
Rent control	(-)		(+ +)		(+ + +)				
Restriction on land transactions in periphery		(- -)	(+ +)	(+ +)	(+ + +)			(+)	(+)
High stamp duty on land transactions		(-)			(+ + +)				

Increase	(+)
decrease	(-)

most government actions listed in table above are usually implemented with very limited objectives and without any considerations for their impacts on land supply and demand, the city shape in the long range , and their attendant implications for economic and resource inefficiency. For instance, when building ring roads the objective is usually to alleviate congestion in a given area by allowing through traffic to bypass the city center. Very little thought is given to the impact on land supply and land price.

Because the objectives of urban regulations and investments do not consider the One System approach, it is not surprising that many government actions often contradict each other. For instance, in Bangalore, the local government finances a Bus Rapid Transit (BRT) system that tends to concentrate jobs in the center of the city. At the same time, the floor area ratio in the CBD has been kept lower than in the suburbs, thereby preventing the concentration of jobs in the CBD that would have been the justification and rationale of the BRT in the first place.

This type of contradictory action between two different branches of the local government—transport and land use planning—is rather typical. Transport engineers want high densities along transit routes to ensure a high number of passengers for the transit they design. Planners faced with congestion in the city center find it easier to regulate a decrease in densities to alleviate congestion. This is where a planning framework can be of value. A framework helps to ensure that misalignment of actions is reduced drastically.

Targeting policies

RECOGNISE THE VERY DIFFERENT NEEDS OF EXISTING URBAN AREAS AS OPPOSED TO NEW DEVELOPMENT

One of the biggest factors influencing the sequencing of investments, and their capital costs, is whether the focus of development is a newly urbanizing area, or part of the existing city. Most cities include both types of situations, and it is important to adjust and target the strategies accordingly.

—New development

In newly urbanizing areas, the extent of One System integration is wide open: the major constraints may be financial resources and the capacity of the design team. The clear advantage of new urbanization is the opportunity to apply best land use practices and spatial design principles, and to integrate land use planning and design of infrastructure systems. The stage can be set for a cost effective way of incremental urbanization, through optimal sequencing. Reserving rights of way for roads and services is easier, as is the allocation and designation of land for key government/utility functions and open spaces.

An example from Freiburg, Germany is the alignment of transit services with land development planning. By not granting occupancy permits for new residences until light rail transit services begin operating for a block, newcomers avoid habits such as purchasing and using cars for commuting. In this way, the road requirements in developments are kept to a minimum.

The pace of change however, may be a complex issue governed by the individual schedules and the financing capacity of the different land owners and government actors. Often, in most cities, one of the biggest roadblocks to implementing well thought through spatial plans in new areas are the ground level realities of land ownership, and the limitations of the city's influence on land and its own finances. Special policies may be required to help unorganised landowners cooperate, and to avoid the incremental and largely unplanned expansion into new areas. An example of such a policy is Urban Land Pooling and Land Readjustment. This method is particularly interesting as it tackles two problems at once: land and finance. It is briefly described in the box below.

—Retrofitting and Redevelopment of Existing Areas

One of the difficulties we all face when confronted by existing urban areas is the 'illusion of permanence.' The physical reality of buildings, roads, and trees conveys a very strong message that only through superhuman effort will radical changes occur. But, of course,the reality is almost the reverse. Maintaining neighbourhoods in their current form typically requires vast amounts of energy and time on a day-to-day basis, simply to delay the deterioration of buildings and roads, and to provide services to all residents and businesses. In fact, the operating and maintenance costs for many city neighbourhoods are often so high that it is possible to justify a complete retrofitting of neighbourhoods, and in some cases even a redevelopment, if the disruption to people's lives and businesses is not an issue.

Badly planned cities represent a constant drain on resources. In dealing with existing urban areas, cities can use a range of measures to enable the existing built form to perform much more effectively. These usually fall into two categories: retrofitting and redevelopment. Retrofitting existing areas of the city entails working with the existing built stock and infrastructure and making improvements to enhance their performance, without redeveloping the entire area. Examples of retrofitting measures include implementing end use efficiency in the energy and water sector; reducing, reusing and recycling waste; and adapting existing transport infrastructure (roads) to be used more efficient (for instance, by designating routes for bus rapid transit and lanes for bicycles).

Redevelopment entails demolishing and rebuilding certain areas of the city, and is typically more complicated. Redevelopment is challeng-

BOX 1.4

Urban Land Pooling and Land Readjustment

This is an innovative technique for managing and financing urban land development. Local and central governments are undertaking such projects to assemble and convert rural land parcels in selected urban-fringe areas into planned layouts of roads, public utility lines, public open spaces, and serviced building plots. Some of the plots are sold for cost recovery and the other plots are distributed to the landowners in exchange for their rural land parcels. To be viable, the values of urban plots distributed to landowners after subdivision need to be significantly higher than before the project begins.

In a typical project, the authorized land pooling and readjustment agency selects and designates the urban-fringe area to be developed, and identifies the land parcels and owners to be included. A draft scheme is then prepared to plan, define, and explain the project, and to demonstrate its financial viability.

Majority landowner support for each proposed project is a key requirement for the successful application of the technique, and is therefore an important consideration in selecting projects sites. Although the emphasis is on landowner agreement and support for each proposed project, the land pooling and readjustment agency also has to be able and willing to use the government power of compulsory purchase against any minority holdout landowners in the designated project area, if this becomes necessary.

The sharing of the project costs and benefits among the landowners, such as increased land values, is based on their land contributions to the project. The calculation of each landowner's share can be based on the area of his or her land parcel as a proportion of the total land area, or based on the estimated market value of his or her land as a proportion of the estimated market value of the total area.

There is an important legal difference between land pooling and land readjustment in land ownership: in a Land Pooling project, land is legally consolidated by transferring ownership of the separate land parcels to the Land pooling agency, with the later transfer of ownership of most new building plots back to the landowners. In a Land Readjustment project, the land parcels are only notionally consolidated with the land readjustment agency having the right to design services and subdivide them on a unified basis. Then, at the end of the project the landowners exchange their land parcel title documents for those of their new building plots.

There are many successful examples of such projects—for instance in Japan, Korea, and Indonesia. A similar process of land pooling and land readjustment is practiced in the state of Gujarat in India, where the projects are called 'town planning schemes.'

Excerpt from *Approaches to Urban Slums,* Eds.Barjor Mehta and Arish Dastur, The World Bank, 2008.

The following illustrates the 'before' and 'after' scenarios of Land Readjustment in Gujarat, India.

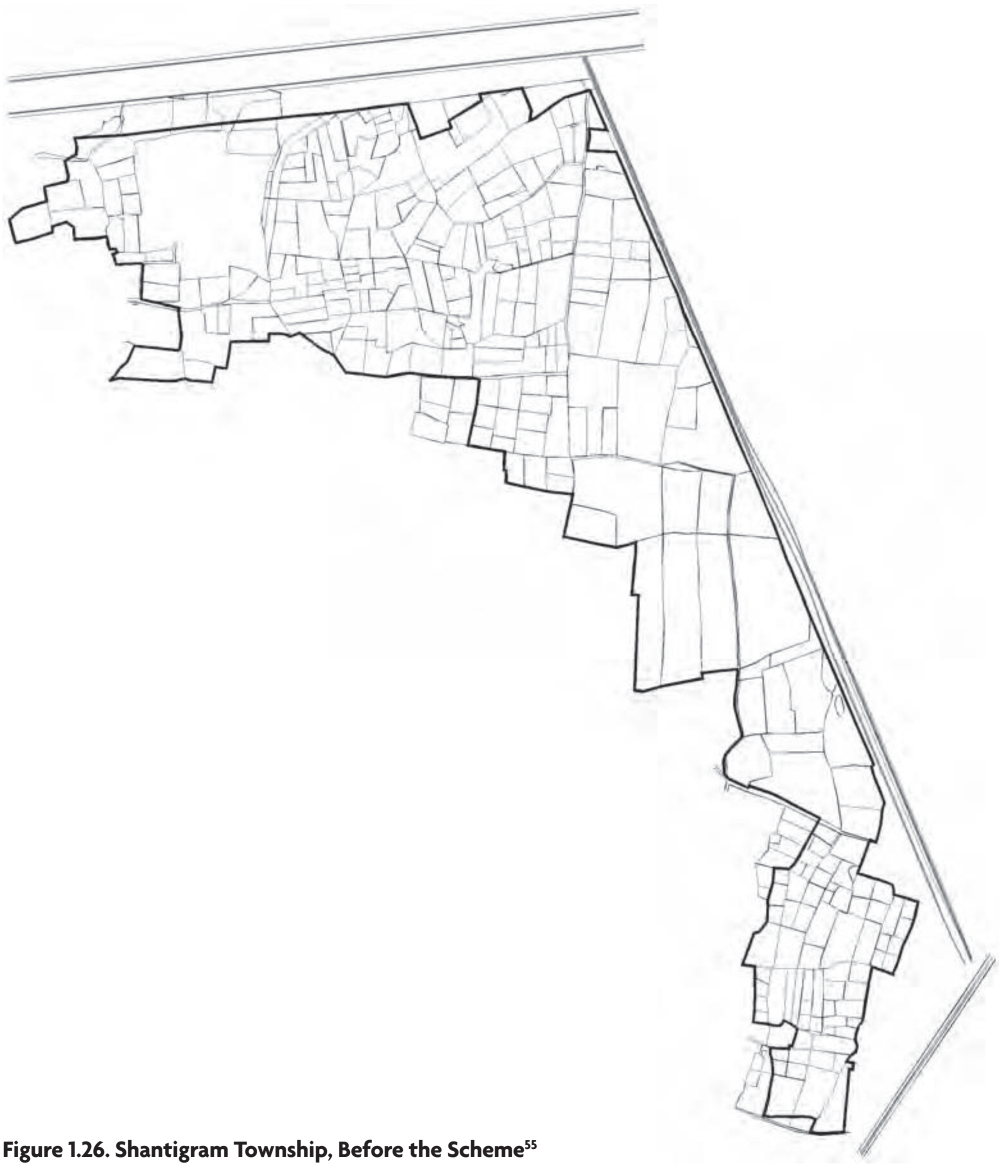


Figure 1.26. Shantigram Township, Before the Scheme[55]

ing due to the political, social, and economic costs of making changes to land use and existing structures. New zoning or transportation corridors cannot be imposed unilaterally, or quickly; nor is it easy to upgrade the systems of so many unrelated buildings. Many stakeholders must participate in decision-making. Projects require longer time frames so that communities have time to adjust. An incremental approach may be required, which makes the sequencing of strategies difficult. Development may need to include, for example, complex arrangements for slum upgrading, and arrangements for new utilities and rights of way. The pace of change may need to evolve incrementally, in sync with the natural turnover rates for the stocks. Or it may be necessary to wait until the service quality and operational costs justify large scale urban redevelopment.

However, cities can explore creative and cost effective ways of remodeling the distribution, density, and use of the existing built form by increasing the floor area ratio, allowing the transfer of development rights (see

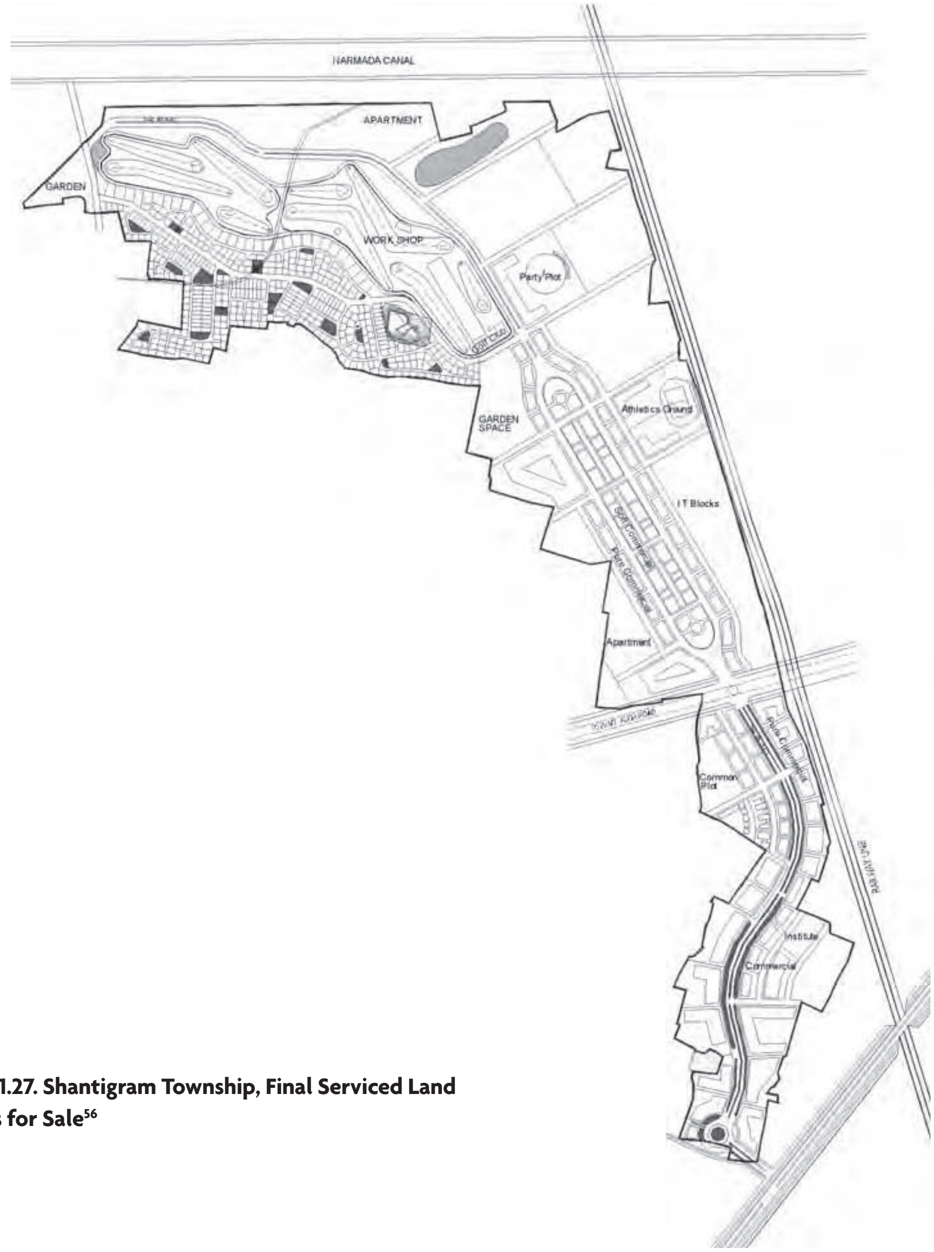


Figure 1.27. Shantigram Township, Final Serviced Land Parcels for Sale[56]

Curitiba case in Part Three), re-zoning and changing land use patterns, and, importantly, by revising and enforcing building codes and standards. These might create incentives for private redevelopment efforts. In some cases, land readjustment may be used, though it is much harder to convince stakeholders in an existing urban community, who already have built up urban structures, to demolish their properties for the purpose of the city's redevelopment. However, if accompanied by a sizable increase in FAR, or in the case of slums, by formal recognition and/or the introduction of basic services like drainage, water, and sanitation—the returns may make good economic sense. Redevelopment projects at a larger scale for certain areas/districts of a city have also been successful in enhancing the sustainability of existing areas—such as in the case of old manufacturing sites being redeveloped for waterfront residential uses. Because the old sites are not being used, it is easier to coordinate projects and gather consensus. It is significantly more disruptive and unlikely to be able to redevelop existing residential neighbourhoods. In such cases, retrofitting the existing structures is often more realistic—or creating incentives as mentioned earlier by increasing FAR in exchange for greater compliance with new resource efficient constructions.

Stepping Stones towards the One-System Approach

Provide 'just-in-time' Training and Capacity Building

The city leadership must arrange multiple opportunities for local professionals to become comfortable with the One System approach. An Eco² Catalyst Project, for example, provides a very concrete opportunity to train professional staff in new procedures and methods. Ideally, the training occurs in a timely fashion, since new skills need to be immediately applied or they are lost.

A special effort is warranted to ensure the relevant institutions and people become well informed, supportive, and capable. Training can include invitations to local consultants and firms who can benefit from exposure to the Catalyst Project and any new approaches. Without training, these local experts may tend to obstruct projects and refuse support. Cultivating local expertise is an investment, and will ultimately determine what can be achieved city-wide, and possibly in other cities in the country.

A training program in the One-System Approach can benefit from a variety of Eco² resources:

Other cities: Interested cities can access critical expertise from Eco² partner cities and agencies. It can be especially helpful to learn from other cities that have successfully implemented approaches and created the institutional frameworks for sustaining such efforts. This may include best practice cities, and also other cities engaged in an Eco² Pathway.

Part Two, Methods: To apply the One System approach for design, analysis, formulation and implementation of options outlined in Chapter 5, it will be necessary to use the methods and tools in the City-Based DSS, in Part Two of this book. The full scope of integration options can be explored using methods and tools to develop and assess the performance of integrated solutions. Familiarity is particularly required with Material Flow Analysis and Overlay Mapping.

Part Three, Sector Notes and Case Studies: The Sector Notes in the "Field Resource Guide" can provide more information on individual sectors with more specific and detailed ideas. The Case studies from Best Practice cities, also featured in the 'Field Resource Guide,' can introduce staff and consultants to examples of approaches in the real world – and reveal critical lessons learned.

Conduct a Series of Preparatory Integrated Design Workshops

Integrated design workshops create important opportunities for planners, designers, and engineers to come together and use new methods and information. The number and the scope of the workshops will vary with the situation. Sometimes, it is best to plan one or two short workshops to clarify goals, set targets, and share information among stakeholders. The directions and priorities can be refined, and aligned with the city's shared planning framework. The framework (if already established) can be used within workshops to orient discussions or stimulate creative thinking on different topics, and then later to evaluate preferred strategies and actions. Workshops may also be warranted on analytical methods, producing, for example, a 'business as usual' scenario for benchmarking purposes. This scenario can include Material Flow Analysis and Meta-diagrams, overlay mapping, risk assessment, and other analytical exercises. Workshops can also be used to review and finalise a 'Design Brief' to prepare for more intensive design work.

Explore Design Solutions, and Prepare a Concept Plan for Review

An integrated design process should be used to generate alternative proposals for designing, constructing, and managing the project. An intensive, multi-day Urban Systems Design Charrette (discussed in Part Two of this book) is a tool that can facilitate the integrated design process, helping to generate creative and effective proposals in the shortest time. A well planned systems design Charrette can often produce a final Concept Plan that is more than 90 percent complete. A Charrette that involves regulatory and management personnel can help to reveal what existing policies may need to be revised or removed to enable innovation. A design Charrette can benefit the project indirectly by generating goodwill among stakeholders, and by helping experts to become familiar with new concepts and technologies. The integrated design process should culminate in a recommended Concept Plan for implementation, including any policy reforms.

Align Policy Tools among all Stakeholders to ensure Successful Implementation

Use the procedures outlined in Chapter 5 to implement the project in an integrated fashion. This may help sequence investments, enable contributions from partners and residents, coordinate strategies among stakeholders, and align and target policies to match the planning framework. A collaborative exercise can help all interested parties explore how they can use complementary policy tools to help implement the Concept Plan and achieve the intended outcomes. A Strategic Action Plan can be prepared to clarify who is responsible for what tasks, and to show how policies interact. Where appropriate, a feasibility plan and a detailed master plan can be prepared with specifications and guidelines for each element and for each phase of the work.

CHAPTER 6

An Investment Framework that Values Sustainability and Resiliency

This chapter introduces the accounting method and framework that are needed to understand the full costs and benefits of projects and policies. It begins with an introduction to the basics of lifecycle costing for cities, and the policies and methods that make this possible. Next, the chapter explores the need for an expanded framework for economic accounting by Eco² cities. The framework gives equal consideration to different categories of assets: manufactured capital, natural capital, social capital and human capital. The chapter explores an expanded framework for risk assessment that incorporates foresight methods, including long-term forecasts for all sectors, and a design philosophy that increases the resiliency and adaptive capacity of city lands and infrastructure. As before, the chapter concludes with some suggestions for key actions or stepping stones that might direct the city as it learns to invest in sustainability and resiliency.

The Core Elements of Investing in Sustainability and Resiliency

Incorporation of Lifecycle Costing

Life cycle costing (LCC) is a decision support method that can help cities improve project cost/benefit accounting measures and derive better estimates of the financial and economic costs and benefits associated with any development project. As the term implies, life cycle costs include all the costs incurred by a project throughout its life cycle, including construction, operation, maintenance, rehabilitation, disposal, and replacement.[57] Part of the challenge faced by all cities today is integrating cash flows over time. This includes optimizing capital and operating costs, ensuring adequate cash flows over the longer term, and recapitalizing investments so that funds are available for replacement of assets at the end of a project's life cycle.

LCC is especially important to the long-lived investments that are a large part of city infrastructure and land development. LCC is important for decisions regarding:

- Fleets, decisive in determining new vehicle acquisitions;
- Infrastructure, especially relevant for water, transportation, and energy systems;
- Land use planning as it pertains to infrastructure costs;
- Civic buildings, relevant for premium efficiency targets for new and existing stock; and
- Residential and commercial buildings.

LCC requires that a life expectancy and rate of deterioration be estimated for each type of asset. It then becomes possible to quantify maintenance and rehabilitation requirements. The maintenance of city infrastructure systems—pipes, facilities, pumps, and roads—can be extremely costly, and can have significant impact on the cash flow and financial sustainability of any project. It also impacts the fiscal health of a city; in fact the lack of policies based on LCC has left many cities essentially bankrupt and unable to manage their assets.

Operating and maintenance costs for long-lived elements like buildings and pipelines can represent over 90 percent of lifecycle costs. The City of Hamilton in Canada estimated that initial construction accounts for only 8 percent of a civic building's cost over its 30-40 year life, whereas operation and maintenance accounts for 92 percent. It is obviously dangerous to place too much emphasis on initial capital costs when making large public investments in city infrastructure and buildings. Nevertheless, it is still common worldwide for cities to have separate capital and operating budgets, and to make investment decisions based on the initial capital investment costs without considering the net present value of future flows of associated operations and maintenance costs. If, on the other hand, life cycle costs are well quantified for a variety of development scenarios, they can be minimized at both the design and implementation levels of land use and infrastructure planning.

LCC makes possible a more prudent and responsible approach to long-term financing of investments. The calculations can be fast, and comprehensive. For example, a new neighbourhood development project can be analysed for a variety of densities and configurations, and then each scenario can be compared in terms of the capital and operating costs for utilities and services, including roads, water, sewer, garbage, schools, recreation facilities, public transit, private vehicle use, fire protection, and policing. Interest rates for borrowing, tax rates, and service revenues can be calculated for different development plans and fiscal policies.

Lifecycle costs are typically annualized (converted into an annual cost) over a long period (75-years, in case of this neighbourhood construction project) allowing for operation, maintenance, and replacement of all utilities. All costs can be allocated on a *per household* basis for residential developments, or normalised for standard office space.

Part Two includes details on how the LCC method can be applied to Eco² cities, and includes information on simple spreadsheet-based computer tools that can make LCC very easy and fast. The tools include a preset list of many life cycle cost categories that are worth considering for development projects, but that are typically ignored. All of the default values can be adjusted to match the historical costs for any specific country and community.

Included in Part Two is an example of how a LCC tool has helped the City of Fort St. John, Canada, to assess the potential costs and benefits of a proposed concept plan for demonstrating a sustainable neighbourhood. A design workshop had proposed smaller lots, narrower streets, more tightly packed buildings, a greater diversity of building types, more public open space between buildings, and more integrated and multi-use designs of open spaces (including greenways, green infrastructure for storm water management, community gardens, all season pathways, and a large commons around a school and community centre). The proposed design represented a significant departure from conventional neighbourhoods in the City. It was thus necessary to move beyond debate and opinion into a comprehensive analysis of costs and benefits.

Fort St. John compared the new approach to a base case scenario, modelled on adjacent existing neighbourhoods. Capital costs were estimated and allocated to each household. Operating costs were calculated, including those for water, roads, sewer, school transit, recreation facilities, police, and fire. In the final analysis, the LCC assessment helped to clarify the potential gains from the new approach. Per household capital costs averaged US$35,000 less compared to the base case; annualized operating cost savings were estimated at US$6,053, a reduction of more than 25 percent relative to the base case. Of course, the sustainable neighbourhood plan had potential benefits unrelated to capital and operating costs, including improvements in liveability, streetscapes, social interaction, and amenities. However, the comprehensive financial analysis helped to 'win over' the whole community, and provided the city council with a stronger argument for defending changes to standard practices. All politicians find it easier to make the right decisions, and to stand strong in the face of vested interests or institutional inertia, when provided with simple, transparent arguments for how alternatives can save taxpayers money, and reduce liabilities. This is an important role for life cycle costing.

Reserve Funding

One of the most effective tools for sustainable financing is a reserve fund. The concept behind a reserve fund is to set aside money incrementally and gradually, so that sufficient funds are available for financing upgrades and replacement at the end of a project's life cycle. Not only does such an approach help to ensure the viability of an investment and it various components, but it also avoids dumping huge liabilities and a potential financial crisis onto future generations. Inadequate capitalization of infrastructure systems also unfairly shifts maintenance and replacement costs towards the end of a system's life. Reserve funds make good economic and ethical sense.

The biggest challenge with reserve funds are keeping them truly reserved. Funds are subject to raids by those who see opportunities to spend the funds elsewhere. Consequently, reserve funds must be earmarked and legally protected.

A reserve fund is particularly necessary for non-revenue generating projects. It is important to keep an appropriate amount in reserve as determined by the overall investment plan. A larger reserve is not necessarily better, since the fund is exposed to inflation risk. To reduce the amount of such a fund, it is desirable to pool similar assets, and, as far as possible, to keep the annual investment amount level.

How much is sufficient for the reserve fund? In the case of the reserve fund for educational facilities of Tokyo Chuo ward, the fund covers the total investment cost, which will be required in a few years. However, even if the fund does not cover the total required investment cost entirely, it could be considered sufficient, if Chuo ward can mobilize additional funds from other sources. Important sources of external funds for cities are issuance of municipal bonds and bank borrowings. In order to raise

Reserve Fund for School in Tokyo Chuo Ward

Like many other cities in Japan, Chuo ward, one of the 23 wards in Tokyo Metropolitan Government, keeps a fund for maintenance, rehabilitation, and replacement of school facilities. It sets aside annually an amount close to the depreciation amount for its 16 elementary schools and four junior high schools. The fund can be used only for the intended purposes, unless the ward council agrees otherwise. As of the end of the fiscal year 2009, the balance of the fund reached around Japanese Yen 10 billion (US$100 million), which is sufficient to build three school buildings. Chuo ward plans to replace three school buildings in a few years, under its long term investment plan.

Tokyo Waterworks. How to Finance US $10 Billion Water Pipeline Replacement Project

Fees and charges are important elements for the revenue generating enterprises, such as water companies, when an appropriate level of reserve fund is considered. The Tokyo Waterworks, serving 12.5 million people in Metropolitan Tokyo, has been financing operational expenses as well as capital expenditures with water tariff revenues. Various reserve funds are set aside to meet the fluctuations of these costs. Currently, the Tokyo Waterworks is facing a daunting task to replace its old existing water pipes, starting in ten years time. The total investment is estimated at around Japanese Yen 1 trillion (US$10 billion), which accounts for 40 percent of its total assets of Japanese Yen 2.5 trillion (US$25 billion) at present value. To meet this challenge, the Tokyo Waterworks started working to level this Japanese Yen 1 trillion planned investment to the extent possible: (i) by planning maintenance and rehabilitation well ahead of the project; and (ii) by making a detailed plan for construction. In parallel with keeping annual investment level, the Tokyo Waterworks already started accelerating debt repayments so that the debt outstanding can be maintained at the current debt level of Japanese Yen 0.5 trillion even after financing the project. Such accelerated repayments have been covered by revenues from the water tariff, in spite of the fact the Tokyo Metropolitan Government lowered its water tariff on January 1, 2005. The Tokyo Waterworks intends to achieve financing a Japanese Yen 1 trillion replacement project within a normal level of tariff adjustment.

these external funds in a timely manner, it is important for cities to manage the terms and amount of debt within their borrowing capacity. It is also important to level the investment requirement over long investment period through various ways so that annual capital funding requirements can be minimized. The lifecycle costing method provides a useful base for long term investment planning.

Equal Attention to All Capital Assets: an Expanded Framework for Accounting

A persistent challenge when accounting for the cost of urban development projects is the measurement and valuation of the many indirect benefits and costs. Economic analysis has evolved over the last few years in an attempt to get a better handle on these indirect costs, and to provide decision-makers with an assessment that more accurately reflects the true, full costs and benefits of any particular option. For example, cost benefit analysis, the primary method for assessing economic viability, has been expanded to incorporate many indirect effects into the monetary values. Cost effectiveness, the other standard method currently used for assessing the economic viability of a project, also has been expanding to examine some of the indirect benefits. Despite the efforts towards fuller cost and benefit accounting, the reality is that most development projects proceed without a good understanding of the real nature of the impacts on people, ecologies, and social systems. Many of the indirect costs of concern to communities cannot easily be measured or explained, nor can they be easily converted into credible monetary values. Techniques for converting impacts into monetary values have been debated for many years, and continue to seek for right solutions.

A more comprehensive economic analysis requires that more attention be given to environmental accounting as a separate, rigorous method. Every project needs a standard protocol for assessing the environmental effects by category, using well defined methods such as input output analysis, life cycle analysis, and materials flow analysis. One example of an expanded approach to quantifying impacts is the Environment Load Profile (ELP) adopted in Hammarby Sjöstad, Stockholm (more details on ELP in Part Two). A separate set of indicators can be used to express each category of effect in parallel with the economic analysis. Sometimes, the effects can be added together to advantage: air quality, for example, is commonly addressed in terms of an air quality index that bundles together multiple factors like quantities of particles, organic compounds, and nitrogen oxides.

A number of techniques have been developed for attempting to value a wider range of environmental and ecological effects to arrive at one or several overarching measurement of natural capital. A notable example is the ecological footprint, which converts energy and material use into the total area of productive

> "For too long now ministries of finance and planning have paid scant attention to the exploitation of the natural resource base or the damaging effects of environmental pollution, while countries have been developing National Environmental Action Plans that read as if they were written *by* the Environment Ministry for the Environment Ministry, with no links to the Economic Ministries."
>
> **Expanding the Measures of Wealth—Indicators of Environmentally Sustainable Development, World Bank**

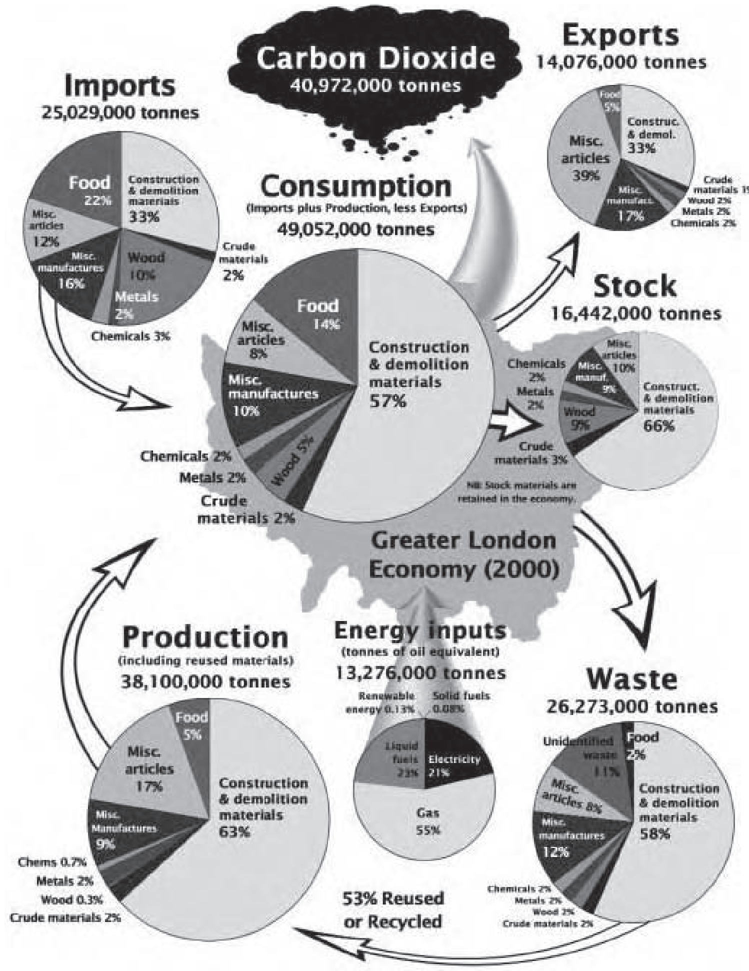


Figure 1.28. Summary of Resource Flows Through London in 2000

This summary for Greater London reveals all inputs and outputs, and helps to explain why the city's ecological footprint is approximately 300 times the size of city's land[59]

land that would be required to sustain such flows indefinitely. Many cities and new neighbourhood developments have seen the value of a single rating of this type, and have calculated their ecological footprint as an indication of overall impact on natural capital. For example, the City of London calculated that each person in the city on average requires 6.63 green hectares of land to support their lifestyle—or more than three times what is actually available per person on a planetary scale. The City of London discovered that their combined ecological footprint is 293 times the actual land area of the city, mostly as a consequence of the high rates of food and material consumption.[58]

All techniques for adding up or aggregating ecological impacts into a simple metric suffer from a number of significant problems.[60] For example, the ecological footprint has trouble coping with the very important issue of water flows, which vary so much in value depending upon where you are located. Another problem is that a city which annexes agricultural land suddenly appears much less of burden on the planet, when the reverse may true. Multi-functional land use—something that is encouraged by Eco²—is ignored when all land is divided into discrete categories for ecological footprint analysis. By using a single unit—ha of ecological land—the footprint ignores the major differences in ecological system values—things like biodiversity, species scarcity, and habitat uniqueness. In fact, all indicators that aggregate impacts tend to ignore the many local factors that relate to the quality of ecosystems, the sensitivity of local environments to emissions and wastes, and the differences from place to place in the value of natural capital.

Despite these types of method problems, it is important to find a method that can quickly summarise the range of impacts arising from any development scenario, using standardised measurement protocols for comparability, and using simple graphical tools for quickly communicating the basics to interdisciplinary teams of designers and decision-makers. The European Union's COST 8 Program struggled with the challenge of assessing environmental effects when they undertook a multiyear project to analyse and describe sustainable infrastructure projects in cities throughout Europe. After reviewing all the options for assessing impacts, they chose a very simple matrix for summarizing key effects. Their final publication entitled *Towards Sustainable Infrastructure* describes 44 sustainable infrastructure projects, and a Matrix for each project. They concluded that "The need for a holistic assessment of sustainability with many dimensions and numerous impacts requires a technique and tool capable of reviewing all relevant aspects in a compact space, i.e. hopefully even in one page with a visually effective presentation."

What Eco² cities need is a framework for evaluating the costs of projects that is flexible enough to accommodate a wide range of measurements, and yet is sufficiently balanced to ensure that the trade-offs and impacts on critical thresholds and targets can be well understood. The emphasis on integration at many levels means that a broad and balanced assessment is much more important than might otherwise be the case. Eco² needs a framework that is designed to reveal not only who benefits and who pays specific costs, but also how well a project has maximised benefits of all types. The framework must be transparent, allowing a mix of professionals and residents to easily follow what is actually being measured, why it is being measured, and how the numbers relate. The framework needs to combine categories of benefits and costs in ways that they can be tracked as a whole, so indicators on ecological health, for example, can be given equal consideration with indicators on economic wealth. Fortunately many economists and communities have been experimenting with frameworks over the last ten years, and it is now possible to learn from best practices, and adopt a framework for accounting that is suitable for Eco² cities.

ECOLOGY		ECONOMY		SOCIAL ASPECTS	
Are emissions to air, water, and soil within the restrictions set locally and internationally? Are emissions decreasing?	↑	Is the cost/effectiveness and/or cost/benefits of the system reasonable compared to other systems? Compared to other needs in the city and to political goals?	↗	Has the planning and decision-making for the infrasystem been done in a democratic and participative way?	↘
Is the use of natural resources reasonable compared to other comparable systems? Is the use decreasing? (e.g. fossil fuels, water, phosphorus, potassium)	↘	Are the citizens willing to pay for the services offered? Are the services affordable to all citizens?	→	Is the function and the consequences of the system transparent to and accepted by the citizens? Is the system promoting a responsible behaviour by the citizens?	↗
Is the system allowing a reasonable bio-diversity with regard to the kind of area studied? Is the bio-diversity increasing?	↗	Is the organization(s) that finance, maintain and operates the system effective?	↗	Is the system safe to use for the citizens? (hazards, health, wellbeing)	↗
Is the system more or less sustainable than a conventional system regarding ecology?	→	Is the system more or less sustainable than a conventional system regarding economy?	↗	Is the system more or less sustainable than a conventional system regarding social aspects?	→

Source: European Science Foundation 2006.[1] Lahti, P., Calderón, E., Jones, P., Rijsberman, M. & Stuip, J. (editors), Towards Sustainable Urban Infrastructure. Assessment, Tools and Good Practice.

Figure 1.29. Design Assessment Matrix

The Matrix developed by COST 8 was used on many case studies of sustainable infrastructure in Europe. It is intended to provide decision-makers with instant and reliable insight into the sustainability of any design option. Arrows indicate performance on a sample project.

Protecting and Enhancing Capital Assets

An appropriate method for use with Eco² Cities is the *Four Capitals* approach as outlined by Paul Ekins. This is a method that has evolved from a number of assessment tools that have been used in urban development, and that is flexible enough to include any type of measurement, and yet well-balanced. It has been successfully used on a number of sustainable planning projects in European countries.

Most economic analysis incorporates an inventory and valuation of capital assets; however the focus is primarily on manufactured goods and systems that produce or facilitate the delivery of goods and services. This kind of capital is referred to as 'manufactured capital,' and includes the hard infrastructure of cities.

The four capitals method begins by recognising that benefits can flow from many other sources than manufactured capital. We need to account for the quality of labour (human capital), the networks through which labour is organised and which create the context for economic activity (social capital), and the natural resources and ecological systems which provide inputs into the economic process and maintain life on earth (natural capital). A more detailed definition of these four capitals, as provided by Paul Ekins and James Medhurst in 2003, is quoted below. [62]

"Manufactured Capital (or human-made) capital is what is traditionally considered as capital: produced assets that are used to produce other goods and services. Some examples are machines, tools, buildings, and infrastructure.

Natural Capital: In addition to traditional natural resources, such as timber, water, energy, and mineral reserves, natural capital includes natural assets that are not easily valued monetarily, such as biodiversity, endangered species, and the ecological services provided by healthy ecosystems (e.g., air and water filtration). Natural capital can be considered as components of nature that can be linked directly or indirectly to human welfare.

Social Capital: Social capital, like human capital, is related to human wellbeing, but on a societal rather than individual level. It consists of the social networks that support an efficient, cohesive society, and facilitate social and intellectual interactions among its members. Social capital refers to those stocks of social trust, norms, and networks that people can draw upon to solve common problems and create social cohesion. Examples of social capital include neighbourhood associations, civic organizations, and co-operatives. The political and legal structures that promote political stability, democracy, government efficiency, and social justice (all of which are good for productivity as well as being desirable in themselves) are also part of social capital.

Human (Cultural) Capital: Human capital generally refers to the health, wellbeing, and productive potential of individual people. Types of human capital include mental and physical health, education, motivation, and work skills. These elements not only contribute to a happy, healthy society, but also improve the opportunities for economic development through a productive workforce."

All four types of capital are defined and identified through the flow of benefits they provide. Sustainable development is mostly about how to maintain or increase the four capitals so that the flow of benefits is sustained indefinitely. Some trade-offs may be considered acceptable—for example, a reduction in the net area of ecological systems may be offset by increases to the net productivity of ecologies resulting from good design and management practices. However, many systems, like ecologies, and assets require critical thresholds to be respected or the system begins to break down. For example, smaller green spaces may be more productive, but they may fail to provide sufficient habitat space for some species and, as a result, biodiversity declines.

The four capitals method is good choice for Eco² Cities because:

- It incorporates critical intangible assets into the decision-making framework;
- it looks at externalities (indirect costs and benefits) in a more comprehensive fashion than other options now available;
- It allows for easy comparisons between very different categories of costs and benefits, and allows cities to focus on critical thresholds (e.g., limits that should not be crossed) and to recognise the tradeoffs that frequently occur between one type of asset and another;
- It fits very well into the economic accounting already in place in many cities, because it uses an inventory of capital assets, and it makes use of much of the data that is already collected by cities on a regular basis;
- It reinforces the important concept that assets need to be conserve and enhanced, since it is these assets that provide the flows of goods and services that ultimately contribute to human wellbeing.

Use Indicators to set targets and to monitor impacts

Monitoring the capital assets of a city, and balancing the trade-offs between types of capital, requires standardised measurements, or indicators, that correspond to the capacity of assets to provide goods and services. Indicators that cover all four capitals are referred to as indicators of sustainable development, or 'SD' indicators. They include monetary values, where these are available and appropriate, and also many physical dimensions.

The Table below provides an example of just a few of the indicators used by various cities participating in a European project for Sustainable Development Planning. Based upon the European experience, the quality of indicators

Table 1.3. Sample Indicators for the Four Capitals Approach

The sample indicators were used by 19 urban regions in Europe as part of Sustainable Development Assessment[63]

Manufactured Capital	Natural Capital	Social Capital	Human Capital
GDP per capita	*CO2 emissions*	*Wage differentials and poverty*	*Employment growth and rates*
Gross fixed capital formation	*Air Quality*	*Disparity between income of average, highest and lowest deciles*	*Creation of new high skill jobs*
Employment (by sector)	*Stocks of endangered species*	*Male/female wage differentials*	*Levels of education and vocational training*
Change in real income	*Value per drop of water*	*Number of social welfare recipients*	*Public and private R&D expenditures*
Travel times and average speeds	*Quantity of collected waste*	*Districts with special development needs*	*Numbers of patent applications*
% population connected to internet	*Green Areas (km2)*	*Out migration of young people*	*Number of business start-ups*
Agricultural produce	*Energy use per capita*	*Number of cooperative, inter-municipal projects and strategies*	*Improvement in human health*
Inflation rate	*Resource Efficiency*	*Crime rates*	*Participation rate in education and training*

> ### What makes a good indicator?
>
> **Affordable and practical:** can the data be collected easily, at little or no cost? Is the analysis simple and easily automated?
>
> **Relevant:** do the indicators actually measure the key issues of concern? Do they respond sufficiently to indicate when progress is achieved?
>
> **Clear explanations and measurement protocols:** is it easy to define what is actually being measured, and how?
>
> **Comparability:** is this a standard measurement fro which other measurements can be found to provide comparisons and benchmarks of performance?
>
> **Aligned with objectives:** is the effort to measure appropriate given the priorities established in the planning framework?

ends to vary by capital: manufactured capital tends to be over-simplified by use of only GDP measurements; social capital, on the other hand, has too many different indicators; human capital is very difficult to measure directly; and natural capital indictors can be difficult to calculate.

The precise choice of indicators for a city and a specific project will vary with circumstances. In general, indicators need to be affordable so that they can be measured on a regular basis—otherwise what is the point? They also need to be relevant—measuring the larger changes that we are trying to affect. The relevance varies depending upon who is going to be using the indicator. For a city council and its city partners, performance indicators are required that help to clarify the intended long-term results—or performance. A common performance indicator for manufactured capital is *GDP per person;* another might be *the asset value of city-owned infrastructure.* The other capitals tend to be more difficult to capture. In the case of Natural Capital, performance indicators need to address at least their different types of ecological services: sinks (capacity to absorb wastes); sources (capacity to provide useful products and services); and life support (capacity to cycle resources and regulate environments so they support life).

In addition to broad performance indicators that measure how well key targets or goals are being achieved, it is helpful to develop a set of indicators for monitoring progress at the strategic level, and at the operations level.

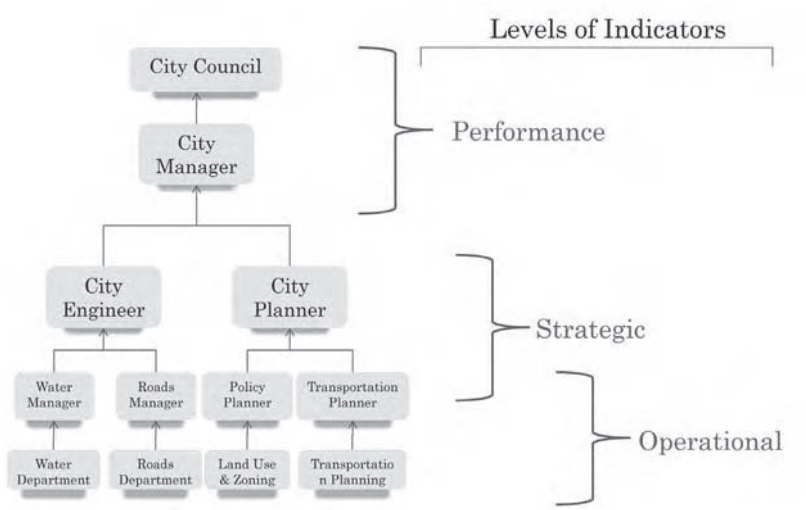


Figure 1.30. Targeted Indicator Type, by Level of City Personnel[m]

Figure 1.30 illustrates how three very different levels of indicators correspond to the scope and responsibility of city personnel. As scope narrows, so too does the indicator. For example, a new distributed electricity system for the city might need feedback at three levels of detail:

- **Performance:** percentage of residents in service territory receiving power from new system;
- **Strategic:** percentage of buildings retrofitted according to new energy efficiency standards;
- **Operational:** average time required to repair outages;

Each project may require a family of indicators, because decision-makers will be interested in different time frames and levels of detail.

Proactive Risk Management for All Threats

Standard practice for financial risk management involves an analysis of any investment in terms sensitivity to changes in the key factors used for determining costs and benefits. Each factor has a certain probability of changing over time, with consequences on the financial bottom line. This assessment of risk based upon known probabilities for change in the direct economic factors is referred to as sensitivity analysis. It is the principle risk assessment method for urban development projects, and it is an important and necessary part of due diligence. If a 15 percent drop in ridership is sufficient to undermine the financial viability of a new transit system, city leaders will want to know the odds of such an occurrence. Sensitivity analysis is not a replacement for good judgement, but is it a good way to educate decision-makers about what variables might undermine the critical viability of an investment. The other well-known method for risk assessment is a Monte Carlo assessment, which expands the analysis to include the possible correlations between changing variables—essentially by making many random changes to variables in combination.

What is missing from these standard risk assessment methods is the many indirect, difficult to measure risks that threaten the viability of an investment. Also missing are an assessment of uncertainties—the factors which simply cannot be assessed statistically, but which nevertheless represent significant threats. In a similar fashion to economic analysis, the risk assessment needs to be coupled with methods that expand the scope of what is examined and rated. In reality, cities today face many threats and hazards that are largely external to the financial calculations, but that can nevertheless impact the viability of projects. These include sudden disruptions to systems such as natural disasters (earthquakes, hurricanes, tsunamis, etc.) and the possibility of rapid socio-economic-environmental change such as the recent global financial crisis. Over the next 30 years, for example, it is highly likely that we will witness fundamental changes in energy, communication, transportation technologies, climate, demographics, global markets, environmental regulations, the probable onset of epidemics, and the availability of critical resources like water, food, and fossil fuels. Thirty years is the blink of an eye for a city. The infrastructure investments planned for the near future will need to perform for much longer than 30 years. But will they? How can Eco² cities assess and improve the overall *resiliency* of development projects?

Expanding risk assessment to include resiliency and adaptive capacity

Resiliency is a concept that is traditionally used to describe two characteristics: the *robustness* of a system—i.e. its ability to continue to perform by resisting changing conditions, and the *adaptability* of a system—i.e. its ability to continue to perform by responding appropriately to changing conditions. Resiliency can be used as a potential design criterion for all urban systems including built infrastructure, culture, and governance.

The basic idea is that it is possible to better manage risk by forecasting the impacts of external forces on urban areas, and by designing and operating urban land uses and infrastructure in ways that are inherently more resilient. This means including in any assessment indicators that help designers, managers, and decision-makers understand the relative capacity of systems to survive and recover from shocks and rapid change. The World Bank's primer on Climate Resilient Cities, provides information on how cities can better access and manage the risks associated with climate change.

Elements of resilient design appear to reinforce a number of the ecological design strategies that are so effective at improving efficiency. Remote generating plants, incinerators, treatment plants, and communications facilities are far more vulnerable to catastrophic failure than a network of modular, distributed systems closely integrated into the fabric of the city. Thus, urban security helps to reinforce distributed systems—a design strategy already proposed as a way to improve urban resource efficiency and environmental sustainability. The positive synergy between security and efficiency (or resiliency and sustainability) is an important outcome for integrated design solutions.

One measurement of resiliency might be redundancy—a strategy mentioned in the previous chapter as an example of ecological design. Redundancy for urban systems may mean that critical resources are supplied by a variety of systems, each capable of drawing resources from as wide a geographic area as possible. In the eventuality that droughts, floods, or other disasters affect any one area, an alternative source of supply is already in place to meet at least minimum requirements. For each type of critical resource, the region may develop redundancy through a diversity of supply options, or through a contingency plan. Redundancy may also need to consider the entire supply chain for each critical system, all the way back to the ecological resource. Redundancy can then be provided for the weakest links in the chain. Links are the processes or 'nodes' that provide essential services, wherever they are located. When we discover nodes that are essential, but not duplicated elsewhere in the system, we have found a weak link.

Redundancy and self-reliance work on different scales. Even links within the region can benefit from contingencies. For energy systems, for example, this may mean a mix of sources, some local and some renewable. For potable water, this may mean distributed reservoirs and multiple sources of water.

Localized and distributed infrastructure systems may be more flexible and responsive in the face of external threats. To the extent that systems are self-organizing, they do not require lots of external regulation or direction in order to function or adapt to opportunities or constraints. Such systems can operate by a set of rules, similar to the market place, rather than a mechanistic, top down approach that imposes a final solution from start to finish.

—Adaptability and durability

Adaptability can be broken down into a number of simple strategies that are familiar to most engineers and designers:

- flexibility or enabling minor shifts in how systems function or spaces are used;
- convertibility, or allowing for changes in use for parcels of land or buildings, or changes in inputs for infrastructure systems; and
- expandability, or facilitating additions (or deletions) to the quantity of land or space dedicated to particular uses.

Infrastructure that is designed to adapt easily, at a low cost, is likely both to survive longer, and to operate more efficiently throughout its lifetime. An example might be combined trenching (utilidors) that allow easy access to pipes and wires.

Durability is a concept that can further extend the useful lifetime of materials and technology, and is complimentary to adaptability. In practice, adaptability and durability can be achieved through changes in design, and through the use of alternative zoning, materials, and technologies. For high performance, adaptable designs might begin with the concept of a fixed investment cost. The object is then to achieve maximum durability by means of flexibility and adaptable design features, while at the same time minimising the running costs for energy, cleaning, maintenance, and operation. Part of a durable design strategy may be to set minimums: for example no secondary components that last less than 30 years. In other cases, the solution may be to minimise maintenance and service costs for components.

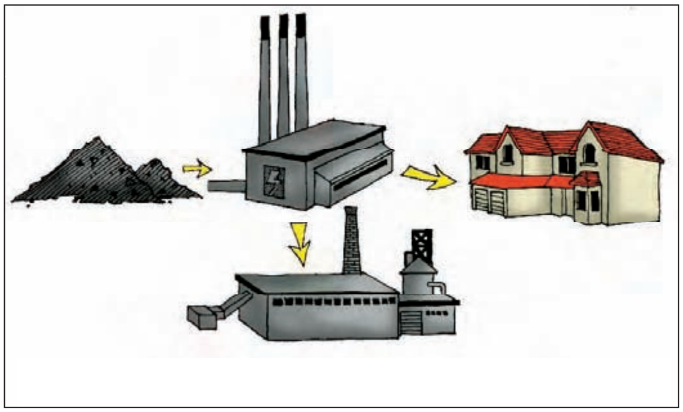


Figure 1.31. Inflexible Energy System
This coal-fired energy system is brittle because it cannot adapt, expand or convert.

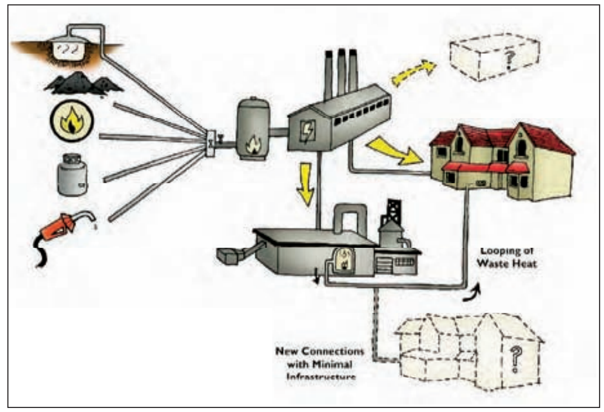


Figure 1.32. Adaptable Energy System
This is a resilient system because it is more adaptable by design.

—Monitor performance, learn from results, adapt and improve system

An integrated approach to monitoring has two dimensions: firstly, it means considering performance objectives right from the beginning of project design and using these targets as a basis for comparing actual performance against intended results; secondly, it means integrating monitoring into a feedback and accountability process that ensures adjustment of policy and systems to achieve or exceed the intended results. Both of these dimensions need to be addressed in each Eco² Project.

Establishing performance targets at the commencement of a design project can be a positive experience that helps to focus and inspire the project design team. Selection of targets requires a means of measuring performance easily and affordably. Choice of performance indicators should be based upon best practices from other locations, and on the analytical methods used for system design such as material flow analysis. Measurements only have value when a basis exists for comparison, so it helps greatly to use well established indicators with standardized data collection and calculations. Ideally, the targets for performance are established only after reviewing a number of precedents and case studies, including sister cities and Best Practice cities.

After project completion, it is important to integrate the monitoring program into regular reporting, staff evaluations, and management philosophy. When monitoring is used to guide continuous learning and improvement, it is referred to as adaptive management. Adaptive Management originated with fisheries and forestry biologists who discovered that natural ecosystems were so complex and interconnected that all management efforts failed. It became necessary to assume things wouldn't work—to plan for failures. As urban environments become more complex, and as we consider a broader range of goals for environmental, social, and economic sustainability, it helps to adopt the 'Adaptive Management' solution invented by ecologists.

From this perspective, all policy and practice is considered experimental, and has lasting value only if proven over time. Policy in itself can become a problem if it cannot be easily adjusted to accommodate new knowledge. When monitoring programs are integrated into an adaptive management process, the Eco² long-term planning framework must be included. The framework provides a transparent context for target-setting and evaluation. On one hand, the framework keeps targets connected to end-state goals, and, on the other hand, the framework connects targets to project strategies and actions.

Stepping Stones for Investing in Sustainability and Resiliency

Use the Life Cycle Costing method to better understand costs and cash flows

An Eco² Catalyst Project is an opportunity to make LCC a standard part of project planning. Every city can develop this capacity. Suitable methods and tools are introduced in Part Two of this book.

Develop and adopt indicators for assessing the four capitals, and for benchmarking performance

Indicators can be selected from lists provided by knowledge institutions and industry coalitions. A good place to start is the long list of SD indicators used by cities in OECD countries or progressive cities in developing countries. Choices need to be guided by the selection criteria listed earlier. An indicator is not successful unless it is regularly measured and reported.

Forecast the impacts of plausible changes

Forecast the impacts of plausible changes in climate, markets, resource availability, demographics, and technology. Forecasting the impact of external forces can help begin the process of proactively incorporating resiliency and adaptive capacity to better manage risks. Foresight workshops can assist in clarifying the various cause and effect chains that can lead to significant impacts on different urban infrastructure systems and the city as a whole. Some of the external forces that can be examined through such workshops—in addition to climate change—include: changes in global markets, resource availability, demographics, and technology. These are discussed in Part Two. The World Bank's primer on Resiliency and Climate Change is a good starting point for understanding climate-related risks.

Implement an Eco² Catalyst Project, in ways that protect and enhance capital assets, and reduce vulnerabilities

The best way to learn the Eco² accounting methods in practice is on an Eco² catalyst project. This will require a multi-criteria assessment of projects, using the methods and tools described in Part Two of this book. Generally, what is needed is to develop a base case scenario—using business as usual assumptions, and then use this base case as a benchmark for evaluating any alternatives that have been proposed during the project design exercises. Eventually, the accounting methods should provide a sound basis for making recommendations on the preferred investment strategy.

Monitor and feedback results, then learn and adapt to improve performance

Monitoring requires a set of indicators adapted to the city and project and budget. What is most important is that indicators are actually reported over time. This means a budget allocation for data collection, analysis, and publication. The collection of measurements over time adds strength to the process of urban development. The feedback on key indicators makes it easy to see trends and patterns, educate decision-makers of how well the city is doing, provide benchmarks, set targets for upgrading future projects, and provide a solid basis for employee and contractor accountability. The key to evaluation and learning is consistency and perseverance.

CHAPTER 7

Moving Forward Together

The Eco² Cities program is a collaborative exercise that requires close working relationships among all stakeholders and a willingness to consider and to apply new concepts and methods together. Of course, cities are in the driver's seat. This book is designed to explain the key principles of Eco², how they translate into core elements and stepping stones, and to provide cities with the methods and tools—all of which will enable them to develop their own Eco² pathway. As explained at the beginning of this book, the opportunities for positive changes are especially great at present. We strongly encourage cities to take their first step towards ecological and economic sustainability, while the window of opportunity to make lasting impact is still open.

For forward-looking cities in developing countries which intend to adopt Eco² approach, possible support is available from best practice cities worldwide, the international community, including donor agencies, and academia. Cities are encouraged to tap the unique resources of each of these partners. In this context, the World Bank Group[64] together with other partners is in a position to provide: 1) Technical Assistance and Capacity Building; and 2) Financial Support to cities that demonstrate strong commitment to implement the Eco² program.

Knowledge Sharing, Technical Assistance, and Capacity Building

One of the most effective methods of knowledge sharing, technical assistance, and capacity building is peer to peer engagement with best practice cities. It is conceivable that such engagement could be supported through donor funding. At the same time, the international community has a wide range of programs that provide technical assistance and capacity building. Academic institutions can be engaged in the process: for instance, the Environment Load Profile tool which was used in Stockholm was jointly developed by the City of Stockholm, The Royal Institute of Technology, and a private firm Grontmij. Other options for technical assistance include the World Bank Group's technical assistance and capacity building support, which can be made available to cities either through a catalyst project, or through stand alone funding.

Technical assistance and capacity building can provide support to cities on many stepping stones of their Eco² pathway. They can also help with a more detailed application of the core methods and tools. Some examples of possible support include: 1) adapting Eco² to suit a city's unique demands and priorities; 2) conducting diagnostic analysis using the Eco² methods and tools; 3) developing Eco² pathways and plans (including investment and financial plans, to materialize the vision and strategies); 4) enhancing institutional capacities to implement Eco² projects, with particular attention to the key principles; 5) equipping local institutions with the technical requirements (GIS for instance) to use of Eco² methods and tools; 6) designing a national strategy to institutionalize the Eco² program through a national financing mechanism ; 7) implementing an integrated design workshop or a forecasting workshop; and 8) focused study tours or secondment opportunities in Eco² best practice cities.

Ultimately knowledge sharing, technical assistance, and capacity building agendas will be based on the specific needs of each city.

Financial Resources

In general, cities can access a range of financial resources from the international community and donor agencies. Many of these financial resources can be used to fund the many options of technical assistance outlined earlier. Larger donor agencies like the Multilateral Development Banks (The World Bank, The Asian Development Bank, etc.) may also provide financial resources for infrastructure investment under Eco² projects. What is most important from an Eco² perspective is that the number and diversity of financing tools are increasing, and that it is possible to combine such instruments to fit the different dimensions or phases of an Eco² project. For instance, let's consider the case of the World Bank.

In most cases, cities seeking financial support from the World Bank Group need to submit their requests through their respective national governments to ensure that the provision of limited loans, credits, or grants is consistent with national priorities and strategies.[65] The World Bank Group has diversified financial tools that can be used in combination to finance Eco² projects, which are mentioned below along with other donor financial instruments. Unlike a conventional 'one project' financial instrument approach, the World Bank Group could package these instruments to facilitate an integrated approach that is critical to the success of the Eco² program, and to the success of specific investment projects.

1) Development Policy Loans (DPLs) provide quick-disbursing financing to support policy and institutional reforms at both national and sub-national government levels.

2) Specific Investment Loans (SILs) finance a broad range of specific infrastructure investments (water supply, wastewater management, power generation and distribution, solid waste management, roads, public transport, etc.).

3) If policy and regulatory reform leads to significant reduction of GHG emissions in specific components based on the Carbon Development Mechanism (CDM) methodology, or if direct investments do the same (for instance, through solid waste management), then the World Bank's Carbon Finance Unit can enable the purchase of emission reductions. This can increase the bankability of projects by adding an additional hard revenue stream.

4) The International Finance Corporation, also part of the World Bank Group, can

finance corresponding private sector investments (for instance: energy efficient buildings or technologies).

5) The Global Environment Facility (GEF) is a global partnership that provides grants to address global environmental issues for projects related to six focal areas: biodiversity, climate change, international waters, land degradation, the ozone layer, and persistent organic pollutants. An Eco² project may qualify for a GEF grant if it focuses on one or more of these areas.

6) Climate Investment Funds (CIFs), which provide concessional financing, could be made available if projects contribute to the demonstration, deployment, and transfer of low carbon technologies, with significant potential for long-term GHG savings.

7) By insuring investments against political risks, the World Bank's Multilateral Investment Guarantee Agency can help certain developing countries attract private investment.

By integrating, sequencing, and linking these financial instruments, World Bank Finance could enable an integrated approach to the sequenced implementation of a city's Eco² related financing needs. Of course, all these instruments do not need to be used in every case, but Figure 1.32 below provides a sample of how instruments might be mixed together. The World Bank Group can also help national governments and Eco² cities to mobilize co-financing resources from other donors, as indicated on the far right of the same figure.

Features of these financial instruments are explained in Part Three of this book.

Financial resources are important. They enable many of the possibilities discussed in this book. However, the reader should keep in mind that some of the most remarkable innovations and approaches profiled in this book were actually implemented without the luxury of these complex external financial resources. The true test of the Eco² Cities Program will not be its ability to link cities with finance, but to facilitate a process by which cities can adapt and apply the 4 Eco² principles to unlock their full potential.

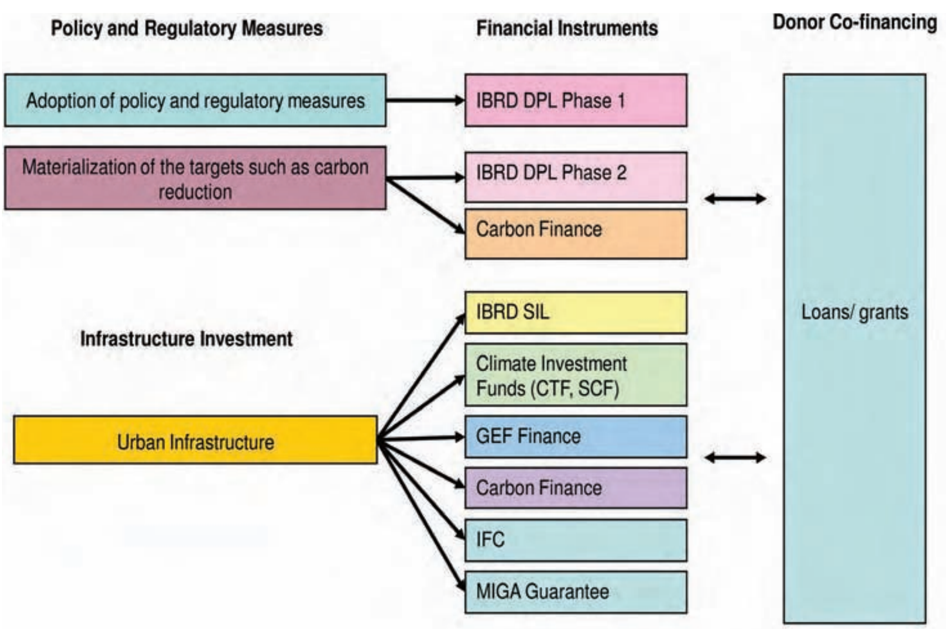


Figure 1.33. Financial Instruments

The World Bank Group's Financial Instruments and the instruments of multi-donor facilities administered by the World Bank could be packaged and sequenced to support a more integrated approach to financing Eco² Projects

PART 2

A City-Based Decision Support System

Methods and Tools for Eco^2 Cities

Introduction

Part Two is for everyone who wants to become familiar with some of the core methods that together provide cities with a Decision Support System (DSS). It explains the role of these methods in assisting cities on their Eco² Pathways. As explained earlier, the Decision Support System is part of a City-Based Approach, since it enables cities to develop their capacity to operationalize the core elements of the Eco² Program. Even if you are not expecting to work with the methods directly, understanding what they do helps to bring the core elements to life.

Each Chapter deals with a different category of methods and tools. *Chapter 1: Methods for Collaborative Design and Decision-Making* is an overview of the **operational and process** methods that help cities undertake leadership and collaboration. *Chapter 2: Methods for Analyzing Flows and Forms* provides an overview of the most practical **analytical methods.** The combination of analytical methods helps cities to develop the 'transdisciplinary' platform described in Part One, by revealing the important relationships between spatial attributes of cities (forms) and their physical resource consumption and emissions (flows). *Chapter 3: Methods for Investment Planning Assessment* is an overview of **accounting methods,** and includes details on how to apply Life Cycle Costing and Proactive Risk Mitigation and Adaptation.

The methods support the typical planning process at different times and in different ways. Some methods can be used repeatedly. For example, the meta-diagrams that summarize resource flows can be used firstly as a way to baseline how a location is currently performing, and then later to help with diagnosing, target setting, scenario development, and cost assessment.

All methods are proven approaches to getting the work done. They are expected to remain relevant for many years. The fundamental purpose of methods is to simplify the process of analysis, assessment, and decision-making. They provide practical ways for cities to take leadership, collaborate, and analyze and asses various ideas for Eco² projects.

Wherever possible, methods are accompanied by tools. By tools we refer to such things as templates, checklists, diagrams, maps, and specialized software applications—anything that is convenient to use and helps us quickly operationalize a method. The tools mentioned in the Eco² Program are examples, and hopefully their quality and quantity will increase as the program evolves.

Due to limited space, Part Two only introduces the core methods. One of the first Stepping Stones on the Eco² Pathway is to plan a process for capacity building, which must include a facility for using methods. Part Two of this book is a good place to begin. It sets out the scope of skills and knowledge that are required, and provides an introduction to the key methods and tools, and also to sources of additional information. Capacity building can continue as cities follow through on suitable methods, obtain more information, acquire specific tools, employ outside technical support, and apply new methods to their catalyst projects.

Capacity building plans are usually developed in stages, beginning with the most simple tools and applications. The benefits are still substantial. For example, sophisticated computer print outs are not necessarily more effective than maps drawn on transparencies by individuals with lots of ground knowledge (community mapping). Sometimes, computers and fancy presentations can actually get in the way.

All capacity building plans should focus on tools that can accommodate varying levels of data and skill, allowing the capacity to evolve over time. Tools can help this evolution if they are:

- **Transparent**—analytical tools must be easy to understand and adjust, so that even beginners can follow the rationale, and the flow of information. Complex 'black box' computer models are inappropriate.
- **Scalable**—tools easily adapt to the level of effort warranted by the project, and to the level of knowledge and skill of the user. As conditions change, the same tool should accommodate a larger scope, or more precise inputs.
- **Web-friendly**—by designing most tools so they can make full advantage of the Internet, it becomes easier to train people, update tools, share results, interchange data and results, and use the tools to enhance stakeholder and public participation.
- **Modular**—past experience[1] with using tools for city planning suggests that it is a mistake to adopt models and tools that are overly general and all-inclusive in their purpose. Models work best when they are limited to specific tasks, and flexible enough to work on their own or in combination with other tools. A modular approach, based on strong theoretical foundations but allowing for changes in key assumptions, can more easily adapt to the complexities of the real world, and to changing user needs.

Acquiring capacity in particular methods and tools may appear challenging. Training seminars, and user friendly software, can make the process more manageable. So too can advice and assistance from the Eco² Program advisors, partners, and best practice cities. Despite the challenges however, most cities in developing countries will need to adopt new methods and to invest in capacity building. If anything, problems in the developing countries are often more complex and demanding than those faced by wealthier cities in developed countries, and thus the need for effective decision-support systems is that much greater. It is an investment that will yield compounded benefits.

CHAPTER 1

Methods for Collaborative Design and Decision-Making

Organizing and Managing Collaborative Working Groups

Adopting some basic rules for collaboration

Collaboration is a method by which diverse groups join together for a common purpose, without necessarily altering their mandates, relinquishing their authority, or sharing their budgets. The power structures are retained. In fact, the reason why collaboration works is that nobody is forced to give away their power. What changes is that information flows are greatly enhanced, and the potential is greater for joint action. Collaboration is especially effective for integrated design of urban areas, because so many different parties can influence results. Any particular system may be significantly affected by land use policies, private development projects, on-site systems, demand side management programs, efficiency standards, use of shared rights-of-way, and so on. Collaborative Committees begin by agreeing to a simple set of rules or principles. It also helps to have a common vision of the desired long- term outcomes.

One key rule is that wherever agreement on strategies is reached within the collaboration, each member will use its unique mandate and resource base—in a more or less coordinated fashion—to contribute to the agreed strategy.

Balancing the membership and structuring inputs from varying levels of authority

Ideally, a collaborative working group is composed of a balance of sectors: government, private, civil, and academic (knowledge institutes).

A balanced membership means that a collaborative working group needs to be carefully constructed to include a full range of perspectives: short-term and long-term, private and public. A convenient approach is to establish roughly proportional representation from different sectors: government, civil, private and academic. Each sector brings different priori-

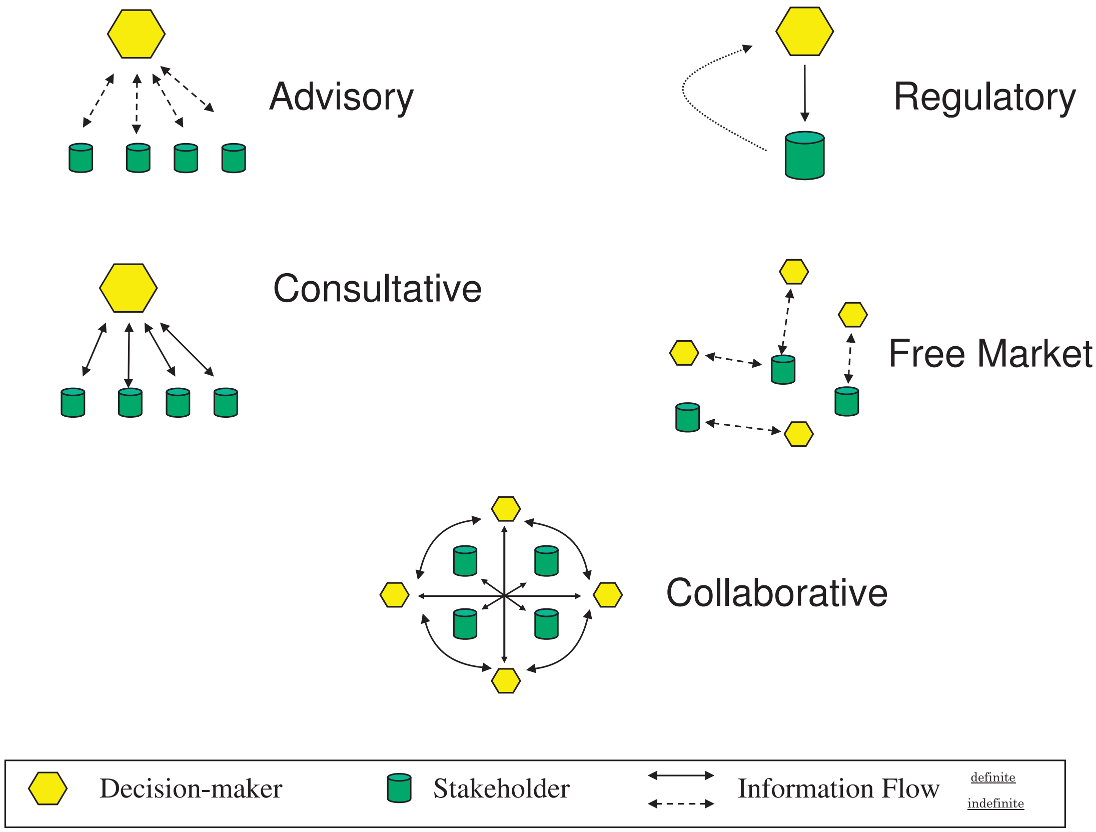


Figure 2.1. Collaborative Model.
A collaborative model replaces hierarchical structures and increases the potential for exchange and cooperation.

ties and perspectives that help to create balance. For example, if the government sector is often the best informed, it is the least willing will to take risks. Civil sector groups, if well represented, can help provide the motivation and vision to keep everyone from seeing only the problems and barriers. Input from the academic and knowledge sector can be especially useful to expanding the scope of discussions and—at later stages—incorporating high quality research and expertise into the design exercises and planning proposals. The precise mix of stakeholders from each sector must be carefully considered, since each city will be subject to different political relationships and institutional structures. Also, the composition should vary to reflect the scope of the planning and projects under consideration.

On the public sector side, stakeholders can include all the agencies and departments with scope to impact cities. These may be national, state, municipal, and district. At each scale, there may be additional regulatory, infrastructure development, and service delivery agencies responsible for land, water, energy, transport, and waste management. Some of these agencies may participate in public private partnerships, and this requires involvement of networks. Neighbouring jurisdictions are also potential stakeholders. Collaborating with adjacent cities and regions can result in strong synergies in such areas as integrated planning for reuse of waste materials, coordination of transport and land development, and through cooperative economic development.

The private sector and households are key players in energy and resource use, as well as in local pollution and global GHG emissions—and they need to be considered as part of the Eco^2 process. In a recent report commissioned by

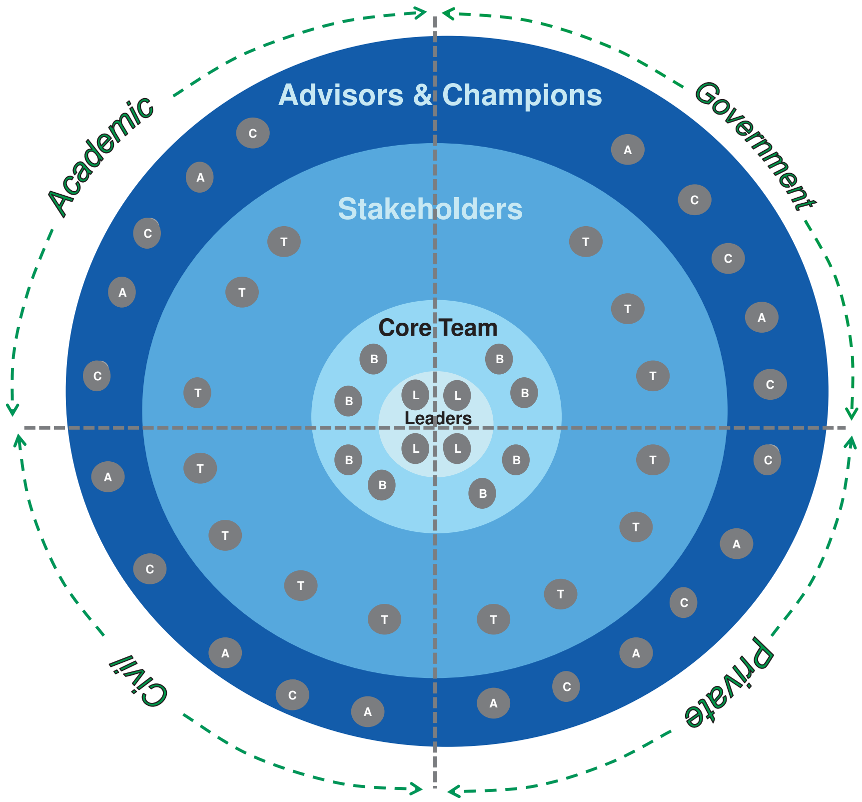


Figure 2.2. Collaborative Working Group.
The make-up of a collaborative working group should seek to balance input from government with equal measures of leadership and expertise from the private, civil, and knowledge sectors.

Siemens and undertaken by McKinsey and Company on Sustainable Urban Infrastructure in London, they strongly reflect this view: "As this report makes clear, many different stakeholders are involved in making sustainability-related decisions. Success will require cooperation, rather than dictation from any one of these. Certain things can take place at the national and municipal government levels, but the most powerful actors in all of this are consumers,[2] who can through their purchasing decisions bring about 70% of all possible CO_2 abatement. Absolutely crucial to lowering emissions, therefore, will be removing the barriers to them doing so."[3]

The urban poor are also stakeholders in the city. Good urban planning creates more access for public and non-motorized transport, and supports lower cost services and the reduction, re-use, and proper treatment of harmful waste—all outcomes that will directly and tangibly improve conditions for the poor. At the same time, fiscal gains made by the utilities or a city can be applied to benefit poorer sections of society. For example, the congestion tax in London not only reduced traffic by 21 percent (70,000 fewer cars/day) and increased the usage of buses and cycles in the zone, but a large portion of the £137m raised in financial year 2007/08 is being reinvested to improve public transport in London.

Collaborative Committees function well when they have a strong champion, a hard-working secretariat, and a balanced membership. Figure 2.2 presents an example of how a city-wide collaborative might be organized. A single all-policy working group provides a new institutional structure for collaboration. At the centre are one or more leaders who direct the process and provide everyone with a sense of purpose and confidence. The secretariat is a

Figure 2.3. Core Team and Sector Advisors.

The core team can be supported by a ring of sector champions, each of whom connects the working group to a larger network of experts and stakeholders. New urban infrastructure places special emphasis on such sectors as energy, transit, water, environment, and materials management. However, other sectors may also offer substantial contributions.

small group that serves the collaboration by undertaking research on critical issues, facilitation at meetings, and communications between meetings and event planning. An effective secretariat can help build confidence and can make the process feel productive, fun, and worthwhile to all members. The collaborative process may require a core team if the collaborative is undertaking to create a pact or strategic plan. Alternatively, the collaborative can guide and direct the planning work accomplished by staff from the various stakeholders.

Developing a Shared Framework for Aligning Visions and Actions

A common framework can greatly enhance communications and coordination

Frameworks are the mental maps that we use to make sense of the work schedule—what comes first and second, how our particular contribution fits with the work of others, and so on. Typically, there are big differences in the frameworks that different individuals bring to a project. These differences could be in how groups understand the goals of a project, or who influences who, or how their plans are expected to jive with other plans. Developing a common framework can help overcome these disconnects, and make a diverse group of largely autonomous stakeholders operate more as a team.

A framework for urban planning and design moves from start to finish. An example of such a framework is the pyramid shown in Figure 2.4. At the pinnacle is the scope of the framework—clarifying the extent of the urban area to be included, identifying types of urban systems to be considered, and diagnosing the strengths and weaknesses of the system as it currently operates.

After scoping and diagnostics, a framework typically expands to include a shared vision statement and a set of long-term goals. These broad statements are then unbundled into more specific and immediate targets, strategic plans, actions, and ongoing learning processes. The framework can include any principle, goal, or strategy that the user desires, and it can be easily molded to fit any current planning framework, methods, and terminology. In this sense, it is a form of 'methodological pluralism'—everything fits inside the framework.

Perhaps most importantly, a framework builds in accountability—helping to avoid short-term political decisions that are inconsistent with goals and targets. It also creates the opportunity to monitor performance against specific goals and targets, and to update plans and adapt to changes without losing sight of the original intentions. If the vision changes over time, then all subsequent layers of the framework can be adjusted accordingly. Or, if the implementation actions encounter surprise, or produce inappropriate results, then the problem can be traced back to the choice of strategy, and corrective changes can then be made at all subsequent levels.

The first stage is to define boundaries and understand current performance

Because a long-term planning framework supports collaborative decision-making, the scope of the framework must match the platform for collaboration. If a city is leading a triple tier collaboration process, for example, then the planning framework will need to extend to include visions and actions relevant for the entire urban area, and for all participating stakeholders.

Whatever the platform, scoping and diagnostics help to set the stage. Clear boundaries inform all participants what is included, and excluded, from the planning framework. An extensive inventory or information collection process clarifies what is now known, and not known. Some basic analysis of existing system performance can establish how well different systems are performing relative to similar cities or best practice case studies. This is sometimes referred to as a city profile. Often, the amount of work involved in scoping and profiling a city exceeds the work required for all other stages of the framework. Nevertheless, it is an extremely worthwhile investment, as the results serve to direct all further activity.

Vision statements are elaborated into end-state goals

The vision can be a simple statement, or even an artist's drawing; its purpose is to be inspirational and broad. If the scope is limited to infrastructure design and land use planning, then the vision should focus primarily on these areas.

Figure 2.4. A Long-term Planning Framework
connects visions to actions and includes a process for learning and adaptation The Sheltair Group, 2006

A set of 'end-state' goals can elaborate on the vision with stand-alone goal statements. End-state goals define the ultimate condition that is desired by a city, even if this is something that may not be realized for many years. Typically, an end-state goal is expressed in a single definitive statement, followed by a commentary. Canada's capital region has a number of end-state goals: a few relate directly to infrastructure performance, such as achieving sustainable urban metabolism, or extending the use of 'green' infrastructure. Both these goals are shown below:

- *"The natural resource demand by each neighborhood is consistent with the long-term capacity of the city's infrastructure and the region's resource base."*
- *"Trees, gardens, ponds, wetlands, hedgerows, streams, greenways, green roofs and engineered ecologies have become the elements of a cost-effective 'green infrastructure' that cleans and constrains storm water flows, contributes to a quieter and more pleasant*

micro-climate, shades buildings in summer, improves air quality, and generally contributes to the livability and biodiversity of neighborhoods."

Although such goals describe a long-term condition, they serve an immediate strategic purpose by providing a common reference point for all design and planning, and a basis for collaborative decision-making.

End-state goals for Eco² Cities should address, at a minimum, the basic urban services (energy, water, and so on) and the ecological performance of the urban region. Cities can choose to use their own format and language, or they can adapt their framework goals from examples provided by the Eco² Cities Program. Either way, goals should reflect the local conditions and cultural values, and need to be discussed and endorsed by key stakeholders. Because the goals are long-term, the process of building consensus around the goal statements tends to be a positive experience, building a common purpose shared among stakeholders and residents.

Target-setting can help to translate goals into clear objectives

Sometimes, it helps to develop intermediate targets to support specific end-state goals. The targets are based upon indicators that quantify the city's desired performance with respect to one or more goals. By setting targets for specific time periods, the city helps to direct the pace of change and the priorities for investment. For example, the city of Stockholm has set a target for all new construction to be carbon neutral by 2030; over 70 percent of New Zealand's cities and towns have adopted a zero waste landfill target, with a timeline for each milestone on the journey; San Diego and Irvine California have achieved their targets for comprehensive coverage of reclaimed water to commercial properties.

As part of adopting a set of end-state goals (and setting targets if desired) it can help to assess performance and set priorities. Using expert judgment and local knowledge, each goal can be subjected to a series of questions: How close is the city to achieving its goal today? What forces are likely to influence future success? What direction is the city now moving—are things getting better or worse? How fast is the pace of change? This type of rapid evaluation is helpful when setting priorities for Eco² projects.

Strategic planning requires that planners evaluate alternative scenarios

This exploring stage in a planning framework provides the opportunity to develop a range of alternative scenarios or approaches, and to assess their relative values in terms of how well they achieve guiding targets and goals. While city governments and departments may already have a strategic plan, the framework can help to extend and align the time horizons for such plans, and to integrate strategies that address the long lifecycles of such investments. At the scale of the urban region, strategic planning is especially helpful, although many urban regions in developing countries are currently operating without a shared strategic framework.

In a growing urban region, the umbrella plan that sets the context for all other planning is sometimes referred to as a Regional Growth Strategy (RGS). The RGS ensures that the various infrastructure plans—transportation, water, energy—all share the same assumptions about land use, demand, and development priorities. The RGS takes regional population growth and employment projections into account and gives the region, including its component parts (towns, counties, cities) long-term planning direction. It is the regional growth strategy that ensures integration of the parts into a functional whole. In addition to providing the 'big picture' of how a city fits into its surroundings, the RGS provides the broad brush strategies for connecting neighborhoods, and directing new growth and investment. The RGS should always address the critical issues that must be solved at the scale of the urban region, which might include restricted water supply, air quality, and transportation management. The RGS may also identify priorities for housing, regional services, parks, economic development, and climate change initiatives. The most effective regional growth strategies are developed through a consensus-building process that achieves agreement (sign-off) from the surrounding regions, and from the mix of towns or stakeholders within the region.

To be effective over the long-term, the RGS must provide a phased approach to accommodating the projected growth in population and jobs, including the identification of areas suitable for infill and densification, and the timelines for development of specific urban reserve areas. To ensure that the different elements of the city interact and support each other, the RGS will typically adapt some of the best practices from successful regions, including:

- **A hierarchy of regional growth centers** connected to each other and to the growth concentration area via transportation corridors with efficient and convenient transit.
- **One or more growth concentration areas** that provide the city with a destination center for shopping, business, and the arts.
- **Medium or high density developments** located along the transportation corridors and at all transportation hubs.
- **Distinct, complete neighborhoods and districts** that include a mix of land uses, a healthy ratio of jobs to housing, and well-defined open spaces.
- **Clearly defined containment boundaries,** with permanent, functional edges that separate and protect urban areas, rural areas, and natural areas.
- **A fine grained network of greenways and blueways** that connect all residential areas to a network of parks and to a representative cross-section of the regions native ecologies.

Catalyst Projects help to change paradigms

"Folks who do systems analysis have a great belief in 'leverage points.' These are places within a complex system (a corporation, an economy, a living body, a city, an ecosystem) where a small shift in one thing can produce big changes in everything. People who manage to intervene in systems at the level of paradigm hit a leverage point that totally transforms systems. . . there's nothing physical or expensive or even slow about paradigm change. In a single individual it can happen in a millisecond. Of course individuals and societies do resist challenges to their paradigm harder than they resist any other kind of change."

Donnella Meadows 1999, Leverage Points, Places to Intervene in a System

A regional growth strategy need not be a complicated undertaking. Some the best-known regional growth strategies have been produced quickly and were initially introduced as a simple vision and map. However, most often the process takes a couple of years from start to finish, plus the added time to initiate and secure funding. The process requires major investments in capacity building, field research, mapping and analysis, collaboration, and public process. Consequently, the completion or renewal of an RGS may be something that happens in parallel with other Eco^2 projects, or at a later date.

Absent a long-term, complete and up-to-date RGS, the shared planning framework may not function as well. Without a long-term framework, for example, it might be more difficult to integrate Eco^2 projects into long-term land use and development, and some opportunities for design and policy integration may be lost. However, the Eco^2 Pathway may incorporate interim solutions that offer a significant amount of guidance without a major investment in time or resources. One such solution is to organize a regional design charrette, and then to use the outputs from the charrette as the 'first iteration" or first cut of a RGS.

Implementation of the key strategies should begin with Catalyst Projects

Implementation of strategies can be achieved through project planning and investment. The first projects implemented in accordance with the Eco² Pathway are referred to as catalyst projects. The function of a catalyst project is to accelerate learning and to promote acceptance and understanding of the Eco² Pathway. A catalyst project can be site-specific or city wide. It should be designed to demonstrate the potential for greater integration of designs and polices. Almost any type of infrastructure investment or land development can be adapted for this purpose. However, the best choices are catalyst projects that work with people or locations that are already moving in the right direction. It also makes sense to choose a catalyst project based upon the city's priorities for change. If the end state goal is to provide everyone with affordable housing, and the actual price of housing is becoming less affordable every day, then some kind of intervention is clearly warranted. As long as the project details are not predetermined, the process of collaboration and integrated design, supported by new methods and tools, will lead to a more efficient, multi-purpose system design, and a more coordinated set of enabling polices.

Because of the focus on learning and integration, the catalyst projects are not strictly pilots or demonstrations. The emphasis is on learning, and on catalyzing change by influencing all subsequent projects. They help to transform a city into a 'learning society.'

A city might plan for one active catalyst project in every neighbourhood, as a way to begin implementing the Eco² Pathway, and as a contribution to local pride and place-making. Figure 2.5 evokes a neighbourhood catalyst project, and illustrates how the project serves to anticipate and re-direct performance in an area where the trend is otherwise moving in the wrong directions.

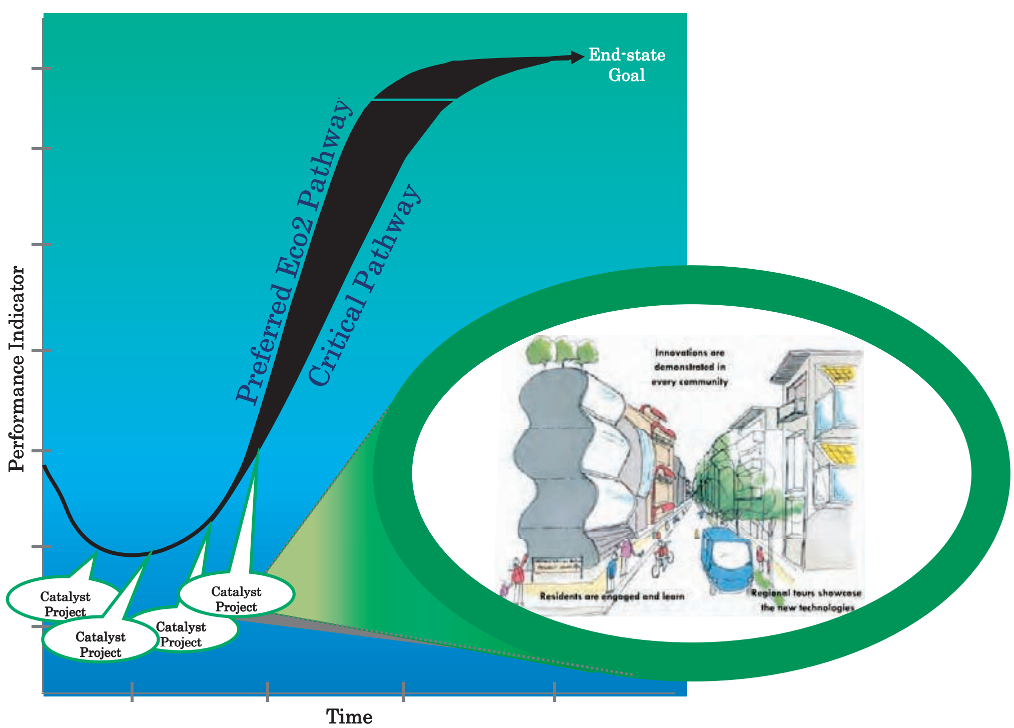


Figure 2.5. Catalyst Projects are interventions in the short-term designed to accelerate changes that are needed to create an Eco² Pathway that will reach the targets and end-state goals of the long-term planning framework.

Implementation Policies should be integrated across each policy tool/instrument and stakeholder

To ensure that all stakeholders are engaged, and that a full set of policy tools and instruments has been considered, it is useful to create a matrix of stakeholders and policies by category. An example of such a matrix is presented in Figure 2.6. The different policy tools and instruments are listed across the top, and the different stakeholders down the side. Developing such a matrix is the output of a collaborative exercise based upon a shared planning framework. The matrix is a tool for strategic planning, and also a way for any collaborative working group to see the potential of teamwork. Each stakeholder tends to have different levers of control or influence, and these produce different, but complementary, actions for implementation.

Conducting a Regional Systems Design Charrette

At every tier, a collaborative committee provides an important institutional structure for promoting and facilitating integrated design. Unlike the traditional planning and design process, which begins with a small team lead by an architect, planner, or engineer, and later adds experts when needed, integrated design engages a wide range of specialists, local stakeholders, and partners at very early stages. The objective is to use their expertise to influence seminal design decisions before opportunities are constrained, and to find the synergies and out-of-the-box solutions that lead to practical and affordable Eco² solutions.

The prior existence of a formal collaboration process among senior decision-makers means that the groups are likely to be more comfortable with participating in the integrated design process. Ideally, the collaborative committee will agree that design workshops are worthwhile, and will contribute their best designers. The collaborative agreements can also ensure that the results of such workshops are properly assessed and integrated into the final project plans.

The Systems Design Charrette

Many kinds of design workshops can be used to facilitate the Eco² Pathway. One of the most important workshop is a 'systems' design charrette. A charrette is an intensive workshop that can last 4 to 7 days, and that typically brings together a diverse group of specialists, designers, and residents. During the charrette, a number of small mixed teams will work side by side, day after day, with occasional interaction with each other, and with scheduled visits from public and VIPs.

Over the past few years, the techniques for design charrettes have evolved. Initially, the charrette was a tool used primarily to stimulate creative design solutions in building form and the use of interior space. A new building or group of buildings would be drawn in different configurations, with input from many experts. More recently, the technique has been applied to entire neighborhoods, cities, and regions, with excellent results. The larger spatial areas can be treated as 3 dimensional spaces, with attention given to scale, walkability, streetscapes, and public space. Specific locations can be used as case studies. Engineers and planners can address urban resource flows, and include schematics and plans for alternative infrastructure. In this way, the design charrette expands to address all urban systems at the city scale.

In a charrette, the scale will vary to match the project. If the objective is to create a long-term regional plan, the scale will need to encompass the entire urban area, and the rural fringe. One team might focus on boundaries and connections, another on the formation of complete neighborhoods, and another on infrastructure systems (urban systems). All teams are directed by the end-state goals. At first, the small teams talk and share information and ideas. Then the process progresses from simple

Catalyst Strategy 1: Protect & Connect Ribbons of Blue, Webs of Green

Rehabilitate and protect natural and built systems through reconnecting viable networks of blue ways, green spaces, and corridors.

citiesplus

Stop, Start or Continue?

Stop - measures that need to be halted

Start - measures that need to be initiated

Continue - measures that should be continued or expanded

Governance Reform:

Mandates of each level of government need to change to enable more proactive iniatives and preventative measures.

A reformed governance system would include a shift towards a watershed based approach to planning and implementation with mechanisms that allow for the establishment and support of subwatershed stewardship groups.

Role of Citizens:

- Be environmental watchdogs during the development process
- Report infractions by development proponents if activities impact fish when sites are developed
- Advocate density levels that promote creation of greenspace

	Investment & Planning Initiatives	Research, Demonstration & Leadership	Education & Inspiration	Legislation, Regulation & Enforcement	Market Instruments
Federal Agencies	• Continue Fraser River Estuary Management Plan • Continue support for watershed and stream stewardship initiatives	• Start using federal lands to showcase sustainability strategies such as green roofs • Start using alternative development standards for developments on federal lands • Support establishing showcase sustainable communities	• Draft and pass a federal Environmental Bill of Rights • Continue regulating and enforcing instream works; alternations to riparian zones; and discharge of deleterious substances into fish habitat	• Stop taxation of capital gains on lands donated for conservation purposes • Continue allowing gifts of ecologically sensitive lands and easements to qualify for charitable tax receipts	• Continue stewardship outreach • Continue making available the Lost Streams of the Lower Fraser Valley • Continue supporting education about marine and freshwater ecosystems
Provincial Agencies	• Continue development of strategic land use plans, and land and resource management plans • Continue watershed restoration programs	• Start or continue use of provincial lands and buildings to showcase sustainability strategies such as green roofs • Sponsor research at universities to define characteristics of well-functioning greenways	• Start process to develop and adopt provincial groundwater legislation • Draft and pass a provincial Environmental Bill of Rights	• Continue tax exemption status for privately owned environmentally significant lands protected by conservation covenants • Stop property transfer tax for donations of ecological lands	• Incorporate discussion of sustainability and ecosystems into school curriculums • Develop provincial recognition programs for organizations showing leadership in habitat and stewardship work
Regional Agencies	• Develop a regional stream stewardship centre • Coordinate stream stewardship activities in conjunction with expanding and maintaining the Green Zone • Develop a habitat and watershed atlas for the region	• Prepare model bylaws, such as stormwater bylaws for customization by municipalities • Improve understanding of aquifer protection and restoration, particularly in the eastern part of the region	• Strengthen commercial and industrial waste bylaws for discharges to the sanitary sewer system and direct discharges to streams	• Start increasing rates for sewage treatment services • Create an endowment fund for daylighting streams of regional significance • Leverage resources for habitat acqusition with NGOs	• Prepare & disseminate educational materials on the value of streams & habitat • Make habitat atlas available in print and on-line formats for schools, developers, community groups, and NGOs
Municipal Agencies	• Include environmental goals and objectives in Official Community Plans and specify development permit areas • Develop strategies for daylighting streams • Develop watershed management plans	• Conduct pilot projects for daylighting streams through municipally-owned lands • Naturalize parts of municipal parks • Naturalize boulevards	• Use the full range of legislative tools to protect riparian and sensitive habitat areas • Adopt tree protection bylaws • Accelerate seperation of combined sewers to eliminate combined stormwater overflows	• Use provincial enabling legislation to exempt landowners holding conservation covenants from property taxes for those portions of their land • Use density bonusing to facilitate habitat protection	• Continue or start sponsoring and supporting stream stewardship groups and education activities
Private Sector	• Work with all levels of government on planning initiatives	• Start voluntary conservation practices by landowners • Enter into voluntary stewardship agreements with NGOs • Sponsor greenspace acquisition and restoration of streams		**ANYBODY** (Implementation Measures for *Anyone* to Implement)	**EVERYBODY** (Implementation Measures for *Everybody* to Implement)
NGOs	• Work with all levels of government on planning initiatives • Provide volunteers for helping with implementation • Form habitat and stream stewardship groups	• Start land trusts to acquire habitat lands and hold conservation covenants • Work with all levels of government and the private sector on research and demonstration projects	• Continue to hold outreach activities and prepare publications to raise awareness and foster education on habitat and stream stewardship • Form habitat and stream stewardship groups		

Figure 2.6. A Policy Matrix indicates how each participant within a Collaborative can use various policy instruments to support a specific catalyst strategy.

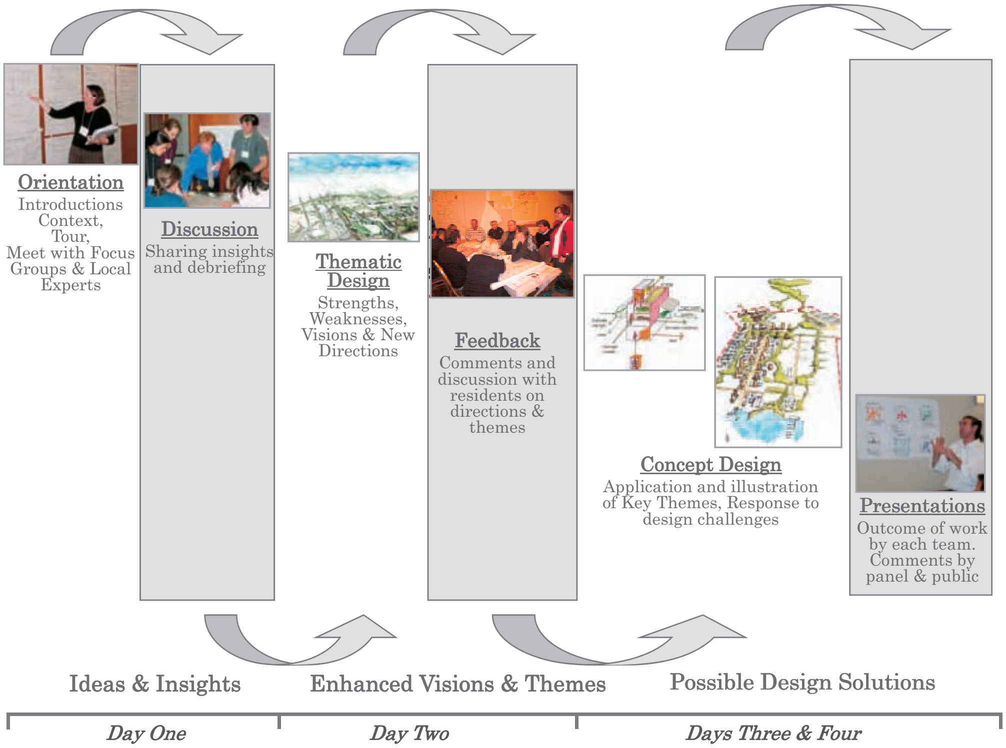


Figure 2.7. A Regional Design Charrette is an intense exercise that progresses over several days through Orientation, Thematic Design, and Concept Design, with lots of opportunities for discussion, feedback, and presentations. (adapted from Lennertz)[4]

drawings to complete plans, layered maps, sketches, meta-diagrams, and schematics. The pace of the workshop accelerates until it ends with a surprising amount of work accomplished. In the words of Professor Condon, a Canadian expert who has lead many such workshops, a charrette is "...the best way to get the most creative proposals to address the most difficult problems from the most accomplished designers in the most compressed period."

A charrette is a collaborative approach to design that can offer much more creativity and interdisciplinary thinking than is normal for city planning. At the beginning of the charrette, the teams review and discuss the city's long-term planning framework. During the workshop, the teams engage frequently with invited members of the public and specialists, by means of many small presentations and intense discussions and drawing sessions. This broad and meaningful engagement contributes to a positive outcome, with less fear and resistance from stakeholders, and a greater potential for reaching consensus on contentious issues like how to apply best practices in the local context.

A regional design charrette concludes with a plenary presentation to stakeholders, VIPs and public, and the preparation of a well-illustrated publication with recommendations on a regional growth strategy. The Eco^2 Program can provide cities with manuals and case studies on charrettes.[5]

CHAPTER 2

Methods for Analyzing Flows and Forms

Meta Diagrams and Materials Flow Analysis

The Meta Diagram is one of the most powerful tools available for systems thinking about infrastructure design and performance. It has two dimensions: (1) it is a visualization tool that illustrates complex information in simple and standard ways; and (2) it is a calculation method that tracks the flows of energy, water, and materials through cities. This section will explore both dimensions of the Meta Diagrams, and how they help to develop a systems perspective and can contribute, in many ways, to the process of integrated infrastructure design.

The visualization tool is a type of Sankey diagram, and like all Sankey diagrams, its function is to illustrate flow directions and quantities. Figure 2.8 provides an explanation of how a Sankey is constructed and interpreted. By illustrating both quantity and direction of flows, the Sankey displays more information on a single page than any other graphic. As is commonly said, one Sankey is worth a thousand pie charts.

The calculation method is referred to as Materials Flow Analysis (MFA). MFA tracks flows as a balanced set of input-output accounts. The inputs are either resources derived directly from nature (rainwater, for example, or local sunshine and biomass) or resources imported from other regions. Inputs are then tracked as they flow through the city's infrastructure and buildings. Typically, the input flows are first processed—for example, rain might be filtered, sunshine converted to electricity, or biomass burned to create heat. After processing, the flows are used to satisfy demand for services—things like drinking, lighting, and cooking. After servicing demand, the flows may again be processed—sewage might be treated, for example, or biogas captured and recycled. Finally, the flows are returned to nature as waste and emissions to the air, water, and land, or they might be stored or exported to other regions. Whatever the resource or pathway, inputs always equal outputs.

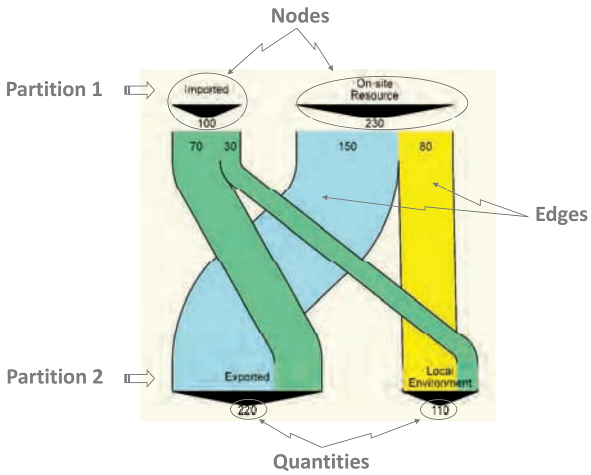


Figure 2.8. A Sankey Diagram is comprised of partitions, nodes, edges, and arrows. A partition represents the transitions or stages within the flow where transformations may occur. The nodes are the divisions within a partition; they represent processes or events that regulate or transform the quality of flows. Edges are the paths (or noodles) that emerge from nodes and that direct flows to nodes on the next partition. The width of the edges is proportional to the flow quantity. Arrows indicate flow direction.

When analyzed by the MFA method, a city's infrastructure is similar to the metabolism of a living organism that consumes natural resources to stay alive. When Sankey diagrams are used to illustrate these nature-to-nature flows, they are referred to as Meta Diagrams. Flows of resources can be illustrated for individual developed sites, or for whole cities. Flows are typically averaged over one year, although both the time period and spatial scale can be selected to answer whatever questions are of interest the most.

Figure 2.9 provides an example of a Meta Diagram for water flows through a parcel (house site) in New Delhi. The Sankey has five pre-established partitions: SOURCES, CONVERTERS, DEMANDS, RECONVERTERS, and SINKS. CONVERTERS and RECONVERTERS are general terms for the on-site urban infrastructure or appliances that store, convert, regulate, separate, process, or recycle any flow. A CONVERTER is on-site and upstream of all service demands, while a RECONVERTER is on-site and downstream of at least one service demand. In the example shown, the majority of water flowing through this parcel arrives as rain, about 60 percent of which passes directly through the site, and is absorbed into the ground. The remaining rainwater is captured by the roof and stored in a cistern, from where it is mixed with a neighborhood ground water system, and used to supply many household needs. The greatest single use of fresh water is the cooling system. The diagram quickly reveals some advanced looping systems, with water from kitchen and baths reclaimed and used for toilet flushing, and with water from the septic tank re-used for pipe irrigation.

Meta Diagrams constructed at the parcel scale, such as the one shown, can be summed to create a Sankey for a collection of parcels, the neighborhood, or city. An example of a citywide Meta Diagram (Figure 2.10) shows baseline water flows for the City of Irvine, a community of 180,000 people south of Los Angeles, California. The climate for Irvine is very dry (13 inches per year), and the city has developed one of America's most complex and advanced water systems. The diagram provides all the key information on a single page.

> "The built environment as a self organising system functions as a 'dissipative structure' requiring a continuous supply of available energy, material, and information necessary to produce and maintain its adaptive capacity and rejecting a continuous stream of degraded energy and waste back into the ecosystem (entropy)"
>
> **William Rees, 2002**

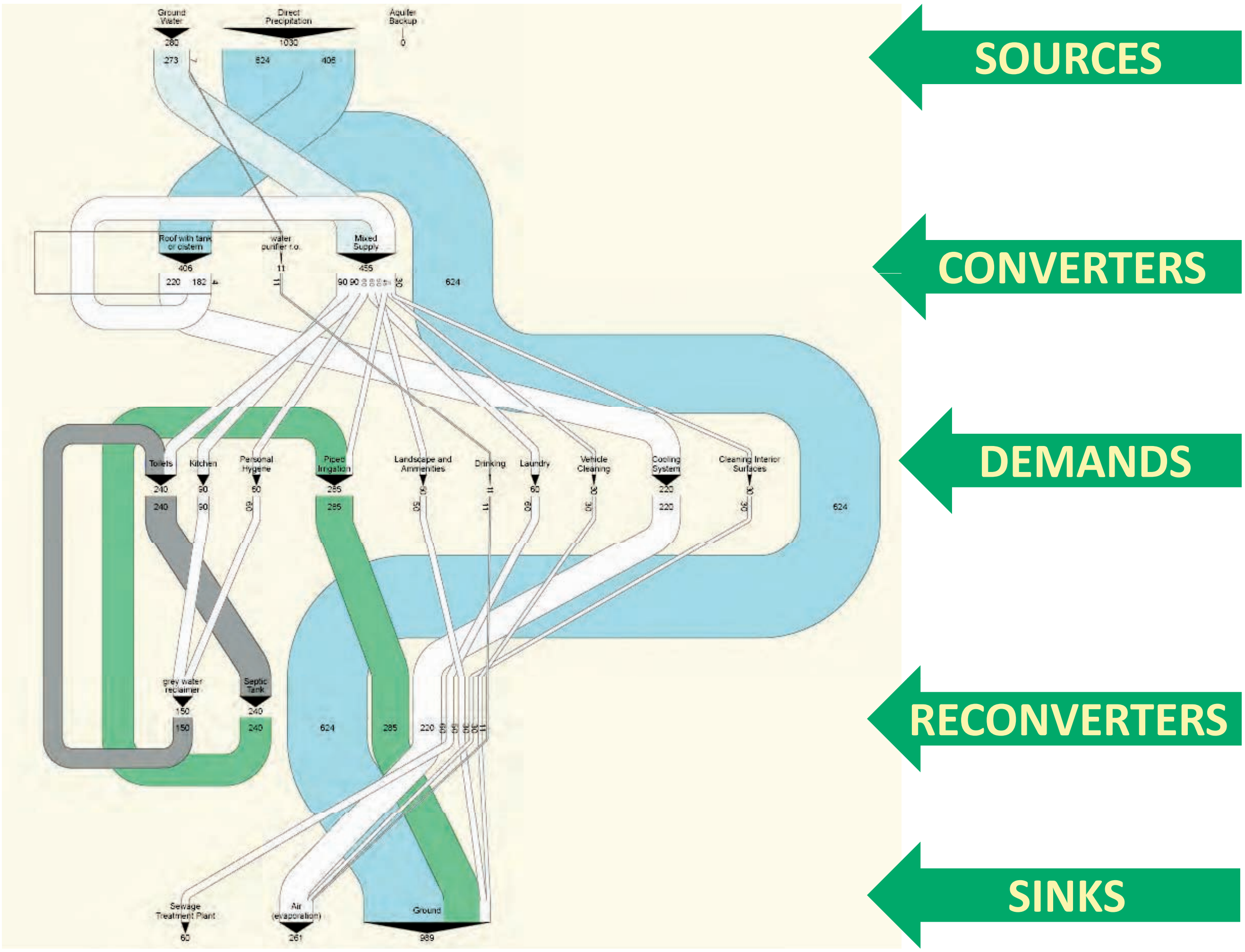


Figure 2.9. A Meta Diagram Example that uses the five standard partitions to visualize water flow (liters per day) for a new advanced detached home in New Delhi, India

Five Reasons for Using Meta Diagrams in System Analysis and Design

1. Understanding the whole picture

A Meta Diagram can be designed to quickly convey many aspects of a system to people of diverse backgrounds. Few people actually know the whole picture. In fact, in most cases there is nobody in the entire city who can actually describe the energy system, including the diversity and relative weights of primary energy inputs, the relative importance of different energy demands, the amount of fossil fuels embodied in local electricity, and percentage of energy that is cascaded to secondary uses. But after two minutes with a Meta Diagram, people will likely know the basics.

Typically, a Meta Diagram is constructed to reflect the substances, processes, and time periods relevant to specific decisions. Sometimes, a combination of Meta Diagrams is most effective. If energy flows are averaged over a year, for example, they provide a good benchmark for tracking overall efficiency and understanding ecological footprints. However, annual energy flows fail to reveal the sea-

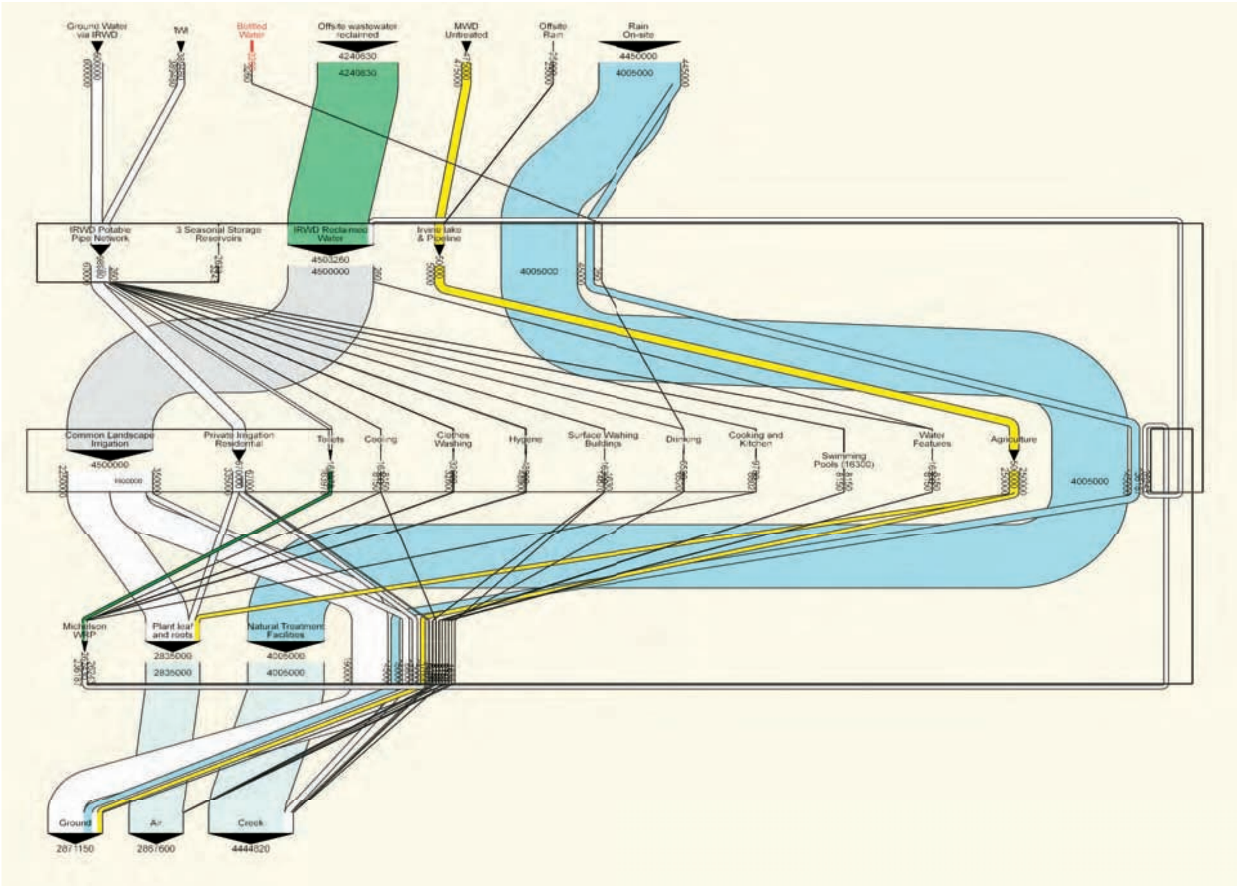


Figure 2.10. Baseline Water Flows for City of Irvine, California. This Diagram illustrates effective use of reclaimed water for irrigation of commercial and public land (ft.3/day avg.). Irvine has the most advanced city water system in the United States. Note the diversity of water sources, including water harvesting off-site and stored in an artificial lake, and large amounts of piped water from the Metropolitan Water District imported from northern California. Fresh water is stored in ground aquifers, and then harvested by the Irvine Ranch Water District, combined with expensive imported water, and used for hygiene, cooking, surface washing, and so on. Most of the water flowing through the city's land is rainfall, which is treated in constructed wetlands and released into a creek. A second large flow of water is from wastewater reclamation, and is used to irrigate landscapes during the driest periods on public and commercial properties. Interestingly, the largest use of fresh water (imported and ground) is irrigation of lawns around private homes. This diagram illustrates the importance of finding a way to legally and safely use reclaimed water for irrigating residential properties: a strategy the water district is now exploring.

sonal and daily peaks that impact costs, which are often key determinants in system design. Thus, a Meta Diagram based upon peak hour energy flows for the peak month (or daily flows for water during the driest month), might be useful for understanding the big picture, especially when evaluating system design alternatives.

2. Creating a common language for interdisciplinary groups

Meta Diagrams help everyone to understand infrastructure as a whole system, and then focus on those parts of the system where resource use is high, and where opportunities may exist for significant efficiency, re-use, or substitution. The diagrams provide a common language for exploring the key opportunities for integrated, holistic solutions.

By compiling and comparing a diversity of Meta Diagrams, it becomes possible to identify a simple pattern language for physical flows, at any scale (Figure 2.12). The first pattern, *Traditional,* is typical of the oldest and also the poorest houses in India and China. Total resource use is relatively small, but the mix of primary resources is very complex. For example, among energy flows each fuel is carefully matched to the requirements of the end use for optimum efficiency and lowest cost, with coconut husks used for heating water, LPG used for cooking stoves, firewood used open cooking, solar used for clothes drying, kerosene used for lighting, electricity used for refrigeration, and petrol used for motor scooters. The *Traditional* home may be poor and old, but the energy systems are relatively sophisticated.

The second pattern, *Modern,* is based upon the recent, tract-built houses in urban suburbs surrounding Shanghai, but is typical of suburban homes worldwide. Total resource use is almost an order of magnitude higher than traditional homes, even though family size has typically dropped 60 percent or more. The primary mix of energies is simple, since almost all energy demands are gas or coal-generated grid electricity, with the exception of cooking and transportation.

The third pattern, *Ecological,* is typical of more sustainable, integrated systems that incorporate Demand Side Management (DSM), and reuse. The Resource load is mid-way between the *Traditional* and *Modern*. It combines the complexity of the *Traditional* with the convenience of the *Modern*. Some energy re-cycling (cascading) increases the service value of the flows, which increases the total flow at the demand partition relative to the other source and sink. The primary mix is even more complex than *Traditional,* due to the use of hybrid systems with intelligent controls, and the greater diversity offered by networked local energy services. However, the greatest difference may be the increased flexibility and adaptability of the *Ecological* home.

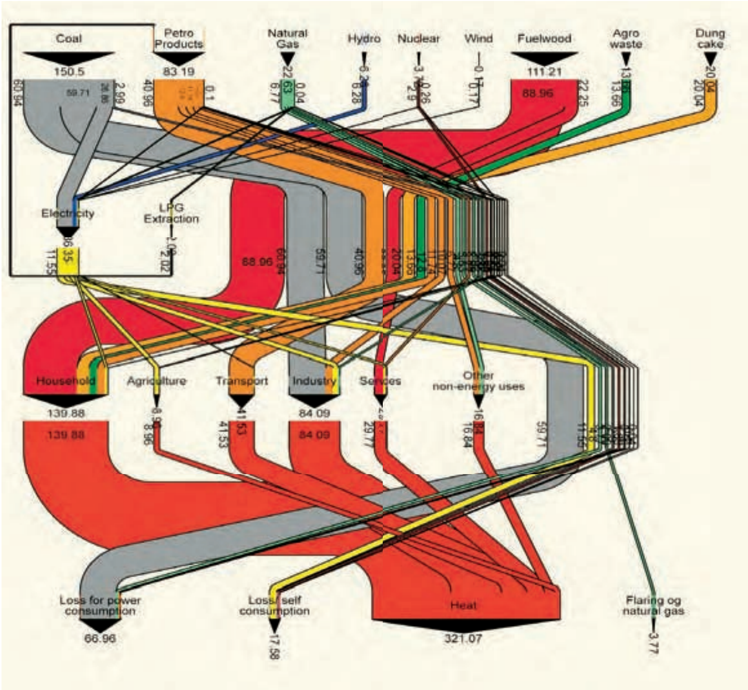


Figure 2.11. Example of a Countrywide Meta Diagram. This Meta Diagram portrays energy flows for the country of India. Note the predominance of coal, used primarily for manufacturing, and oil, used for transportation. In addition, note how much coal is wasted as heat, and the second ranking of informal biomass as fuel. Electricity use is relatively low, and per capita consumption is low, but emissions are high.

Source: Data from TERI Energy Data Directory & Yearbook 1997, Analysis by S.J. Prakash & Associates, Delhi. Non-commercial biomass data taken from Down To Earth magazine, December 15, 2002, Society for Environmental Communications, 41, Tughlakabad Institutional Area, New Delhi, India 110062.

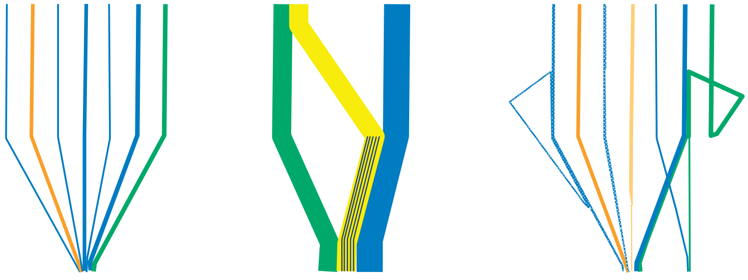


Figure 2.12. Patterns of Meta Diagrams: Physical Flows. A Meta Diagram's 'pattern language' shows the possible evolution in technology for mass and energy flows at the parcel and regional scales.

3. **Developing and communicating alternative development scenarios**

Scenarios for future development can be presented as Meta Diagrams and compared with the base case or other scenarios. Figures 2.13 and 2.14 portray scenarios for energy use in a town in Shanghai Province, and convey a radical change in the electricity mix. Figure 2.15 is a schematic that elaborates on the scenario for Jinze Town, showing the system components for a typical downtown neighborhood on a canal. The schematic provides information on the spatial configuration of the technologies referenced in the Meta Diagram.

Generating scenarios with Meta Diagrams can be rather simple once base cases are completed. A new energy source or converter can be added and connected to parcels. Or, the population of each category of parcel can be adjusted to reflect plans for upgrading buildings. For example, we might replace 1,000 older dwelling units with 1,000 retrofitted dwelling units, and then instantly see the impacts on water, energy, and material flows, and on total economic costs and carbon emissions. Because every parcel uses the same database structure, Meta Diagrams can be added together. For example, it is easy to combine parcels to create a systems perspective of

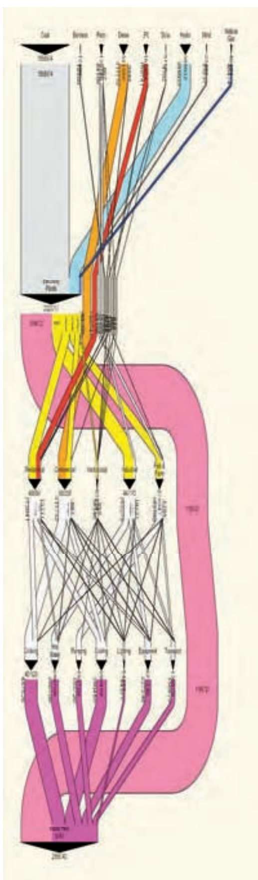


Figure 2.13. Meta Diagram for Jinze Town, Shanghai, Current Energy System

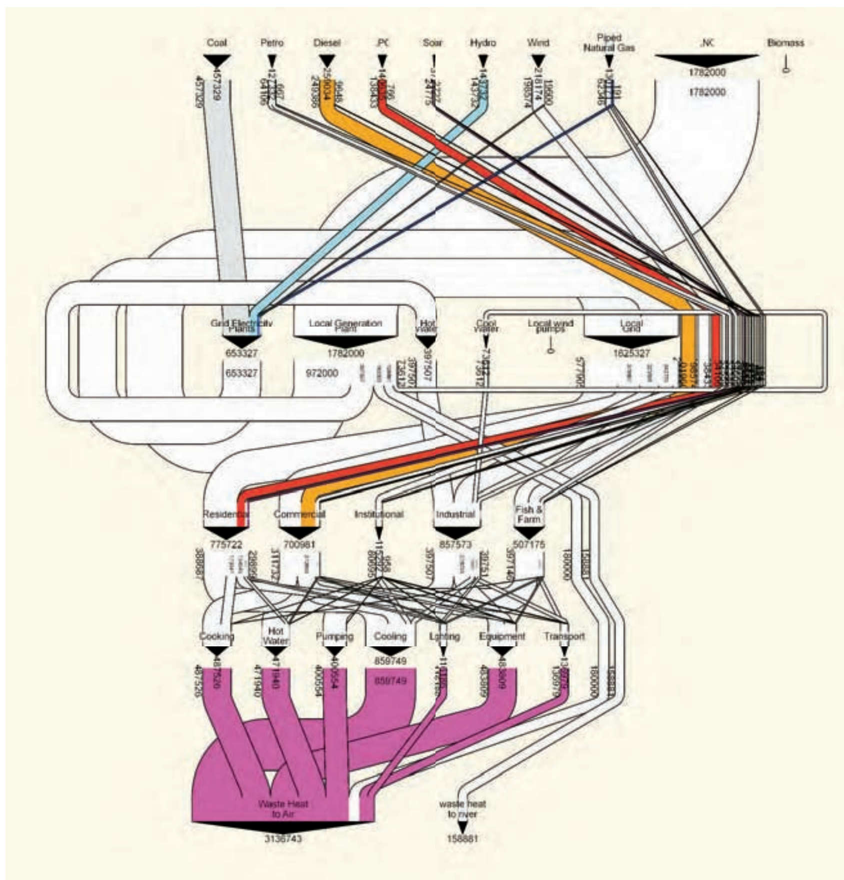


Figure 2.14. Meta Diagram for Jinze Town, Shanghai, Advanced System. This Meta Diagram provides a scenario for an advanced system that helps to reduce emissions and costs and increase local jobs and energy security. The advanced system represents a substantial change: for example, a local electricity generation facility is powered by LNG, and provides a majority of electricity needs as well as hot and cool water for industry (cascading).

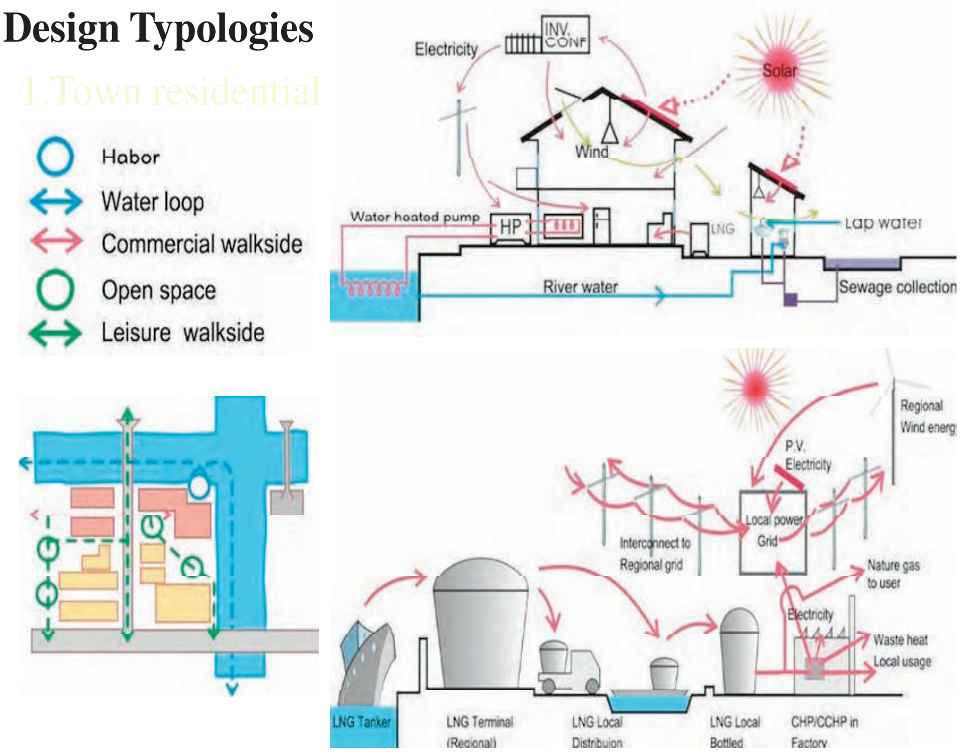


Figure 2.15. Schematic for Downtown Neighborhood. This schematic elaborates on one of the design typologies that underlies the advanced energy systems for Jinze Town (shown earlier). Note that the combination of a centralized LNG electricity grid with distributed infrastructure, including Solar PV with grid, Solar DHW, a river heat pump, and wind driven ventilation.

Source: Bridge of Jinze, Bridging to the Web, 2006, Jingsheng Lee (ed.) faculties of Architecture and Engineering, Tongji University, Shanghai, as part of Bridging to the Future project

resource use for a specific neighborhood, development project, or category of housing. A parcel can be any discrete surface area: for example, a park, a house on a private lot, a shopping mall, a sewage treatment plant, or a roadway. All parcels are connected. Each parcel will demand resources from other parcels, and if infrastructure is distributed, the infrastructure can serve other parcels with resources.

4. Setting priorities for research and design

Understanding where waste is occurring, and the relative importance of different resources and demands, is essential for establishing research and design priorities. Each node presents opportunities for substitution, efficiency, looping, and cascading. Figure 2.16 portrays an energy analysis for a proposed town of 50,000 people in Southern India. In this case, the combination of Meta Diagrams helps to emphasize the importance of addressing transportation demand in future plans. Often, a combination of Meta Diagrams helps to zero-in on particular issues. A Meta Diagram for the driest month helps to assess the potential for self-reliance. A Meta Diagram that shows only residential demands in precise detail is helpful when preparing policy for a residential neighborhood.

5. Calculating performance indicators in transparent and comparable ways

The Meta Diagram can be used not only for system analysis but also to generate specific indicators of performance. In fact, every flow portrayed on a Meta Diagram is a potential indicator that can be monitored over time, or compared with other locations or other scenarios. The

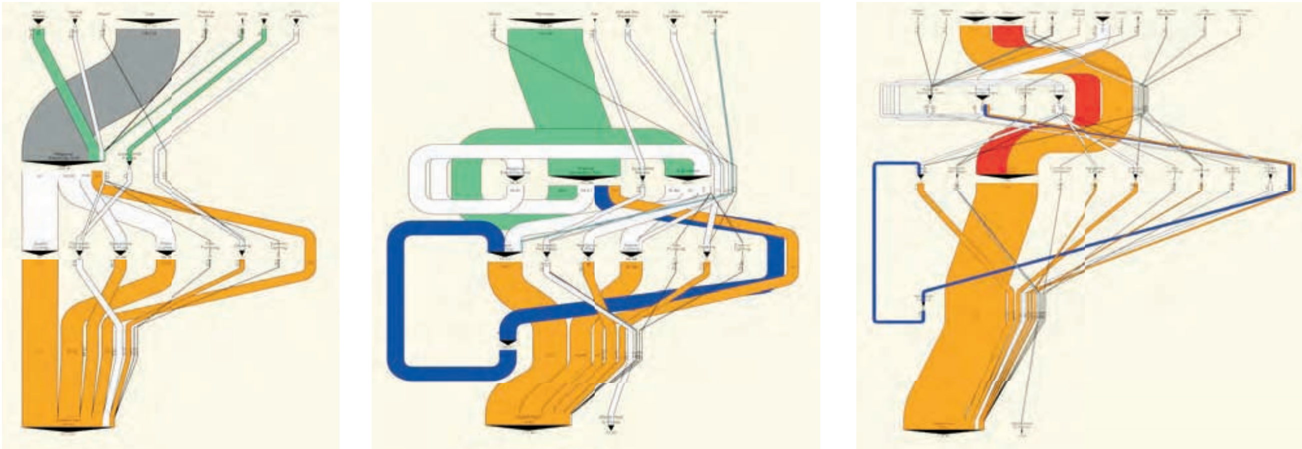


Figure 2.16. Meta Diagrams on Energy for Proposed New Town. This series of energy Meta Diagrams was used to guide development plans for a proposed new town near Poona, India. The first Meta Diagram is a business as usual scenario, and shows how current development practice in Southern India creates high use of coal-generated electricity. The second Meta Diagram portrays an advanced system with biomass brought by train and used in a local district energy plant, with cascading of energy. The third Meta Diagram includes the transportation energy that was ignored by the designers and is missing from the prior Meta Diagrams. Note that because residents are expected to commute, transportation-related energy exceeds all other energy combined. The third Meta Diagram suggests that a priority for urban design in affluent new towns must be to reduce the need for commuting, and to provide incentives for quality transit.

balanced 'nature-to-nature' flows on a Meta Diagram can be converted to money or emissions where relevant, and thus provide an average lifecycle inventory of all costs. An MFA provides a consistent method for tracking all consumption, emissions, and expenses at each stage in the lifecycle, and is thus the preferred method for assessing both internal and external costs. The Meta Diagram helps to clarify exactly what is included, and excluded, in calculations. For example, the total water consumption for any particular use can clearly be subdivided into off-site potable water, on-site water (the roof catchment), and re-claimed water. Without this type of separation, it is impossible to understand a water consumption indicator. By standardizing the Meta Diagram format, it becomes possible to directly compare results from different locations or time periods, creating comparable benchmarks for assessing how well a system is performing, and the trend lines. Comparable benchmarks also help with the important process of establishing long-term targets for resource use. For example, the resort municipality of Whistler, one of Canada's leading examples of sustainable planning, was unable to agree on long-term performance targets for a set of indicators until they were able to benchmark their current performance with the other leading resorts in North America.

How to Create Meta Diagrams even where Data is Lacking

Creating Meta diagrams is easy once the data is properly stored in a database or spreadsheet. In fact, simple software applications will draw the diagrams automatically.The difficult part is collecting the baseline data to portray existing conditions, or to construct a business-as-usual scenario. Two kinds of baseline information can be used (Figure 2.18):

1. **Top Down Data:** establish how much of any given resource (energy, water, material) was actually sold or delivered or imported during the most recent period. If dealing with a green field development, then top down data can be used from a neighboring

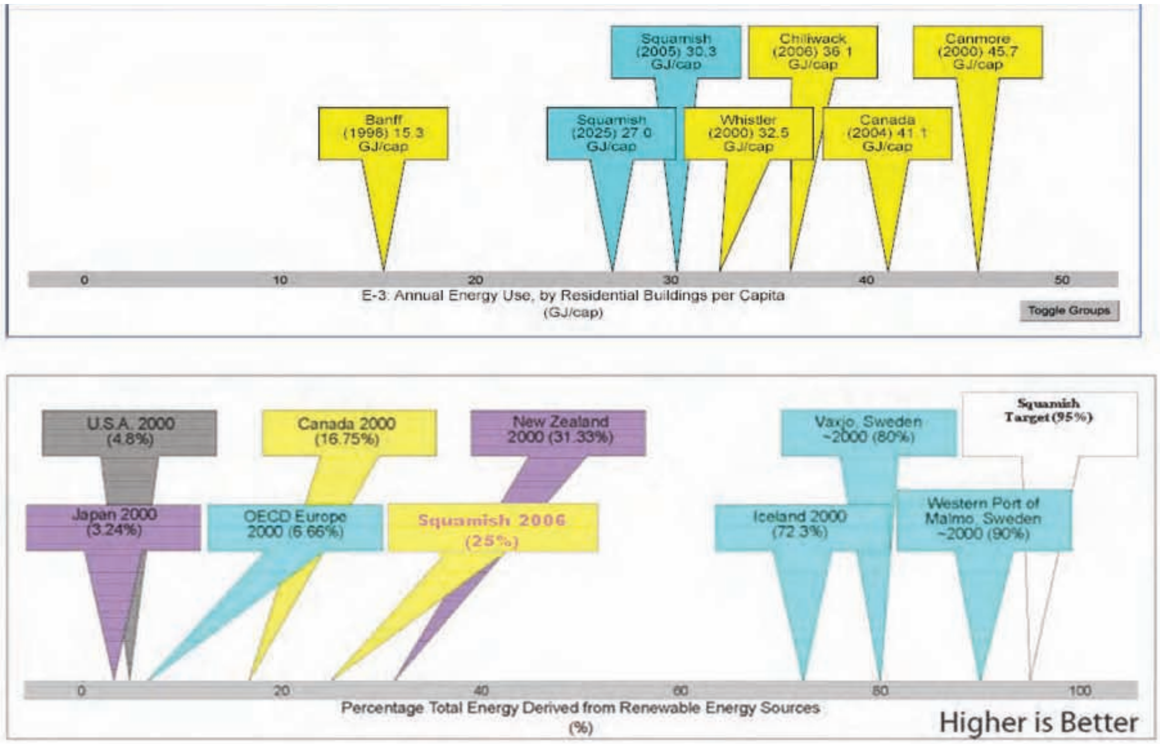


Figure 2.17. Annual Energy Use is an Indicator for Squamish, Canada. On both of these benchmarking scales, it is possible to compare how Squamish performs today with other locations. On top, annual energy use by residential buildings is compared to other mountain resort communities. On bottom, the percentage of total energy derived from renewable energy sources is compared with percentages in countries around the world. Note that Squamish has set a target for renewables of 95% by 2025.

site as a proxy for business as usual. Once the inputs are known, the rest of the database can be constructed using population data and default values for demand by end use category. For example, we might imagine a situation where the population is 10,000, and the average person uses 200 liters/day of municipal water divided into toilets (40 percent), showers (5 percent), surface washing (8 percent), and so on.

2. **Bottom-Up Data:** aggregate the flows of any given resource by beginning with detailed flows generated at the scale of different types of 'parcels'—discrete pieces of land with their attendant buildings end users. This approach provides much greater precision and is preferred when dealing with existing stocks of buildings. Parcels are grouped into different categories based upon their land use and demand profile; for example 'prewar low rise multi-unit residential' or 'recent strip mall commercial.' Aggregating parcel information requires that experts first visit and audit several typical parcels within each category, and use these parcels to create a solid reference database. Reference parcels are then used to create proxy values for all of the parcels within each category. The total (aggregate) flow for the Meta Diagram is calculated simply by multiplying the proxy flows by the population of parcels within each category. Using such short cuts, it is possible to quickly determine an accurate baseline flow (+/-10 percent). Figure 2.19 Shows an example from Squamish, in Canada, where a diverse collection of reference parcels was audited and

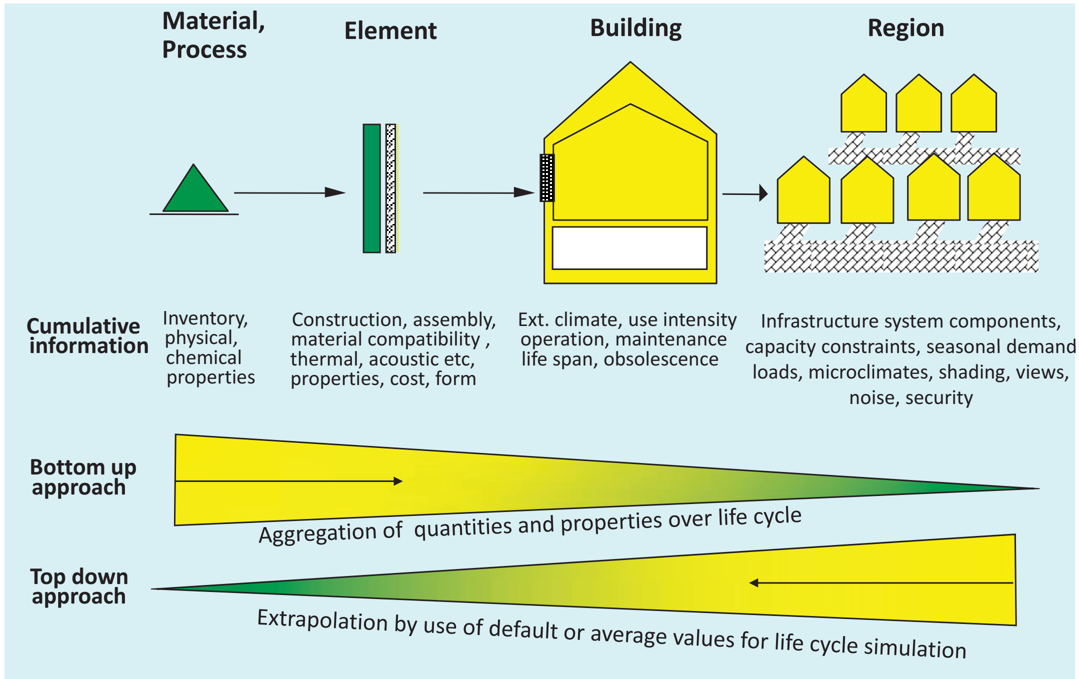


Figure 2.18. Approaches to Developing Meta Diagrams

used to create an Energy Meta Diagram for the whole region.

Tools for aggregation

When developing a reference data base on existing stock, all data collection occurs at the scale of an individual parcel. Flows are recorded in a pre-defined matrix that corresponds with the Sankey diagram structure. In other words, the flows for each node on the parcel are connected with nodes upstream or downstream to account for their source and destination. By cross-referencing flows in and out of each partition and node, the matrix functions as the numerical equivalent to the Meta diagram. A matrix can be automatically generated either from empirical (field) data collected on each archetypal parcel, or from hypothetical data deduced from a theoretical parcel design.

Field date and hypothetical data for reference parcels needs to be converted into flows of resources. The conversion is accomplished using standard models for predicting thermal loads, water demand, and so on. For example, a data collection form can keep track of primary data such as type of appliance and number of occupants, and then this data can be used to calculate the probable flows of water, energy, materials, and people for each purpose. Data collection forms need to accommodate a wide variety of lifestyles and building types. Figure 2.20 shows an excerpt from a data collection form developed for water flows. Similar forms can be used for energy and organic materials. The forms are fairly simple, but they do require that connectivity is recorded. For example, the forms shown record exactly where the roof drainage water is output—to the ground, cistern, street, garden, sewer, storm drain, or some combination of such destinations.

The data collected on each parcel can automatically generate the inputs for a universal flow matrix as shown in Figure 2.21. The matrix can then be used to directly produce files for generating Meta Diagrams using various diagramming tools.

Figure 2.19. Auditing Reference Buildings to Create a Meta Diagram. A carefully selected set of reference buildings from the City of Squamish, Canada were visited, audited, and used as proxies for the different categories of building stock. Using these reference buildings, a complete Energy Meta Diagram has been generated for the region. The result reveals a very simple energy mix, with almost no cascading or on-site generation. This is typical of a region like Squamish, where energy prices are low. The high proportion of energy used for personal transport is typical of a dormitory community; in Squamish, tow-thirds of the working population is employed elsewhere.

A parcel can be any discrete surface area: for example, a park, a house on a private lot, a shopping mall, a sewage treatment plant, or a roadway. The single format for data structure allows for each parcel to demand flows, and to serve other parcels as a supply (or service) node. Thus, the data structure allows for 'transformer parcels' that evolve over the long-term to become part of integrated and distributed infrastructure systems. For example, a single-family home may begin as a water or energy demand node in the regional system, but if the roof is retrofitted to catch rain water or solar energy, the database easily accommodates the changes. The use of this standardised data structure also helps to visualise the process of stock aggregation. Designers can move from a Sankey at the parcel or building scale, to a Sankey at other scales, simply by stacking the database for each parcel within the larger area, and adding the cells. The systems perspective is always maintained.

Effective Overlay Mapping

A Picture is worth a thousand words

The best way to communicate complex information to planners and designers is through pictures—maps, photos, schematics, or a combination of these. The history of using maps to quickly convey complex relationships begins with Ian McHarg's *Design with Nature*.[6] Although McHarg's simple overlays of transparencies are still good tools, the options have evolved considerably with geographic information systems (GIS) on computers and the web. GIS is now a mature, affordable, and widely-used technology for mapping and spatial analysis that will soon be part of standard practice in all cities in all countries. All large metropolitan areas now have GIS departments, and routinely use GIS to assist with design and management.

In the context of building capacity for Eco² projects, cities require GIS and related visualization technologies to support the interdisciplinary planning process. Initially, the GIS ap-

WATER DEMAND	Units	Values	List of Options					
Laundry								
Clothes washing system		None	None	Full size stnd top loading	Full size, side load or short cycle	Compact (<45 liters) top loading	(<45 liters) side load	Advanced water efficient
Number of full loads created	per person week	0	0	0.5	1	1.5	2	2.5
Washing appliance	liters per load	0						
Personal Hygiene								
Shower use	per person week	0	0	1	2	3	4	5
Bath use	per person week	0	0	1	2	3	4	5
Shower system and length		None	None	Standard long (8 minutes)	Standard Short (5 minutes)	Low Flow Long	Low Flow Short	Bucket
Bath		None	None	Full	Normal	Bucket		
Hand & face, shaving, brushing		None	None	Tap on constantly & long	Tap on constantly short	Tap on constantly	Tap off except when essential	
Showering system	liters per shower	0						
Bath	liters per bath	0						
Hand & face, shaving, brushing	liters per person	0						
Kitchen								
Cooking Frequency	meals per person day	0	0	1	2	3	4	5
Dishwashing System		None	None	Basin or Sink	Stnd Machine	Water Eff. Machine		
Number of full loads created	per person week	0	0	0.5	1	1.5	2	2.5
Dishwashing system	liters per load	0						
Toilets								
Primary toilet water system		Standard f	None	Standard flush	Low flush	Low volume dual flush	Extra low w' dual	Compost Toilet
Primary toilet use	flushes per person day	4	0	1	2	3	4	5
Secondary toilet water system		None	None	Standard flush	Low flush	Low volume dual flush	Extra low w' dual	Compost Toilet
Secondary toilet use	flushes per person day	0	0	1	2	3	4	5
Primary toilet category	liters per flush	22						
Secondary toilet category	litres per flush	0						
Drinking								
Irrigation								
Cummulative operating time for all irrigation pipes & outdoor watering taps (excluding reuse of	hours per month	0	0	0.5	1	1.5	2	2.5
Potted Plants and Pools								
Typical quantity of water per	liters per month	0	0	2	4	6	8	10
Interior Surface Cleaning								
Frequency of interior surface	times per week	7	0	1	2	3	4	5
Quantity of water used (excluding reuse of wash water)	liters per event	4	0	1	2	3	4	5
Exterior Surface Cleaning								
Days per month exterior	number of days	0	0	1	2	3	4	5
Duration of watering	minutes per cleaning	0	0	5	10	15	20	30
Vehicle Cleaning								
Number of 4 wheel vehicles cleaned on-site	number of vehicles	0	0	1	2	3	4	5
Number of 2 wheel vehicles cleaned on-site	number of vehicles	0	0	1	2	3	4	5
Frequency of cleaning	per vehicle each week	0	0	1	2	3	4	5
Evaporative Cooling								
Typical frequency of use during	hours per month	0	0	50	100	150	200	250
Category of cooling system		None	None	Small (residential), no bleed	Multi-unit, no bleed	Large	Small with bleed	Multi-unit with bleed
Consumption of water by cooler	liters per hour	0						
Humidification								
Typical monthly water consumption	liters of water per month	0	0	5	10	15	20	25
Client Demand								

Figure 2.20. Sample Forms for Standardised Data Collection on Water Flows. Computerised forms used to collect standardised data on water demand and water flow connections at the scale of a land parcel.

		FLOWS INTO:															
	Exported from region in pipes	Source											Upstream Converter	Demand at Parcel	Downstream Converter	Sink	
FLOWS OUT OF:		Direct	Roof r	Pond	Reserv	River	Lake	Ground	Aquifer	Ocean	Transp	Imported	Purification system	Laundry	Gray water recycling system	Septic tank	
	Direct precipitation												0	0			0
	Roof run-off into storage tank												0	0			0
	Pond												0	0			0
	Reservoir												0	0			853
Source	River												0	0			0
	Lake												0	0			0
	Ground water												0	0			0
	Aquifer												0	0			0
	Ocean												0	0			0
	Transported as bottles imported into region												0	0			0
	Imported as raw water via pipes into region												0	0			0
	Purification system												0	0			0
	Well and pump												0	0			0
	Mixing system												0	0			0
	Water factory for region												0	0			0
Upstream	Water factory for neighbourhood												0	73			853
Converter	Water storage tank												0	0			0
	Regional water pumping station												0	0			0
	Desalination plant												0	0			0
	Clients for water												0	0			0
	Custom water input 1												0	0			0
	Laundry														0	0	73
	Personal hygiene														0	0	370
	Kitchen														0	0	50
	Toilets														0	0	352
Demand at	Drinking														0	0	0
Parcel	Irrigation														0	0	0
	Potted plants and pools														0	0	0
	Interior surface cleaning														0	0	4
	Exterior surface cleaning														0	0	0
	Vehicle cleaning														0	0	3
	Evaporative cooling														0	0	0
	Humidification														0	0	0
	Client demand														0	0	0
	Gray water recycling system															0	0
	Storage tank for pumping to truck or boat															0	0
	Sewage treatment plant regional															0	0
	Sewage treatment plant neighbourhood															0	853
Downstrea	Reclamation plant															0	0
Converter	Clients for water															0	0
	Custom water output 1															0	0
	Septic tank																0
	Detention pond																0
	Reed bed																0
	Infiltration trench																0
	Oil trap & drain																0
	Planter with infiltration system																0
	Constructed wetland																0
	Sluice & floodway																0
	Run-off onto surrounding hard surfaces																0
	Lake																0
Sink	River																0
	Run-off and infiltration into surrounding ground																0
	Aquifer recharge																0
	Ocean																0
	Evaporation into air																0
	Exported from region in pipes																0
	Exported from region in trucks																0
	Exported from region in pipes																0

Figure 2.21. Sample Universal Flow Matrix for Water. An example for water flows at the parcel scale organised into a universal matrix that identifies all flows by quantity and direction, from source to sink.

plications need not be demanding or time consuming: all that is required is (1) the capacity to produce simple 'overlay maps' that consolidate spatially-referenced information and help planners recognize relationships and patterns on the landscape; and (2) the capacity to calculate a few simple spatial indicators such as density, diversity, and proximity. Such capacity is absolutely essential to support charrettes, foresight workshops, and other integrated design exercises.

Unlike many GIS applications, the generation of overlay maps, and the calculation of spatial indicators, can provide exceptional value for a small investment in time and human resources. Moreover, new technology is now allowing for visualization in a wider variety of formats, which further contributes to decision-making. For example, simple contour maps (also referred to as Digital Elevation Models or DEMs) are combined with air photos (e.g., Google Earth) to produce 3-D imagery. Such techniques provide planners and others with the ability to fly through a digital landscape that has acquired the look and feel of a proposed development. With additional training, specific objects in the GIS database can be given attributes related to resource consumption, and GIS can evolve into a scenario development tool (e.g., Community Viz).

Getting real value from mapping

One of the challenges with overlay mapping is avoiding the very common problem of GIS for GIS. Traditionally, GIS work has been far removed from decision-making, and has been surrounded by a mystique that obscures the very simple nature of the tool and its role in planning. Without lots of advance notice and direction, GIS departments produce maps that

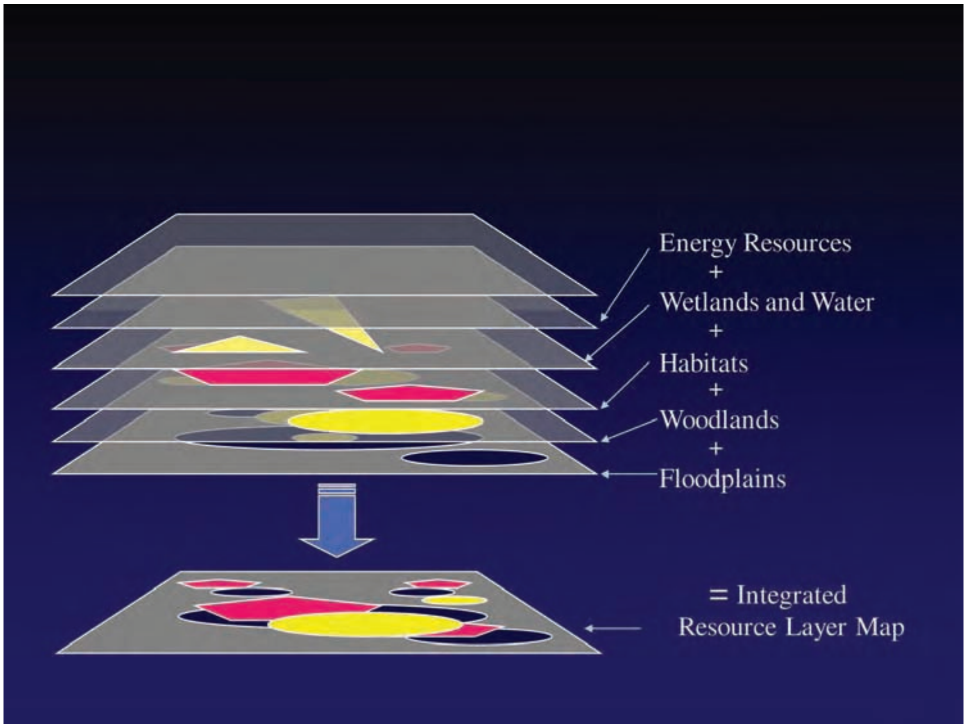


Figure 2.22. Layering Data. This example illustrates how a number of layers of information on the natural capital of a region have been visually integrated on a single map. This information can be useful for strategic land use decisions, as well as infrastructure system design options.

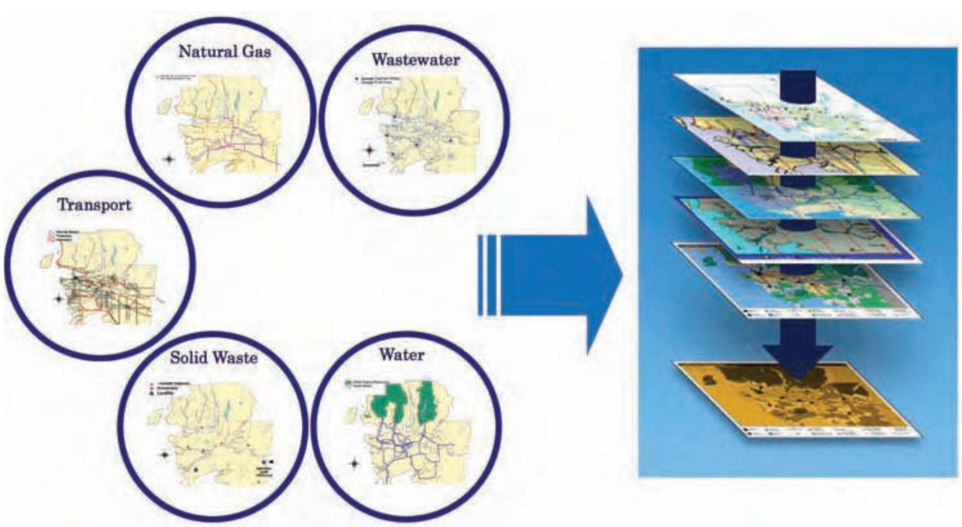


Figure 2.23. Overlay Mapping. In this example of overlay mapping, multiple infrastructure systems have been layered onto a single map, depicting the location of manufactured capital assets.This information, as well, can be useful for land use planning, and optimizing the use of existing infrastructure systems..

are complex and colourful, but provide little added value. To realise the great potential of overlay mapping, it can help to consider the following suggestions.

1. Provide clarity on the key questions that decision-makers are asking

For example, where are the ecological assets? And where are the threats to urban systems? Integrated design workshops depend upon the use of maps to inform interdisciplinary groups about many factors that influence performance of infrastructure systems. For example, maps can help to create an integrated understanding of where the potential exists inside and near a city for taking advantage of existing assets. A map might show the locations with potential for generating renewable energy from wind, micro-hydro, biomass, geothermal, tide, industrial process, and other sources. Overlay mapping also provides a useful way of evaluating existing infrastructure systems, comparing their capacity in specific locations to the projected demand from growth population, and economic activities. With such information consolidated on a single map, it becomes relatively easy for groups to integrate local energy assets as they plan new energy infrastructure systems. The same overlay process works for all sectors.

An example of hazard mapping at a larger scale is the work recently completed by Gujarat State Disaster Management Authority (GSDMA) in India on a Composite Risk Atlas to assist the various departments concerned in disaster mitigation planning for areas that are most vulnerable to natural and man-made hazards. The GIS consulting team compiled one of the largest and most detailed digital GIS databases prepared in India, and then generated an atlas that reveals the relative risks to life and capital from earthquakes, cyclones, storm surges, floods, chemical accidents, and droughts.

An example of overlay mapping for risk is shown in Figure 2.24. In this example, regional growth planning for energy and transportation for the City of Squamish is informed by the distribution and intensity of risks on the landscape, including risks of landslides, earthquakes, floods, and unstable soils. All risks have been consolidated as layers on a single, multi-hazard risk assessment map. This community is located in a flood-prone and geologically active area, and the map reveals very few locations to safely develop land for residential and commercial use. Moreover, the existing natural gas and electricity infrastructure systems, and the major transportation routes for rail and road, are already exposed to high risk since they are located in the fan of projected debris from landslides off the east slope of the mountains. Even the electrical substation has been wrongly located in this hazardous area, due to the lack of overlay mapping.

Another example of innovation in overlay mapping is the collection of maps in Figure 2.25, which displays a series of maps for the same Squamish region; each map focusing on a different renewable energy asset. By overlaying the energy asset maps it becomes easier to plan development that is based on local renewable energy resources. For example, the new residential development can be located in areas where sunshine permits year-long use of solar water heaters, and where the new buildings stay clear of the windy ridge north of town, where mean wind speeds are sufficient to support a wind farm.

It is not unusual for land-use and infrastructure plans to proceed without any reference to risk of natural disasters, or to other critical landscape relationships such as local resource assets, ecological functions (such as rainwater catchment, food production, wind protection), and unique or ecologically sensitive areas that contribute to local biodiversity and ecological health. Design teams and policy experts are able to adapt to this information only if it is available in a timely and easy-to-understand format.

A more common and especially useful application of overlay mapping is to map the

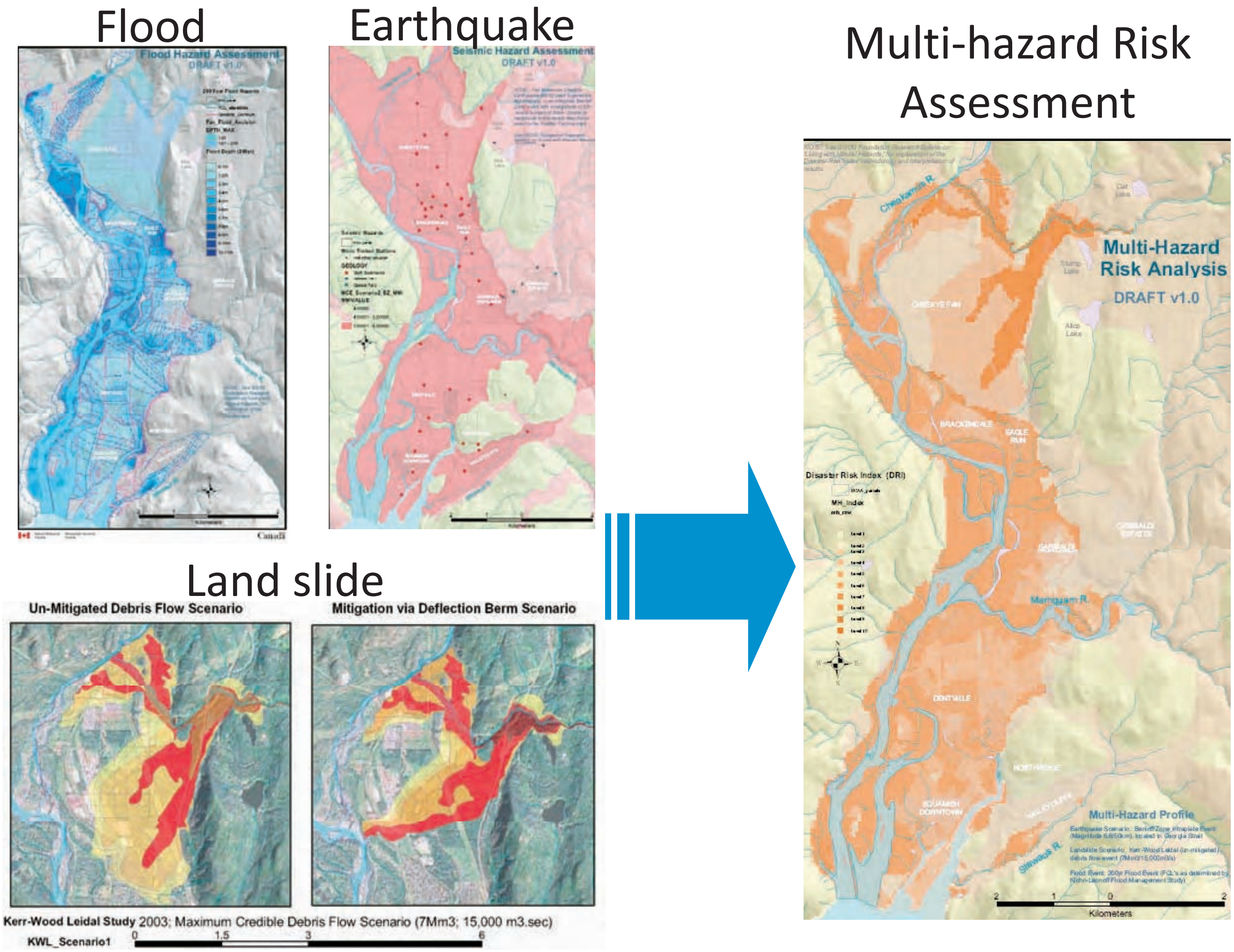


Figure 2.24. Example of an Overlay Map for Risk Assessment. Combinations of landscape risks can be overlaid to create a multi-hazard risk assessment map that quickly and easily communicates where landscapes are suitable for specific types of uses.

Source: Overlay maps completed by Pathways Group at Natural Resources Canada, and presented as a contribution to Bridging to the Future project, 2006, International Gas Union.

capacity of existing infrastructure, and compare this with projected demand for services. Many urban regions are now using this type of overlay mapping to assist with growth management. Areas with surplus capacity in infrastructure systems are the most appropriate locations for new development or infill—all other factors being equal. Areas with especially high demand may be appropriate for localised infrastructure systems; for example high energy demands make district energy systems cost effective, and by mapping such areas it becomes possible to implement the policies that make buildings suitable for hooking up to a local network. This kind of forward-looking policy helps to create a municipal ecology, where many different locations functions as both supply and demand nodes for flows of resources.

2. Focus on quality inputs

The difficulty with overlay mapping, similar to the Meta Diagram diagrams described earlier, is the scarcity of reliable data. Maps may be beautiful to look at, but their utility is dependent on the accuracy, breadth, and availability

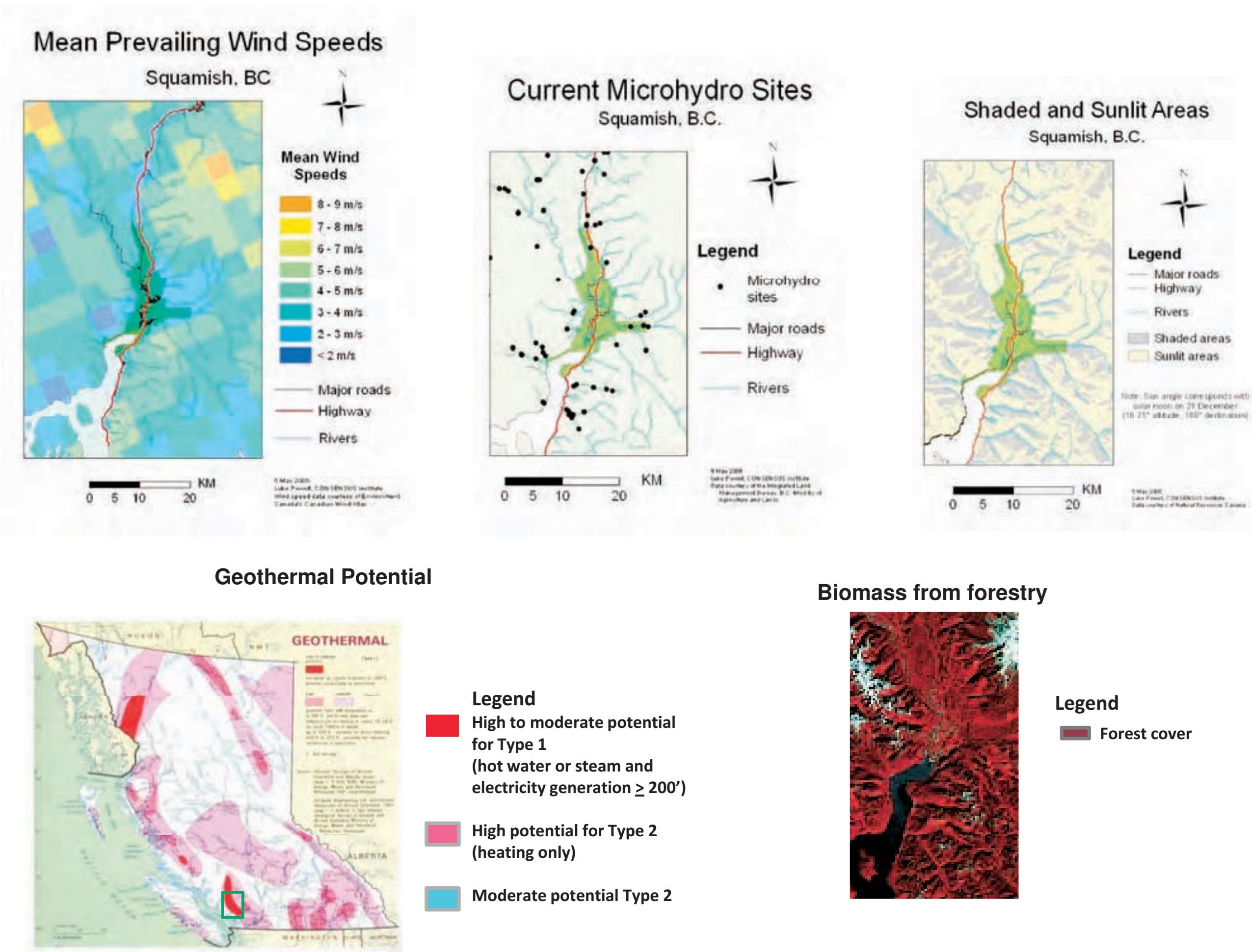


Figure 2.25. Example of an Overlay Map for Renewable Energy Sources. Single energy asset maps can be viewed together, or overlaid, to produce a picture of all the areas in the region that have easy access to renewable energy resources. With appropriate growth management, this city is well positioned to achieve energy independence, and carbon neutrality.

of supplied data. In reality, the mapping of such things as ecological resources within and around a city is a relatively simple task that can be performed by any recent college graduate. However, the science of inventorying resources is not so simple. A substantial investment is sometimes required to survey resources and document conditions throughout a region, involving experts from varying disciplines. Since every location is unique, there are few shortcuts. One technique for speedy data collection is to use air photos, in combination with GPS, to rapidly create data on the length and area of the natural and built elements of a region, including such data as building footprints, the length of key streets and shorelines, and the characteristics of the open space. Regardless, the information collection and storage plan is the most important part of the method, and needs to be addressed as part of an Eco² Pathway. A good example of how a broad information strategy leads to better mapping tools can be found in the World Bank's *Climate Resilient Cities, 2008 Primer,*[7] which includes a step by step approach to identifying 'hot spots' that are especially vulnerable, and then exploring mitigation options.

3. Integrate Local Knowledge

Another key part of the information strategy is to engage knowledgeable local residents' in the mapping work. Lately, the process of 'community mapping' has been successfully applied in many locations. Local people have a truly surprising amount of information to contribute, much of which cannot be obtained in any other fashion. Workshops can be organised for tapping into this information, and creating maps that are far more informative under a process that is more inclusive.

4. Take advantage of technologies for sharing results

The use of web-based GIS applications is an emerging technology which can leverage the benefits of mapping. Colourful maps and images on the Internet offer increased potential for public and stakeholder participation, and help decision-makers to collect diverse viewpoints about how to improve the quality and acceptability of plans.

5. Work towards scenario-based GIS

As capacity builds within a city, the overlay mapping methods can evolve to include powerful scenario-based GIS. Such applications can rapidly alter maps to reflect changes in design, and automatically generate precise calculations of spatial indicators and resource flows. An example is Community Viz—a software package developed for cities and made available at a minimal cost through a charitable foundation (the Orten Foundation). Community Viz greatly reduces the time required to create plausible scenarios for urban system design, and for establishing a standard protocol for use of indicators and benchmarks. It also provides a convenient basis for sharing data and integrating results across departments or institutions. In the Squamish application described above, Community Viz was used as a common platform by three separate design teams: *Smart Growth* (urban form and transportation); *Pathways* (risk management and natural hazards); and *Bridging to the Future* (30-year pathways for sustainability).

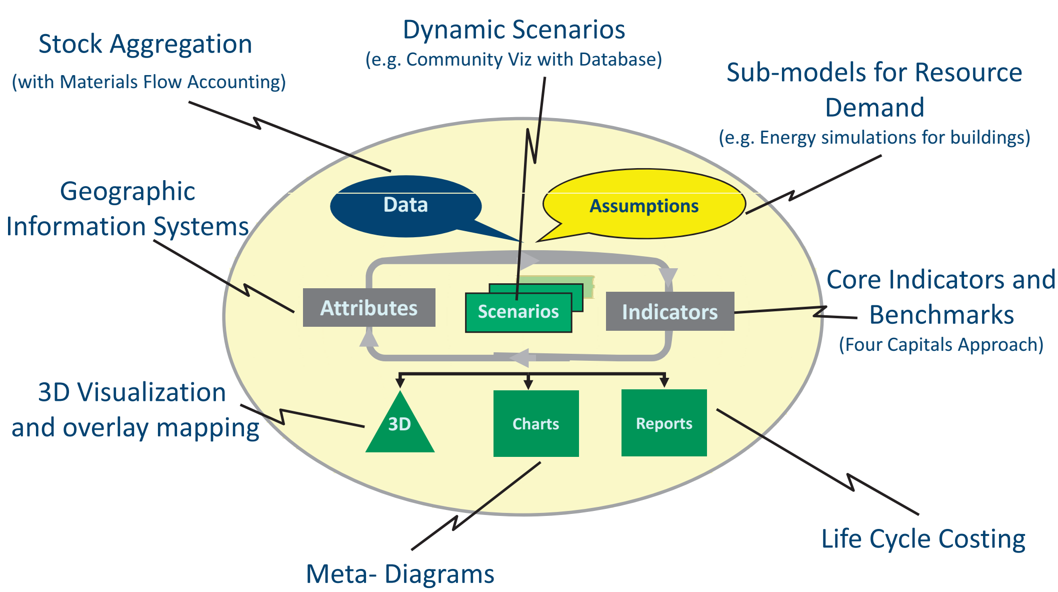


Figure 2.26. Community Viz. Community Viz is a GIS application based upon scenarios and indicators that can be used in concert with other methods to produce much of the information required for assessing development options.

Adapted from Community Viz Users Guide. 2009 Orton Family Foundation, www.communityviz.com

CHAPTER 3

Methods for Investment Planning

Investing wisely in urban development is a complex process. A large number of professionals (architects, designers, suppliers, engineers, economists and financial planners) must be engaged, each of whom brings a different concept of what is important, and how it can be measured. Construction occurs over many phases and many years (programming and planning, design and engineering, construction, operation, and dismantling). The final product is composed of many levels of subsidiary products: materials, components and technologies, whole buildings, infrastructure systems, and open space. And at each phase and every scale, different actors are involved in the decision-making process. The complexity of interactions between these actors and between the many elements is one of most significant challenges faced by anybody trying to assess the real costs and benefits of alternative plans for development. Investing wisely in urban development is about coping with complexity.

A number of assessment methods are available to help cities cope with complexity. The following methods are worth considering. Each of these can be applied using simple and scalable tools that adjust to needs and capacity of the user.

First and foremost is Life Cycle Costing (LCC), which is used to understand many of the indirect and contingent costs associated with any project design over the expected lifetime of the facilities. Some LCC tools work with complete urban environments, including both spatial elements and infrastructure. Other LCC tools work exclusively with specific types of infrastructure facilities, like treatment plants and power plants. We will look at both types.

The second method to consider is environmental accounting, which attempts to add up the lifetime environmental impacts of a project. Environmental accounting includes Material Flow Analysis, but further expands the scope to include the broader impacts of specific projects on the environment, including resource use and

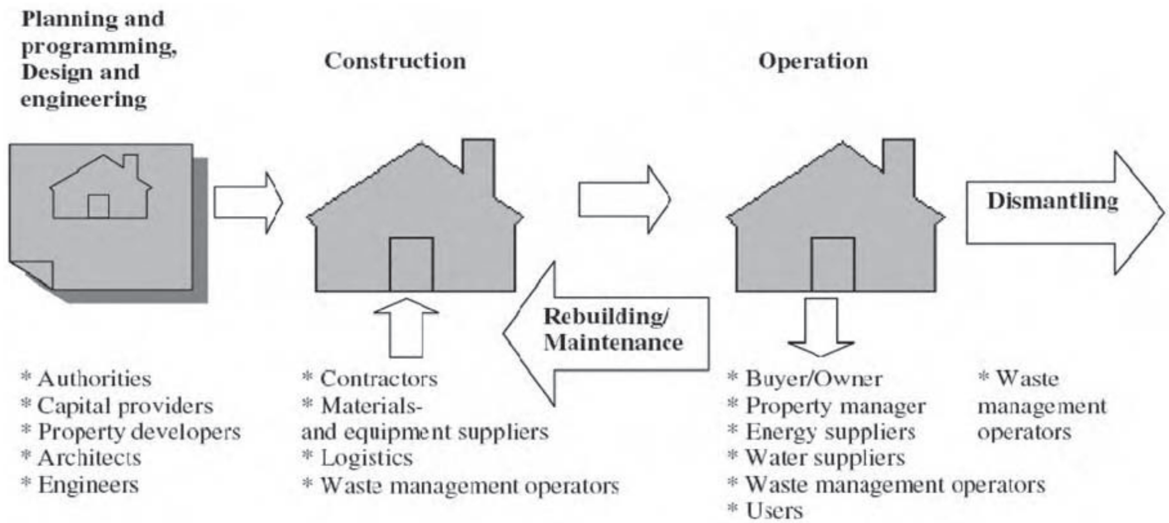


Figure 2.27. Building Life Cycle. The life cycle of a building is long, complex, and influenced by many different professionals.

Source: Karolina Brick, Barriers for Implementation of the Environmental Load Profile and Other LCA-Based Tools (Stockholm: Royal Institute of Technology, 2008).

depletion and the costs of emissions. This method can be useful for demonstration projects, because it helps to reveal the whole picture, including those issues where impacts are likely to be highest. Lifecycle environmental accounting can help to identify the areas where problems are greatest. For example, ecological priorities among rapid industrialising countries include cutting back on excessive amounts of heavy masonry used in construction, converting inefficient and polluting energy systems used to produce materials, and enhancing the durability of concrete and other key materials that affect the lifetimes of buildings and infrastructure. The challenges with undertaking environmental accounting on projects are the time and effort needed to consider all of the inputs and outputs, including those that are embodied in the materials and services procured for the project.

A third method is risk assessment, something that is especially important during times of rapid change, and yet largely ignored by urban professionals. A full assessment of risk requires that cities consider a variety of future possibilities, and research the likely impact of trends in many areas, from climate change to technology. Scenario planning and adaptation are difficult but very rewarding exercises, and are a key part of the Eco² Pathway.

A fourth and final method is the overall valuation of city performance on an Eco² Pathway as well as on a project by project basis by using the right set of indicators to assess costs and benefits. To some extent, the other methods generate monetary and other indicators of success, and can be used directly for valuation. However, as explained in Part One, we will be reviewing how to select indicators of performance that are useful to decision-makers at varying levels, and that cover the full range of assets within a city: manufactured capital, natural capital, human capital, and social capital. The challenges are to find ways to measure these assets that are balanced, affordable, dependable, and comparable, and to present the results in a format that can easily be understood by decision-makers.

This book does not address valuation given that city and project valuations are specific and contextual. However, the World Bank and the Eco² Program dispose of myriad instruments to help cities in valuation activities.

Life Cycle Costing

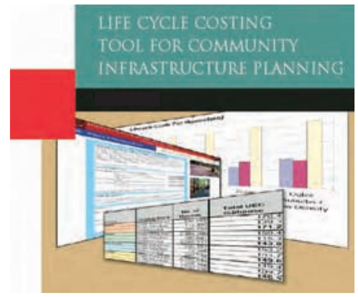
One of the most significant factors influencing decision-making about urban area development is the long-term impact on city finances and the costs for residents and businesses. Unfortunately, when it comes to complex integrated designs that include new land use and new infrastructure, the costs and revenues are often very difficult to estimate. Good common sense arguments might exist for alternative Eco² designs, but without accompanying financial analysis, decision-makers may be understandably reluctant. This is especially true given prevalent misconceptions and misinformation. Moreover, it is not always easy to recognize the 'win-win-win' potential, and the assumption may be that change may be costly, at least until a financial analysis is complete.

The debate over costs has two dimensions: what are the true costs over the long-term? And how equitably are costs and benefits distributed? A Life Cycle Costing method is the only way to address both of these questions.

Life Cycle Costing (LCC) for urban infrastructure applies to everything—from buildings to roads, pathways, right-of-ways, parking lots, wires, pipes, ditches, bridges, and the associated treatment plants, sub-stations, open spaces, and facilities. Most of these infrastructure elements have exceptionally long lifetimes and can account for large quantities of lifecycle material and energy flows. By adopting LCC, the design and purchasing choices can be adjusted to optimise the system over its entire life. Sewer pipes, for example, may change from concrete to welded steel, if due consideration is given to durability, cleaning, maintenance, and other recurring costs over the full life of the system, and to the potential for adaptability and recycling. Road surfaces may change from asphalt to concrete, if due consideration is given to the improved efficiency and fuel savings achieved by trucks tires on concrete. Linear in-the-ground infrastructure grids may adopt 'combined trenching' and easily accessed 'utilidors,' if these are shown to offer greater adaptability and lower operating costs over the long life cycle of such systems. LCC can produce even greater changes in practices for spatial planning, as described in Part One.

Application of LCC to integrated Land Use and Community Infrastructure Planning

LCC can assist with the evaluation of alternative spatial planning activities by providing credible estimates of the full long-term costs for infrastructure and impacts on taxes, fiscal health, affordable housing, and commercial space. The benefits are best understood by describing a specific example where LCC has been applied. The example presented here is based on a tool developed by a Canadian public agency for use in integrated design exercises. The tool, entitled *Life Cycle Costing Tool for Community Infrastructure Planning,* allows users to estimate the major costs of community development, particularly those that change with different forms of development (for example, linear infrastructure) and to compare alternative development scenarios. The tool is geared towards estimating planning level costs and revenues associated with the residential component of a development, although financial impacts of commercial and other types of development can be incorporated provided that infrastructure requirements are specified correctly. The tool is suited to assessing development projects ranging in size from a collection of houses to a block-by-block infill development to an entire subdivision or neighbourhood. A good measure of the applicability of the tool to a given project is whether or not alternatives can be conceived that would result in significantly different densities or infrastructure requirements, or make use of different green infrastructure alternatives.



Note: Life Cycle Costing Software available from Canada Mortgage and Housing Corporation

This tool is a spreadsheet (Excel) based application that makes it quick and easy to estimate life cycle costs for almost any type of land use and infrastructure alternative. The tool includes costing variables with default values that can be adjusted to match the local or national costs for the city location. Outputs include an integrated financial assessment with monetary values for the following major categories:

- Hard Infrastructure, including roads, sewers, storm water facilities, schools, and recreation centres;
- Municipal Services, including transit services, school transit, fire services, police services, and waste management services;
- Private User Costs, including driving costs and home heating costs;
- External Costs, including air pollution, climate change, and motor vehicle collision; and
- Green Infrastructure alternatives.

Defining two scenarios for the City of Fort St. John

In 2008, the City of Fort St. John conducted a design charrette to create a Sustainable Neighbourhood Concept Plan for a 37 hectare green field site on the edge of the urban area. The city had three goals:

1. To adopt a more proactive and engaging planning process for managing growth;
2. To create a new demonstration neighbourhood that embodies the community's long-term goals and objectives; and
3. To field test new approaches for guiding future mixed-use development throughout the region.

As part of the design charrette the development costs and value of the Sustainable Neighbourhood Concept Plan was compared against a *"baseline scenario"* that was based upon the typical low density neighbourhoods that currently exist in Fort St. John. The *"sustainable neighbourhood scenario"* is an alternative that incorporates the principles and recommendations that arose from the Charrette process. The analysis by the *Life Cycle Costing Tool for Community Infrastructure Planning* allowed scenarios to be run for a whole neighbourhood.

Table 2.1. Comparative Statistics of Two Scenarios: City of Fort St. John

FACTOR	BASELINE—LOW DENSITY	SUSTAINABLE- MEDIUM DENSITY
Site Area	37 Ha (93 Ac)	37 Ha (93 Ac)
% Residential Area 1	94	90
% Commercial and Community	6	10
Service Area of Parks space.	App. 2.7 Ha	Not estimated. Multi-use open
Single Family Units	188	56
Duplex Units (large lot)	72	0
Mini-lot Duplex Units	0	84
Townhouses (2 St.)	0	108
Townhouses (3 St stacked)	0	138
Apartments (3 or 4 St.)	144	516
Apartments Above Commercial	0	30
Commercial Units	8	15
Total Residential Units	368	932
Gross Unit Density U/Ha (U/Ac)	11 (4)	28 (12)
Adult Population	682	1542
Children Population	206	380
Total Population	888	1922
Neighbourhood Roads-compact (m)	0	2410
Collector Roads (lin m) [2]	3200	1930
Arterial Roads (lin m)	920	920
Total Roads (m)	4120	5260

1. Includes roads, parks, schools etc. associated with residential

2. Includes two types of collector roads, one 17M ROW and one 15M

The calculations are very comprehensive, including typical capital and operating costs for utilities and services, including roads, water, sewer, garbage, schools, recreation facilities, public transit, private vehicle use, fire protection, policing, etc. Interest rates for lending, tax rates, and service revenues are also calculated. Lifecycle costs are annualized (converted into an annual cost) over a 75 year period allowing for operation, maintenance, and replacement of all utilities. All costs can be allocated to a per household basis.

All cost and services demand assumptions were the same for the two calculations. The only differences were that the *sustainable neighbourhood scenario* has a smaller neighbourhood street width, green storm water infrastructure, and green roofs on public buildings (reducing the size of the storm water infrastructure), and higher energy efficiency building standards. The *sustainable neighbourhood scenario* also has a higher density and greater mix of housing types and land uses. Table 2.1 (left) compares the two scenarios.

a) Baseline scenario—low-density, primarily single-family residential and apartment

A simple mask method was used to assess the road and lot layout and number of units that would typically be developed on this site. A scaled 'mask' was created and placed over an existing neighbourhood near the site that has mostly single family homes as well as parks, etc. The approximate number of lots and length and type of streets captured inside this mask was counted, and allowances made for including a school and community centre. The three elements that were then added were a small strip of commercial uses, some duplex lots, and several small scale three-storey apartment buildings. Public open space was limited to parks, school grounds, and street rights of way.

b) Sustainable neighbourhood scenario—medium density, varied housing forms and mixed use

The sustainable neighbourhood plan developed in the 2008 Charrette was the basis of the second scenario. A 3D model was developed from the workshop sketches, using a variety of housing forms listed in the Residential Section above. Though the precise, detailed neighbourhood design was not established, zoning areas, building forms, street types, and public buildings are scaled accurately so that the outcome is a plausible result. Generally, this is a much more compact plan than the baseline scenario. Buildings are more tightly packed, with more intermediary public open spaces. There are several more uses and building types than in the baseline scenario. Neighbourhood streets roads are also narrower, in line with Canadian Alternative Development Standards.

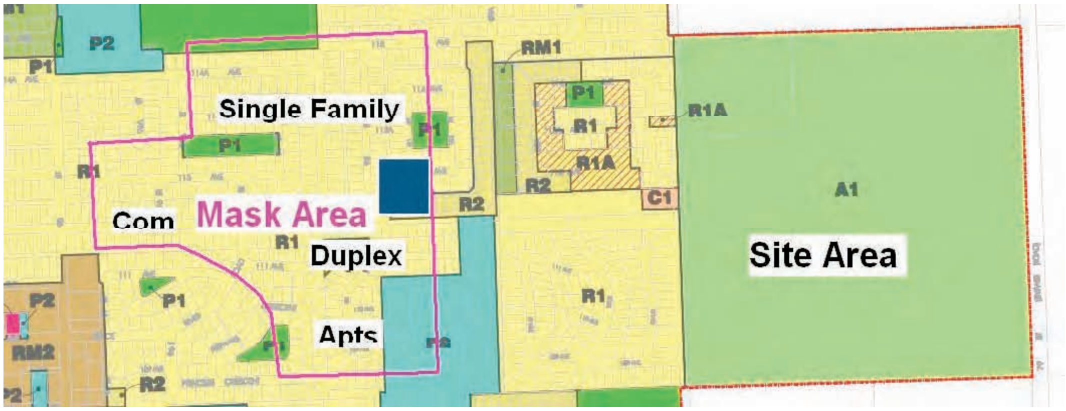


Figure 2.28. Baseline Low Density Scenario Developed Using a 'Mask'

The sustainable neighbourhood plan includes:

- a small area of large-lot single family residents;
- a number of small areas of mini-lot duplexes;
- a few small areas of two storey townhouses;
- several areas of three storey stacked townhouses;
- 3 or 4 storey apartment buildings along the east part of the 112th Avenue extension;
- A seniors-oriented district of 3 or 4 storey apartment buildings to the east of the hospital site;
- A row of mixed use commercial units with apartments above and along the 112th Avenue extension, just north of the hospital site;
- A school and a community centre;
- A public lookout at the water tower;
- Energy efficient homes.

Public open space is integrated and multi-use, including greenways, community gardens, bike paths, cross-country ski trails, and a large commons around the school and community centre.

Analysis of costs and value for the scenarios

Baseline scenario—costs and value

Using typical costs for roads, sewers, water supply, schools and other services, the baseline scenario results in about US$36,000 in initial capital costs for each residential unit. The estimated cost of a storm water pond is included in "green infrastructure." The estimated cost of a water pumping station is included in "user defined costs." Note that roads dominate the capitals costs.

Using the capital costs developed above, the baseline scenario results in about US$6,500 in operating costs for each residential unit. The estimated operating cost of the water pumping station is included in "user defined costs."

All infrastructures depreciate, so a true representation of their costs must include their replacement over time, including inflation in construction costs. This graph illustrates what the annual operating costs are for all types of infrastructure when spread over a 75-year lifetime. The true annual lifecycle cost per household (US$8,432) is about 30 percent more than the initial operating cost (US$6,520).

A rough estimate of the taxes, user charges (such as for garbage collection) and initial de-

INITIAL CAPITAL COSTS

		Total Development $	Residential Portion $	Household Costs $/hh	Percent Breakdown %
HARD INFRASTRUCTURE	Local Roads	7,560,890	7,107,236	19,313	54%
	Regional Roads	0	0	0	0%
	Water Distribution and Water Treatment	672,000	672,000	1,826	5%
	Sanitary Sewers and Wastewater Treat.	766,000	766,000	2,082	6%
	Storm Sewers and Water Management	3,178,600	2,987,884	8,119	23%
	Schools	1,347,446	1,347,446	3,662	10%
	Recreational Facilities	6,771	6,771	18	0%
MUNICIPAL SERVICES	Transit Services	112,530	105,778	287	1%
	Fire Services	20,976	20,976	57	0%
	Police Services	11,040	11,040	30	0%
GREEN INFR.	Green Infrastructure Items	80,000	75,200	204	1%
USER DEFINED	User Defined Costs	160,000	150,400	409	1%
	Total Costs	**$13,916,253**	**$13,250,732**	**$36,007**	**100%**

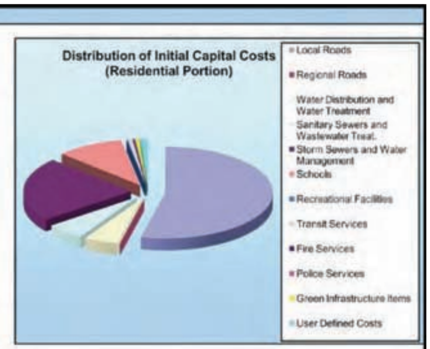
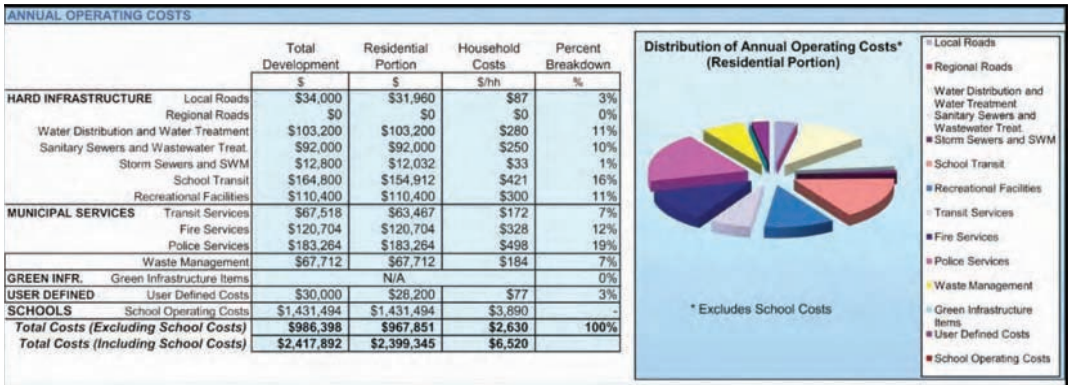


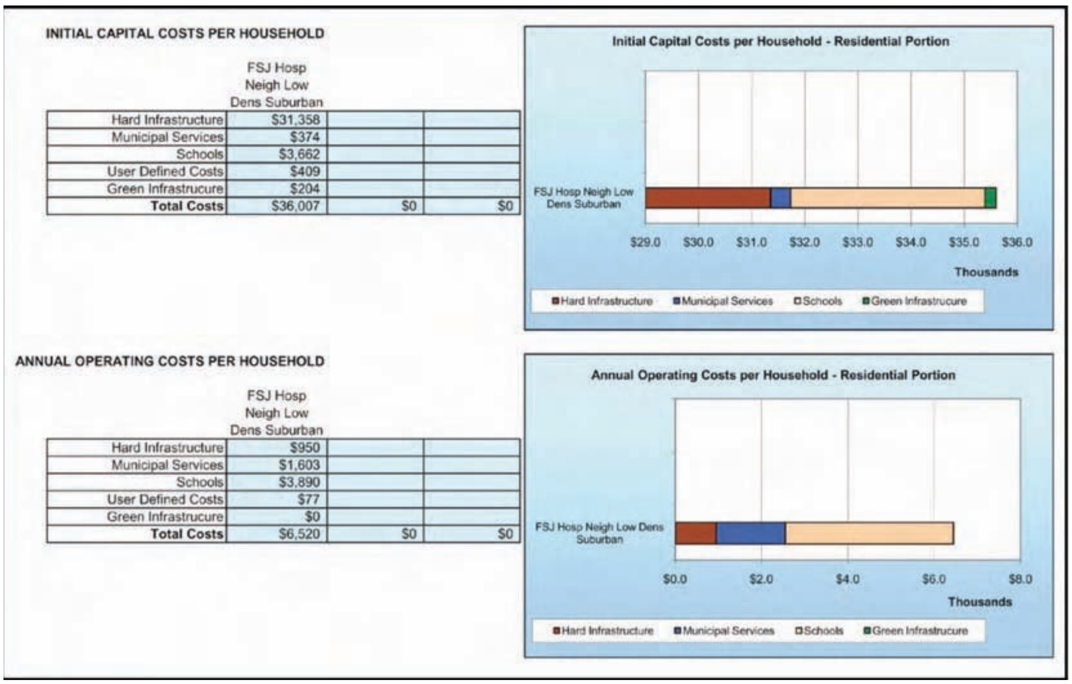
Figure 2.29. Baseline Scenario—Initial Capital Costs



ANNUAL OPERATING COSTS

		Total Development	Residential Portion	Household Costs	Percent Breakdown
		$	$	$/hh	%
HARD INFRASTRUCTURE	Local Roads	$34,000	$31,960	$87	3%
	Regional Roads	$0	$0	$0	0%
	Water Distribution and Water Treatment	$103,200	$103,200	$280	11%
	Sanitary Sewers and Wastewater Treat.	$92,000	$92,000	$250	10%
	Storm Sewers and SWM	$12,800	$12,032	$33	1%
	School Transit	$164,800	$154,912	$421	16%
	Recreational Facilities	$110,400	$110,400	$300	11%
MUNICIPAL SERVICES	Transit Services	$67,518	$63,467	$172	7%
	Fire Services	$120,704	$120,704	$328	12%
	Police Services	$183,264	$183,264	$498	19%
	Waste Management	$67,712	$67,712	$184	7%
GREEN INFR.	Green Infrastructure Items		N/A		0%
USER DEFINED	User Defined Costs	$30,000	$28,200	$77	3%
SCHOOLS	School Operating Costs	$1,431,494	$1,431,494	$3,890	-
Total Costs (Excluding School Costs)		$986,398	$967,851	$2,630	100%
Total Costs (Including School Costs)		$2,417,892	$2,399,345	$6,520	

Figure 2.30. Baseline Scenario—Annual Operating Costs per Unit



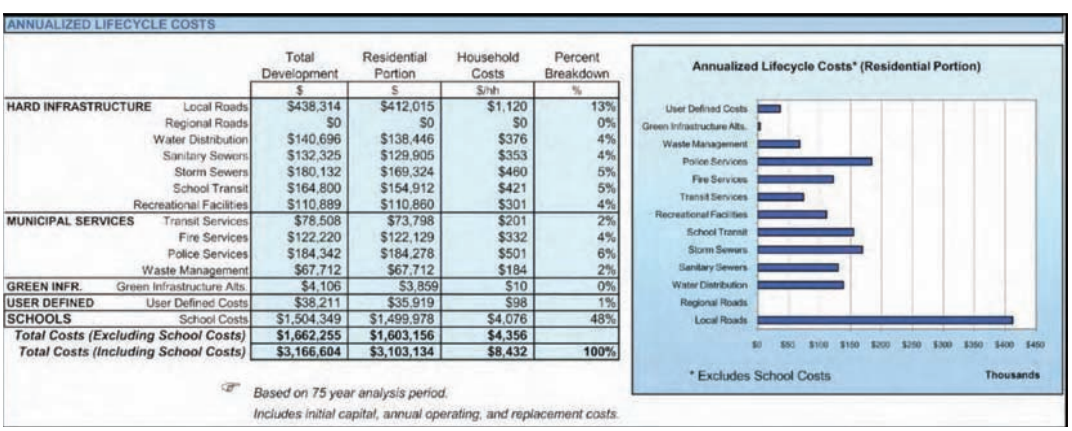
INITIAL CAPITAL COSTS PER HOUSEHOLD

	FSJ Hosp Neigh Low Dens Suburban		
Hard Infrastructure	$31,358		
Municipal Services	$374		
Schools	$3,662		
User Defined Costs	$409		
Green Infrastrucure	$204		
Total Costs	$36,007	$0	$0

ANNUAL OPERATING COSTS PER HOUSEHOLD

	FSJ Hosp Neigh Low Dens Suburban		
Hard Infrastructure	$950		
Municipal Services	$1,603		
Schools	$3,890		
User Defined Costs	$77		
Green Infrastrucure	$0		
Total Costs	$6,520	$0	$0

Figure 2.31. Baseline Scenario—Graphic Representation of Initial Capital Costs and Annual Operating Costs per Unit



ANNUALIZED LIFECYCLE COSTS

		Total Development	Residential Portion	Household Costs	Percent Breakdown
		$	$	$/hh	%
HARD INFRASTRUCTURE	Local Roads	$438,314	$412,015	$1,120	13%
	Regional Roads	$0	$0	$0	0%
	Water Distribution	$140,696	$138,446	$376	4%
	Sanitary Sewers	$132,325	$129,905	$353	4%
	Storm Sewers	$180,132	$169,324	$460	5%
	School Transit	$164,800	$154,912	$421	5%
	Recreational Facilities	$110,889	$110,860	$301	4%
MUNICIPAL SERVICES	Transit Services	$78,508	$73,798	$201	2%
	Fire Services	$122,220	$122,129	$332	4%
	Police Services	$184,342	$184,278	$501	6%
	Waste Management	$67,712	$67,712	$184	2%
GREEN INFR.	Green Infrastructure Alts.	$4,106	$3,859	$10	0%
USER DEFINED	User Defined Costs	$38,211	$35,919	$98	1%
SCHOOLS	School Costs	$1,504,349	$1,499,978	$4,076	48%
Total Costs (Excluding School Costs)		$1,662,255	$1,603,156	$4,356	
Total Costs (Including School Costs)		$3,166,604	$3,103,134	$8,432	100%

Based on 75 year analysis period.
Includes initial capital, annual operating, and replacement costs.

Figure 2.32. Baseline Scenario—Representation of True Lifecycle Costs, including Replacement

ANNUAL LIFECYCLE COSTS PER HOUSEHOLD	FSJ Hosp Neigh Low Dens Suburban		
Hard Infrastructure	$2,610		
Municipal Services	$1,638		
Schools	$4,076		
User Defined Costs	$98		
Green Infrastrucure	$10		
Total Costs	$8,432	$0	$0

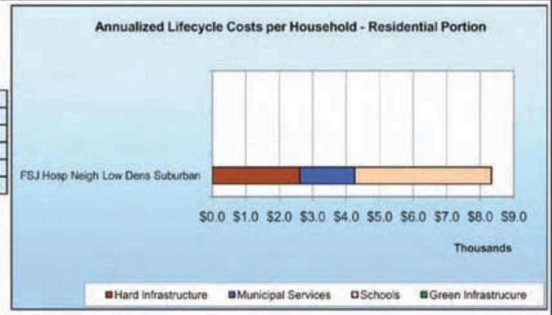


Figure 2.33. Baseline Scenario—Graphic Representation of True Lifecycle Cost

REVENUES	Total Residential ($)	Revenues per household or unit ($)
Annual Property Taxes	$1,800,368	$4,892
Annual User Charges	$144,159	$392
Total Initial Development Charges	$2,736,000	$7,435
Annual User Defined Revenues	$0	$0
Annualized Value of Revenues*	$2,084,943	$5,666

** Based on 75 year analysis period. Includes annual property taxes, initial development charges, user charges and user defined revenues*

Figure 2.34. Baseline Scenario—Estimate of Taxes, User Fees, Initial DCCs

velopment costs charges for the baseline scenario. It had not been decided how the City of Fort St. John will share or recover development costs from the private sector, so these results are hypothetical.

Sustainable neighbourhood—costs and value

Using typical costs for roads, sewers, water supply, schools and other services, the sustainable neighbourhood scenario results in about US$16,500 in initial capital costs for each residential unit, less than half the costs of the baseline scenario. The estimated cost of a green roof for the school and community centre as well as the (now smaller) storm water pond is included in "green infrastructure." The estimated cost of a water pumping station is included in "user defined costs." Note that roads still dominate the capitals costs as in the Baseline Scenario.

Using the capital costs estimated above, the sustainable neighbourhood scenario results in about US$5,200 in operating costs for each residential unit, about 25 percent less than the baseline scenario. The estimated operating cost of the water pumping station is included in "user defined costs."

Annualised life cycle costs for the sustainable alternative are estimated at US$6,053 per unit, or about 17 percent more than the initial operating cost (US$5,185). This difference is about half of the difference for the baseline scenario, mainly because of the number of households sharing the infrastructure more efficiently.

These initial results indicate that taxes from the sustainable neighbourhood could be slightly lower (mainly due to smaller homes), and initial development charges would also be lower than the baseline scenario.

INITIAL CAPITAL COSTS		Total Development	Residential Portion	Household Costs	Percent Breakdown
		$	$	$/hh	%
HARD INFRASTRUCTURE	Local Roads	8,233,564	7,410,208	7,951	48%
	Regional Roads	0	0	0	0%
	Water Distribution and Water Treatment	843,000	843,000	905	5%
	Sanitary Sewers and Wastewater Treat.	965,500	965,500	1,036	6%
	Storm Sewers and Water Management	3,198,200	2,878,380	3,088	19%
	Schools	2,485,580	2,485,580	2,667	16%
	Recreational Facilities	17,149	17,149	18	0%
MUNICIPAL SERVICES	Transit Services	254,430	228,987	246	1%
	Fire Services	53,124	53,124	57	0%
	Police Services	27,960	27,960	30	0%
GREEN INFR.	Green Infrastructure Items	326,500	293,850	315	2%
USER DEFINED	User Defined Costs	160,000	144,000	155	1%
	Total Costs	**$16,565,007**	**$15,347,737**	**$16,468**	**100%**

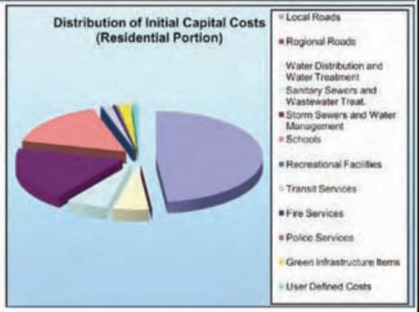


Figure 2.35. Sustainable Neighbourhood Scenario—Initial Capital Costs per Unit

ANNUAL OPERATING COSTS		Total Development	Residential Portion	Household Costs	Percent Breakdown
		$	$	$/hh	%
HARD INFRASTRUCTURE	Local Roads	$47,260	$42,534	$46	2%
	Regional Roads	$0	$0	$0	0%
	Water Distribution and Water Treatment	$246,150	$246,150	$264	11%
	Sanitary Sewers and Wastewater Treat.	$233,000	$233,000	$250	11%
	Storm Sewers and SWM	$12,800	$11,520	$12	1%
	School Transit	$304,000	$273,600	$294	12%
	Recreational Facilities	$279,600	$279,600	$300	13%
MUNICIPAL SERVICES	Transit Services	$152,658	$137,392	$147	6%
	Fire Services	$305,696	$305,696	$328	14%
	Police Services	$464,136	$464,136	$498	21%
	Waste Management	$171,488	$171,488	$184	8%
GREEN INFR.	Green Infrastructure Items		N/A		0%
USER DEFINED	User Defined Costs	$30,000	$27,000	$29	1%
SCHOOLS	School Operating Costs	$2,640,620	$2,640,620	$2,833	-
	Total Costs (Excluding School Costs)	**$2,246,788**	**$2,192,116**	**$2,352**	**100%**
	Total Costs (Including School Costs)	**$4,887,408**	**$4,832,736**	**$5,185**	

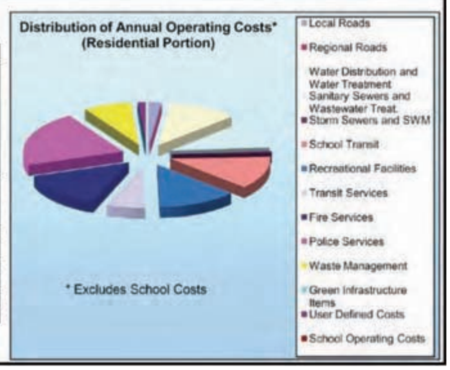
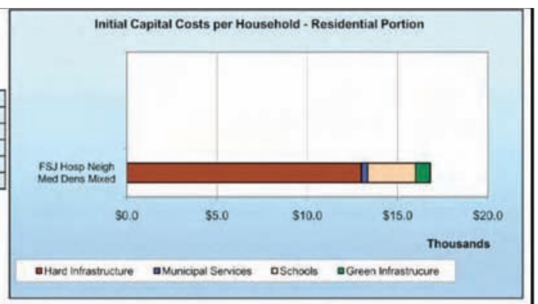


Figure 2.36. Sustainable Neighbourhood Scenario—Annual Operating Costs per Unit

INITIAL CAPITAL COSTS PER HOUSEHOLD

	FSJ Hosp Neigh Med Dens Mixed		
Hard Infrastructure	$12,998		
Municipal Services	$333		
Schools	$2,667		
User Defined Costs	$155		
Green Infrastrucure	$816		
Total Costs	$16,968	$0	$0



ANNUAL OPERATING COSTS PER HOUSEHOLD

	FSJ Hosp Neigh Med Dens Mixed		
Hard Infrastructure	$872		
Municipal Services	$1,451		
Schools	$2,833		
User Defined Costs	$29		
Green Infrastrucure	$0		
Total Costs	$5,185	$0	$0

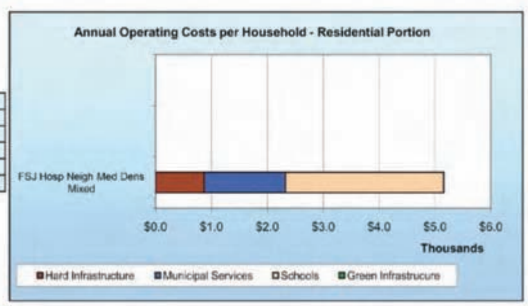


Figure 2.37. Sustainable Neighbourhood Scenario—Graphic Representation of Initial Capital Costs and Annual Operating Costs per Unit

ANNUALIZED LIFECYCLE COSTS

		Total Development	Residential Portion	Household Costs	Percent Breakdown
		$	$	$/hh	%
HARD INFRASTRUCTURE	Local Roads	$487,545	$438,790	$471	8%
	Regional Roads	$0	$0	$0	0%
	Water Distribution	$293,187	$288,483	$310	5%
	Sanitary Sewers	$283,827	$278,744	$299	5%
	Storm Sewers	$181,164	$163,047	$175	3%
	School Transit	$304,000	$273,600	$294	5%
	Recreational Facilities	$280,839	$280,715	$301	5%
MUNICIPAL SERVICES	Transit Services	$177,507	$159,756	$171	3%
	Fire Services	$309,535	$309,152	$332	5%
	Police Services	$466,867	$466,594	$501	8%
	Waste Management	$171,488	$171,488	$184	3%
GREEN INFR.	Green Infrastructure Alts.	$16,757	$15,081	$16	0%
USER DEFINED	User Defined Costs	$38,211	$34,390	$37	1%
SCHOOLS	School Costs	$2,775,013	$2,761,574	$2,963	49%
Total Costs (Excluding School Costs)		$3,010,926	$2,879,841	$3,090	
Total Costs (Including School Costs)		$5,785,939	$5,641,415	$6,053	100%

Based on 75 year analysis period.
Includes initial capital, annual operating, and replacement costs.

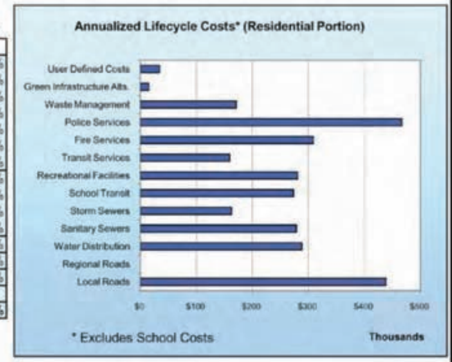


Figure 2.38. Sustainable Neighbourhood Scenario—Representation of True Lifecycle Costs, including Replacement

ANNUAL LIFECYCLE COSTS PER HOUSEHOLD

	FSJ Hosp Neigh Med Dens Mixed		
Hard Infrastructure	$1,556		
Municipal Services	$1,481		
Schools	$2,963		
User Defined Costs	$37		
Green Infrastrucure	$42		
Total Costs	$6,079	$0	$0

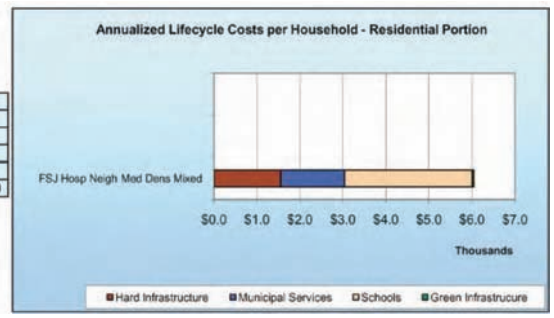


Figure 2.39. Sustainable Neighbourhood—Graphic Representation of True Lifecycle Cost

REVENUES

	Total Residential ($)	Revenues per household or unit ($)
Annual Property Taxes	$3,951,140	$4,239
Annual User Charges	$355,929	$382
Total Initial Development Charges	$5,712,000	$6,129
Annual User Defined Revenues	$182,196	$195
Annualized Value of Revenues*	$4,782,414	$5,131

** Based on 75 year analysis period. Includes annual property taxes, initial development charges, user charges and user defined revenues*

Figure 2.40. Sustainable Neighbourhood Scenario—Estimate of taxes, User Fees, Initial DCCs

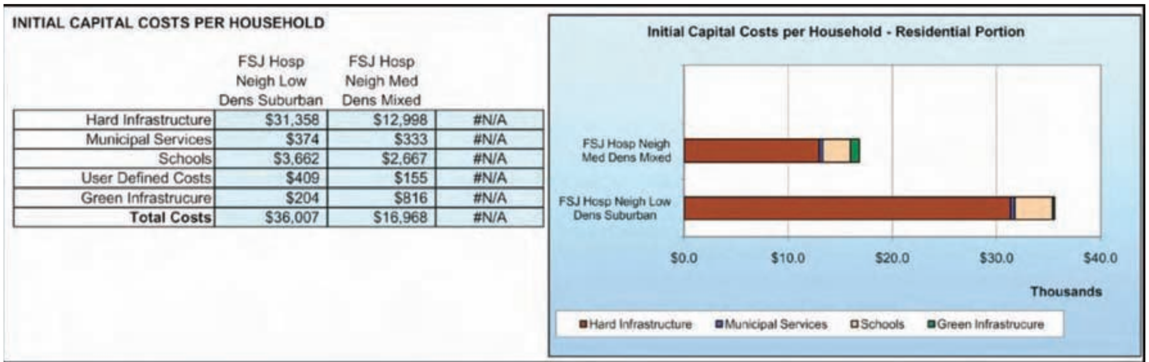
Comparative analysis of costs and value

Figure 2.41 demonstrates the huge savings in initial capital costs between the sustainable neighbourhood and baseline scenarios. Decision-makers can emphasize this substantial savings in efforts to overcome reluctance to pursue innovative solutions.

Figure 2.42 illustrates the modest reductions in operating costs per household for the sustainable neighbourhood scenario, mainly due to more households sharing infrastructure. In addition, the costs of schools are distributed among more homes with fewer children.

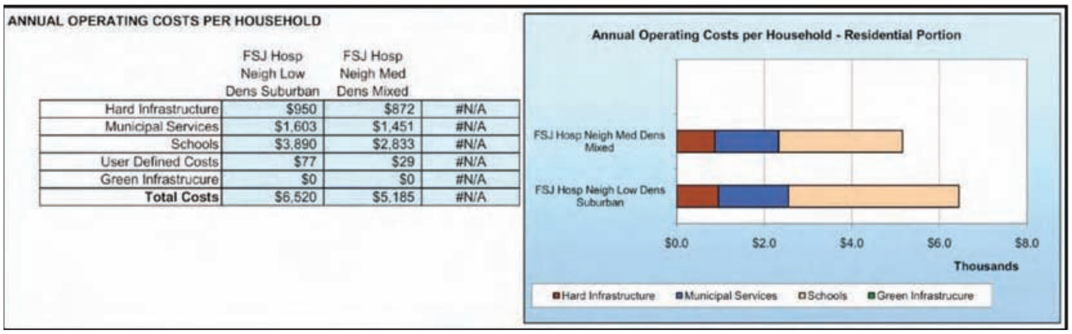
Figure 2.43 illustrates the significant reductions in estimated annual municipal costs and necessary revenues for the sustainable neighbourhood over a 75 year period.

Figure 2.44 summarizes the estimated annual lifecycle costs per household for the two neighbourhoods over a 75 year period.



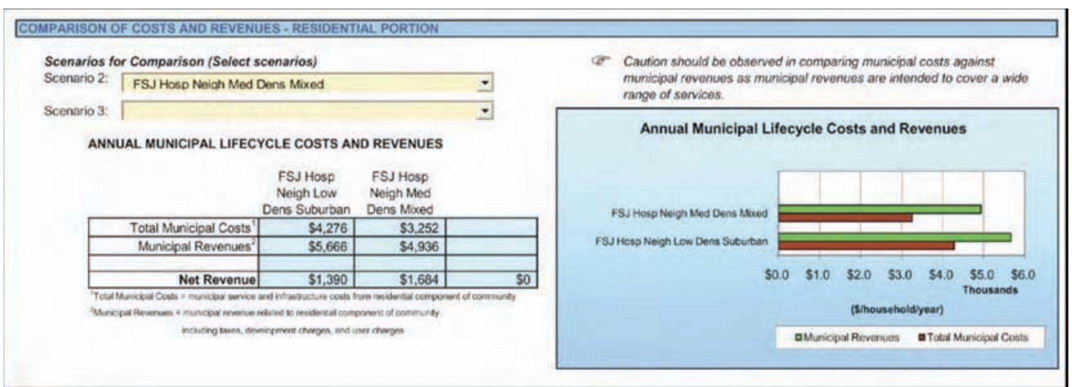
	FSJ Hosp Neigh Low Dens Suburban	FSJ Hosp Neigh Med Dens Mixed	
Hard Infrastructure	$31,358	$12,998	#N/A
Municipal Services	$374	$333	#N/A
Schools	$3,662	$2,667	#N/A
User Defined Costs	$409	$155	#N/A
Green Infrastrucure	$204	$816	#N/A
Total Costs	$36,007	$16,968	#N/A

Figure 2.41. Comparison between Baseline and Sustainable Neighbourhood Scenarios—Initial Capital Costs



	FSJ Hosp Neigh Low Dens Suburban	FSJ Hosp Neigh Med Dens Mixed	
Hard Infrastructure	$950	$872	#N/A
Municipal Services	$1,603	$1,451	#N/A
Schools	$3,890	$2,833	#N/A
User Defined Costs	$77	$29	#N/A
Green Infrastrucure	$0	$0	#N/A
Total Costs	$6,520	$5,185	#N/A

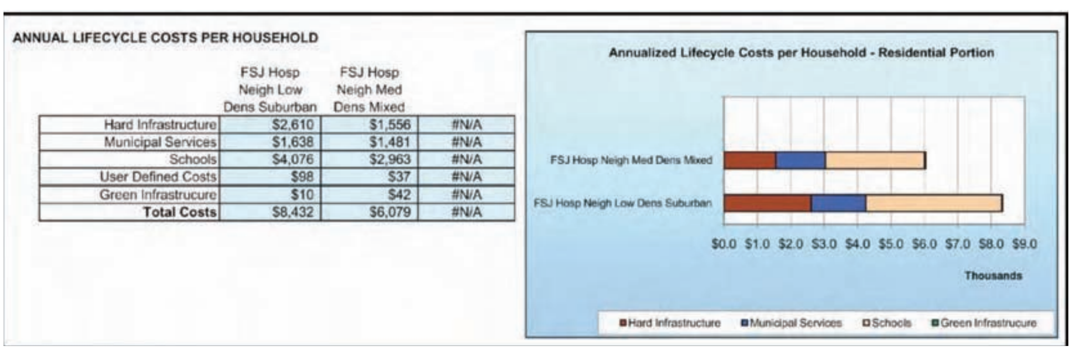
Figure 2.42. Comparison between Baseline and Sustainable Neighbourhood Scenarios: Annual Operating Costs



	FSJ Hosp Neigh Low Dens Suburban	FSJ Hosp Neigh Med Dens Mixed	
Total Municipal Costs[1]	$4,276	$3,252	
Municipal Revenues[2]	$5,666	$4,936	
Net Revenue	$1,390	$1,684	$0

[1] Total Municipal Costs = municipal service and infrastructure costs from residential component of community
[2] Municipal Revenues = municipal revenue related to residential component of community including taxes, development charges, and user charges

Figure 2.43. Comparison between Baseline and Sustainable Neighbourhood Scenarios—
Annual Municipal Costs & Necessary Revenues over 75 Years



	FSJ Hosp Neigh Low Dens Suburban	FSJ Hosp Neigh Med Dens Mixed	
Hard Infrastructure	$2,610	$1,556	#N/A
Municipal Services	$1,638	$1,481	#N/A
Schools	$4,076	$2,963	#N/A
User Defined Costs	$98	$37	#N/A
Green Infrastrucure	$10	$42	#N/A
Total Costs	$8,432	$6,079	#N/A

Figure 2.44. Comparison between Baseline Scenario and Sustainable Neighbourhood Scenario—
annual lifecycle cost per household

Insights from the LCC Case Study

Specific development cost inputs will need to be updated as design continues

There are many hard and soft cost assumptions built into the model that are fairly reliable, because they are taken from national databases and localized to the City of Fort St. John. However, the specifics of development are not certain enough at this conceptual level to obtain highly accurate results. Furthermore, the way in which the City of Fort St. John, as the land owner, will handle development costs and municipal service costs by recovering them through sales and development cost charges has not been determined. For the moment, it has been assumed that the city will carry approximately 20 percent of services costs and pass 80 percent on to the developer. Municipal costs and revenues are thus preliminary. However, once the spreadsheet model has been set up, it can readily be updated to test more detailed scenarios before decisions are finalised.

LCC helps to clarify the greater affordability and value of sustainable options

In the sustainable neighbourhood scenario, the effects on home prices and operating costs are not explored in detail. Clearly, the compact development form results in savings for municipal servicing per household that can be passed on to residents through lower purchase prices or rents. In addition, the sustainable neighbourhood scenario assumes smaller home sizes that reduce capital costs per household. For example, a typical mini-lot duplex may be around 120 to 200 square meters (1,300 to 2,200 square feet), compared to 220-300 square meters (2,400 to 3,200 square feet) for a typical detached single family home (median 60 percent less floor area). Furthermore, green, energy efficient building standards are proposed for the sustainable neighbourhood that will result in lower operating costs and lower repair and replacement costs (because these are more durable homes).

It is estimated that the median price of a mini-lot duplex can be lower than a standard single family lot, in the following order of magnitude:

- Land Price: approximately 25 percent below single family lot due to smaller land area and lower servicing costs.
- Home Price: Approximately 35 percent below single family lot due to smaller home size and economies of duplex construction. This also accounts for the slightly higher cost of better quality, energy efficient construction.
- Operating cost of a mini-lot duplex home can be about 50 percent less than single family due to energy efficiency, water savings, more durable construction, and a reduced yard area to maintain.

In today's world of economic uncertainties and unstable costs for energy and services, it can confidently be said that the more compact, energy efficient and durable home is likely to retain its value much better than the large, inefficient homes of the past.

LCC is especially effective in helping the Municipality cope with future costs

Every established city today is facing trouble managing replacement costs for declining infrastructure. Some are in a more serious situation than others, due to low revenues in a declining economy and deferred replacements that are long overdue. At the same time, there have been major increases in capital costs over the past few years due to the demand for global construction materials, energy prices, and other factors. In short, it is a difficult time for financing infrastructure, and an opportune time for innovative solutions.

As cities look to the future, it will be increasingly important to adopt development solutions that reduce future municipal costs and increase resiliency. The sustainable neighbourhood example offers much lower capital costs per unit, reduced municipal costs over time, lower costs to residents, and better value in the long term. It is also a more adaptable model, offering more options for a wider demographic with very high environmental quality and social amenities. The simple LCC tool has helped the city clarify these benefits prior to making any decisions about how to proceed. A number of other tools[8] are available that perform similar functions; adopting an appropriate choice of tool is a key part of capacity building for the Eco² Pathway.

LCC for a single infrastructure facility

While the City of St. John used LCC for community-wide planning, the LCC tool can also be applied to infrastructure facilities on a case by case basis. One of the challenges for integrated design is to quickly assess a range of very different engineering options for infrastructure. How do you get informed estimates of how different technologies might perform, without commissioning an expensive series of feasibility studies? Where do you find engineers and economists with sufficient experience to fairly compare the alternatives over their lifecycle? As before, the solution is usually to employ scalable spreadsheet tools that allow users to employ default values established by previous projects in other locations, and to quickly alter assumptions as the design concept evolves and as new information becomes available.

An example of an LCC tool for infrastructure facilities is the **RETScreen Clean Energy Project Analysis Software**—a decision support tool that builds the capacity of planners, decision-makers, and industry to implement renewable energy, cogeneration, and energy efficiency projects. The software, provided free-of-charge, can be used worldwide to evaluate energy production and savings, costs, emission reductions, financial viability, and risks for various types of Renewable-energy and Energy-efficient Technologies (RETs). Available in multiple languages, the software includes product, project, hydrology, and climate databases, a detailed user manual, and a case study based college/university-level training course, including an engineering e-textbook. By using the software to explore options at the outset, cites can greatly reduce the cost of pre-feasibility studies. The rigorous structure of the software model also helps to ensure that decision-makers are fully informed, and that analysts are trained in how to analyse the technical and financial viability of projects of all kinds. The software is sponsored by the Government of Canada, and has received contributions from many universities. It has been used in 222 countries.

As part of the **RETScreen Clean Energy Project Analysis Software,** an *Emission Analysis* worksheet is provided to help the user estimate the greenhouse gas emission reduction (mitigation) potential of the proposed project. A *Cost Analysis* worksheet is used to help the user estimate costs (and credits) associated with the proposed case. These costs are addressed from the initial, or investment, cost standpoint, and from the annual, or recurring, cost standpoint. The user can refer to the RETScreen Product Database for supplier contact information to obtain prices or other required information.

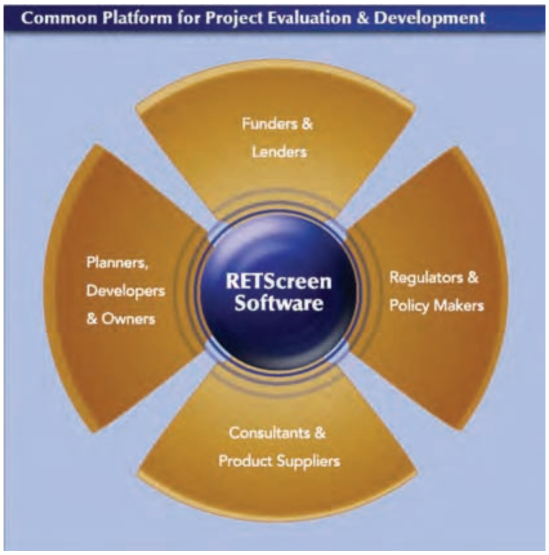


Figure 2.45 RETScreen Software

A *Financial Analysis* worksheet is provided for each project evaluated. This financial analysis worksheet contains six sections: *financial parameters, annual income, project costs and savings/income summary, financial viability, yearly cash flows* and *cumulative cash flows graph*. One of the primary benefits of using the RETScreen software is that it facilitates the project evaluation process for decision-makers. The *Financial Analysis* worksheet, with its financial parameters input items (e.g., discount rate, debt ratio, etc.), and its calculated financial viability output items (e.g., IRR, simple payback, NPV, etc.), allows the project decision-makers to consider various financial parameters with relative ease.

A *Sensitivity and Risk Analysis* worksheet is provided to help the user estimate the sensitivity of important financial indicators in relation to key technical and financial parameters. This standard sensitivity and risk analysis worksheet contains a settings section and two main sections: sensitivity analysis and risk analysis. Each section provides information on the relationship between the key parameters and the important financial indicators, showing the parameters which have the greatest impact on the financial indicators. The sensitivity analysis section is intended for general use, while the risk analysis section, which performs a Monte Carlo simulation, is intended for users with knowledge of statistics.

Environmental Accounting

In the City of Stockholm ("Stockholm"), the municipal government, together with the Royal Institute of Technology (KTH) and an engineering consultant firm, developed a tool to help plan and assess the development of a southern city district (Hammarby Sjöstad).

RETScreen® Financial Summary - Wind Energy Project

Annual Energy Balance

Project name		Wind Turbines
Project location		Squamish, BC
Renewable energy delivered	MWh	4,870
Excess RE available	MWh	-
Firm RE capacity	kW	-
Grid type		Central-grid

Financial Parameters

Avoided cost of energy	$/kWh	0.0950	Debt ratio	%	70.0%
RE production credit	$/kWh	0.025	Debt interest rate	%	14.0%
RE production credit duration	yr	10	Debt term	yr	15
RE credit escalation rate	%	2.5%			
			Income tax analysis?	yes/no	No
Energy cost escalation rate	%	5.0%			
Inflation	%	2.5%			
Discount rate	%	12.0%			
Project life	yr	25			

Project Costs and Savings

Initial Costs				**Annual Costs and Debt**		
Feasibility study	1.8%	$	70,000	O&M	$	132,000
Development	2.5%	$	95,000			
Engineering	21.0%	$	800,000	Debt payments - 15 yrs	$	434,250
Energy equipment	61.4%	$	2,338,200	**Annual Costs and Debt - Total**	**$**	**566,250**
Balance of plant	5.8%	$	220,000			
Miscellaneous	7.5%	$	287,141	**Annual Savings or Income**		
Initial Costs - Total	100.0%	**$**	**3,810,341**	Energy savings/income	$	462,687
				Capacity savings/income	$	-
Incentives/Grants		$	-	RE production credit income - 10 yrs	$	121,760
				Annual Savings - Total	**$**	**584,447**
Periodic Costs (Credits)						
Drive train		$	400,000	Schedule yr # 10,20		
Blades		$	-			
		$	-			
End of project life - Credit		$	-			

Financial Feasibility

			Calculate energy production cost?	yes/no	No
Pre-tax IRR and ROI	%	16.3%			
After-tax IRR and ROI	%	16.3%			
Simple Payback	yr	8.4			
Year-to-positive cash flow	yr	8.3	Project equity	$	1,143,102
Net Present Value - NPV	$	727,868	Project debt	$	2,667,239
Annual Life Cycle Savings	$	92,778	Debt payments	$/yr	434,250
Benefit-Cost (B-C) ratio	-	1.64	Debt service coverage	-	1.09

Yearly Cash Flows

Year #	Pre-tax $	After-tax $	Cumulative $
0	(1,143,102)	(1,143,102)	(1,143,102)
1	41,075	41,075	(1,102,027)
2	65,104	65,104	(1,036,923)
3	90,341	90,341	(946,583)
4	116,846	116,846	(829,737)
5	144,683	144,683	(685,054)
6	173,919	173,919	(511,134)
7	204,625	204,625	(306,509)
8	236,873	236,873	(69,636)
9	270,741	270,741	201,105
10	(205,724)	(205,724)	(4,619)
11	183,907	183,907	179,288
12	219,144	219,144	398,432
13	256,252	256,252	654,684
14	295,326	295,326	950,011
15	336,468	336,468	1,286,479
16	814,034	814,034	2,100,512
17	859,634	859,634	2,960,147
18	907,637	907,637	3,867,784
19	958,166	958,166	4,825,950
20	355,903	355,903	5,181,853
21	1,067,325	1,067,325	6,249,178
22	1,126,234	1,126,234	7,375,412
23	1,188,227	1,188,227	8,563,638
24	1,253,461	1,253,461	9,817,099
25	1,322,103	1,322,103	11,139,202

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5/14/2009;BhF_Wind.xls

Figure 2.46. Example of RETScreen Financial Summary. The above is an example of a financial summary showing the financial viability of a wind energy system for the District of Squamish.

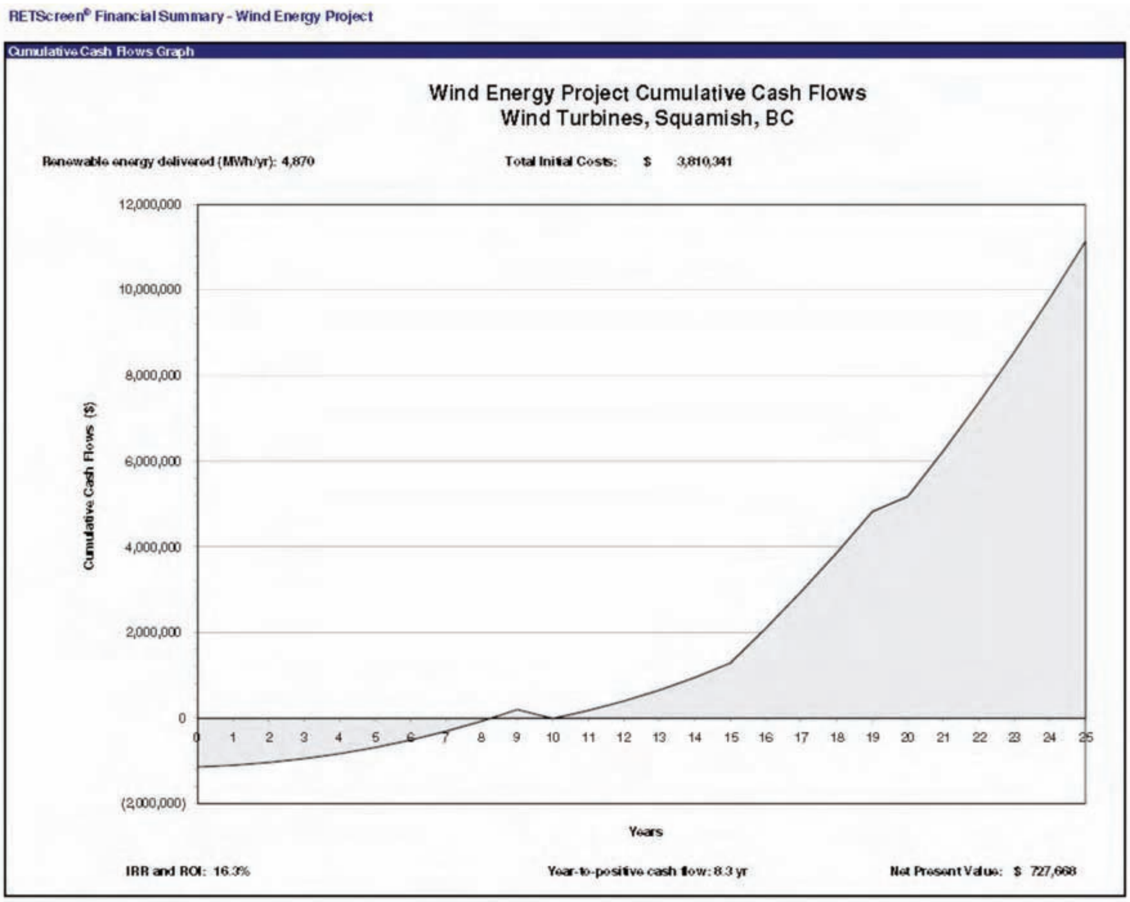


Figure 2.47. Example of RETScreen Financial Summary—Visual. Graph related to the financial summary of the wind energy system for the District of Squamish.

The tool, called the Environmental Load Profile (ELF), has proven successful in evaluating and providing critical feedback to Stockholm's cutting edge initiative in sustainable development. Stockholm developed this tool to demonstrate how different decisions and strategies for urban development might prove significantly more beneficial in enhancing long-term environmental and urban sustainability.

The Environmental Load Profile

The ELP is a Life Cycle Assessment (LCA)-based tool, built on defining the relevant activities from an environmental perspective and on quantifying the environmental loads originating from these activities, such as emissions to air, soil, and water, as well as use of non-renewable energy resources. It takes into account all activities related to a project, such as materials, transport (transport of materials, supplies, and persons), machinery, electricity, heating, and material recycling.

The main strengths of the ELP is that the tool is flexible and dynamic, which makes it suitable to apply both as a planning and evaluation tool. By factoring in variables, the ELP can calculate the environmental loads that different planning decisions will cause at various project phases, including construction, use, demolition, and redevelopment. It is possible to test scenarios: for instance, different construction methods can be compared on environmental performance prior to taking decisions on which method to use. Hence, it is possible for decision-makers to include environmental concerns early on in the process.

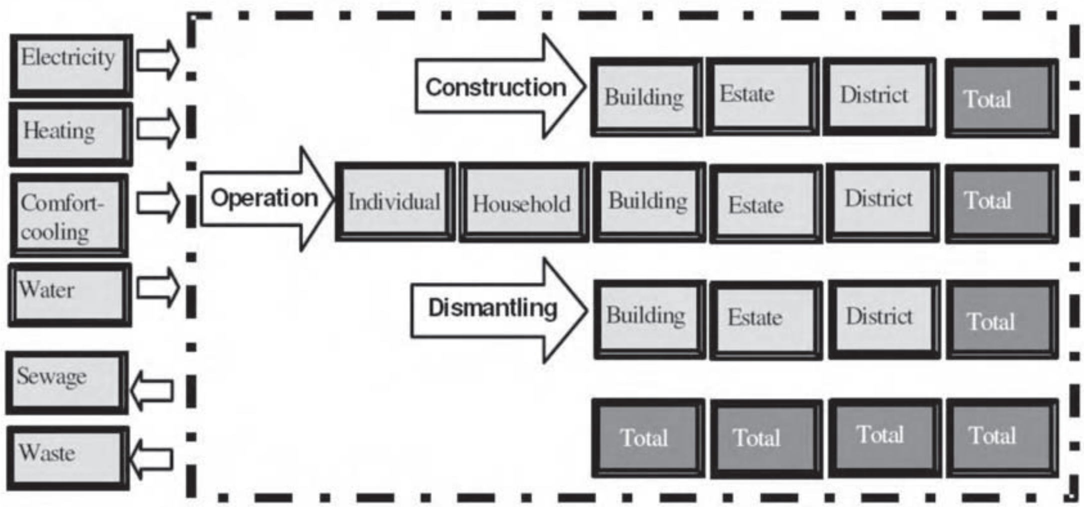


Figure 2.48. Environmental Load Profile (ELP). Environmental loads are quantified for different services and different scales, and the results can be totalled to reflect any combination of concerns.

The ELP can also be used to evaluate the environmental performance of an existing city district or building based on the consumption of resources such as water and energy during the usage phase. The ELP enables analyses of environmental performance at multiple levels. The tool takes into account activities of individuals (e.g., cooking, laundry), buildings (e.g., building materials, district heating, and electricity), un-built real estate area (e.g., materials, working machines) and the common area (e.g., materials, personal transport, transport of goods). By aggregating all factors, the environmental load of the whole city district can be analyzed. If each factor is analysed separately, the different activities of the city can provide useful information for city planning.

The ELP enables comparison of alternative designs, construction, and infrastructure. The ELP encompasses two life cycle calculations:

1. Effects from each of the life cycle stages: construction, operation, and dismantling; and
2. Effects from the life cycle of building materials and electricity flowing in and out of buildings, and the city district.

The ELP in the follow-up of Hammarby Sjöstad

In Stockholm's Hammarby Sjöstad project, the city imposed tough environmental requirements on infrastructure solutions and technical installations in buildings. Since the first area, Sickla Udde, was completed in 2002, environmental goals and performance have been monitored using the ELP's different areas. Figure 2.49 illustrates the results from four of the areas. As compared to a reference scenario, the results were: a 28–42 percent reduction in nonrenewable energy use; a 41–46 percent reduction in water use; a 29–37 percent reduction in global warming potential; a 33 percent reduction in photochemical ozone creation; a 23 percent reduction in acidification potential; a 49 percent reduction in eutrophication potential; and a 27 percent reduction in radioactive waste.

The overall environmental goal set for Hammarby Sjöstad was to reduce the environmental loads by half (*"twice as good"*) compared to urban development loads from the early 1990s. Even though the goal "twice as good" has not yet been reached, reductions of environmental loads in the area are significant. The main contributor to the improvements was the effective

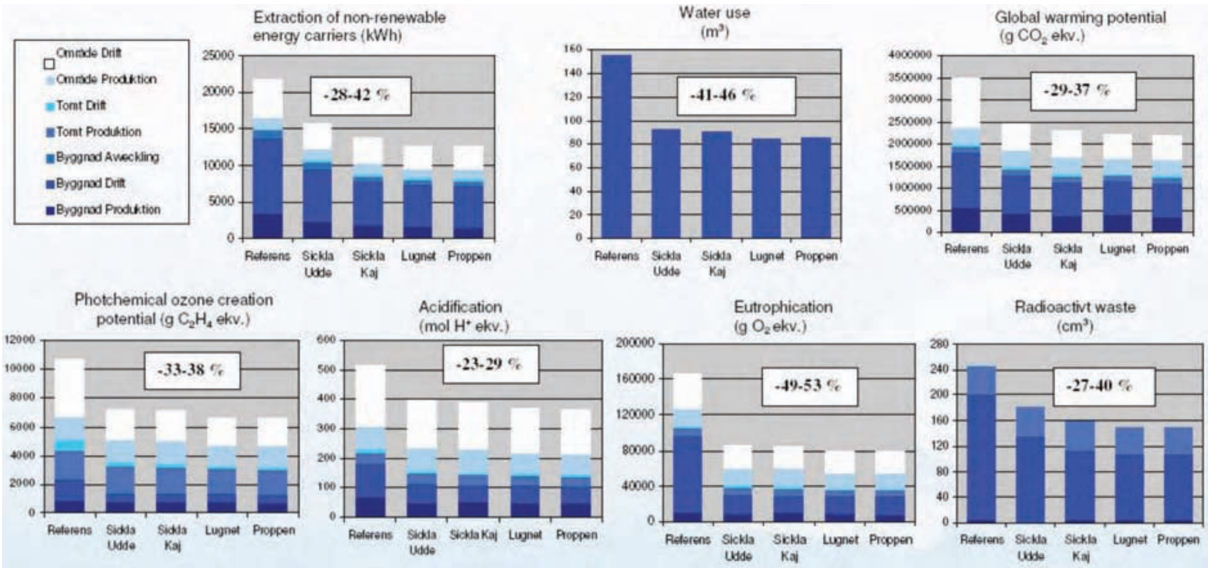


Figure 2.49. ELP-related Achievements in Hammarby Sjöstad. *Environmental impacts* per apartment and year compared to the reference. The environmental load profiles illustrate both the effect of the property developer's measures, and the effects from improved energy production and wastewater management (Levin et al, 2004).

planning of the area, such as for district heating, urban transport, waste, and wastewater management.

The monitoring of the Hammarby Sjöstad environmental program contributes to the technical and economical understanding of appropriate societal and financial environmental measures for the continued development of the district. Results of the monitoring may also be useful in planning or undertaking similar projects.

The ELP in the planning process

Environmental planning has not been the norm in the past, and it is apparent that there is still much room for improving and reducing the environmental impacts of urban development initiatives. Having a proactive approach and analyzing the potential to improve the planning process makes it more likely that cost-effective measures may be adopted that significantly contribute to increased sustainability.

Further improvements may be possible in three areas: 1) the upstream system (streams of materials and services flowing into the area); 2) the core system (the actual project); and/or 3) the downstream system (management of waste flows and reuse of materials).

(i) Improvements in the upstream system can be realized through improved energy production (electricity and heating) and raw materials production.

(ii) Improvements in the core system can be realized through improved construction and maintenance, installation of solar cells or heat recovery systems, and human behavioural change, particularly to promote energy conservation.

(iii) Improvements in the downstream system can be realized through improved waste and wastewater management, including recycling and reuse.

By using the ELP in the planning process, different options can be analysed and various interventions can be vetted from an environmental point of view. By adding the cost of environmental impacts to the analysis of alternatives, the lifecycle perspective can be visualised.

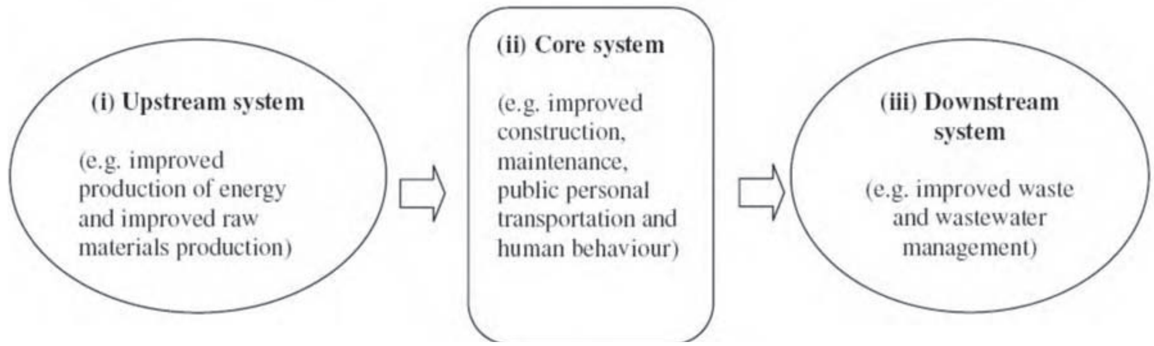


Figure 2.50. Opportunities to Reduce Environmental Impacts. Opportunities to reduce the environmental impacts in the building sector in the upstream system, the core system and in the downstream system.

It is becoming more important to have good decision making tools like the ELP. The ELP allows for comprehensive assessments and more precise target-setting. By following-up on outcomes and providing feedback to stakeholders and actors, the ELP also contributes to building knowledge and gradual improvement.

Foresight Workshops and Resiliency Planning

A Method for mitigation and adaptation

Credible forecasting is essential for all development planning

All cities require the capacity to forecast. A city's land use plan is typically driven by population and economic demand, and relies on plausible forecasts of the demand for land and services. Thus, credible forecasting is a necessary part of directing public investments, and is essential for gaining support from potential financial partners and other stakeholders.

Forecasting is always a challenge. Demand for services—of any type—can vary greatly, depending upon the assumptions made regarding population growth, occupant lifestyles, new technology, and pace of development. Transformative forces can also impact demand. For example, population migrations, climate change, and globalization can lead to large scale changes in local demand for land and services. Sea level rises might alter the location of shorelines and dislocate neighborhoods and infrastructure. Increased frequency of wind storms might require more space dedicated to tree breaks, pedestrian shelters, and underground services. A global economic crisis, fuel price hikes, or changes in rainfall patterns might increase the need for food security and require more space and water for urban gardens and local agriculture. The range of threats and mitigation plans for cities today cover a very broad spectrum and are subject to constant change.

In reality, the forecasting challenge far exceeds the capacity of any city at the moment. The best place to begin is to generate the best possible demand and supply forecasts, using whatever data and practical models available. Over time, it becomes possible to augment such forecasts with insights on how changes in climate, technology, and other external factors might influence key assumptions.

The first step is developing the capacity for forecasting land use demands

At a minimum, standardized methods should be used to estimate demand for housing, commercial space, and industry. The demand is driven by population growth and economic indicators. Generally, the process begins by assuming reasonable population growth rates under margins of uncertainty over a 30-year period. This creates both high and low growth scenarios.

Population growth is translated into housing demand by dividing the population into subsets based on age and socio economic status. Then, one associates with each subset a propensity for different types of housing: low rise apartments, large detached houses, high rise dwellings, and so on. Predictions can thus be generated for the demand for different types of housing.

The second challenge is to forecast supply. Ideally, this is accomplished using a GIS tool that allows for easy contingent analysis. Existing zoning or a set of zoning options is used as a basis for equating land areas with potential numbers of housing by type. Based on these assumptions, each area of land has a build-out capacity, and this limits the supply of units in the city. It is then a simple matter of comparing the demand forecast with the supply forecast, and identifying gaps for specific types of housing. The same forecast provides a basis for estimating gaps in infrastructure capacity—for roads, transit, water, and energy.

A similar forecasting process can be used for commercial and industrial demand and supply. Ideally, the residential forecasts are considered in concert with the commercial and industrial, due to interdependencies.

Foresight Workshops can be used to better understand Impacts of external forces

A number of techniques have been developed specifically to engage large groups of experts in envisioning the long-term future and developing appropriate design strategies. Some traditional foresight tools have proven to be quite difficult to apply—for example, the 'Delphi' technique, developed by RAND researchers in the 1950s has not been particularly successful as a predictive method. However, a host of other visioning and exploring techniques can now be used to bring groups of experts together as part of 'think-tanks' or workshops on future urban issues. Such techniques can be referred to as 'creativity tools,' and include trial and error, brainstorming, morphological analysis, method of focal objects and lateral thinking. In urban planning and design, communicative planning has been promoted as a field-tested method for engaging stakeholders and experts in a more dynamic, open-ended enquiry. An example is the Sustainable Cities Program's *European Awareness Scenario* (Bilderbeek, 1994). Extensive engagement exercises of this type have at times been intellectually and physically trying for participants. These exercises thus carry some risk that stakeholders may lose interest. In this context, the success of collaborative planning may depend on tools that promote a simpler 'systems approach' and involve stakeholders in more intense, time-limited exercises, such as design charrettes and foresight workshops.

A Foresight Workshop consists of a progressive series of presentations and exercises intended to introduce designers and planners to the potential for proactive risk management through resilient land use and infrastructure design. Typically, it begins with an exploration of how external forces might impact urban and rural systems within the region. A summary presentation or a set of papers may be provided that covers the local context on the five major forces: Demographics; Climate Change; Technological Change; Globalisation; and Sudden Shocks. Foresight Papers review the patterns and trends for each force and how it might impact the urban region.

As part of the workshop, sub-teams may explore how forces might impact different urban systems: mobility; housing; buildings; land use; energy; materials and waste; water; health; information and communications; security; agri-food; and the economy. The sub-groups can use graphical tools to assist in forecasting.

Decision trees, influence diagrams, and belief nets are examples of tools that support the 'front end' of a decision analysis. A particularly effective technique is to use Influence diagrams for structuring and facilitating dialogue. For many people, an influence diagram is the easiest way to understand a series of cause and effect chains, although, strictly speaking, the causality is not always direct or restricted to the elements shown, and thus the terms ‘influence’ or ‘relevance’ are used. These diagrams are easy and intuitive to draw; they allow easy numerical assessments. Most importantly, they visually communicate independencies between variables. By visually displaying changing assumptions, they allow groups to focus on internal dependencies as a whole, rather than in disjointed sections. Aspects of inference, prediction, and decision can be drawn using simple nodes and arrows, and discussed at a non-technical level, with a view to reinforcing a systems perspective. These diagrams also can provide a foundation for more complex modeling between groups.

An example template for an influence diagram is shown in Figure 2.52. Each unique cause and effect chain leads to potential impacts on economic, social and, environmental aspects of the region. With help from specialists, sub-teams can employ such diagrams to map cause and effect chains, and impacts on the four capitals for each major force and urban system.

The interdisciplinary sub-teams can then explore specific **interventions,** or alternative designs, for mitigating any significant negative impacts in their influence diagrams. In this way, the influence and intervention diagrams become a framework or mind map, helping interdisciplinary groups to explore the longer-term vulnerabilities of the region, and then develop mitigation strategies. A Foresight Workshop can orient design teams to unfamiliar topics, like security and resiliency. Such a workshop also initiates capacity building in the larger field of resiliency planning. Most designers and planners have little understanding of future studies, including on such topics as technology scans; S. Curves and innovation cycles; risk management; and the accelerating pace of change in many urban systems. While many of these concepts are difficult to grasp and integrate into daily practice, the Foresight Workshop exercises allow pragmatic issues to be discussed, and complex concepts to be presented, in visual formats that can be easy to understand and reference.

A Foresight Workshop also creates the possibility for generating initial design solutions that promote resiliency. These workshops represent opportunities to explore adaptable designs. Designs that are versatile and durable favour simplicity, factor in redundancy, allow upgrades, opt for independence, and minimise destructive change. These workshops are also chances to demonstrate the benefits of ecological design solutions, such as compartmentalization and modularization, which help to reduce the vulnerability of systems to the failure of any single part.

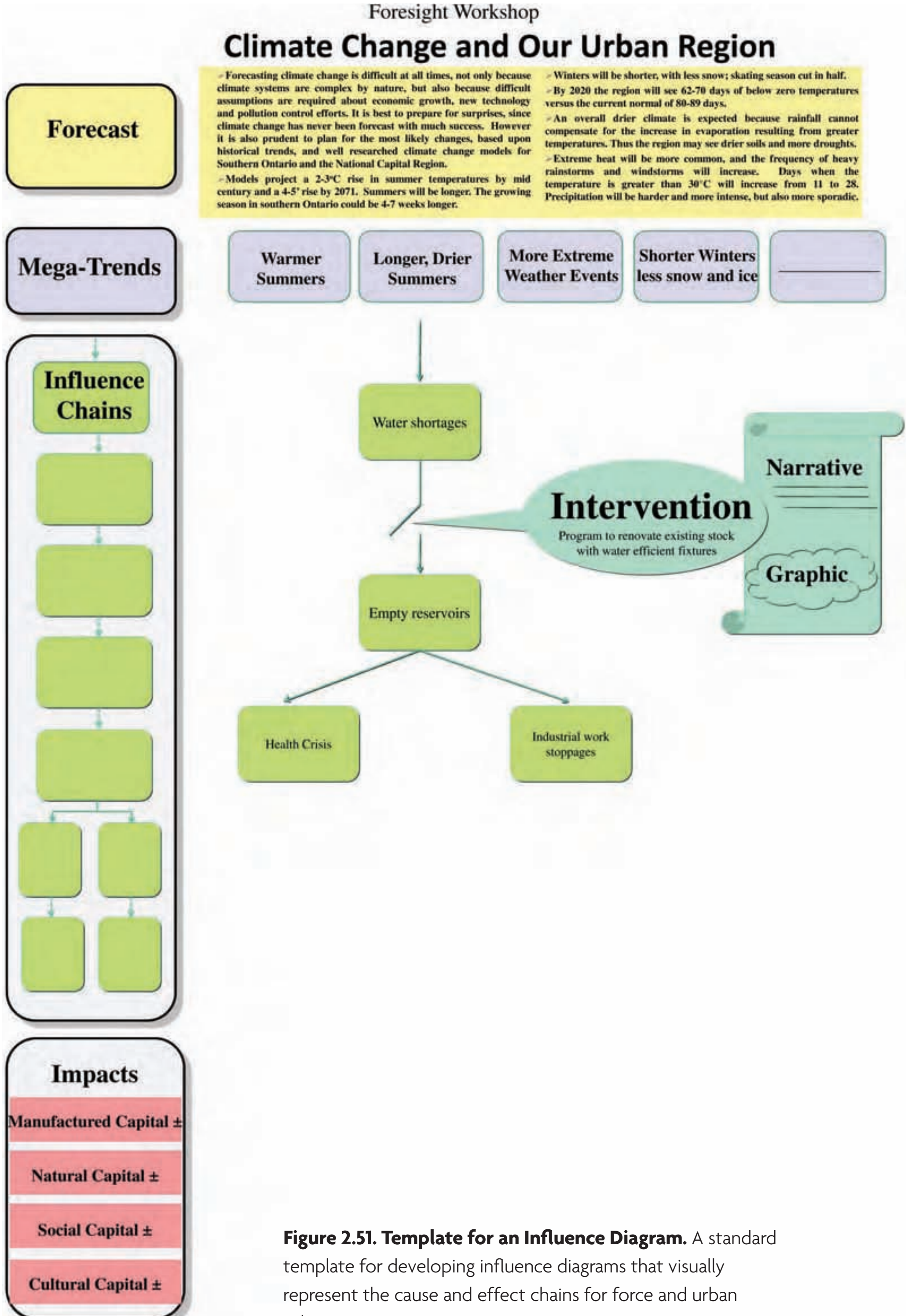


Figure 2.51. Template for an Influence Diagram. A standard template for developing influence diagrams that visually represent the cause and effect chains for force and urban subsystems.

PART 3

Field Reference Guide

A City-by-City and Sector-by-Sector Lens on Urban Infrastructure

Introduction

The Eco² Field Reference Guide is a technical resource specially tailored to build ground level and technical knowledge. This part of the book contains background literature designed to support cities in developing in-depth insight and fluency on relevant issues at two levels. This section provides a city-by-city and sector-by-sector lens on urban infrastructure. It begins with a series of case studies from best practice cities around the world. Each city offers the program a different example of how various elements of the Eco² approach can be applied. Most of these cities have already agreed to be partners in the Eco² Cities Program. The next section comprises of a series of Sector Notes, each of which explores sector specific issues as they pertain to urban development. The sectors include energy, water, transport, and solid waste. This section also includes a note on managing the spatial structure of cities. Together, these sector notes provide insight on how each sector functions and how they interrelate. As we view these issues through a city-by-city and sector-by-sector lens, the bigger picture starts to emerge. Finally, Part Three concludes with information on the specific financial instruments of the World Bank Group and some multi-donor funds.

CASE 1

Curitiba, Brazil

Cost is no barrier to ecological and economic urban planning, development, and management

Curitiba shows that cost is no barrier to ecological and economic urban planning, development, and management. Curitiba has developed a sustainable urban environment through integrated urban planning. To avoid unplanned sprawl, Curitiba directed urban growth linearly along strategic axes, along which the city encouraged high density commercial and residential development linked to the city's integrated Master Plan and land-use zoning. Curitiba adopted an affordable but innovative bus system rather than expensive railways that require significant time to implement. Curitiba's efficient and well designed bus system serves most of the urban area, and public transport (bus) ridership has reached 45 percent.[1] The city now has less traffic congestion, which has reduced fuel consumption and improved air quality. Green area has increased, mainly from parks created to improve flood prevention, and regulations that have enabled transfer of development rights to preserve green areas and cultural heritage zones. As part of efforts to concentrate shops and facilities in the city center and along dense axes, Curitiba's car-free city central zone, including its main streets and recreational facilities such as parks, became more walk-able, lively, and attractive to citizens. Crime also decreased. In addition, citizens, particularly the poor, are provided with opportunities to participate in environmental activities and educational programs.

Figure 3.1 Cityscape of Curitiba
Source: IPPUC

The social, economic, and environmental elements of Curitiba's sustainable development are facilitated by integrated land-use, public transport, and street network plans. Much of the success of Curitiba can be attrib-

Figure 3.2 Policy Integration in Curitiba
Source: IPPUC

Profile of Curitiba and Metropolitan Region[a]

Curitiba

- The Capital of the State of Parana in the south of Brazil
- Land area: 432 km^2
- Population (2008): 1.83 million
- Annual Population Growth Rate: 1.86%
- The city is bordered by the Iguaçu River in the east and Passaúna Park in the west.
- The city is located at the center of Brazil's largest economic corridor comprising major cities such as Brasilia, Rio de Janeiro, São Paolo, and Porto Alegre, and South American cities such as Montevideo and Buenos Aires,

Curitiba Metropolitan Region (RMC)

- RMC consists of 26 municipalities including Curitiba.
- Land area: 15,622.33 km^2
- Population (2008): 3.26 million
- Population Growth Rate: 2.01%

Map 3.1 Location of Curitiba
Source: IPPUC

Population Growth in Curitiba[b]

YEAR	1960	1970	1980	1991	2000	2007	2008[c]
Population ('000 persons)	361	609	1,025	1,315	1,587	1,797	1,828
Population Density (persons/km^2)	836	1,410	2,373	3,044	3,674	4,161	4,232
Green Area (km^2/ person)		1 >					51.5

a. Figures are from presentation by IPPUC (Institute for Research and Urban Planning of Curitiba). 2009. "The City of Curitiba: Planning for Sustainability—an Approach all Cities Can Afford" presented at the World Bank, Washington D.C., March 31.
b. Figures are from IPPUC (Institute for Research and Urban Planning of Curitiba). n.d. http://ippucnet.ippuc.org.br (accessed: January 15, 2009).
c. Figure for 2008 from presentation by IPPUC (Institute for Research and Urban Planning of Curitiba). 2009. "The City of Curitiba: Planning for Sustainability—an Approach all Cities Can Afford" presented at the World Bank, Washington D.C., March 31.

uted to its Institute for Research and Urban Planning of Curitiba (IPPUC), an independent public authority that handles not only research and planning, but also implementation and supervision of urban plans. The IPPUC has coordinated different aspects of urban development and ensured continuity and consistency in planning processes amid turnover in city administrations. This is an illustration of successful path dependency in urban development in terms of spatial, institutional, and cultural aspects.

Approaches and Ecological / Economic Benefits

Curitiba took various innovative approaches to ecological and economic urban planning. The following are its five major approaches.

1. Innovative Land Use Planning Integrated with Transport Planning

Urban sprawl and concentrated traffic in Curitiba's downtown area was anticipated due to rapid population growth. The city formulated a Master Plan in 1966 that integrated land-use and transport plans. Curitiba decided to direct urban growth linearly by designating structural axes radiating from the city center (Figure 3.3). Major economic activities are concentrated along these corridors, and the city appears to have a linearly formed downtown. At the same time, the city center was reinforced with high density development (Figure 3.4). The structured corridors became major public transport routes under a Bus Rapid Transit (BRT) system that includes dedicated lanes and bus stops nearly every 500 meters.

To realize this plan and guide linear urban growth, Curitiba implemented detailed zoning plans that reflect the Master Plan's strategic vision, geographic and geological constraints, water and wind directions, Curitiba's industrial profile, and urban cultural and social factors. In 2000, Curitiba had 50 types of specific zoning categories (Figure 3.5). Each zoning category defines requirements related to land-use, building-to-land ratio, floor-area ratio (FAR), and maximum building heights. For example, in the city center area, the zone ZC category allows development of residential apartments and commercial and service facilities (except supermarkets) subject to specific parameters: FAR up to 5, first floor building to land ratio up to 100 percent, and no limit in building heights in most areas (however, to ensure aesthetics, buildings are normally limited at 20 floors, and to secure flight routes, some areas have building height limitation). In addition, many zones facing structural axes (i.e., zone SE) allow development of residential apartments and commercial and service facilities with FAR up to 4, first floor building-to-land ratio up to 100 percent, and no limit in building heights in most of the areas (again, to ensure aesthetics, buildings are normally limited at 20 floors, and to secure flight routes, some areas have building height limitation).[2]

To shift the land use and growth pattern into linear forms and to provide good access to transportation services, new development was permitted *only* in areas reachable by public transportation. As Curitiba was designed for people, not cars, public transport coverage and service frequency are critical. Bus service reaches almost 90 percent of the city area (Figure 3.6),[3] and all citizens can access public transportation services by walking less than 500 meters. Bus service is provided nearly every five minutes. Curitiba initially acquired land and reserved right-of-way along the strategic axes, which enabled the city to build social housing in these areas. Subsequently, major economic activities and urban functions, in-

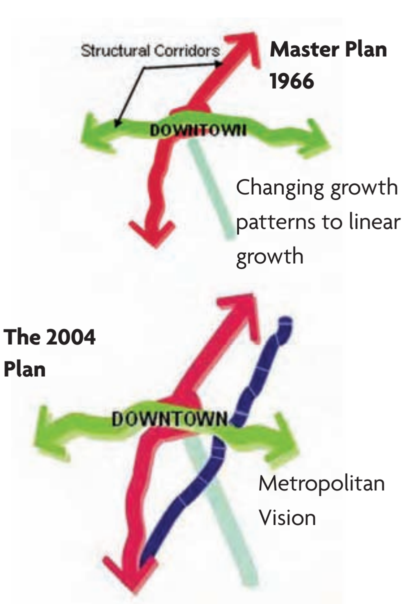


Figure 3.3 Urban Growth Axes
Note: Presentation by IPPUC (Institute for Research and Urban Planning of Curitiba). 2009. "The City of Curitiba: Planning for Sustainability—an Approach all Cities Can Afford" presented at the World Bank, Washington D.C., March 31.

Figure 3.4 Density of Curitiba (2004)
Note: IPPUC (Institute for Research and Urban Planning of Curitiba). n.d. http://ippucnet.ippuc.org.br (accessed: January 15, 2009).

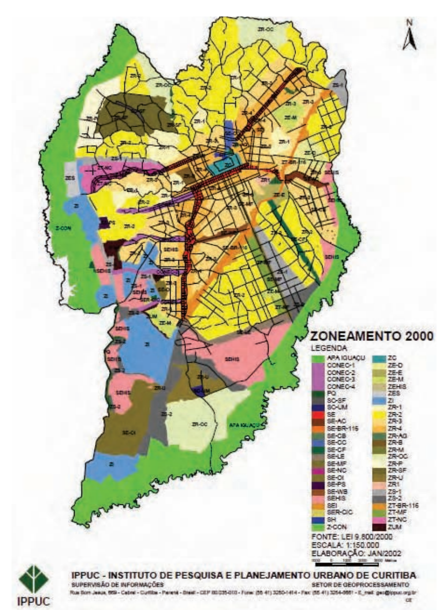


Figure 3.5 Zoning of Curitiba (2000)
Note: IPPUC (Institute for Research and Urban Planning of Curitiba). n.d. http://ippucnet.ippuc.org.br (accessed: January 15, 2009).

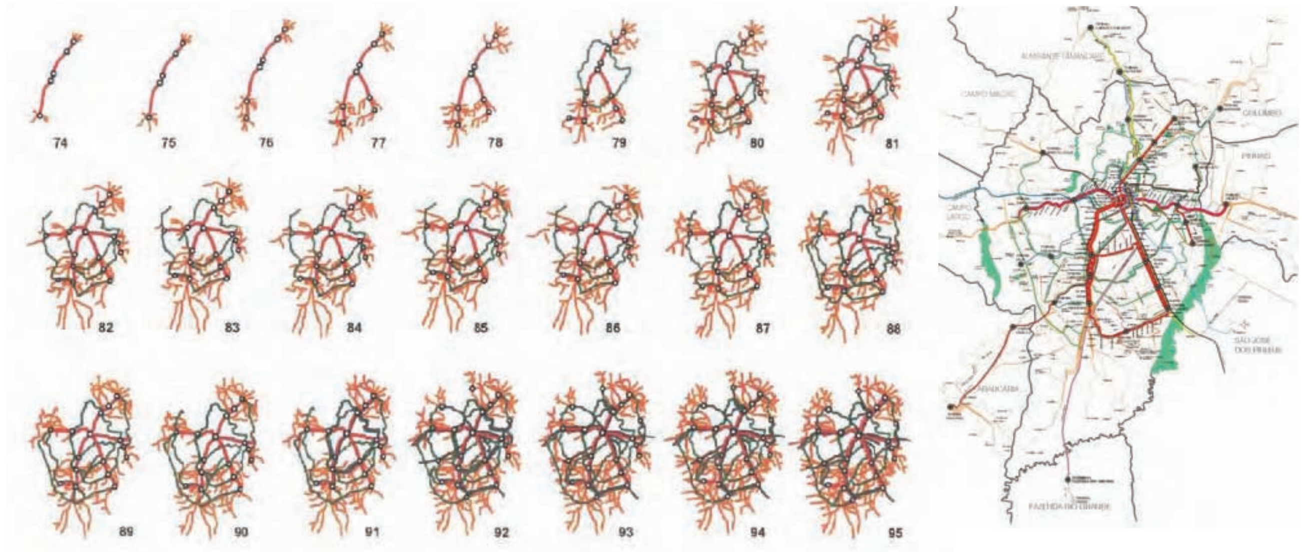


Figure 3.6 Evolution of the Integrated Bus Network (1974–1995, and 2009)
Note: Presentation by IPPUC (Institute for Research and Urban Planning of Curitiba). 2009. "The City of Curitiba: Planning for Sustainability—an Approach all Cities Can Afford" presented at the World Bank, Washington D.C., March 31.

cluding residential neighborhoods and schools, were reorganized densely along these axes.

To accommodate BRT routes and fulfill transportation needs along the axes, the city designated functions to existing roads under its Trinary road system. The five major axes now accommodate both dedicated BRT lanes and roads to access buildings. Cars that do not need to access services along the axes can bypass these areas by using roads parallel to the axes (Figure 3.7). In addition, to avoid concentrated traffic in the city center, a former mayor decid-

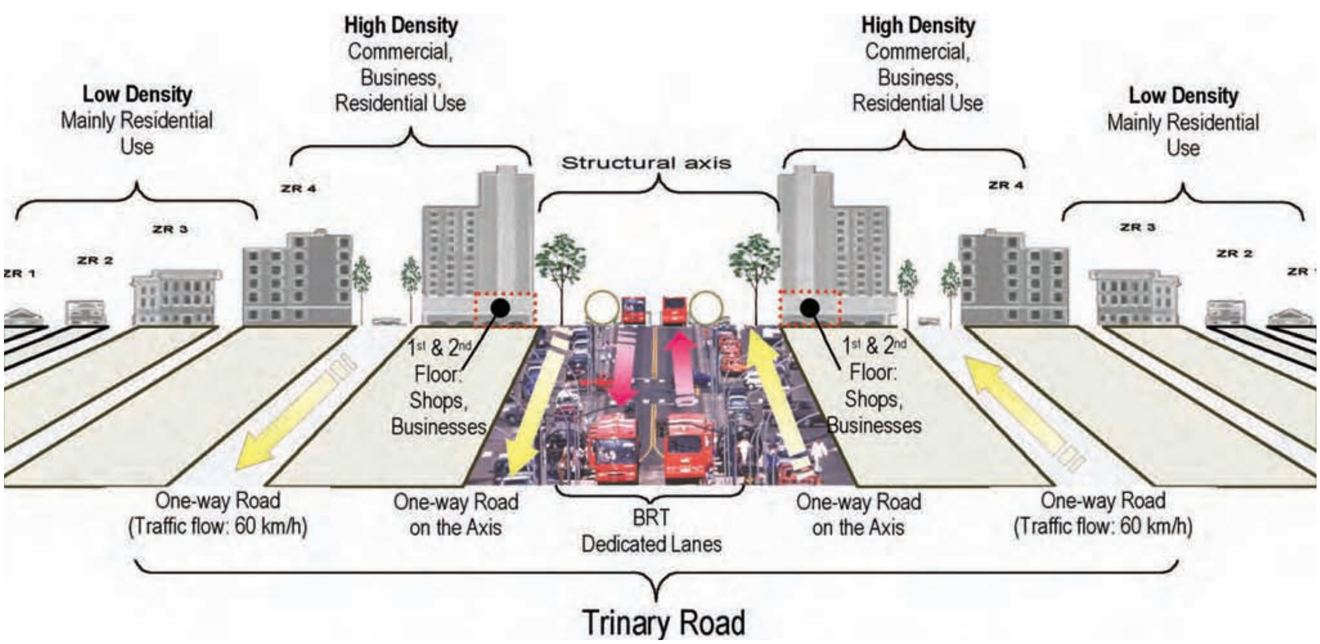


Figure 3.7 Trinary Road System and Structure
Note: Based on presentation by IPPUC at the World Bank on March 31, 2009. The City of Curitiba: Planning for Sustainability- an Approach all Cities Can Afford, and Hattori, K. (2004) 人間都市クリチバ (Human City Curitiba). Kyoto: Gakugei Shuppan Sha.

ed to transform certain streets in the city center into pedestrian streets that prohibit cars.

Under these measures, Curitiba's spatial growth and urban land use patterns have been efficiently controlled and defined. Traffic is diverted from the city center or axes thanks to an effective mixture of land use planning and a well-conceived public transport network. Because housing, service facilities, and job centers have been incrementally developed along the axes and linked to the BRT, distances between homes, jobs, and schools have shortened, and many people travel by bus. Bus ridership as a percent of all commuting trips reaches 45 percent, and 70 percent of these bus trips bypass the downtown area.[4] As a result, the city has reduced car emissions and congestion, thereby saving time and enhancing economic activity. A calculation based on 2002 data estimated that Curitiba loses R$2.55 million (US$1.2 million) annually from time lost to severe congestion. Curitiba's per capita loss from severe congestion is about 6.7 and 11 times less than per capita losses in Rio de Janeiro and Sao Paulo, respectively. In 2002, Curitiba's annual fuel losses from severe traffic congestion equaled R$1.98 million (US$930.000). On per capita terms, this loss is about 13 times and 4.3 times less than those in Sao Paulo and Rio de Janeiro, respectively. In contrast, in 2000, congestion in United States' 75 metropolitan areas caused fuel and time losses valued at US$67.5 billion. Curitiba's fuel usage is also 30 percent lower than in Brazil's other major cities.[5] Reduced car emissions have decreased air pollution, which can threaten public health. Curitiba now has one of the lowest rates of ambient air pollution in Brazil.[6] In addition, emission of greenhouse gases that affect climate change has fallen.

Traffic flow has been diversified by assigning a logical and efficient road hierarchy, which has obviated needs to undertake substantial remedial works, such as widening street space, which can entail destroying buildings and disrupting neighborhoods. By making the most of infrastructure and adding new functions and traffic rules, the city saves construction costs. By avoiding extensive unplanned urban sprawl, investment in infrastructure is minimized and concentrated along the axes, and installation of water pipes or cables into new areas is avoided. More people come to the city center to walk pedestrian streets, increasing economic opportunities for local shops compared to mainly car driven streets.

2. Integrated Public Transport System

The construction cost of Curitiba's BRT system was US$3 million/km, which was more affordable than a tram system (US$8–12 million/km)

Table 3.1 Time and Fuel Loss Due to Congestion[a]

	CURITIBA (2002)	SAO PAULO (2002)	RIO DE RIO DE JANEIRO (2002)	UNITED STATES[b] (2000)	TOKYO, JAPAN[c] (1994)
Time Loss Total (million US$/ year)	1.20	79.94	27.48	—	—
Time Loss Total (US$/year/ per capita)	0.67	7.34	4.51	—	—
Fuel Loss Total (million US$/ year)	0.93	73.23	13.47	—	—
Fuel Loss Total (US$/ year/ per capita)	0.52	6.72	2.21	—	—
Time+ Fuel Loss Total (million US$/ year)	2.13	153.17	40.94	67,500 (75 cities total) 900 (average)	4,900
Time+ Fuel Loss Total (US$/ year/ per capita)	1.19	14.07	6.72	—	4,100

a. Confederacao Nacional Do Transporte (2002) *Transporte de Passageiros.* Vassoler, I. (2007) *Urban Brazil.* New York: Cambria Press.
b. Downs, A. (2004) *Still Stuck in Traffic.* Washington DC: Brookings Institution Press.
c. Calculation based on loss of travel speed from 30km/h to 18km/h. Tokyo Metropolitan Government. 2000. *Transportation Demand Management Tokyo Action Plan.*

or a subway (US$50-100 million/km).[7] The BRT along the main axes works like a surface subway system. Moreover, compared to normal buses, bus run times are one third and costs are 18 percent less owing to several factors: a 72 km dedicated bus lane, a fare system requiring payment before boarding, and a tube-shaped bus station design that eases bus entry and exit.[8]

The bus system is color coded and designed for various scales and levels of service (inter-district, feeder, inter-municipal etc.) to reach more areas of the city (Figure 3.9). The bus system adopts a flat "social fare". No matter how far a person rides a bus or how many times a person transfers, one pays only one fare. The poor tend to live in the urban periphery and need to travel long distances to commute, while the wealthy tend to live in the center and need to travel less far. 80 percent of citizens are estimated to benefit from the "social fare".[9] Frequent high quality services and inexpensive fares encourage people to use buses. As noted, 45 percent of total trips are made in buses. 5 percent of trips are by bicycle, 27 percent by foot, and 22 percent by private car,[10] which is surprisingly low given that Curitiba has the second highest car ownership rate in Brazil.

Figure 3.8 Bi-articulated BRT Bus and Bus Station
Source: IPPUC

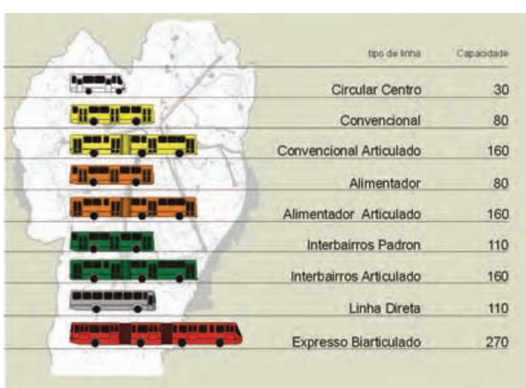


Figure 3.9 Color-coded Buses and Their Capacities
Source: IPPUC

Buses running on the BRT's dedicated lanes are bi-articulated, and fleets are kept relatively young—on average little over 5 years and not more than 10 years old. Buses are well maintained, and are less polluting. The greater carrying capacity of Curitiba's bi-articulated buses (270 people) and reduced travel times linked to their use resulted in 50 percent less energy consumed compared to non-articulated conventional bus services.[11]

The BRT system pays for itself. Bus fares finance the system—generating profit for the bus companies, covering costs for human resources, as well as the maintenance and depreciation of buses without government subsidy. According to law established in 1990, transportation revenue is exclusively dedicated to paying for the BRT system.[12] In comparison, in some German cities with light rail, fare revenue covers only 30 percent of operational costs, thus subsidies from the federal government are required. In the United States, subsidies for light rail often come from consumption taxes.[13] The operation of the BRT in Curitiba is managed by a city agency entitled *Urbanização de Curitiba* (URBS), but served by private bus companies. The bus companies are paid based on distance traveled, not by number of travelers, so they are encouraged to operate even in areas with fewer riders. Moreover, people are more motivated to use buses when bus service is frequent.

3. Green Area Enhancement and Flood Control

To improve its citizens' quality of life, Curitiba decided to enhance green areas and recreational facilities, such as parks and bike paths within the city. Surrounded by rivers such as the Iguaçu, flooding has been a big problem in Curitiba. Instead of controlling water flow using concrete structures, Curitiba created natural drainage systems. Riverbanks were converted into parks where overflow water can be absorbed in the soil, and lakes were constructed to contain floodwaters. River and rain water flooding can be held naturally in the lakes and parks surrounding the lakes (Figure 3.10). The ecosystem is thus preserved naturally. As the park area gradually releases flooded water that has been absorbed into the ground, rather than draining water rapidly through concrete drainage into rivers, flooding downstream can be avoided. In addition, people are less exposed to flood-linked environmental hazards and diseases. In short, the costs of building parks and relocating slum (favela) dwellers are estimated to be five times more economical than building concrete-made canals.[14] Enormous costs are required to construct drainage canals and flood control apparatus, not to mention the costs of flood damage and disease control measures that may have been avoided.

Flood control areas are normally used as parks and recreational areas. Green area has been enhanced from less than 1m^2/person in the 1970s[15] to 51.5m^2/person.[16] There are 34 parks in the city, and green area covers about 18 percent of urban land.[17] Bicycle paths are provided along streets and inside parks, with the total length of the bike network about 120 km. Though the park area was expanded, the city lacked budget to maintain park grass. Instead of hiring mowers, sheep are kept in the parks to eat grass and provide natural fertilizer, which has reduced park maintenance costs by 80 percent while enhancing the ecological image of the city.

Flood prone lands used to be occupied by slum dwellers. Curitiba acquired those lands and relocated the slum dwellers to better land and provided compensation. After the park was established, the zone facing the park became an area with high-end housing. Houses with good views of the park and lake have high real-estate values, thus property tax revenue has increased. Property taxes collected from these high-end houses are estimated to be equivalent to the cost of park construction, including slum relocation and compensation.

Figure 3.10 Barigüi Park.
This area was once flood-prone and occupied by slum dwellers. It is now a converted 140ha park with a 40ha of lake.
Source: IPPUC

Figure 3.11 Slums in Flood-prone Area
Source: IPPUC

Many trees can be found in Curitiba. There are 300,000 trees along public streets that create shade and prevent heating.[18] Trees absorb pollutants as well as CO_2. Curitiba's reserved forest areas capture an estimated 140 tons of CO_2 per hectare, which can reduce impacts on climate change.[19] In addition, shade from trees

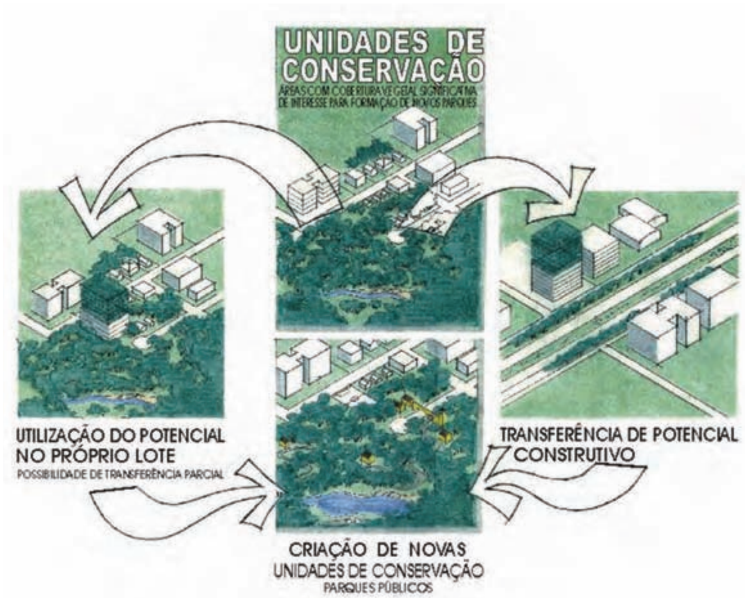


Figure 3.12 Transfer of Development Rights for Environmental Preservation
Source: IPPUC

cools buildings and the environment, which saves energy.[20] City regulations restrict the area of developable private land depending on the ratio of land to forest or trees. To encourage urban trees, compensation is offered to landowners, such as relaxation of floor-area ratios and tax reductions. For example, by having one Paraná Pine tree on private land, the city tax is discounted by 10 percent. Also, rights to develop forest areas can be exchanged for rights to develop other city areas (Figure 3.12). The IPPUC regulates and monitors the implementation, negotiation, and transfer of development rights between interested parties (i.e., private developers and landowners) guided by market principles. As such, the city does not need to undertake relocation or assume land acquisition costs of creating green areas or preserving historical areas.

4. Solid Waste Management

Curitiba has several innovative programs in solid waste management. Curitiba's landfill was strained, and the city did not have sufficient revenue to build an incinerator. To slow the growth of waste, Curitiba initiated unique waste management programs that depend on citizens rather than constructing new and expensive waste treatment facilities. What is innovative is that these programs not only reduced the growth of waste, but also offered opportunities for poor people, which is one of the critical aims of the city.

Curitiba's "Garbage that is not Garbage" program encourages people to separate discards into recyclable and non-recyclable waste. To raise awareness of this program, children are educated to understand the importance of waste separation and environmental protection. Campaign mascots are created and school activities are organized. One to three times a week, trucks collect paper, cardboard, metal, plastic, and glass that have been sorted at homes. This recycling saves the equivalent of 1,200 trees a day,[21] and local parks contain displays on

Figure 3.13a Curitiba's Waste Program: "Garbage that is not Garbage" Program
Source: IPPUC

Figure 3.13b Curitiba's Waste Program: "Green Exchange" Program
Source: IPPUC

the numbers of trees saved. Money raised from selling recyclables supports social programs, and the city employs the homeless and those in alcohol rehabilitation in its garbage separation plant. Recycling also leads to other benefits. For instance, recycled fiber is used to produce asphalt for roads. Recycling has also eliminated piles of discarded tires, which can attract mosquitoes that transmit dengue disease. Proper tire collection has decreased dengue disease by 99.7 percent.[22] Nearly 70 percent of residents participate in Curitiba's recycling program. 13 percent of Curitiba's waste is recycled, which greatly exceeds the 5 percent and 1 percent recycling rates in Porto Alegre and Sao Paulo, respectively, where education on waste dissemination has not translated into significant impacts.[23]

A "Green Exchange" program was also started in Curitiba's slum areas that are inaccessible to waste collection vehicles. To encourage the poor and slum dwellers to clean areas and improve public health, the city began offering bus tickets and vegetables to people who brought garbage to neighborhood centers. In addition, children have been allowed to exchange recyclables for school supplies, chocolate, toys, and show tickets. The city purchases vegetables at discounted prices from farmers who have trouble selling abundant products. Through this program, the city saves the costs of arranging waste collection in slum areas, which often have inadequate roads, and helps farmers to unload surplus produce. The program also helps to improve nutrition, transport accessibility, and entertainment opportunities among the poor. Most importantly, slums are cleaner and have less disease and less garbage dumped in sensitive areas such as rivers.

5. Curitiba Industrial City

In the 1970s, Curitiba's economy was based mainly on the service sector. To attract investment, boost employment, and reduce poverty, the IPPUC decided to introduce manufacturing industries. To further this goal, the local government established the Curitiba Industrial City (CIC) on the city's west side, taking into account wind direction to avoid polluting the central city. The CIC has extensive green areas encompassing 4300 hectares, and is well connected to the bus network. Many employees at the CIC live close to the CIC and commute by bicycle.

The CIC has strict environmental regulations and "polluting" industries are not allowed. After three decades, the CIC today includes more than 700 companies, including global firms such as an automaker producing BRT buses and information technology companies. The CIC has created about 50,000 direct jobs and 150,000 indirect jobs. About 20 percent of Parana State's exports originate from the CIC.[24]

6. Social Considerations

Although Curitiba's economy is relatively developed compared to those in other Brazilian cities, many poor people still live in slums. To encourage the poor to obtain jobs and promote an inclusive community, Curitiba has adopted various innovative social approaches.

The city converted the undeveloped land under a high voltage line in a southern area of the city into a "Job Line" that helps people to start businesses and encourages growth of the local economy. Two social incubators provide trainings and facilities to establish local business, and 12 entrepreneur sheds were created.[25] In addition, these facilities offer entrepreneurial capacity building. Underutilized occupied land was cleared, people were relocated, and public transport services were commenced, which represented steps toward land recovery.[26]

One of the largest problems in Curitiba has been slums. Those who do not have their own land occupy and settle on private land. Often, these areas become derelict, causing river pollution and fomenting crime. Rather than spending time and money on relocating squatters and cleaning occupied areas, the city pre-purchased

Figure 3.14 Illegal Occupancy
Source: IPPUC

lands that might be occupied from landowners at low prices. The city then provided this land as "legal" land for "unofficial" occupancy. A formal land use zoning category (SEHIS) was developed for such land, thus these areas were integrated into city plans and residents can feel included. Simple land arrangements and water and electricity are offered because such services risk being illegally procured if not provided, which can cause fatal accidents. Occupants feel some sense of ownership over this land, and can begin to arrange roads and create quality living environments. Under city agency coordination, the value of occupied land can be reimbursed over long-term loans. In addition, legal home addresses can be provided for occupiers, which can help people to find jobs.[27]

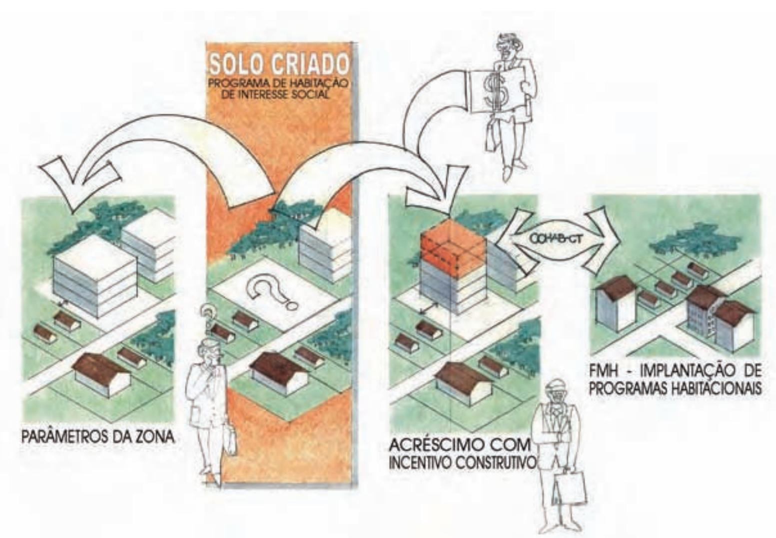


Figure 3.15 Transfer of Development Rights and Social Housing
Source: IPPUC

Curitiba provides social housing (COHAB) in the suburbs, where land prices are relatively cheap, and in the city, especially between the city center and industrial areas. Rather than encourage homogeneous income groups in neighborhoods, Curitiba encourages a mix of populations so that society becomes inclusive. Housing includes both apartments and small detached houses. The poor can often initially afford small detached houses, and owners can be provided an incentive to work by allowing them to build extensions. In Curitiba, development rights can be purchased. Money paid by developers to purchase rights to develop sites can then be used to build social housing in other areas.

City services are decentralized and are provided in major bus transit terminals. People do

Figure 3.16 Social Housing
Source: IPPUC

not necessarily travel to the city center for such services. Allowing people who live far from the city center to procure services close to home promotes equal opportunity. A flat bus fare also helps people to reach bus terminals that have city offices. In addition, city services such as education, health, cultural, and social service facilities are distributed equally throughout the city. This system provides equal, high quality, and accessible services to all citizens regardless of income.

7. Culture and Heritage Preservation

Curitiba maintains an attractive and lively cityscape. This is a result of well planned urban design and successful cultural heritage preservation. Vehicular streets in the city center were converted into pedestrian streets to allow people to enjoy the urban cultural atmosphere. Under Curitiba's 1977 Metropolitan Area Heritage Plan, 363 buildings were identified for preservation. However, as most buildings were on private land, managing their preservation was difficult. The city thus adopted a policy under which development or "building" rights can be transferred to other areas in the city. In 1993, the city identified special preservation units. Money earned from selling these structures' development rights must be used only to preserve buildings. Under these measures, money needed for preservation is mainly market generated, and the city does not need to fund preservation. In addition, Curitiba's Coresda Cidade project revitalized 44 historic buildings in the city center, and painted these buildings in their original colors. The area targeted by this project used to be crime prone and run-down. However, after revitalization, people came to the area, building owners took better care of the buildings, and the crime rate fell by an estimated 30 percent. Moreover, Curitiba provides a good case of a city revitalized by heritage preservation and good urban design. In addition, cultural facilities, which were previously lacking in the city, were established in innovative ways. A historical gunpowder house was converted into a theatre. An opera house was established in the middle of a deactivated quarry crater, surrounded by a beautiful landscape of metal tubes and glass. A botanical garden, one of the main tourist attractions, was also created in once neglected open space.[28]

Figure 3.17 Pedestrian Streets in the City Center
Source: IPPUC

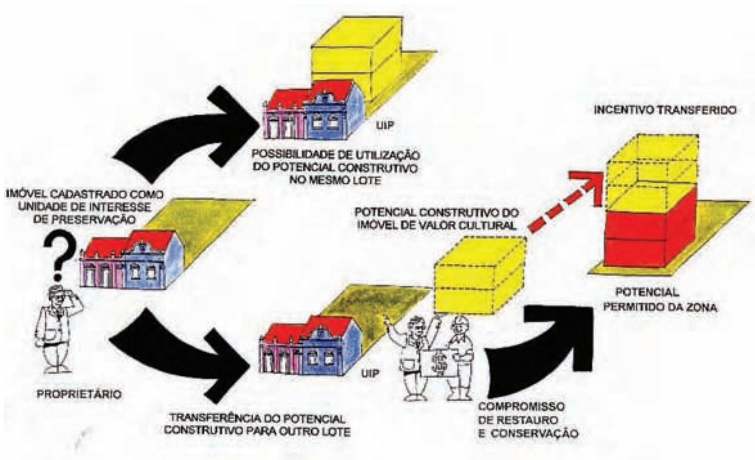


Figure 3.18 Transfer of Development Rights for Heritage Preservation
Source: IPPUC

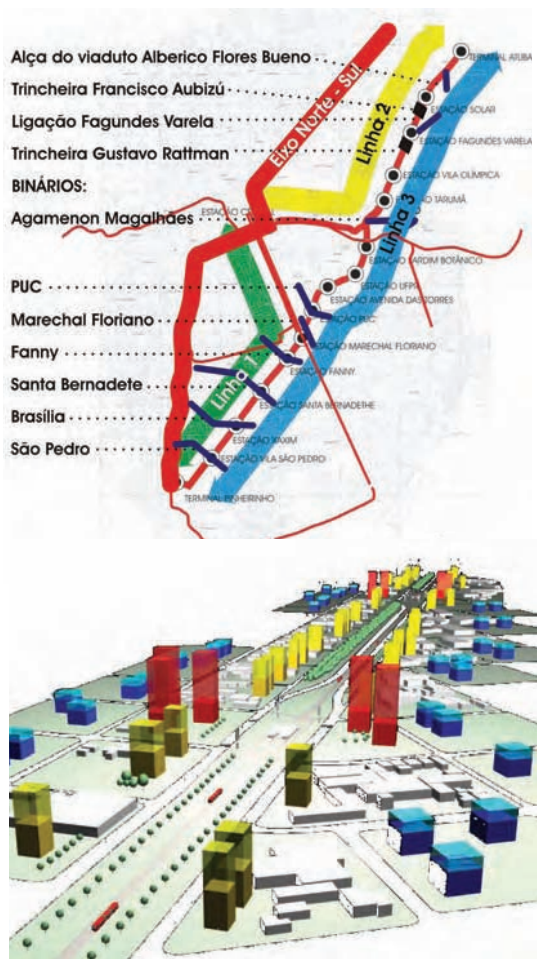


Figure 3.19 Green Line
Source: IPPUC

Future Challenges for Curitiba

Green Line: The Federal Highway 116 used to cut across the city, with dangerously heavy traffic; mainly freight trucks traveling South America's economic corridor. This cut the city into two sections in an inefficient way. In response, a beltway was created to divert traffic outside the city's boundary, and a former federal highway was converted into Curitiba's sixth axis, or the city's "Green Line." This line is expected to reduce traffic on the five axes. A new BRT route will be introduced and mixed-use high density development is planned along the Green Line to make the area more attractive. Land-use is being carefully planned to not interfere with wind circulation by creating building "walls." A linearly shaped biodiversity park will also be created along the Green Line, and only indigenous plant species will be cultivated (Figure 3.19).

Regional Integration: As the greater Curitiba Metropolitan Region (RMC) is growing, Curitiba now faces a new challenge: how to integrate city and regional planning. Migration from surrounding areas has resulted in housing shortages, which might lead to more slums. In addition, even if Curitiba has a good primary BRT system and integrated land-use, development in surrounding areas that is unconnected to the public transportation system (such as large shopping malls) may favor car use and increased traffic. In this context, Curitiba is taking steps to strengthen regional planning capacity, and is creating inter-municipal partnerships.

Lesson Learned from the Curitiba Case

Leadership and Continuity: Mayors of Curitiba have strongly focused on urban planning. Many mayors brought technical backgrounds, such as in engineering and architecture. Since the formulation of Curitiba's Master Plan in the 1960s, the direction of urban planning has been largely consistent between administrations. Curitiba places a premium on implementation and rapid action to address urban issues; if there is a 70 percent of chance of success, the city puts plans quickly into action.

Institutionalized Planning and Expertise: Curitiba's practices affect the city in several positive ways. Curitiba's success was linked to strong mayoral leadership and people's active participation in city programs. It was also attributable to IPPUC, the integrated planning institute that has been playing an important role as a "municipally independent public authority" that researches, formulates, implements, and supervises urban plans. The IPPUC provided integrated, cross-sector urban planning and oversight of implementation and monitoring, while ensuring consistency amid changes in political leadership. These holistic approaches to urban planning were brought about by planners' creativity, imagination, and good understanding of local culture. For more than 50 years, engineers and architects have undertaken urban planning to address key urban issues in integrated ways. The work of the IPPUC ensures continuity and consistency in planning processes that extend beyond the mayoral cycles since 1966, when the IPPUC was established. Curitiba made the most of its existing infrastructure and local characteristics without spending much money on new construction. Although Curitiba's activities were accomplished with little budgetary resources, tremendous benefits were achieved.

Citizen Ownership and Eco-consciousness: Citizens are encouraged and are provided opportunities to comment during urban planning processes. Public hearings with the mayor are held frequently, and proposed plans are evaluated and discussed with the community. People can speak directly to the mayor and city officials. More than 250 public hearing have been held since 2005. Citizens are actively involved in planning, as people have made the link between good urban planning and a better quality of life. The city provides opportunities for people to participate in other urban activities, such collecting garbage, constructing neighborhood roads, and maintaining green areas, which strengthen citizen ownership and maintenance of urban facilities. Children are also enrolled in environmental education activities, such as the urban waste program. Moreover, behaving in environmentally friendly ways is now the norm for Curitibanos.

Local Character: Curitiba considers its local situation, including its budget, capacity, and social conditions, when devising urban strategies. Taking into account municipal capacity, local officials develop innovative solutions to solve urban problems. For example, rather than waiting for adequate revenues to construct a subway, Curitiba implemented the BRT system, which proved affordable and quick to implement without time-consuming construction work.

CASE 2

Stockholm, Sweden

Integrated planning and management through systematic stakeholder collaboration can lead to significantly greater life cycle benefits

The City of Stockholm ("Stockholm"), the capital of Sweden, has pursued integrated city planning and management to be a sustainable city. The city has a comprehensive urban vision, environmental programs, and concrete action plans to reduce greenhouse gas emissions and tackle climate change. The city implements integrated urban planning approaches that consider ecological benefits and efficient resource use.

The ongoing redevelopment in the southern district of the city (Hammarby Sjöstad) is a good model for understanding integrated approaches to sustainable urban planning and redevelopment. The area aims to be two times more sustainable than Swedish best-practice in 1995 (the environmental program was adopted in 1995). The area implements integrated resource management (waste, energy, water, sewage) through systematic stakeholder collaboration, and has transformed linear urban metabolism into a cyclical one known as the "Hammarby Model." Primary assessments of the initially developed districts of Hammarby Sjöstad show that the area has achieved, *inter alia,* 28 to 42 percent reductions in non-renewable energy use, and 29 to 37 percent reductions in global warming potential.[29]

Figure 3.20 Stockholm Cityscape
Photo: Lennart Johansson, Stockholm City Planning Administration

Stockholm provides great leadership in planning and implementing sustainable urban development strategies. The city's "one-system" approach to resource use has been successfully implemented. In addition, Hammarby Sjöstad applied the Environmental Load Profile (ELP) tool to assess and monitor environmental performance of the development project.

Profile of Stockholm

- The capital city of Sweden, located in the northern part of Europe
- Total area: 209 km^2 (Land area: 188 square kilometers, water area: 21 km^2)
- Population (2008): 795,000
- By 2030, Stockholm's population is expected to increase by150,000

Note: Stockholm Office of Research and Statistics. 2008. *Data Guide Stockholm 2008*

Map 3.2 Location of City of Stockholm

Source: Google map

Source: City of Stockholm website

Stockholm's Approaches to Sustainable Development

Stockholm pursues comprehensive sustainable development policies. In 2007, the city adopted a strategic document entitled "Vision 2030" that charts the way forward to strengthen sustainable urban development. This document indicates that Stockholm will grow to more than a million people, and nearly 3.5 million in the greater region, by 2030. The city is expected to face new demands from globalization, trade shifts, migration, increased elderly populations, and environmental challenges. Based on the Vision 2030 document and other strategies, Stockholm has adopted an approach to urban development that moves from a strategic to a local level.[30]

Aligned with the Vision 2030, the Stockholm Environment Programme approved in 2008 established 6 environmental goals or principles for 2008 to 2011: 1) environmentally efficient transport; 2) safe goods and buildings free of dangerous substances; 3) sustainable energy use; 4) sustainable land and water use; 5) waste treatment with minimal environmental impacts; and 6) a healthy indoor environment.[31]

In addition, Stockholm has an Action Programme on Climate Change. This plan invites wide cooperation from public and private organizations and individuals who live and work in the city. Various measures have already been taken, including adoption of bio-fuels, expansion of district cooling, and promotion of economical driving. As a result, emissions of greenhouse gases fell from 5.3 tons CO_2-e/person in 1990 to 4.0 ton CO_2-e/person in 2005. The city recognizes the importance of energy efficiency to reduce emissions and tackle climate change, but also prioritizes cost-effectiveness through resource conservation. Devising ways to engage stakeholders in actions that are environmentally and economically sustainable remains a challenge for the city. Stockholm's long-term target is to be free of fossil fuels by 2050.[32]

Stockholm's Approaches to Sustainable Urban Development

As suggested in the above strategies, sustainable urban development is a key aim. Stockholm can more easily implement integrated and sustainable land use and transport plans as the city has traditionally exerted substantial authority over land planning and ownership. In 1904, Stockholm started purchasing land for future development. As a result, as much as 70 percent of urban land belongs to the city.[33] This large share of city-owned land prevented speculative land investments by developers and investors, and empowered the city in planning and implementing development. In other words, the city has a solid platform for development. Developers construct buildings and housing on public land corresponding to city plans. Because rights-of-way were easily secured, transport development was straightforward and other development was promoted around transport stations. Development benefits are now being returned to the public by planning new town areas. In addition, parks and green areas cover 40 percent of Stockholm's land,[34] and citizens enjoy an ecologically rich environment.

To promote sustainable development, Stockholm's planning strategy targets "densification"—building the city inwards by reusing developed land (Box 3.1). This is the overall objective of the Comprehensive Land-use Plan adopted by the City Council in 1999.

Old and partly abandoned industrial and harbor areas (brownfields) adjacent to the inner city are being reused and redeveloped as part of the city development strategy. Several of these strategic development areas are directly linked to a new rapid tram system, and also have direct access to other public transport systems, such as the metro line. The areas have unique qualities, as their locations often are close to water and natural areas. Some areas have been under construction for a couple years, and will provide housing as part of the city's housing programs. Other areas are at planning stages. The areas are being planned for mixed use development, with attractive housing and business facilities, and dense structures that will create a more urban atmosphere in formerly suburban areas.

Hammarby Sjöstad, one of the ongoing first redevelopment areas, is a full-scale demonstration site, and offers an example of an integrated urban development approach illustrating system solutions, innovative technology, environmental awareness, and active cross-sector collaboration.

BOX 3.1

Development Strategies of Stockholm

- Re-using already developed land (brownfield)
- Locating new development in areas with good access to public transport
- Respecting and enhancing the character of the city, e.g., the cityscape, the built environment and the green structure
- Redeveloping semi-central areas, transforming industrial areas into urban areas of mixed uses and variation
- Establishing focal points in the suburbs
- Meeting local demands
- Developing public spaces

Source: City of Stockholm

Hammarby Sjöstad

The on-going redevelopment project for Hammarby Sjöstad (which means 'city surrounding Hammarby Lake') is set on a former industrial and harbor brownfield area on the south side of Hammarby Lake, and to the south of the city center. The aim of the project is to expand the inner city into an attractive water setting, while converting a run-down industrial area into a modern, sustainable, mixed-used neighborhood. Soil will be decontaminated by removing tons of oil, grease, and heavy metals.[35] The ecosystem will be revitalized and existing eco-assets, including trees and parks, will be preserved. The redevelopment will unlock land and property values by revitalizing brownfield land. Moreover, a once shattered area will be reinvigorated, and about 11,000 new residential units and 200,000 square kilometers of new office and service areas will be created.

The urban vision and concept for this new district was born in the early 1990s. The area's

(1) Profile of Hammarby Sjöstad

- A southern city district in Stockholm
- Total area: 200 hectares (including 50 hectares of water)
- Planned Population: 25,000
- 11,000 apartments projected
- 200,000 km^2 of retail and office space projected
- About 35,000 people are expected to live and work in the area.
- Today, more than half of the development has been completed, and it is anticipated that the district will be fully developed by 2017.
- One among three Ðecocycle’ districts in Stockholm (Hammarby Sjöstad, Skärholmen, and Östberga)

Map 3.3 Inner City of Stockholm with Adjacent City Development Areas

Source: Stockholm City Planning Administration

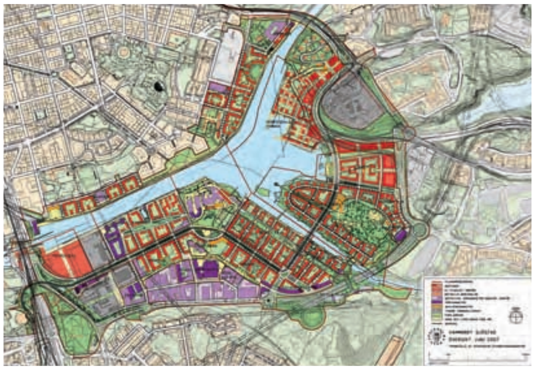
natural continuation of Stockholm’s inner city toward waterfront has influenced planned infrastructure and building designs. Hammarby Sjöstad adds a new layer to Stockholm’s development: a modern semi-open zone comprising a mix of traditional inner city perimeter blocks and open and contemporary urban zones. Inner-city street dimensions, block lengths, building heights, and densities are well harmonized, and offer openness, sunlight, parks, and water views.

The area is also well connected to public transport tramlines. According to a 2005 survey, two-thirds of all resident trips were made via public transport, bicycling, and walking, and one third by car.[36] High public transport ridership and bicycling and walking have helped to reduce car emissions and associated greenhouse gases. Mixed land uses are promoted and land policy requires that ground floors along main streets be used for commercial uses. This encourages people to walk or cycle to visit streets with lively shop fronts. To attract shops and services to the new development area, financial subsidies have been provided. Moreover, the area’s economic activities were established in the development’s early phases. Urban and building designs make the most of the waterfront. Myriad designs were created by different architects to provide a diverse, lively and high quality urban life.

Stockholm desired that Hammarby Sjöstad be two times more sustainable than Swedish best-practices in 1995 (the environmental program was adopted in 1995) on a range of indicators, most notably energy efficiency per meter squared. In Sweden, the average annual rate of energy use in some regular new developments is 200 kWh/m^2. Cutting edge Swedish developments and practices produce an efficiency of 120 kWh/m^2. The Hammarby Sjöstad project aims for 100 kWh/m^2. The project also sets other targets: water conservation, waste reduction and reuse, emissions reductions, reduced hazardous construction materials, application of renewable energy sources, and implementation of integrated transport solutions. Stockholm is already a sustainable city, but the City Council intends that this project demonstrate further innovations in sustainable urban development.

(2) Hammarby Model

The environmental goals for Hammarby Sjöstad, which was originally intended to be the Olympic village in Stockholm’s bid for the 2004 Summer Olympics, were audacious. The area’s integrated environmental solutions can be understood as an eco-cycle known as the “Hammarby Model.”



Map 3.4 Master Plan of Hammarby Sjöstad
Source: Stockholm City Planning Administration

The eco-cycle addresses energy, waste, water, and sewage for housing, offices, and other commercial structures. Core environmental and infrastructure plans for this area were jointly developed by three city agencies: the Stockholm Water Company, the energy company Fortum, and the Stockholm Waste Management Administration. Project management was spearheaded by a project team comprising representatives from city departments overseeing planning, roads and real estate, water and sewage, and waste and energy. The project team is housed in the Department of Roads and Real Estate (now called the Development Department). The model is an attempt to turn linear urban metabolism, which consumes inflowing resources and discards outflowing wastes, into a cyclical system that optimizes use of resources and minimizes waste. This model streamlines infrastructure and urban service systems, and provides a blueprint for achieving sustainability objectives. For instance, this model shows how sewage processing and energy provision interact, how refuse should be handled, and the added value to society of modern sewage and waste processing systems.

- *Building Materials*: Environmental considerations apply to all materials, whether

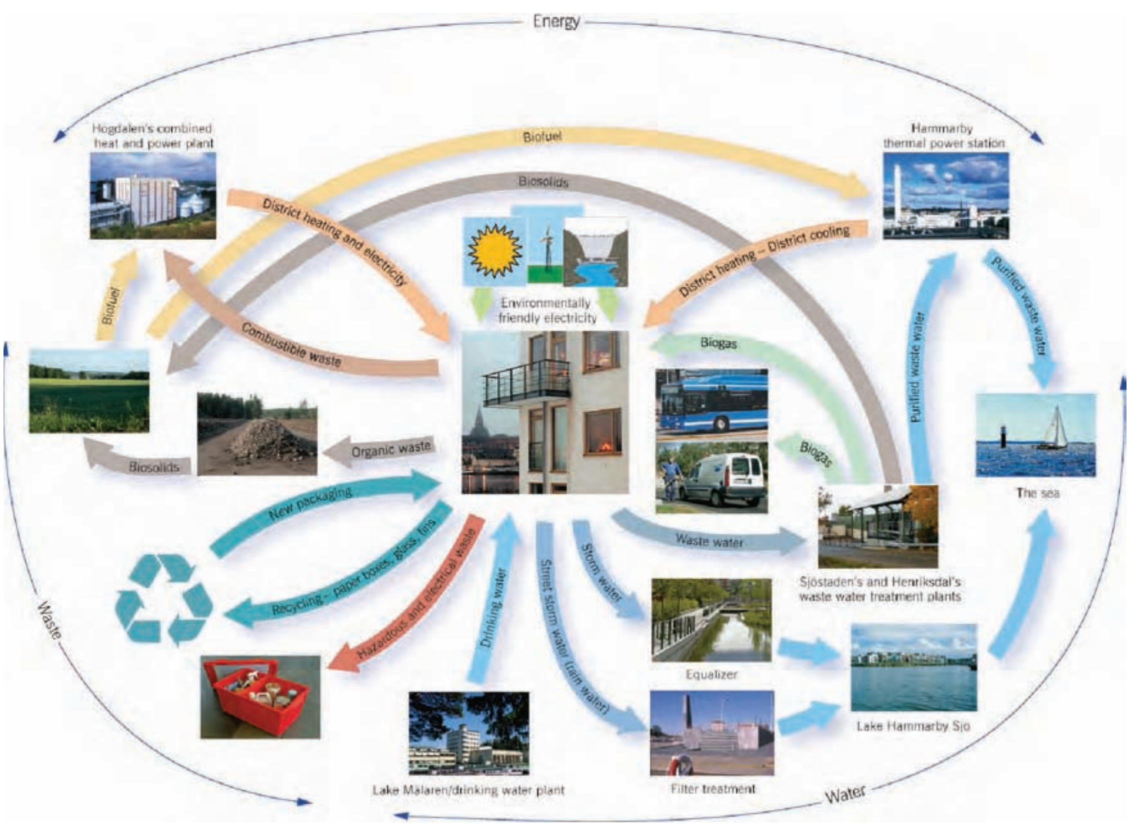


Figure 3.21 The Hammarby Model
Source: City of Stockholm, Fortum, Stockholm Water Company

used visibly in facades, underground, or internally. This includes structural shells and installed equipment. Only sustainable and tested eco-friendly products are employed. Potentially hazardous materials, such as copper and zinc, are avoided to prevent leakages of unwanted substances into the environment.

- *Water and Sewage*: Storm water is unconnected to sewerage systems to improve the quality of wastewater and sludge. Rainwater from streets, or non-domestic storm water, is collected, purified by a sand filter, and released into the lake. This reduces pressure on the wastewater treatment plant. Rainwater from surrounding houses and gardens flows through open drains to the channel. This water runs through a series of basins, known as an equalizer, and then to the lake. Hammarby Sjöstad has its own wastewater treatment plant built to test new technology. Four different and new processes for purifying water are currently being tested.
- *Biogas*: Biogas is produced in the wastewater plant from digestion of organic waste and sludge. The wastewater from a single household produces sufficient biogas for the household's gas cooker. Most biogas is used as fuel in eco-friendly cars and buses.
- *Green Spaces*: Roofs covered in stonecrop or sedum plants are not only attractive. These plants absorb rainwater that would otherwise drain into sewers, adding pressure on the wastewater treatment plant. Moreover, the region's carefully preserved oak forests, green areas, and other planted trees help to collect rainwater instead of draining it into the sewage system. This vegetation also ensures cleaner air and balances the dense urban landscape.
- *Waste*: Combustible waste, food waste, newspapers, paper, and other discards are separated and deposited in different refuse chutes in or adjacent to buildings. The refuse chutes are linked to underground, vacuum powered pipes that lead to a central collection station. An advanced control system sends the waste to large containers, one for each waste category. Refuse collection vehicles thus collect the containers without driving into the area, and refuse collection workers avoid heavy lifting.
- *District Heating/ Cooling*: Treated wastewater and domestic waste become sources for heating, cooling, and power. A combined heat and power plant uses domestic waste as fuel to produce district heating and electricity. Wastewater from the treatment plant fuels the production of district heating in the Hammarby heat plant. Cooled by heat pumps, the treated cooled wastewater can also be used in the district cooling network.
- *Electricity (Solar Energy)*: Solar energy is transformed into electrical energy in solar cells. The energy from a single solar cell module covering one square meter provides around 100 kWh/year, which is equivalent to the energy used by three square meters of housing space. There are solar panels on many roofs used to heat water. Solar panels on residential buildings often provide sufficient energy to meet half of buildings' annual hot water requirements.

Hammarby Sjöstad has its own Environmental Information Center "GlashusEtt." This Center facilitates communications on environmental considerations to the area's inhabitants, and showcases Hammarby to international visitors.

(3) Environmental Load Profile

To assess environmental performance and follow up on the targets set in the project's environmental program, an environmental assessment tool was developed called the Environmental Load Profile (ELP).[37] The ELP is a Life

Figure 3.21a Hammarby Sjöstad Cityscape
Photo: Lennart Johansson, Stockholm City Planning Administration

Figure 3.21b Residential Area in Hammarby Sjöstad
Photo: Lennart Johansson, Stockholm City Planning Administration

Cycle Assessment (LCA) tool. The ELP defines relevant activities from an environmental perspective and quantifies the environmental loads originating from these activities, such as emissions, soil pollutants and waste, and use of water and non-renewable energy resources. It accounts for all project development and implementation activities, including material acquisition, transport of inputs and people, construction methods, electricity, heating, material recycling, etc.

The main strengths of the ELP are that the tool is flexible and dynamic, which makes it suitable to apply to any conditions for planning, simulation, and evaluation. By factoring in well constructed variables, the ELP can calculate the environmental loads of different planning decisions during a project's construction, use, demolition, or redevelopment. It thus adopts a life-cycle approach. Testing scenarios are facilitated. For instance, different construction methods can be compared prior to taking decisions. Hence, decision-makers can understand environmental issues early in project planning. The ELP can also evaluate the environmental performance of existing city districts or buildings based on consumption of resources such as water and energy. The ELP enables analyses of environmental performance at multiple levels. The tool takes into account activities and impacts of individuals (e.g., cooking, laundry), buildings (e.g., building materials, district heating, electricity), un-built areas (e.g., materials, working machines) and common areas (e.g. materials, transport of people and goods). By aggregating these factors, the environmental load of a whole city district can be analyzed. If each factor is analyzed separately, different urban activities can provide useful information for urban planning.

Findings from evaluations of the initially developed areas of Hammarby Sjöstad compared to a reference scenario are illustrated in Figure 3.22. Results are positive: a 28 to 42 percent reduction in non-renewable energy use; a 41 to 46 percent reduction in water use; a 29 to 37 percent reduction in global warming potential; a 33 percent reduction in photochemical ozone creation production; a 23 percent reduction in acidification potential; a 49 percent reduction in eutrophication potential; and a 27 percent reduction in radioactive waste.

By monitoring the environmental loads from Hammarby Sjöstad, it is possible to plan suitable societal and financial environmental measures to continue development of the district, while offering guidance for similar projects.

(4) Project Management

The two municipal administrations responsible

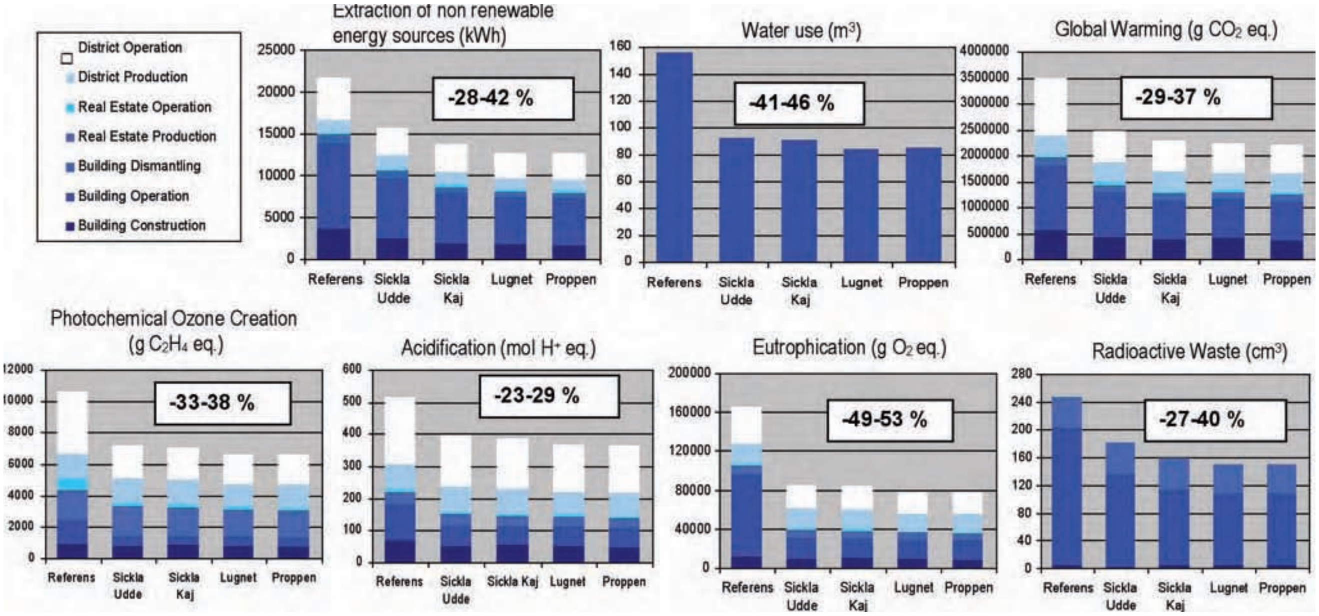


Figure 3.22 Example of Monitoring the Major Reduction of Environmental Load Stems from the Buildings, Real Estate and the City District of Hammarby Sjöstad
Source: Grontmij AB

for planning and managing this project are the City Planning Administration and the Development Administration. These entities are under respective political committee and the City Council.

In mid 1990s, Stockholm and its external stakeholders agreed to cooperate on planning objectives in the area. These stakeholders include the neighboring municipality of Nacka, the Stockholm Local Transport Authority, and the National Road Administration. After negotiating, the stakeholders agreed on a set of common planning features and infrastructure projects (1994/1995). During this period, there was a political steering group and an official management group with representatives of key stakeholders. An organization was established to manage the project. All administrations responsible for planning, development, implementation, and maintenance of the area were involved from its beginning.[38] The city's Waste Collection Administration and the city's associated companies—the energy company and the water company—participated in preparing the project's Environmental Program; moreover, these companies had vested interests as a power station and wastewater treatment plant were located in the area.

During the ongoing development of this project, a steering group with executive officers from involved administrations[39] and a cross-sector official management group have been active. The city, as landowner, can initiate agreements and contract with developers. The city can specify different requirements depending on what issues are important in each phase. Developers have contractual obligations to participate in the planning process (regarding the detailed development plan), the process of defining and implementing quality and design standards, and implementation of aspects of the Environmental Program.

(5) National Level

The Hammarby Sjöstad project was partially supported by a national subsidy program. This program aimed to encourage municipalities to become part of an 'ecologically sustainable society' while providing project-related jobs in municipalities.[40] This so called Local Investment

Program (LIP) lasted from 1998 to 2002, and allocated SEK 6.2 billion (671 million Euros) to 211 local investment programs in 161 municipalities, involving 1,814 projects.[41] This national investment leveraged from municipalities, businesses and other organizations SEK 27.3 billion (2.95 billion Euros), of which SEK 21 billion (2.27 billion Euros) were investments directly related to sustainability and the environment.[42] 20,000 full time temporary or permanent jobs were estimated to be created.[43] Testimony of the effectiveness of the LIP initiative follows:

> According to local authority estimates, it is estimated, that grants awarded to local investment programs [LIP] for the period of 1998-2002 will lead to annual reductions in energy use by 2.1 TWh while carbon dioxide emissions will be reduced by 1.57 million tones per year (equaling 2.8% of Sweden's emissions) and landfill refuse deposits will be reduced by about 500,000 tones per year. Emissions to water will be reduced by 2,460 tones of nitrogen and 180 tones of phosphorous per year, which correspond to 2% and 4% respectively of the current total emissions to the sea.[44]

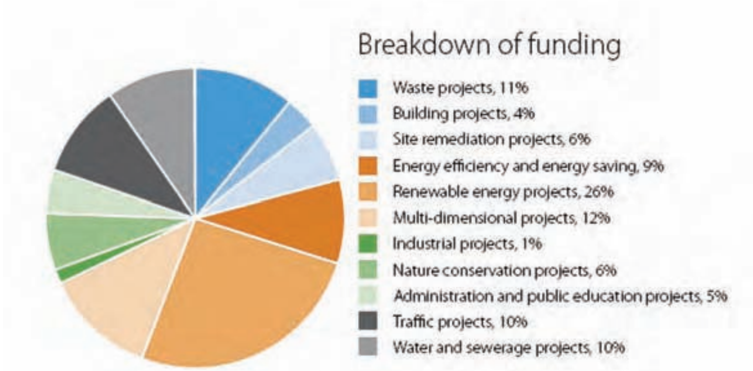


Figure 3.23 Funding from the LIP subsidy program allocated across 'types of projects'
Source: The Swedish Environmental Protection Agency. 2004. *Local Investment Programmes—The Way to a Sustainable Society*. http://www.naturvardsverket.se/Documents/publikationer/91-620-8174-8.pdf (accessed May 14, 2009).

(6) Next phase

Lessons and experiences from Hammarby Sjöstad will be considered while planning and implementing Stockholm's new eco-profiled city districts. These new areas will use the latest environmental technology with a view to being examples of the Sustainable City Concept. Energy, transport, lifestyle, and behavioral issues will be particularly important variables determining whether these projects' objectives will be met.

For instance, the *Stockholm Royal Seaport* is a new urban development with a unique environmental profile. Developing a new ecologically sustainable district places extra demands on the technology in building houses, use of efficient materials, and ways of handling energy. This urban development contains plans for 10,000 new residences and 30,000 new workspaces. Phase one starts in 2009, and about 5,000 units will be developed over the next decade. The first residents will move in 2011.

The vision for the area can be summarized in three comprehensive objectives:

1. *By 2030, the area is a fossil fuel free City District*
2. *By 2020, CO_2 emissions are cut to 1,5 tons per person/year (CO_2 equivalent)*
3. *The area is adapted to expected climate change effects*

Figure 3.24 Vision for the New City District Stockholm Royal Seaport
Photo: Lennart Johansson, Stockholm City Planning Administration

The project's focus areas are energy consumption and efficiency, sustainable transport, climate change adaptation, eco-cycle modeling, and maintenance of a quality lifestyle. Other important goals include having a holistic and integrated process, continuous evaluation and follow-up, and assessment and cooperation among private, public, and academic stakeholders.

Lessons Learnt from Stockholm Case

Great leadership in planning and implementing sustainable urban development strategies shows Stockholm's strong commitment to sustainable development. Success in a project such as Hammarby Sjöstad depends on good coordination among key stakeholders. Stockholm's various departments were integrated into a single fabric led by a project manager and an environmental officer whose responsibilities were to "guide and influence all stakeholders, public as well as private, to realize the environmental objectives of the project."[45] Moreover, integrated planning and management through systematic stakeholder collaboration can lead to significantly greater life cycle benefits.

The ELP can serve as a decision-making tool in cities in developing countries after a few modifications, as this ELP focused on a Swedish context. Nonetheless, the ELP provides a systematic and standardized methodology to quantify costs and benefits of developments. To apply the ELP to developing countries, the following are proposed:

- Expanding the ELP to include assessments of other input variables, such as the impacts that efficient spatial planning, integrated land use, and improved management of solid waste can have on output indicators.
- Improving and fine-tuning the existing program by filling in gaps and streamlining the inclusion of the inputs noted above. Moreover, the complete model needs to be adapted to large scale use, and adjusted to fit developing country contexts.
- Outputs in the current ELP have environmental indicators, such as carbon emissions. Converting these indicators from environmental indicators to economic and fiscal indicators is necessary to help policymakers make better decisions.

CASE 3

Singapore

Integrated urban planning and efficient land and natural resource use through a "one-system" approach

Singapore is an island city-state at the southern tip of the Malay Peninsula. With a limited land area of 700 square kilometers and a population of 4.8 million,[46] Singapore has devel-[47]oped by innovatively implementing urban planning integrated with efficient use of land and natural resources.

Singapore's small size poses challenges related to the availability of land and natural resources. To optimize land use, high-density development is promoted not only for businesses and commercial entities, but also residential structures. High density lends itself to higher economic productivity per unit of land, and facilitates identification of green spaces and natural areas for preservation. Indeed, Singapore is known as the "Garden City." Furthermore, high density development has translated into high usage of public transport as major business, commercial, and residential areas are well connected to an integrated public transport network. In 2004, public transport as a share of all transport modes during the morning peak hour reached 63 percent. High use of public transport helps to reduce greenhouse gas emissions. High public transport ridership also means Singapore has been able to fully cover all system operating costs from fares, a feat only Singapore and Hong Kong have achieved among cities in developed countries.

Figure 3.25. Singapore Cityscape

Singapore imports most of its natural resources, including food, water, and industrial materials, thus careful resource planning is critical. For example, Singapore has adopted comprehensive management of water resources by looping and cascading water, which represents a closed water cycle integrated into "one-system," rather than a "once through" flow water supply system. Water efficiency is considered and integrated into other sector activities as a result of cross-sector coordination among different government departments and

Profile of Singapore

- An island city-state at the southern tip of the Malay Peninsula, 136.8 kilometers north of the equator. Located south of the Malaysian state of Johor, and north of Indonesia's Riau Islands
- Population (2008): 4.84 million
- Land area: 700 square kilometers
- Population Density (2008): 6,814 people per square kilometer
- GDP at current price (2008): $181,947 million
- Water and sewer coverage: 100 percent
- Center of commerce and industry in Southeast Asia.
- Global financial center and trading hub (port)

Map 3.5. Location of Singapore
Source: Google Map (2009)

stakeholders. For example, new housing developments will be equipped with efficient rainwater collection devices so that building roofs turn into water catchment areas.

Singapore introduced various tools and incentives to manage supply and demand of resources. For example, Singapore implemented strategic water tariffs, creative energy policies, road pricing schemes, and a Vehicle Quota System. These measures discourage people and businesses from overusing resources beyond the city's capacity to supply them.

Singapore shows how a city can enhance economic productivity and growth, while minimizing ecological impacts and maximizing the efficiency of resource use. Strong leadership from Singapore's Prime Minister was a major driver of the city-state's sustainable development, complemented by an integrated "one-system" approach and active collaboration from stakeholders.

Approaches and Ecological / Economic Benefits

Singapore is committed to promoting sustainable development. Its Inter-Ministerial Committee on Sustainable Development (IMCSD), which was established in 2008, enables integrated approaches across Ministerial boundaries to formulate strategies for sustainable growth. Several innovative approaches for sustainable development are described below.

1. Integrated Land Use and Transport Planning

Because of limited land resources, land use planning has been very important to maintaining Singapore's environment quality and supporting its economic growth. Since independence in 1959, Singapore has actively expropriated land to obtain public land for public facilities, promote city redevelopment, and catalyze new development. Today, about 90 percent of land is owned by the city state.[48] The city thus has strong authority over urban development plans and their implementation.

Singapore's Urban Redevelopment Authority (URA) under its Ministry of National Development is in charge of urban planning. As noted, Singapore promotes high density development. For example, the Central Business District (CBD) of Singapore has Floor Area Ratios (FARs) up to 13. Ongoing development near Marina Bay next to the CBD aims to produce high density, mixed use development with FARs up to 20.[49] Marina Bay will be more than a commercial center. It will also offer housing, shops, hotels, recreational facilities, and community zones such as green areas and open spaces.[50]

Singapore's high density, built-up areas enabled preservation of open spaces, natural parks, and greenery. As much as 10 percent of Singapore's land is designated as green space, including natural reserves. Green area in Singapore (including roadside greenery) was 36 percent in 1986, but increased to 47 percent in 2007. This gain was realized despite population growth of 68 percent. Moreover, the city enjoys green spaces and biodiversity.

Singapore's transportation plan is coordinated and well integrated with land use planning.[51] New high density developments, such as new towns, industrial estates, and commercial areas, are well connected to the city's Mass Rapid Transit (MRT) system. The MRT network runs underground in the city center and on the surface outside of the city center and in other major areas. The MRT is the backbone of Singapore's public transportation network. Other transport modes, such buses and Light Rail Transit (LRT), are well connected to MRT routes at interchange stations, and serve local areas. To ease transfers, a distance-based through fare structure was introduced.

The integration of the MRT, LRT, and bus networks helped to boost public transport's share of all transport modes (including taxis) to 63 percent in 2004, although this represented a decline from 67 percent in 1997 attributable to higher private car usage. In addition, among major cities in developed countries, only Singapore and Hong Kong have achieved full recovery of public transport operational costs through fares.[52] Because the transport system was integrated into high-density development areas with sizeable populations, the system could maintain financial viability and high quality service. People are highly satisfied with public transportation.[53]

Figure 3.26. Green Area in Singapore

2. Transport Measures

Singapore's Land Transport Authority (LTA) was established in 1995 by integrating four separate land transport departments in order to comprehensively plan, control, and manage relevant policies. The LTA aims to provide a high quality transport system, enhance citizens' quality of life, and maintain Singapore's economic growth and global competitiveness.

Singapore provides incentive to control the number of private cars. In 1990, its Vehicle Quota System (VQS) was introduced, through which government limits the number of new newly registered cars to between 3 to 6 percent each year. If someone wants to purchase a new car, the person needs to apply to LTA's open bidding. Car owners must obtain Certificates of Enrollment (COEs) that are effective for a decade after registration.[54]

To respond to growing traffic and congestion, Singapore introduced an Area Licensing Scheme (ALS) in 1975. The ALS is a road pricing scheme that manages cars entering the CBD in peak hours. In 1998, the ALS was replaced by the current Electronic Road Pricing (ERP) system to boost system effectiveness. The ERP system electronically collects fees from drivers through In-vehicle Unit (IU) equipment installed in cars that enter designated areas of the city center in certain periods of peak traffic. The ERP has several price options, depending on road types (arterial and highway) and periods. Higher prices are applied during the most congested times. In addition, Singapore uses several other demand control measures, such as encouraging off peak driving or park and ride options via financial incentives.

Taken together, these road traffic, public transport, and mobility measures mean that 71 percent of trips in Singapore can be completed in less than one hour.[55] Traffic congestion is alleviated and average traffic speed maintained, thus unnecessary vehicular emissions are avoided. This translates into less greenhouse gases linked to climate change. However, travel demand is expected to increase from 8.9 million trips in 2008 to 14.3 million in 2020. Within Singapore, 12 percent of land is dedicated to roads and 15 percent to housing. Moreover, it is highly unlikely that more land can be dedicated to roads to accommodate travel demand.[56] Singapore must thus accommodate increased demand through public transportation services, not cars.

3. Water Resource Management

Singapore is considered a "water scarce" city-state despite high annual precipitation of 2,400 millimeter per year.[57] Singapore imports water from neighboring Malaysia. To reduce dependency on external water sources, Singapore is taking steps to improve water security and "self supply" water within its own land. The approach Singapore has developed and implemented to achieve this aim is considered successful due to the city-state's institutional effectiveness and its highly efficient control of water demand and supply. Singapore successfully lowered its annual water demand from 454 million tons in 2000 to 440 million tons in 2004,[58] while its population and GDP grew 3.4 and 18.3 percent, respectively. Singapore shows that comprehensive water resource management is achievable using new approaches, and that these approaches can be financially viable.

(1) Institutional Setup that Enabled Integrated Approach

Singapore's Public Utilities Board (PUB), a statutory board under the Ministry of the Environment and Water Resources, manages the entire water cycle, including collection, production, distribution, and reclamation of water. When the PUB was established in 1963, it managed several utilities, including water, electricity and gas. To reduce costs and improve services, the PUB underwent institutional restructuring in 2001. Electricity and gas services were privatized, and sewerage and drainage functions were transferred to the PUB. Since 2001, the PUB has developed and implemented comprehensive and holistic approaches to the water system, rather than managing each water function (water supply, sewage, drainage, etc.) individually. In this way, the water loop is "closed," which enables the PUB to implement its "Four National Taps," a long-term strategy that ensures Singaporeans have sustainable water supplies. The Four National Taps include: (i) water from local catchments; (ii) imported water; (iii) desalinated water; and (iv) NEWater (reclaimed water from wastewater). By approaching the water system holistically, the PUB is able to efficiently address various issues and activities, such as water resource protection, storm water management, desalination, demand management, water catchment management, private sector engagement, and community driven programs, including public education and awareness campaigns. The PUB also runs a Research and Development (R&D) facility where experts research water technology.

The PUB's effective engagement of the private sector is a distinctive aspect. To lower costs, the PUB harnesses the private sector in areas where it does not have competence or competitive advantages. For example, Public Private Partnerships (PPPs) are used for water desalination and wastewater reclamation.

(2) Supply Management

Because water is scarce, Singapore carefully manages its water supply. Sewers cover 100 percent of the city-state area, and all wastewater is collected. Singapore has a separate drainage system to ensure wastewater and runoff do not mix. Wastewater and drainage water are recycled into the city-state's water supply.

The "Four National Taps" strategy considers the following as water sources[59]:

1. *Water from local catchments* (catchment management): Rainwater is collected from

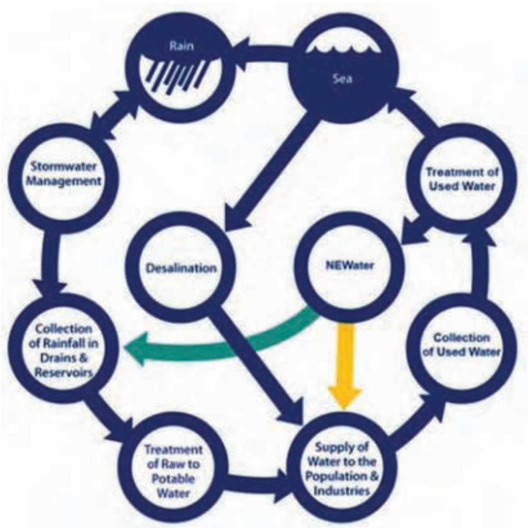


Figure 3.27 Closed Water Loop
Source: Public Utilities Board (PUB) Website <www.pub.gov.sg/about/Pages/default.aspx> (accessed January 2009).

rivers, streams, canals, and drains, and stored in 14 reservoirs. As drains are separated from sewers, rainwater can be directly sent to rivers or reservoirs for later treatment into tap water. Reservoirs are linked via pipelines. Excess water can be pumped from one reservoir to another, thus optimizing storage capacity and preventing flooding during heavy rains. Catchment areas are protected, and polluting activities are prohibited in these areas by strict regulations. By 2009, water catchment areas will expand from half to two-thirds of Singapore's land surface. Pollution causing activities are allowed in only 5 percent of Singapore's land area; all other land is protected. Water catchments provide about half of Singapore's water needs.[60]

To improve environmental and resource management, the government pays close attention to water catchment areas and to the locations of industrial sites. Singapore also pursues integrated urban planning. For example, the PUB and the Housing and Development Board (HDB) collaborate to enhance Singapore's water catchment area. The PUB considers rainfall an important resource, and rainfall collection and drainage systems are installed on the roofs of housing structures developed by HDB. Newly developed properties are equipped with rainfall collection and drainage systems. Collected water is stored in neighboring holding basins, and transferred to reservoirs. This strategy allows even built-up areas to participate in water catchment. Two-thirds of Singapore's land area is expected to participate in water catchment.

2. *Imported water:* Singapore will continue to import water from Malaysia under two bilateral agreements, which expire in 2011 and 2061. Imported water accounts for about a third of the country's water needs.[61]

3. *Desalinated water:* In September 2005, Singapore opened a US$200 million desalination plant, which was PUB's first public-private partnership (PPP) project. This plant can produce 30 million gallons (136,000 cubic meters) of water a day, and is one of the largest seawater reverse-osmosis plants in the region. In 2007, this plant provided about 10 percent of the country's water needs.[62]

4. *NEWater:* Used water (wastewater) is also important water resource. Wastewater is collected through an extensive sewerage system and treated at water reclamation plants. Wastewater is purified using advanced membrane technology to produce high-grade reclaimed water, known as NEWater, which is safe to drink. Because such water is purer than tap water, it is ideal for industry uses (e.g., precision equipment and IT manufacturing) that requires high quality water. Each day, the PUB blends 6 million gallons (mgd) (28,000 cubic meters) of NEWater with raw reservoir water, which is later treated to become tap water. The amount to be blended will increase to 10 mgd (46,000 cubic meters) by 2011. Four NEWater factories operate in Singapore, and a fifth plant is being built under a public-private partnership (PPP) agreement. In 2008, NEWater satisfied more than 15 percent of Sin-

gapore's total daily water needs, and it is expected to meet 30 percent by 2010.

Water supply can be optimized if non-revenue water, or water lost to leaks, is reduced. Singapore's 5.18 percent share of non-revenue water in 2004 [63] was very low, and there are no illegal connections to its water supply systems.

As an integral part of the water loop, the PUB built its Deep Tunnel Sewerage System (DTSS). Though sewerage coverage is 100 percent, the aging sewerage network posed problems. The DTSS comprises deep sewer tunnels that intercept water flows from existing sewerage, pumping stations, and linked sewers. The designed lifespan of the DTSS is 100 years. Because wastewater flows by gravity through the DTSS to a centralized water reclamation plant (the Changi WRP), intermediate pumping stations can be abolished. This removes the risks of surface water pollution caused by failures of intermediate pumping stations, and risks of damage to pumping mains. Water reclamation plants and pumping stations require about 300 hectares of land. New water reclamation plants under the DTSS occupy only 100 hectares, therefore 200 hectares of land can be released for other uses. Building the DTSS proved to be more cost effective (by more than S$2 billion, or about US$1.35 billion) than expanding and upgrading existing infrastructure.[64] The DTSS also enhances the closed water loop by collecting wastewater effectively for NEWater production.

(3) Demand Management

The PUB has a well planned and holistic policy for managing water demand. Water charges are based on consumption, not lump-sum proxies. The water tariff has several rates for different consumption levels. If domestic use surpasses more than 40 cubic meters per month, the unit charge becomes higher than the non-domestic tariff. The basic water tariff has increased each year since 1997. The Water Conservation Tax (WCT) is levied to reinforce water conservation. In addition, a Water-borne Fee (WBF) is charged to cover the costs of wastewater treatment, and the maintenance and extension of the public sewerage system. This represents a financial disincentive for households to consume more water. Consequently, as water bills (inclusive of all taxes) are raised, water consumption decreases. The tariff system has significantly impacted water usage. Although annual water use in Singapore had increased from 403 million cubic meters in 1995 to 454 million cubic meters in 2000, these demand control policies helped lower demand to 440 million cubic meters in 2004.[65]

(4) Social Considerations and Awareness Rising

To ensure equity, the government provides direct subsidies to lower-income families. So-called lifeline tariffs subsidize all water consumers, not only those who cannot afford to pay high tariffs. As such, Singapore provides subsi-

Table 3.2 Water Tariff

	CONSUMPTION BLOCK (M3 / MONTH)	TARIFF (S$ / M3) [BEFORE GST]	WATER CONSERVATION TAX (WCT) (% OF TARIFF) [BEFORE GST]	SANITARY WATER-BORNE FEE (WBF) (S$/M3) [AFTER GST]*	APPLIANCE FEE [AFTER GST]*
Domestic	0 to 40	1.17 (US$ 0.81)	30	0.30 (US$ 0.21)	S$3.00 per chargeable (US$2.07) fitting per month
	Above 40	1.40 (US$ 0.97)	45		
Non-Domestic	All units	1.17 (US$ 0.81)	30	0.60 (US$ 0.41)	

Source: Singapore Public Utilities Board (PUB) Website <www.pub.gov.sg/about/Pages/default.aspx> (accessed May 2009).
* Inclusive of Goods and Services Tax (GST) (7% as of May 2009), rounded to the nearest cent.
** Exchange rate used: 1 Singapore dollar = US$ 0.69 (as of June 4, 2009)

Table 3.3 Water Consumption and Water Bills per Household in 1995, 2000, and 2004

YEAR	1995	2000	2004
Population ('000)	3,524.5	4,028	4,167
GDP (US$ million)	84,288.1	92,720.2	109,663.7
National Water Consumption (million m^3)	403	454	440
Average Monthly Water Consumption (m^3)	21.7	20.5	19.3
Average Monthly Water Bill incl. all taxes (S$)	14.50	31.00	29.40

Source: Tortajada, C. (2006a). Singapore: An Exemplary Case for Urban Water Management. Case Study for the UNDP 2006 HDR.

dies only to targeted poor households. Targeted subsidies are widely considered more efficient in socio-economic terms, as compared to subsidizing an initial amount of water consumed by all households irrespective of economic status. The tariff system makes clear that those who consume more water will be penalized (both by basic tariffs and taxes)—more than even commercial and industrial uses.

4. Other Environmental Approaches

Singapore supports intense economic activity in a small island state. Maintaining a quality environment is thus a critical issue. The Ministry of the Environment and Water Resources (MEWR) (formerly the Ministry of Environment) issued in 2006 the Singapore Green Plan 2012 that addresses six main areas: Clean Air and Climate Change, Water, Waste Management, Conservation of Nature, Public Health, and International Environmental Relations.[66] This plan builds from the 1992 Singapore Green Plan. Since 1992, local officials have actively tackled environmental issues by implementing various activities involving a range of stakeholders including citizens and public and private sector entities.

Energy: To avoid overconsumption, Singapore does not subsidize energy. Electricity supplies are established by market demand and competition, and industries are encouraged to find better solutions and to be energy efficient. To improve cost-effectiveness, natural gas-based electricity generation recently surpassed oil-based generation. The share of electricity produced by natural gas rose from 19 percent in 2000 to 79 percent in 2007. In addition, energy consumption per unit of GDP was reduced and the efficiency of electricity generation was enhanced.[67] To raise the public's awareness of energy concerns, the government introduced E^2 Singapore, a national energy efficiency plan. The government also made investments in energy research and technologies. For example, to capitalize on Singapore's tropical location, the government promoted solar energy research with a view to reinforcing the "clean energy" sector.

Air Pollution Measures: To minimize air pollution, land use plans locate industrial facilities outside of the urban area. Car emissions are another source of air pollution. The VQS and ERP systems help to reduce traffic congestion, and the integrated public transport system encourages public transport ridership. Additional car emissions are avoided, including airborne particulate matter and greenhouse gases. In 2008, 96 percent of days had good air quality under the Pollutant Standards Index (PSI).[68]

Waste Management: Rapid economic and population growth has resulted in increased waste. With limited land for landfills, Singapore incinerates wastes that cannot be recycled or reused. Incineration reduces the weight and volume of waste by, respectively, 10 and 20 percent, and has proven to be an efficient waste treatment process. Electricity produced from incineration provides 2 to 3 percent of the city's electricity needs.[69] Singapore has only one remaining landfill site, which is located 8 kilometers south of the mainland and is the first man-made offshore landfill.

There is no more land available for landfills and disposal of residue from incineration. It is expected that the life of this offshore landfill will surpass its 2040 closure due to citizens' recycling efforts. However, the city is facing waste management challenges, especially as daily waste increased 6 times to 7,600 tons between 1970 and 2000 owing to economic growth, population increases, and improved living standards.[70] To promote recycling and waste reduction, Singapore's National Recycling Program encourages various activities, and per capita domestic waste has fallen despite economic growth. In 2008, the recycling rate reached 56 percent. Additionally, government-industry collaboration has promoted reduced waste from packaging.[71]

River Clean-up: Singapore has successfully cleaned and restored the environmental conditions of once deteriorated rivers. In 1977, Singapore and its Prime Minister supported a major project to clean the Singapore River and Kallang Basin, which covers about one fifth of the city-state's land area. Uncontrolled waste and wastewater from farms, un-sewered houses, and squatters were directly discharging into the rivers. In response, houses and other polluting activities were relocated and efforts were made to improve the physical conditions of the rivers. The riverbeds were dredged, waterfront facilities were upgraded, and greenery was added to riverbanks. Government agencies, grassroots communities, and NGOs contributed to the clean-up. The rivers were revitalized in 10 years at a cost of S$200 million.[72] Today, the river waterfronts, including canals and reservoirs, are well preserved and maintained. These river zones act as water catchments and flood prevention areas, while providing community recreational space.[73]

Singapore's waterways, including its rivers and reservoirs, are designed to be people-friendly. These designs complement Singapore's vision as a city of gardens and water. Waterways and embankments often are recreational sites; moreover, people are reluctant to contaminate a resource they eventually drink. The PUB provides educational opportunities through a visitor centre and learning courses. The PUB also encourages water conservation by providing tips and devices for saving water in households.

Greening: Singapore's "Garden City" campaign has been promoted since the 1970s to green the country by planting trees along roads as well as in vacant plots, reclaimed land, and new developments. Flowers are added too. Since Singapore's independence in 1959, more than a million trees have been planted, and a high standard of landscaping has been achieved in the country. [74]

5. Housing

The government aims to supply affordable housing to its citizens. The Housing and Development Board (HDB) under the Ministry of National Development plans and develops public housing and facilities in new towns. As land is limited, high density development and high-rise buildings are promoted for commercial, business, and residential uses. Urban renovation and development of new and satellite towns are encouraged; 20 such towns have been constructed. New towns are connected to public transportation and Singapore's city center. In 2003, 84 percent of Singaporeans resided in publically built housing, and 92.8 percent had their own housing.[75] Since 1989, the HDB has implemented an Ethnic Integration Policy (EIP) to ensure a balanced mix of ethnic groups in public housing. Singapore has myriad ethnic groups, including Chinese, Malays, Indians, and others. The EIP prevents establishment of racial enclaves, and promotes diverse communities and social integration.[76]

Lesson Learnt from Singapore

Singapore faces challenges related to the scarcity of land and natural resources amid strong economic and population growth. Singapore shows that innovative and comprehensive management of land and other resources is achievable. Singapore capitalized on its understanding of local conditions to develop a high density city that preserves green and open spaces. Public transport works efficiently, and is financially viable and integrated with land uses. Due to Singapore's comprehensive and integrated management of resources, the city is successfully addressing ecological, economic and social concerns while ensuring sustainability and productivity.

CASE 4

Yokohama, Japan

Waste reduction by engaging stakeholders in the private sector and civil society

The City of Yokohama ("Yokohama") provides Eco^2 Cities with a case study on how to realize significant environmental and economic benefits by engaging stakeholders in the private sector and civil society.

Yokohama, the second largest city in Japan after Tokyo, reduced waste by 38.7 percent[77] between FY2001 and FY2007 despite adding 165,875 people.[78] This reduction in waste was attributable to the city's success in raising public awareness of environmental issues, and the active participation of citizens and businesses in Yokohama's "3R" activities (i.e., Reduce, Reuse, Recycle).

Yokohama closed two incinerators owing to its significant reduction in waste, which saved US$6 million in annual operating costs, and US$1.1 billion that would have been needed to renovate its incinerators.[79] As much as 5 percent of the FY2008 budget of the Resources and Wastes Circulation Bureau, the city's waste management entity, comes from selling recyclables (US$ 23.5 million). In addition, the city annually raised US$ 24.6 million by selling the electricity generated during the incineration process.[80]

Yokohama's success demonstrates that a city can achieve waste reduction with the cooperation of its stakeholders, particularly citizens.

Figure 3.28. Waterfront of Yokohama

Reducing waste also results in significant cuts in greenhouse gas (GHG) emissions. In addition, a city can cut expenditures by reducing waste, and generate revenue from recyclables and byproducts of waste treatment. Encouraged by past achievements, Yokohama now aims to further reduce GHGs to lead Japan toward its national GHG reduction target, and demonstrate its place as one of the "Eco-Model Cities."[81]

Table 3.4 Power of Stakeholder Engagement

Reduction of total amount of waste (FY2001–FY2007)	623,000 ton (–38.7%)
Economic Benefit	US$ 1.1 billion capital cost saved by incinerator closure US$ 6 million operational cost saved by incinerator closure Life of landfill sites extended
CO_2 reduction (FY2001–FY2007)	840,000 ton

Profile of Yokohama

- The second largest city after Tokyo in Japan
- Population (2009): 3.65 million
- Land area: 435 km^2
- Population Density (2009): 8,409 persons/km^2
- Yokohama Port was opened for international trade in 1859 when Japan decided to abandon its isolationist policy and initiate modernization and opening to foreign cultures. The city celebrates the 150th anniversary of the port's opening in 2009.
- About 21 percent of people commute out of the city for employment or education (in 2005).
- People are active in participatory civil activities.
- The city was selected as one of the "Eco-Model Cities" in Japan in 2008.

Map 3.6 Location of Yokohama
Source: City of Yokohama

Background and Approaches to Waste Reduction

Yokohama's population has slowly increased by 0.5 to 1 percent per year. Population growth and associated economic activities have generated more waste, and this has put pressure on the lives of the city's landfill sites, which have limited capacities. In 2000, the city had seven incinerators—six in operation, one in non-operation—and two landfill sites (an inland site and a sea-reclamation site). To reduce the environmental impacts of incineration and landfill disposal, and to nudge the society toward a "zero-waste" cycle, Yokohama started its G30 Action Plan in 2003. The G30 aims to reduce waste by 30 percent by FY2010, using FY2001 waste quantities as baselines.

The G30 Plan identifies the responsibilities of all stakeholders—households, businesses, and the city government—to reduce waste through the 3Rs based on "polluter-pays" and "extended-producer-responsibility" principles.[82] The plan provides integrated approaches to reduce waste supported by detailed action programs. For example, Yokohama citizens must separate waste into 15 categories and properly dispose of each category of waste at designated places and times. Businesses are requested to provide products and services that produce less waste, and to actively implement the 3Rs. The city, which is one of the largest entities producing waste, is committed to decreasing waste and to working together with citizens and business as a model player.

To disseminate the G30 approach, the city has conducted environmental education and promotional activities to enhance public awareness and call for collaborative action to achieve the G30 goal. To promote adequate waste separation, the city conducted public activities, including more than 11,000 seminars for neighborhood community associations (in Yokohama, 80 percent of the population participates in neighborhood community associations[83]) to explain waste reduction methods, such as how to segregate waste. In addition, about 470 campaigns were held at railway stations, and about 2,200 awareness campaigns were organized in the mornings at local waste disposal points (and so on).[84] Campaign activities were organized along local shopping streets and at supermarkets, and at various events. The G30 logo has been posted on all city publications, city-owned vehicles, and at city events.

As a result, the waste reduction target of 30 percent was achieved in FY2005—five years earlier than expected (FY2010). By FY2007, waste had fallen 38.7 percent compared to amounts in 2001, despite the growth in population of 165,875 over that period (Table 3.5 and Figure 2.29).[85]

Table 3.5 Waste in Yokohama, FY2001–FY2007

YEAR	2001	2002	2003	2004	2005	2006	2007
Population (million persons)	3.46	3.50	3.53	3.56	3.58	3.60	3.63
General Waste Total (excluding recyclables) ('000 ton)	1,609	1,586	1,532	1,316	1,063	1,032	987
Waste from Household ('000 ton)	935	928	919	855	651	652	628
Waste from Business Activities ('000 ton)	674	658	613	461	412	380	359
Collected Recyclables (incl. compost waste) ('000 ton)	50	50	53	72	166	162	160

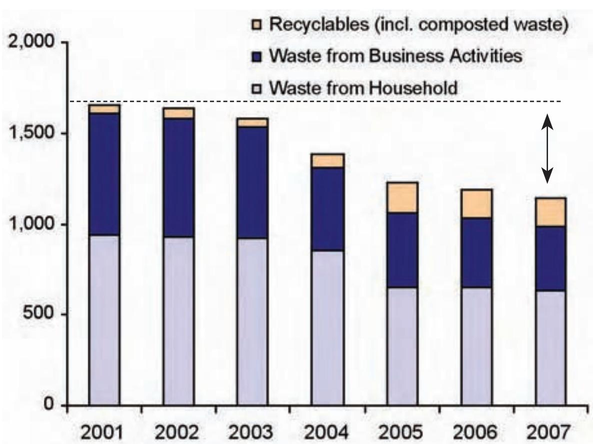


Figure 3.29 Waste Reduction in Yokohama, FY2001-FY2007
Source: City of Yokohama Resources & Wastes Circulation Bureau (2008) *Operation Outline.* (横浜市資源循環局「平成20年度事業概要」)<http://www.city.yokohama.jp/me/pcpb/keikaku/jigyo_gaiyou/20gaiyou/> and City of Yokohama Statistics Portal Site <http://www.city.yokohama.jp/me/stat/> (横浜市：統計書Web版「行政区別世帯数及び人口の推移」) <http://www.city.yokohama.jp/me/stat/toukeisho/new/#02> (accessed February 2009)

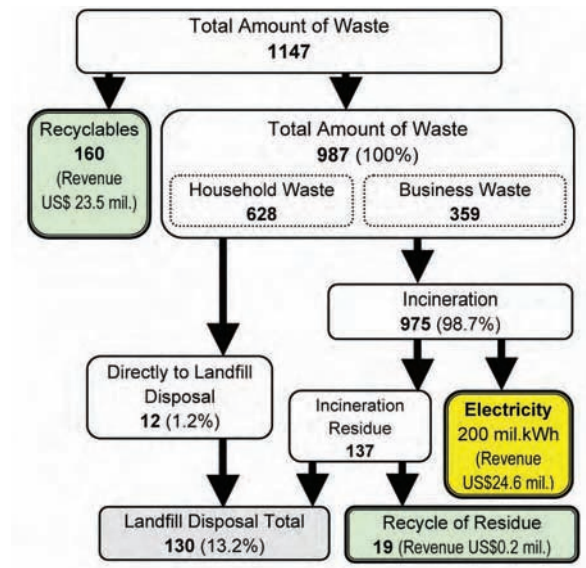


Figure 3.30 Waste Flow in Yokohama, FY2007 (thousand ton)
Source: City of Yokohama Resources & Wastes Circulation Bureau (2008) Operation Outline. (横浜市資源循環局「平成20年度事業概要」) <http://www.city.yokohama.jp/me/pcpb/keikaku/jigyo_gaiyou/20gaiyou/> and Budget Outline (横浜市資源循環局「平成20年度予算概要」) <http://www.city.yokohama.jp/me/pcpb/keikaku/yosan/20yosan.pdf> (accessed February 2009).

Environmental Benefits from Waste Reduction

In Yokohama, almost 99 percent of non-recyclable waste is brought to incinerators for treatment (Figure 3.30). Waste treatment is the largest contributor to CO_2 emissions among the city's public works activities, which include, *inter alia*, office work, waste treatment, water provision, sewage treatment, and public transportation. For instance, CO_2 linked to waste treatment comprised 54.8 percent of total CO_2 emissions from city public works in FY2000.

According to Yokohama's Life Cycle Assessment, the waste reduced between FY2001 and FY2007 was equivalent to avoiding 840,000 tons of CO_2 emissions. This included 760,000 tons of avoided CO_2 emissions from obviated waste collection, incineration, and landfill disposal, and 110,000 avoided tons of CO_2 from recycling waste. Incinerators produce electricity from heat and steam generated by burning waste, and reuse this electricity for their own

Table 3.6 CO_2 Reduction through Waste Reduction FY2001–FY2007

	CO_2 (TON)
CO_2 from reduced waste collection/ incineration/ landfill	760.000
CO_2 reduced by recycling	110,000
CO_2 increase due to additional supply of electricity by electricity company	– 30,000
Total CO_2 reduction	840,000

operations, or sell it to electricity companies or other facilities. However, because reduced waste results in less incineration and electricity production, the electricity company who purchased electricity from incinerators has to produce additional electricity. In Yokohama, this additional supply of electricity was equal to 30,000 tons of CO_2, thus the balance of avoided CO_2 is 840,000 tons (Table 3.6). 840,000 tons is equivalent to the amount of CO_2 that 60 million Japanese cedar trees can absorb in one year. Approximately 600 km^2 would be needed to plant 60 million Japanese cedar trees. This is equivalent to an area 1.4 times larger than the city![86]

Economic Benefits from Reduced Waste

In 2000, the city had seven incinerators, but by 2006 two incinerators had been shut down owing to significant reductions in waste.[87] This saved US$1.1 billion of capital expenditures (CAPEX) that would have been needed to reconstruct and renovate these incinerators. It also saved annual operational expenditures (OPEX) of US$6 million (i.e., US$30 million in savings from obviated annual operational costs, minus US$24 million in expected annual expenditures for intermediate waste treatment/ separation costs, recycling, contracting, etc.).[88]

Yokohama has two landfill sites. When the G30 was planned in 2003, the landfills were forecasted to have 100,000 m^3 of remaining capacity in 2007, and to be full by 2008. However, owing to the achieved waste reduction, the two sites had 700,000 m^3 of remaining capacity in 2007. The value of the additional capacity of 600,000 m^3 is equivalent to US$83 million.[89] In addition, the development of a new landfill site or reclamation area in the sea has been postponed.

Economic Benefits from Efficient Use of Resources

The city's five incinerators produce heat and steam when incinerating waste. The heat and steam are used to operate the incinerators, including their heating, cooling, and generation of hot water (etc.), and to power adjacent public facilities, including an indoor pool and elder care facilities. Turbines in the incinerators produce electricity from the steam. In FY2007, the incinerators produced 355 million KWh of electricity. 42.2 percent of this power was reused by the incinerators, 55.4 percent was sold to electricity companies under competitive tendering, and 2.4 percent was harnessed by nearby public facilities, such as a sewage treatment plant, sludge recycling facility, and seaside line railway (among others). In FY2007, US$24.6 million was earned by selling 200 million kWh of electricity, which is equivalent to one year of electricity for 57,000 households.[90]

Yokohama began earning revenue by selling recyclables, such as cans, bottles, paper, furniture, electronic appliances, and reusable metal and material produced from incinerated ash. Collected recyclables are sold to private companies for further treatment and reuse. Incineration ash is recycled into construction materials. About US$23.5 million of revenue was secured by selling recyclables to treatment companies.[91]

As a result of these measures, about 10 percent of the FY08 US$480 million budget of the Resources and Wastes Circulation Bureau came from selling recyclables (US$23.5 million) and electricity generated from incineration (US$ 24.6 million).[92]

To promote efficient waste management, the city also began contracting key activities, such as waste collection and transportation, to the private sector, which often provides higher quality services at lower costs. Between 2003 and 2005, the city saved operational costs of US$26.4 million by contracting services to the private sector.[93]

Lesson Learned from the Yokohama Case

The Yokohama case shows that cooperation from stakeholders, particularly citizens, is important to achieving city targets. Of course, substantial and consistent efforts are needed at grassroots levels to raise the awareness of citizens and businesses and attempt to change behaviors. However, the measures in Yokohama did not require new technology or huge investments. Moreover, cities can count on "citizen power" to make further headway, once people understand relevant issues, change their behavior, and become active players in implementing plans.

Encouraged by the G30 achievements, Yokohama now aims to further reduce GHGs to lead Japan and demonstrate its qualities as one of Japan's Eco-Model Cities. In Yokohama's 2008 Climate Change Action Policy "CO-DO 30", the city aims to reduce GHG emissions by more than 30 percent by FY2025, and by more than 60 percent by FY2050 (compared to FY2004 levels).[94] Action plans are being established based on seven approaches to realize the plan's targets.[95] In addition, Yokohama aims to increase its use of renewable energy ten times compared to FY2004 baselines. Citizens are actively participating in these activities, including by purchasing city-issued bonds to fund the construction of a new wind-power generator. Finally, in light of Yokohama's reduced waste and the need to soon undertake costly renovations of an aged incinerator, the city is planning to close one more incinerator by FY2010, and henceforth use only four incinerators. Further reductions in CO_2 emissions and operational savings are expected.

CASE 5

Brisbane, Australia

Actions on climate change in a fast growing city in a subtropical region

Brisbane, the capital of the state of Queensland in Australia, was one of the fastest growing capital cities in Australia with 2 percent population growth in 2006 and 2007.[96] The population of Brisbane in 2007 was approximately 1.01 million, making it the first local government area in Australia to exceed the milestone of one million people.[97] Brisbane is among the top 10 fastest growing cities from OECD countries, and the second fastest growing city in the western world.[98] Brisbane's population is expected to grow further over the next two decades.[99]

Since 2000, Brisbane has experienced increased electricity consumption and annual growth in peak electricity loads.[100] As the city is in a subtropical climate, increased domestic air-conditioning has been a major factor prompting higher demand for electricity, along with poor housing design, an energy-intensive economy, and growth in population and disposable income.[101] Demand for electricity is expected to rise consistently through 2030. Brisbane is also experiencing a shortage of potable water during a period when growth and climate change risks straining water resources, thus emphasizing the need to shift to a new form of water management.

In 2007, the Brisbane City Council issued *Brisbane's Plan for Action on Climate Change and Energy,* which delineates 22 complementary actions to be achieved in the short-term (about 18 months) and the long-term (more than 5 years). Brisbane has three major challenges: climate change, high peak oil demand, and greenhouse gas emissions.[102] Analyses suggest that if Brisbane responds intelligently to these challenges, the city can generate significant economic benefits by developing sustainable industries, while saving resources. Brisbane is actively introducing various approaches to sustainable development. In addition, in the city's *Our Shared Vision—Living in Brisbane 2026* policy document, authorities have committed to cutting greenhouse gas emissions in half, reusing all wastewater, and restoring 40 percent of natural habitat by 2026.

Approaches and Ecological and Economic Benefits of the CitySmart Program

To implement actions in *Brisbane's Plan for Action on Climate Change and Energy*, officials initiated the CitySmart Program. This program introduces residents and businesses to practical and affordable ways to implement actions indicated in the climate change action plan. These practical tips help residents and businesses to become energy and resource efficient, thus improving the environment and saving money (Box 3.2).

Residents, for instance, are provided tips related to, inter alia, hot water use, heating and

Profile of Brisbane

- Capital city of Queensland, Australia.
- Located on a coastal plain in South East Queensland. Brisbane's eastern suburbs line the shores of Moreton Bay, and the city's Central Business District is just 27 kilometers away from the mouth of the Bay.
- As a subtropical river city, Brisbane has hot, humid summers and dry, mild winters.
- 2007 Population: 1.01 million
- Population Increase (2006-2007): 2.0 percent
- The largest populated local government area in Australia

Map 3.7 Location of Brisbane
Source: Google Map

cooling, waste disposal, lighting and electronic appliances, bathroom and laundry facilities, house renovations, urban gardening, and installation of rainwater tanks. Moreover, Brisbane aims to reduce the annual carbon footprint of an average household from 16 tons of CO_2 in 2006 to 4.5 tons by 2026. To encourage household participation, the city offers rebates and grants supporting environmentally sustainable projects (Box 3.3). The city recommends that homes reduce their greenhouse gas emissions particularly by: 1) installing solar hot water systems (rebates available) to reduce up to 3 tons of CO_2; 2) undertaking an energy audit and monitoring (rebates available) to reduce up to 3 tons of CO_2; and 3) connecting to GreenPower (renewable energy from government accredited sources) to save up to 9 tons of CO_2.

Brisbane's trees are vital to protect and improve its urban environment. Trees provide shade and transpire water to cool the air and surface temperatures. In subtropical cities, it is important to identify ways to become less dependent on air conditioners to reduce energy use and carbon emissions. Shade allows more people to enjoy outdoor activities. Trees absorb greenhouse gases, including CO_2, and remove pollutants from the air. In addition, trees reduce

BOX 3.2

Summary of Measures in CitySmart Program

- Shifting to energy efficient light fittings
- Installing a rainwater tank in the home
- More efficient use of air-conditioners
- Continuing to recycle and preserve water
- Installing solar panels and solar hot water systems
- Signing up for green energy
- Thinking about alternative public transport solutions
- Reducing vehicle emissions
- "2 Million Trees" planting project

Source: Brisbane City Council, *CitySmart* http://www.brisbane.qld.gov.au/BCC:CITY_SMART:1042909255:pc=PC_2803

BOX 3.3

Example of Grants and Rebates (AUS$)

- \$50 rebate on the installation of an in-home energy monitor
- \$400 rebate for solar hot water
- Rebates for installing a rainwater tank and internal connections to toilets and/or cold water washing machine taps
- Funding up to \$50,000 to local non-profit community groups for installing energy and water saving devices

Source: Brisbane City Council, CitySmart http://www.brisbane.qld.gov.au/BCC:CITY_SMART:1042909255:pc=PC_5014 storm water run-off and evaporation, which is important in cities where water resources need protection. City officials in Brisbane have provided 133,000 free plants to residents to maintain the city's unique subtropical landscape by 2005. Furthermore, the city is committed to planting two million trees between 2008 and 2012. This effort will restore bush-land on a large scale, cultivate new trees along streets, and support the greening of landfill and infrastructure sites.[103]

Brisbane's City Council Offices aim to be carbon neutral by 2026 by adhering to "sustainable" principles in their daily operations. As a result, public sector electricity use and greenhouse gas emissions have decreased (Table 3.7). The City Council also actively engages residents and businesses to promote actions that reduce environmental impacts.

Urban Development in Brisbane

As in many other cities in Australia, most of Brisbane's citizens reside in detached homes built in low-density suburbs outside city boundaries.[104] The Australian suburban lifestyle is highly dependent on private motor vehicles, because for past fifty years suburbs were built on the assumption that the most people will not need public transportation services.[105] The shape of Brisbane also demonstrates this dependence. Peak oil prices will have multiple implications on Brisbane's economy and society, and will increase the need for fuel efficient vehicles and public transport options. The problem of urban sprawl has been addressed for many years for reasons other than peak oil prices. Local and regional planning have incorporated the principles of transit oriented development (TOD), which aims to promote development of mixed residential and employment zones "to maximize the efficient use of land through high level of access to public transport."[106] However, the results are still mixed, as economic structures and traditional housing preferences do not always coincide with these planning initiatives.[107]

Urban Renewal Brisbane[108] is a US$4 billion program to revitalize specific areas of the inner city. The program has been implemented in several urban areas, including Brisbane City Center (the Central Business District (CBD)). This program has incorporated innovative prin-

Table 3.7 Greenhouse Gas Emissions and Electricity Use by Brisbane City Council

	05 / 06	06 / 07	07 / 08	08 / 09
Greenhouse Gas Emissions (ton CO_2-e)				
Direct Emissions[a]		199,284	180,255	
Indirect Emissions from the Consumption of Electricity, Heat and Steam		218,988	205,669	
Other Indirect Emissions		30,148	40,864	
Sub-Total		448,420	426,788	
Green Power		–6,570	–53,317	
Off-sets		—	–95,000	
Sub-Total		–6,570	–150,317	
Nett Emissions		441,850	376,471	
Electricity Use by Brisbane City Council				
MWh	224,603	209,357	200,719	
% of Green Power Purchased	6 %	6 %	25 %	50 %

Source: Brisbane City Council, CitySmart http://www.brisbane.qld.gov.au/BCC:CITY_SMART:1042909255:pc=PC_5475
a. Direct emissions from transport (trucks, buses, ferries), manufacturing (e.g. asphalt production), and on-site generation of energy, heat, steam, electricity and fugitive emissions from landfill and wastewater treatment.

ciples and practices, such as high-quality urban designs, modern construction, mixed land use, higher density development, diverse transit options, and enhanced accessibility.

The Brisbane City Council is working with the development industry to promote sustainable living and working environments. The City Council has developed guidelines to help architects, engineers, planners, developers, and builders incorporate principles the promote sustainability into development applications. While such principles offer broad markers for sustainable development, the guidelines explain how to practically apply them. For example, the buildings in Brisbane used to be designed to be open to breezes, with overhead ceiling fans, shaded areas, and good circulation. However, recent designs depend on air-conditioners that are energy dependent. Today, Brisbane is promoting new approaches to urban construction and spatial designs that create attractive living environments and walkable areas in this subtropical city.

Water Cycle and Water Catchment Management

Brisbane's growing population is increasing pressure on the city's supply of potable water. The average annual rainfall in Southeast Queensland is about 1,200 millimeters (as compared to 2,400 millimeters in Singapore). Although higher than in other Australian cities, Brisbane's rainfall is less predictable, and careful water resource management is required. In recent years, drought has become a serious national problem. States with authority in water management can undertake measures to conserve water, including by applying water use restrictions (with penalties for overuse) and subsidizing rainwater tanks. Brisbane has also pursued integrated water cycle management encompassing water provision, wastewater treatment, storm water management, and strategic land management. Poor land management in water catchments results in lower quality water and higher water treatment costs. As a subtropical city, Brisbane is endowed with creeks and waterways and rich biodiversity. The city is working to restore the health of its waterways and creeks through various means, including removing weeds, encouraging communities to plant native seedlings, and reducing illegal dumping by sponsoring community campaigns.[109]

Public Transport—Bus Rapid Transit System

Brisbane has two Bus Rapid Transit (BRT) systems: the Brisbane South East Busway, which opened in 2001, and the Brisbane Inner Northern Busway, which opened in 2004. These BRTs fall under the jurisdiction of the Queensland Government as well as Queensland Transport, which is committed to public transport provision to support growth and connectivity in greater Brisbane. Brisbane's BRT networks are designed to provide public transportation services to areas that existing rail lines (Queensland Rail) do not cover. Brisbane's South East Busway connects Brisbane's CBD to the city's southeastern suburbs, which edges a sprawling suburban area. The busways are two lane, bidirectional roads used exclusively by buses and emergency vehicles. This permits buses to bypass congestion. The system also provides high-quality and well designed bus stations with good pedestrian access.[110]

Busways reduce the growth of car traffic on roadways mainly due to their greater carrying capacity. One motorway lane can accommodate 2,000 passengers per hour, but one busway lane can carry 15,000 passengers per hour. In addition, busways significantly reduce travel time. For example, a typical route that takes 60 minutes on a Brisbane motorway is reduced to 18 minutes by riding a bus on the South East Busway. Fewer cars and less travel time decrease vehicular emissions, which helps to mitigate climate change and improve air quality. In general, less time commuting translates into greater urban productivity and economic activity. The BRT also affects land development. Along the South East Busway, property values within 6 miles of bus stations rose up to 20 percent; moreover, rates of growth in property values were 2 to 3 times higher than in areas farther from stations.[111]

Lesson Learned from Brisbane

Brisbane has responded to its unique local situation as a subtropical city under growth pressures. Climate change has already started to impact the city; water is scarce and temperatures are higher. Responding to its natural conditions, Brisbane protects water resources, plants trees to improve its urban ecology, and promotes a sustainable built environment. These actions save money for the city and its residents. Many developing country cities are in tropical and hot climates, and may be vulnerable to climatic changes. Some cities may be highly dependent on air-conditioning, which is relatively energy consuming compared to other viable strategies. In this context, Brisbane's measures and actions may provide good examples for how cities might respond to such challenges while remaining ecologically and economically vibrant.

CASE 6

Auckland, New Zealand

Successful collaboration at the regional scale, including the creation of an over-arching long-term planning framework[112]

Auckland is New Zealand's largest medium-sized city. The region is home to over 1.3 million people, about one-third of the national population, and the region's population grew by 12.4 percent between the 2001 and 2006 censuses. Auckland is characterized by ethnic diversity with just over one-third (37.0 percent) of the region's residents born overseas. In the region, there are four cities and three districts, each with its own council, as well as one regional council.[113]

Currently, each council develops its own plans and strategies, which resulted in areas of overlap and competing priorities. Collective regional strategies for growth and urban form, economic development, and transport planning have also been developed. However, they do not have common goals or principles to ensure their alignment.

The Auckland region's lifestyle and employment opportunities continue to attract new inhabitants, but there have been drawbacks in such significant growth, namely a lack of cohesive and effective approaches to ongoing transport problems and concerns about the pattern and nature of urban growth. As a result, the Auckland Regional Growth Forum (RGF) was established in 1996 as a co-operative forum of

Figure 3.31. Auckland Harbor Viewed from East

Map 3.8 Location of Auckland

political representatives from the Auckland Regional Council and the region's territorial local authorities. The RGF's aim is to develop and implement a strategy for managing the effects of growth.

Governments at every level recognize the need for a collaborative, regional-scale process

The interconnectedness of national and local Auckland issues, such as housing and education, with growth and innovation and the major required investments, particularly in land transport, created complex and difficult decisions among multiple authorities. Despite Auckland's importance to the New Zealand economy, and areas of common interest, such as transport and energy provision, the national government had not taken a close role in directing regional and local government planning. Concern emerged that without agreement on an overarching regional strategy and framework, decision-making in the region could be *ad hoc* and adversarial if each stakeholder tried to have a say from its own perspective, without viewing the region as a whole. As a result, there was a clear need for coordinated strategic planning across the Auckland Region to ensure that Auckland could compete as a twenty-first-century city. This was responded to by the preparation of a Regional Growth Strategy (2001), which aimed to provide a vision for what Auckland could be like in 50 years. This was backed up by a spatial growth plan and a legislatively binding Metropolitan Urban limit

In parallel to the work on a regional growth strategy, a three-year Auckland Sustainable Cities Programme (ASCP) was initiated in 2003. In 2006, as a result of the ASCP, the eight local authorities (Auckland City, Auckland Region, Franklin District, Manukau City, North Shore City, Papakura District, Rodney District, and Waitakere City) in collaboration with central government, and at the instigation of their Chief Executives' joint forum, engaged with central government to develop a long-term sustainability framework. Initially termed START (Sustaining the Auckland Region Together), it attempted to evaluate 'forces' which might play a more significant role in the long-term over a 100-year vision to align government efforts and create strategic directions. Drivers for START included the need for resilient systems able to respond to persistent pressures over short and long time horizons with no obvious alternative solutions, and many vested interests with apparently irreconcilable implications.

Making a START: gathering information

The START working group developed a prototype framework with a cascading set of deliverables, including a vision, goals, initial foundation and process principles, initial themes, some potential responses, which included catalyst projects and long-term sustainability goals, and development of indicators to measure progress. Critical to progressive development was consideration of the 'forces' which would shape Auckland's future over the next 100 years. Also significant to the development of the framework was the involvement of 'expert groups' including academics and experts from the business and community sectors, who through facilitated workshops developed theme papers

BOX 3.4

Eight Goals Direct the Auckland Framework

The Framework is built around eight interrelated and long-term goals that will enable the region to take a sustainable development approach:

Goal 1	A fair and connected society
Goal 2	Pride in who we are
Goal 3	A unique and outstanding environment
Goal 4	Prosperity through innovation
Goal 5	Te puawaitanga o te tangata— Self sustaining Maori communities
Goal 6	A quality, compact urban form
Goal 7	Resilient infrastructure
Goal 8	Effective, collaborative leadership

Figure 3.32 Logo of START

for key issues identified in the prototype framework, namely: the built environment, urban form and infrastructure, energy, economic transformation, social development, cultural diversity and community cohesion, and environmental quality. Each group deliberated around four 'sustainability principles'—resilience, prosperity, liveability, and ecology—and considered how they would be influenced by the forces.

In a linked but parallel process, a working group representing all Maori tribes (New Zealand's indigenous people) of the Auckland region developed its own collective long term framework entitled the Mana Whenua Sustainability Framework (2008). The working groups of both processes built linkages between the two frameworks, including a basic common structure, common analysis via the forces and theme papers, a Maori goal in the Auckland Sustainability Framework (ASF), and an indigenous concept of sustainability, which fed into the ASF definition of sustainability. The ASF acknowledges Mana Whenua as the first peoples of the region, and as an intimate part of its ecological and cultural fabric.

In August 2006, a three-day START design workshop enabled 120 representatives from local and central government, academics, and the community and business sectors to contribute expertise and perspectives into further developing the draft 100-year framework (Sustainable Auckland, 2007b). The methodology drew heavily on the Vancouver 'Cities Plus' model (Sheltair Group, 2003), which moved from a high-level vision to responses and indicators with an adaptive management approach to developing a responsive, resilient urban planning framework to address future challenges. The workshop used a 'charrette' format, referring to a process where ideas emerge and evolve quickly. It is an interactive process that harnesses the talents of a range of parties to resolve planning challenges. The charrette form is particularly successful for local government to engage the community in planning processes and the product is usually a tangible output for immediate implementation.

Stakeholder consultations and inter-agency coordination

As a result of feedback and wider strategic discussions following the START workshop, the framework was to include:

- Addition of shifts from business as usual as a key component of the framework
- Goals and key directions being integrated together and the addition of leadership and Māori goals
- Adoption of a revised version of a regional vision developed by a youth contingent
- Development of a draft set of indicators
- Development of the process and tools for applying the framework

A governance and reporting structure was set up with the project being overseen by the council officers' Steering Committee, sponsored by the Chief Executives' Forum responsible for final sign-off of the framework. Consultation with stakeholders and the public took place (February to May 2007) with 19 workshops and around 200 participants, plus written submissions from several individuals, four organizations, and two regional councils. A revised version, now termed the Auckland Sustainability Framework, was endorsed in September 2007

Figure 3.33 Strategic planning among many stakeholders at a 3-day regional charrette

by the RGF after being endorsed by all member local authorities and government agencies. It also received high level support from central government. The ASF's goals and visions were consistent with central government priorities especially in the substantive shifts needed from the present. In turn, it was recognized that the ASF would provide a tool to review national policies as they impact Auckland. However, it was also recognized that it was needed to understand better how goals would be achieved and what indicators would be needed to assess progress.

The ASF is also intended to guide and align regional strategies (e.g., Regional Growth Strategy, Regional Land Transport Strategy, and Auckland Regional Economic Development Strategy). The process of developing a framework was, therefore highly inclusive, with many conversations feeding into the framework and emerging responses. The RGF, for example, facilitated region-wide discussions and joint political decision-making and a councillors' reference group to provide direction and support. Similarly, local authorities and central government formed a senior officers steering group

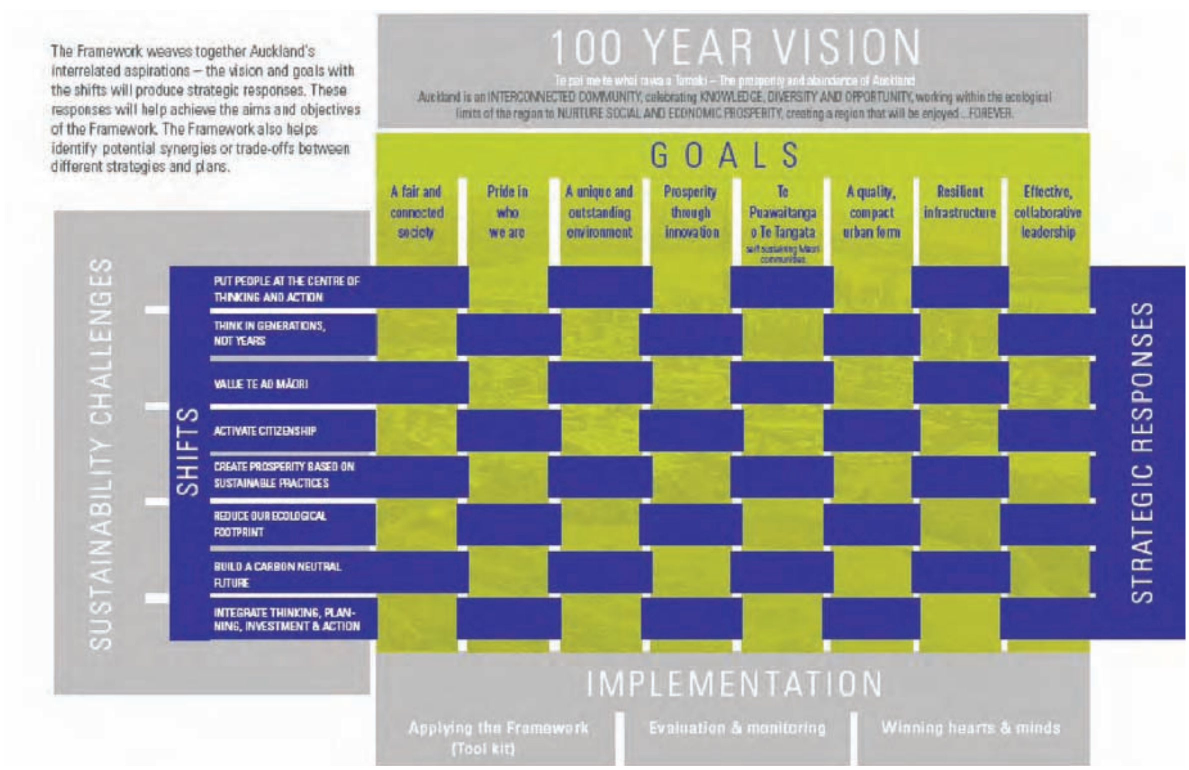


Figure 3.34 Auckland Sustainability Framework (ASF)

Source: Information and inputs on ASF obtained through personal conversation with Claire Mortimer, Landcare Research New Zealand Ltd.

and an officers working group. As stated earlier, a key collaborative element was the relationship between central and local government and common governance elements, primarily through GUEDO, including a joint commitment to developing a shared long-term view of a sustainable Auckland.

The final adopted framework is comprised of:

- Identification of key sustainability challenges that the region will need to address
- A 100 year vision
- Eight long term goals
- Eight shifts from current practice required to meet those goals
- Suggested strategic responses
- A measurement framework and monitoring process
- A toolkit to apply the framework to strategies, significant decisions, and plans and to integrate regional planning

The framework's role is to:

- Align existing regional strategies and projects; e.g., Regional Growth Strategy, Regional Land Transport Strategy, Auckland Regional Economic Development Strategy
- Align future regional strategies and projects
- Be used to guide the development of a regional One Plan
- Provide methods to adapt business-as-usual (e.g., local councils 10 year Community investment Plans).
- Identify strategic responses that must be undertaken to achieve sustainability goals

As stated in the document: "It will provide direction so that our local authorities and central government agencies can work together with a common purpose to embrace the opportunities and face the challenges associated with developing a truly sustainable region."

Keys for Success

Extended Peer Communities

The overall process created considerable buy-in at both political and administrative levels with the resulting framework being owned by all parties. However, there has been a considerable change in political representation at local and national levels since the adoption of the framework, with many new councillors who were not involved in the framework's development, and a national government that has largely redefined sustainability into a narrower concept of natural resource management.

Despite this, the framework has been used to develop a collective investment plan referred to as 'One plan,' as well as a number of local council plans, including the Manukaus 2060 Strategic Framework and the Waitakere City Council's Social Strategy.

Stretching thinking

The Framework and especially the participatory process stretched many participants thinking in relation to these topics:

- Recognizing that the world and Auckland were going to experience exponential change over the next 50 years, and that they have limited time to prepare for those changes
- That they will need to shift many of their business as usual practices
- Expanding understanding of what sustainable development meant, especially through bringing in a Maori perspective
- Development of the Mana Whenua framework

Developing a separate but linked Maori Framework ensured that the long term planning for Maori was by Maori. The depth of indigenous understanding of generational thinking, and the holistic and spiritual understanding of the relationship between the environment and people, was fully realized in the Mana Whenua framework, and went on to challenge and stretch the thinking on the ASF.

Lessons Learnt

There appear to have been two groups less well represented: business representatives and developers who would eventually implement strategies and activities based on the framework. A special process may be needed to engage these groups, since they are typically reluctant to attend open meetings, and require a process that is especially well facilitated and efficient with time.

After the ASF was adopted, the region quickly focused on new priorities. As a consequence, one component of the framework entitled "winning hearts and minds" in Figure 3.34 did not progress. Winning hearts and minds acknowledged the importance of the social learning process that councillors, key staff, and stakeholders experienced through the Framework's development. Continued dialogue and education on sustainability challenges and solutions was required for these key decision-makers and for the public.

While the ASF was adopted as a guiding framework, the ASF has not yet developed any hard targets that plans and strategies are required to meet. The ASF has also not developed bottom line thresholds for public sector decision-making. Without these elements, the ASF may become a useful tool for some parties, but something to ignore by others. The new national government is restructuring all eight local government bodies within the region into a single unitary council, and it remains to be seen whether this new council will adopt the ASF as the region's guiding framework.

Eco² Sector Notes

A Sector by Sector Lens on Urban Infrastructure

Introduction

As cities devise their Eco² Pathways, it helps to survey these through the lens of each urban infrastructure sector. Ideally, this leads to a kaleidoscopic view of the city that recognizes the interrelationships of *energy, water, transport,* and *solid waste*. These interrelationships apply across sectors and vis-à-vis the built form of the city. In this context, the final note on managing the spatial structure of cities provides important lessons on how spatial planning and land use regulations can powerfully impact mobility and affordability.

It is clear that many of these sectors' operational and jurisdictional lines impede innovation and creativity in achieving better outcomes. It is also clear that investments made in one sector can result in savings in another sector (for example, investments in water efficiency usually result in large energy cost savings). Pooling scarce resources to invest in multifunctional and multipurpose common elements can also benefit urban residents (for instance, through single purpose underground infrastructure corridors).

What emerges from a closer analysis is an understanding of how these infrastructure systems interact with a city's spatial form. Infrastructure investments trigger and enable urbanization. However, urban planning and spatial development establish the locations, concentrations, distributions, and nature of demand nodes for sector infrastructure systems. Urban and spatial planning also identifies the physical and economic constraints and parameters for infrastructure systems, including capacity limits, service delivery technologies, and cost-recovery requirements. Good urban planning and spatial development provide proactive 'demand side' management and improve resource efficiency by identifying and assessing the viability of technology and infrastructure options. For instance, public transportation is financially viable only at certain threshold urban densities and forms—and under good urban land use coordination.

In addition to illustrating the opportunities and strategies for realizing benefits within and across sectors, the following notes shed light on critical sector-specific issues that are not under direct control of city authorities, but nonetheless impact city sustainability. These issues may need to be addressed on a sector by sector basis. Moreover, identifying critical pressure points beyond the direct control of city authorities is important to devising an expanded platform for collaboration.

SECTOR NOTE 1

Cities and Energy

Overview

Cities, or urban areas, account for about two-thirds of the world's annual energy consumption. In the coming decades, urbanization and income growth in developing countries are expected to push urban consumption even higher.[114] As the main consumers of energy and as implementers of national and regional sustainable energy policies and programs, cities can play a crucial role in improving our energy and environmental futures by making smart choices in urban development, energy demand management, and energy supplies. In return, cities stand to become more livable, affordable, and sustainable.

Traditionally, urban energy planning and management have aimed to improve access, security, reliability, and affordability. These efforts have focused on developing network-based energy systems (on which cities have become dependent), such as electricity grids, district heating networks, and natural gas pipelines. These efforts remain essential because modern cities simply cannot function without such networks. However, the potential for dire environmental impacts of traditional urban energy use persists, as exemplified in the London Smog disaster of 1952 that killed 12,000 people. Today, heavy urban air pollution in many developing countries is a sober reminder that many growing cities cannot cope with the serious health related impacts of consuming fossil fuels. The first oil crisis of 1973 further highlighted the importance of energy efficiency, conservation, and renewable energy. However, thirty-five years later, achieving progress in energy efficiency and renewable energy remains a tough challenge in both developed and developing countries. The emergence of climate change as a global development constraint, much of it related to the energy consumption habits and infrastructure in cities, also calls for fundamental changes in how countries and cities approach urban development, manage energy demand, and secure energy supplies.

How can cities address their multi-dimensional energy challenges, which affect their success and long-term development prospects? The evolution of urban energy agendas—from access, security, reliability, and affordability to environment and public health concerns, and, more recently, to climate change mitigation and adaptation—has challenged cities and national and regional governments to break away from supply-centric practices and strengthen environmental rules in planning and management. The largely successful control of local and regional air pollution in cities in developed countries is encouraging and suggests possibilities to expand efforts in developing countries. This success relied mainly on relocating factories, switching to cleaner fuels, and adopting stringent national and regional emissions regulations for industries and motor vehicles. As a result, many cities have become more attractive and competitive. Controlling cities' carbon footprints represents the greatest current energy challenge, but urban planners can tap this challenge to strengthen energy security and enhance energy access, affordability, and reliability. To be successful, cities must manage energy demand by promoting energy efficiency across sectors and the uptake of efficient and renewable energy supplies. It is also important, particularly in developing countries, that urban planners support solutions incorporating energy efficiency and renewable energy in urban land use planning and land development. These efforts require that cities are actively involved in energy planning and management, and that they adopt long-term visions for urban development and redevelopment.

Visionary cities are adopting a new paradigm of integrated urban energy planning and management. Recent examples include the PLANYC 2030 of New York City and Plan Climat de Paris.[115] However, implementation hurdles remain and the real test of turning visions into realities lies ahead. City governments are often faced with urgent tasks and competing interests and must prioritize actions against constraints in human and financial resources. City administrations often lack a single department with adequate authority to spearhead a cross-cutting agenda, with the exception of the mayor's office, which commonly cannot sustain efforts because of mayoral term limits. In addition, urban energy planning and management are not entirely within the jurisdiction of city governments. In fact, prevailing urban energy infrastructures, with the exception of district heating systems, are usually not under the direct purview of local governments.[116] Moreover, if cities are to succeed, they need strong support from their national and regional governments.

Why should a city government care about being assertive and making and implementing sustainable energy decisions? The short answer is that it pays. Most energy efficiency and conservation measures are not high-tech or expensive and initial costs can usually be quickly recovered. The municipality of Emfuleni in South Africa, for example, initiated an energy and water efficiency project that cost US$1.8 million and achieved annual savings of about 7 billion liters of water and 14 million kWh. This equated with annual monetary savings of over US$4 million, thus the project paid for itself in under 6 months. Since the contract was financed and implemented by an Energy Service Company (ESCO), the municipality not only saved money from reduced water losses and pumping costs, but also through less investment upfront. The ESCO, on the other hand, recouped its investment quickly by sharing part of the cost savings.[117] As another example, the Växjö Municipality in Sweden began in 1994 to replace its street lights with high efficiency lamps, which reduced energy use by 50 percent. After a project investment of about US$3.6 million, the city saved US$0.75 million per year, which meant the project paid for itself in under 5 years.[118] Cities facing budget shortfalls are well-advised to consider mining current expenditures for energy savings in their facilities and operations.

In cities in developing countries with serious air pollution, energy efficiency and cleaner energy promotes reduced medical bills and productivity, which improves urban livability and competitiveness. A recent joint study by the Chinese Government and the World Bank estimated that the cost of ambient air pollution in China's urban areas—in air pollution-related premature deaths and illnesses—amounted to US$63 billion in 2003, equivalent to 3.8 percent of China's GDP.[119] In fact, China's efforts in the past two decades to modernize energy infrastructure and improve energy efficiency have aimed to reduce the health impacts of air pollution. This is evident in the fast penetration of gaseous cooking fuels, and the rapid expansion of district heating systems in northern Chinese cities, which are also implementing national building energy efficiency standards.

Among fast growing cities in developing countries, shifting to a new paradigm of urban energy planning and management is as much about contributing to global welfare as enhancing capacity to serve growing energy needs at lower costs and with greater security. Good environmental stewardship in energy planning and management is essential to mitigate regional and global environmental impacts that affect the long-term well-being of cities (for example, acid rain, climate change-induced storms, and rising sea levels). Making cities more energy-efficient and more accessible to renewable energy supplies also helps to hedge risks of higher energy costs if a global agreement is reached to drastically reduce anthropogenic GHG emissions. This does not, however, mean that developing cities should address all sustainable energy options at the same time. Pursuing actions on sustainable energy, however cost-effective they may be, requires public and private investment, efforts from city governments and citizens, and strong support of regional and national governments. Cities should, moreover, tailor their efforts to available resources and pursue initial steps toward sustainable energy that generate significant and immediate local benefits.

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

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

Promoting energy efficiency and application of renewable energy technologies in the urban built environment. City governments can promote energy efficiency and renewable energy options in non-municipally owned or operated sectors harnessing their dominant roles in shaping the urban built environment. One of the most critical and effective interventions is enforcing national or regional energy efficiency standards in new building construction and building renovations.[120] A more ambitious green building agenda can also include additional requirements for water efficiency and conservation, adoption of renewable energy technologies, incentive programs for industry and residential users, and other measures to reduce the environmental impact of buildings;[121] and

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

Cities in developing countries face much tougher challenges than their counterparts in developed countries. Often technical capacity is lacking. Competition for resources is fierce. Under growth pressures and capital constraints, compromise is often made to serve more instead of serving more and better.[122] While cities must actively engage in promoting sustainable energy solutions, urban leaders need more support and cooperation from regional and national governments to be successful. Substantial donor support, knowledge, and finance are also needed to encourage cities to enact sustainable energy actions in these three areas.

This chapter reviews the general urban energy landscape, particularly for cities in developing countries. It reviews activities linked to

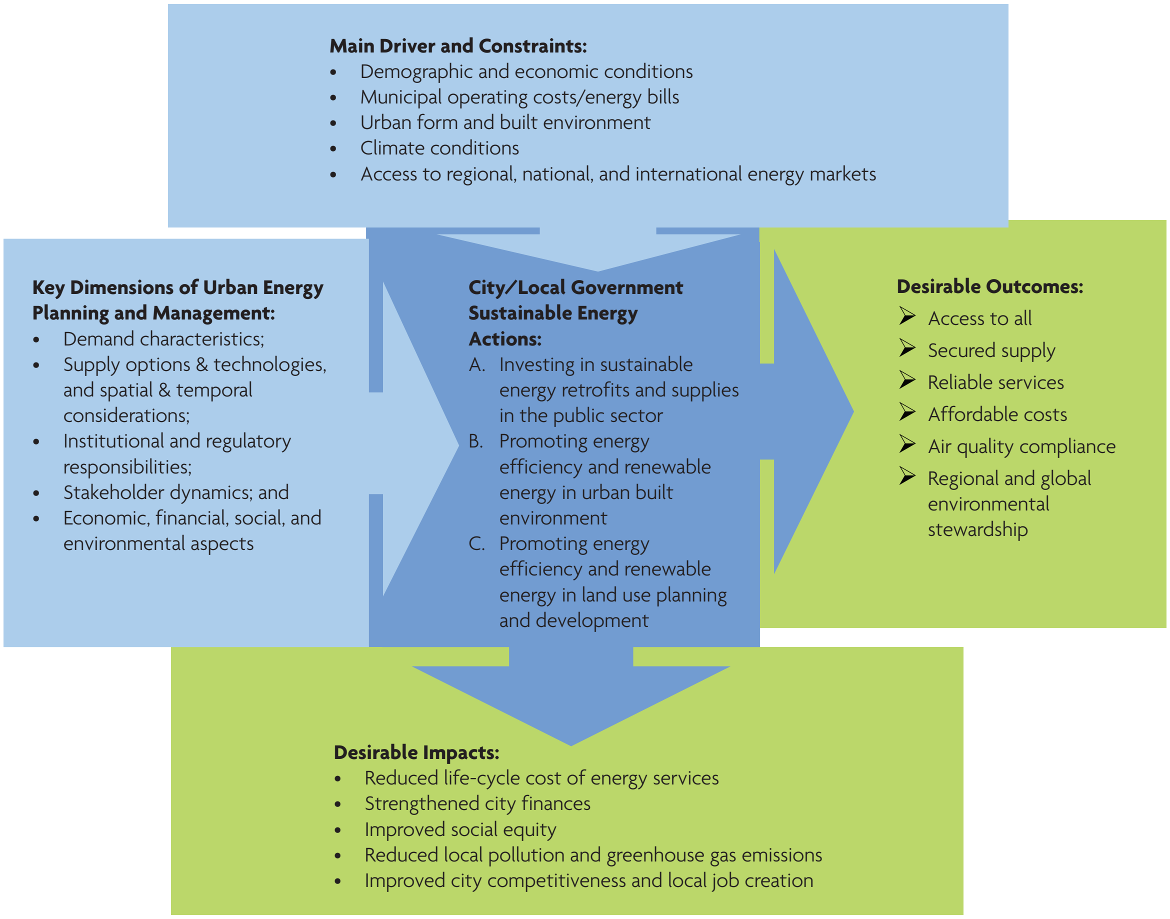


Figure 3.35 A Stylized Framework for Approaching Urban Energy Planning and Management

basic energy consumption, options of energy services and supplies, factors affecting urban energy planning and management, and good practices, lessons, and challenges in urban energy planning and management. Figure 3.35 depicts the aspects of sustainable urban energy planning and practice that this chapter will elaborate.

Urban Energy Planning and Management: Key Dimensions

Understanding Energy Use in Cities

A city's energy profile—amount of use, mix of energy types, and patterns of use by sector or end-use activity—is determined by many factors, including population, income, economic structure, energy prices, end-use efficiencies, climate conditions, urban forms, built environments, and access to regional and national energy markets. Understanding the dynamics or constraints imposed by these factors is the starting point of sustainable urban energy planning. It is important to note that the amount of energy use is not a good indicator for the actual level of energy service rendered or needed (for example, for lighting, cooling, heating, or refrigeration). The critical factor is ***energy efficiency***, which refers to the adoption of improved technologies and practices to reduce the energy required to provide a same output or level of service. In the urban context, it is important to assess how much useful energy can be extracted from the primary source, delivered to end-users, and turned into energy services.[123] For buildings, energy efficiency also implies reducing energy needs by improving structural design and use of materials.[124]

A recent account of urban energy use conducted by the IEA delineated all energy-consuming activities within a city[125]. Based on this account, urban energy use can be lumped into four broad categories: industry, transport, municipal services, and buildings. A breakdown of these categories is presented in Table 3.8.

Buildings that do not conform to the first three categories include a broad spectrum of structures from single-family houses and apartment building to schools and hospitals to offices and shopping malls. Factory buildings are excluded. For statistical purposes, buildings are usually divided into residential and commercial buildings. Residential buildings, which account for most of the urban building stock, are well defined as owner or renter occupied houses or apartments. But commercial buildings are diverse and usually include office buildings, shopping malls, supermarkets, hotels, and other buildings that host commercial or public entities. Government-owned and operated buildings, as well as schools and hospitals are lumped under commercial buildings. Government buildings are separately identified in Table 3.8 as they represent special opportunities for sustainable energy interventions by city government.

Typically, urban energy use in service-oriented cities in developed countries is dominated by buildings and transport, which account for two thirds or more of energy consumption. In rapidly industrializing developing countries, such as China, industrial energy use is often predominant in large cities. Even in Beijing, one of the most modern and high-income cities in China, manufacturing still accounted for about half of energy consumption in 2006[126]. In general, buildings and transport are the fastest growing energy sectors in cities in developing countries. They are also the sectors where sustainable energy measures can have the largest impacts. Countries with growing middle classes typically have explosive growth in electricity for residential air conditioning and larger appliances. Although cities generally do not control appliance efficiency, and equipment standards are under the purview of national governments, cities can adopt incentive programs to encourage the adoption of more efficient appliances.

Though industries form part of the urban landscape, including them in urban energy accounting can lead to skewed views of city ener-

Table 3.8 Energy Consumption in Cities: Main Sectors/Clusters

SECTOR/CLUSTER CATEGORY	SUBCATEGORY	CITY GOVERNMENT SUSTAINABLE ENERGY INTERVENTION, POTENTIAL LEVERAGE
Industry	Manufacture	Indirect, relatively weak
	Construction	Indirect, relatively week
Transport	Private motor vehicles	Indirect, relatively weak
	Commercial motor vehicles	Indirect, relatively weak
	Public transit systems	Direct, strong
	Government motor vehicles	Direct, strong
Municipal Services	Water supply and wastewater treatment	Direct, strong
	Solid waste management	Direct, strong
	Public lighting and traffic lights	Direct, strong
Buildings	Government buildings	Direct, strong
	Commercial buildings (non-government)	Indirect, strong in new constructions
	Residential buildings	Indirect, strong in new constructions

gy consumption and performance as the type and significance of industries varies between cities. For consistency in cross-city energy comparisons, it may be necessary to exclude (or separate) industrial energy consumption from the typical urban energy-consumption sectors indicated in Table 3.9.

For urban energy planners, it is also necessary to separate urban energy demand and consumption into key end-use activities, often within the four main sector categories outlined above. End-use activities are more or less similar across cities, although the energy type supporting specific end-uses can vary even within a city (Table 3.9).

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

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

Energy costs are critical to understanding energy use in cities and are often a primary energy-related concern of city officials. Decisions on sustainable energy must be economic and financial. However, data on the costs for different energy types and aggregate energy costs in urban sectors is often inadequate. Cost information on individual end-use activities, or even simple data on common energy indicators (for examples, kWh/m^3 of water delivered, tons of oil equivalent/person per mode of transport, W/m^2 for building lighting) are also rare.

Few cities in developing countries systematically track their energy consumption patterns and costs. Without adequate energy consumption data and cost information, cities will not be able to effectively plan and implement sustainable energy measures. Recent efforts to establish an international protocol and tools to inventory urban greenhouse gas emissions are helping to build a platform that can facilitate improved urban decision-making on sustainable energy approaches.[127] Besides basic accounting, a critical element of urban energy planning is to inform

Table 3.9 Energy Consumption in Cities: Key End-use Activities and Energy Types

MAIN ENERGY END-USE ACTIVITIES IN CITIES	COMMON ENERGY TYPES USED IN CITIES						
	ELECTRICITY	NATURAL GAS*	LPG**	KEROSENE	GASOLINE DIESEL	COAL	FIREWOOD CHARCOAL
Lighting	■			■			
Cooking	■	■	■	■		■	■
Water heating (domestic hot water)	■	■	■			■	■
Appliances (refrigerator, etc.)	■						
Home & office electronics	■						
Air conditioning	■						
Space heating (cold climate)	■	■				■	■
Motorized transportation	■	■	■		■		
Motive power (stationary)	■						
Processing heat or steam	■	■				■	

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

stakeholders of opportunities for demand management through investments in energy efficiency and conservation programs and alternative supplies. Simple benchmark data, such as quantifiable measures of energy use for lighting and heating, can help city managers identify sectors that exceed norms and plan remedial interventions. Options for additional supplies, such as cogeneration from wastewater treatment plants or methane capture from landfills, can also be assessed. Evaluations of such options require evaluation tools that can help cities examine and compare their energy performance with good/best practices, and understand cost and benefit implications. Development of practical decision support tools and methods for sustainable urban energy planning and management help cities to quickly identify and prioritize sustainable energy actions grounded on local capacities and realities.

Energy Supply Options, Technologies, and Spatial and Temporal Considerations

Modern cities are highly dependent on network-based electricity and, to a lesser extent, natural gas supplies that are connected to regional and/or national networks. There are often power plants located within city boundaries, but these are often owned and/or operated by regional or national electric utilities, or independent power producers.[128] Developing cities generally aim to ensure secure and reliable access to regionally-integrated and network-based energy supplies. District heating systems represent another network-based energy service common in cold climate cities, especially in Europe and China. But they are limited to areas of a city with sufficiently high building density. Supplies of solid and liquid fuels, such as coal and petroleum products, are usually decentralized: different users may buy fuels from different producers or local distributors. The supply of transport fuels is usually vertically controlled by oil companies. In low-income country cities where peri-urban and slum population are significant, firewood and charcoal are often important cooking and, in cold climates, heating fuels. Firewood is locally supplied and is often collected by individual households; charcoal is usually supplied by informal service providers. As a city grows in wealth, there is a progression toward higher dependence on network-based energy supplies and decreasing use of solid fuels (coal and firewood) among households and other dispersed service points. In general, cities and urban areas are almost entirely dependent on external energy supplies (even power plants located in cities need to import fuels).

It is possible to conceive a city's energy supply options and technologies along the three main energy delivery channels depicted in Figure 3.36. In mildly cold and warm climates, centralized heat supply is generally not an economically viable option and is not considered. Electricity and centralized heat are often subject to urban energy optimization in cold climates since they can be produced together through combined heat and power plants. Cooling can be provided by using heat energy to drive a cooling system using absorption chiller technology. Thus, district heating systems can provide cooling services in the summer if it is economically justified. Distributed energy resources (DERs) often produce electricity while providing heating and cooling services. Natural gas not only provides a cleaner alternative to oil and coal, but also brings more flexibility to urban energy services through distributed generation facilities. For a large city, fitting all the pieces together to optimize sustainable energy outcomes is not an easy undertaking. This is especially challenging in developing country cities where energy supplies are less organized or streamlined compared to their developed counterparts, where energy supplies are primarily network-based.

The advance of centralized and distributed

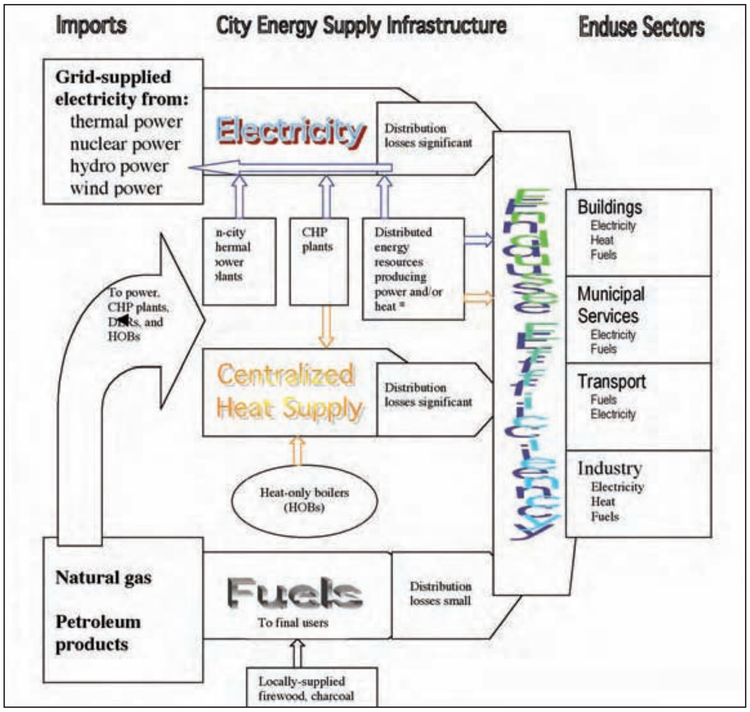


Figure 3.36 Urban Energy Supply Sources and Systems: A Stylized Sketch

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

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

As pointed out earlier, consumption of solid fuels in households and other dispersed end-use points (such as restaurants) tends to fall as gaseous fuels, either LPG or natural gas, become available, or electricity becomes more abundant. Such a transition can take decades and often requires construction of regional and national energy infrastructure. In China, dispersed use of solid fuels in urban areas decreased dramatically in the last twenty years. Solid fuels have been largely eliminated from cooking and are now mainly used in a decreasing number of cold-climate urban households that have no access to centralized heating or natural gas. This trend was achieved with the strong support of national government to boost LPG supply and expand natural gas transmission networks.

Both spatial and temporal concerns are important to developing network-based urban energy infrastructure. Spatial planning entails the layout of the network within the existing and planned built-up areas to achieve the most efficient routing and siting of generation and distribution-facilities based on demand and load distribution. Temporal planning addresses system size based on current and anticipated demand and load and, most critically, the sizing of mains and trunk lines that are difficult to rehabilitate once built. The latter point is especially important in fast growing cities and has significant financial implications. Owing to uncertainty in predicting demand, sizing is part science and part luck. However, decisions on sizing are more reliable when planners are informed of urban energy demand patterns and trends, and can access knowledge from other cities confronting similar situations.

Urban planners should also consider the constraints of overlapping energy supply networks: for example, covering the same urban area with both natural gas and district heating networks, which has occurred in China and some eastern European cities. In China, the scarcity of natural gas, which is piped into households for cooking and water heating, represents a relatively expensive investment for gas companies. As such, space heating is normally provided by separate district heating systems. In eastern European cities, natural gas was introduced more recently, and is competing with established district heating systems. While competition is normally good, it is not necessarily beneficial in this case as it undermines the capital investment in district heating systems. In Germany, many cities do not allow utilities to provide district heating and natural gas services in the same area since both energy

BOX 3.5

Energy Planning in the City of Mannheim (Germany)

To strengthen energy planning, Mannheim was divided into zones based on the type of energy network. A municipal-owned utility supplies natural gas, electricity, and district heating. Electricity is universally supplied. Space heating is supplied by natural gas, district heating, or electricity. In areas with high heat loads, district heating is provided and is the least-cost option. In areas with medium heat loads, natural gas provides decentralized heating. Areas with low heat demand are supplied by electricity via off-peak electric heat storage devices. Large customers such as department stores, hotels, and office buildings are cooled using absorption chillers linked to the district heating system.

By avoiding parallel gas and district heating networks, least-cost energy provision is achieved. In zones served by district heating, gas is no longer offered. Electricity and district heat is produced by a CHP plant in the city. The same utility operates public transport and water supplies. In this way, energy demand and production can be optimized for the most important needs of a city.

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

Source: Kalkum, 2008

carriers provide to a large extent the same service: space heating (Box 3.5).

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

Policies, Legislations, and Regulations

In general, national and regional legislators and governments are responsible for energy sector policies and regulations. Cities have limited influence on these political and legislative processes, except on localized energy services that require government interventions, such as district heating systems. The degree of regulation and government oversight in the energy sector varies by country. In many large economies, the energy sector is subjected to multiple policies and regulations, and is influenced by a mix of government institutions for reasons ranging from energy security to market competition to social and environmental concerns. Network-based energy services usually have regulated service charges to respond to social concerns (e.g., unduly high energy costs for the poor) and to protect against monopolistic price gouging. The prices of solid and liquid fuels are also often subjected to government intervention through taxes and subsidies. Energy sector policies and regulations used to be supply-centric, but have changed substantially since the first oil crisis in 1973. Many countries now have regulations and standards requiring minimum energy efficiency levels for energy-consuming equipment, appliances and building components. These are commonly called minimum energy performance standards. Governments may also initiate special policies and programs to incentivize adoption of renewable energy and energy-efficient equipment. Table 3.10 summarizes the general elements of energy policies and regulations and how cities are affected or involved.

Institutions

The multi-tiered and multi-faceted nature of energy sector management and regulation lends itself to complicated institutional interactions. Box 3.6 provides an example of one of the more elaborate institutional and regulatory settings for urban energy planning and management.

The roles of national and regional governments are critical. National and regional energy policies, legislation and regulations influence the transparency, consistency, and predictability of modern energy supply systems in individual cities, and address common social and environmental issues. National and regional governments also establish general provisions that incentivize cities to adopt sustainable energy practices. These include, for example, renewable energy feed-in tariffs that mandate electric utilities to purchase wind- or solar- generated electricity at set prices, or energy performance standards that set minimum energy efficiency levels for new appliances and new buildings. On the other hand, existing national and regional regulations may hinder cities' sustainable energy measures. For example, in most countries, prevailing regulations on electric utilities discourage utility demand side management and

Table 3.10 Energy Policies and Regulations and Linkages to Cities

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

BOX 3.6

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

Federal

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

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

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

State

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

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

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

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

Regional

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

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

Local

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

Source: Lantsberg, 2005

installation of distributed generation facilities, including renewable technologies.

The role of city government in setting broad energy sector policies and regulations is limited and is likely to remain so because of the nature of modern energy systems. But that does not prevent cities from planning and deciding what, where, and how urban energy infrastructure should be built. Cities can also take measures to influence national policies while seeking to influence local behaviors through voluntary programs and initiatives. Since city governments are intimately involved with every aspect of urban development and management and wield real power to influence urban energy demand, they are uniquely able to tie urban energy supply and demand into one piece. That makes cities one of the most effective actors in pursuing sustainable energy activities. Nevertheless, most cities are not yet organized effectively to pursue sustainable energy planning and management. In the traditional supply-driven and network-oriented urban energy landscape, the role of cities is limited. Even in a sophisticated city like New York, officials realized that a New York City Energy Planning Board was needed to effectively link supply and demand as part of an integrated energy strategy[129].

Stakeholder Dynamics

Urban energy planning and management is shaped by several principal stakeholders: local/city, regional/state, and national/federal governments (and their relevant agencies or authorities); public and private energy utilities, companies, vendors and investors; customers; and public interest entities. Other stakeholders include financiers; equipment and service providers (e.g., ESCOs); city service users; and other local governments (etc.). The relationships among these stakeholders are relatively straightforward: governments regulate urban energy services to ensure quality, safety, environmental controls, and fairness to customers and investors; energy providers produce, transmit, transport, distribute and/or retail energy to customers; and customers pay for energy to sustain services and reward investors. The public interest entities or organizations advocate on behalf of disadvantaged social groups, such as low-income households, to improve access and affordability. These groups also inform and educate other stakeholders about sustainable energy solutions and press for relevant action. In particular, climate change has mobilized many international and domestic public interest entities.

Traditionally, city governments are most concerned about the needs and interests of consumers in their jurisdictions, and strive to safeguard reliable and affordable energy services, especially in electricity (and heating service in cold climate cities). But means of intervention are limited, as illustrated by the example of New York City (Figure 3.37). In this case, the city government has been only marginally involved in planning and managing electricity supply and demand, which officials are seeking to improve through the PLANYC 2030.

City governments are uniquely positioned to influence stakeholder dynamics in favor of sustainable energy because they are significant energy consumers themselves, and are able to influence the behavior of energy consumers in the city. Cities also determine how urban areas are built, including energy supply infrastructure. However, intra-city consultations are often challenging. Energy use cuts across many agencies, but stimulating inter-agency collaboration can be a big challenge, particularly when energy costs and benefits are borne unevenly. Functional areas within agencies, represented by technical staff, environmental officers, budget teams, procurement personnel, and so forth, also bring unique biases, expertise, incentives, and constraints to efforts to improve energy efficiency. Some of these issues can be addressed through policies and programs, but strong lead-

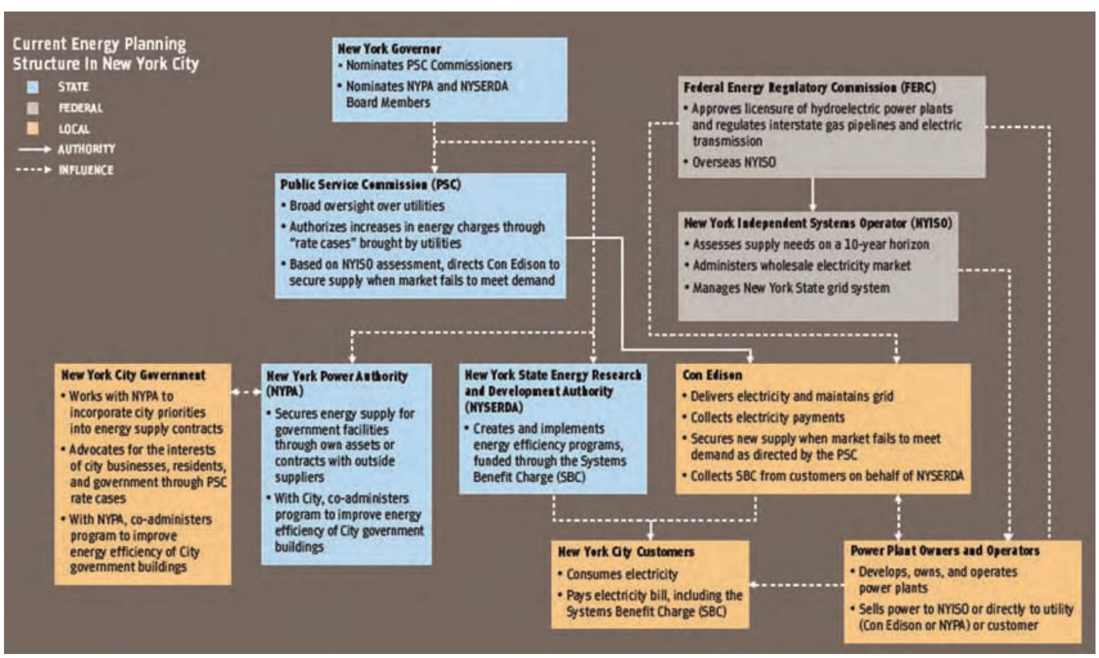


Figure 3.37 New York City: Key Stakeholders of Electricity Supply and Consumption
Source: PLANYC 2030

ership from the mayor's office is often needed to compel parties to work together.

Economic, Financial, Social, and Environmental Aspects

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

Economic justification requires cities to clearly and consistently account for and evaluate the costs and benefits of alternative urban energy solutions to facilitate robust comparisons. This is often challenging as it is difficult to value environmental externalities, such as health benefits or hazards. A critical aspect of economic analysis is to calculate the *lifecycle cost* of alternative energy solutions. Many sustainable energy actions, especially energy efficiency measures, have lower lifecycle costs than business-as-usual alternatives. The Melbourne Council House 2 (Australia), for example, reduced use of electricity by 82 percent, gas by 87 percent, water by 72 percent and corresponding CO_2 emissions by 87 percent, with a financial payback period of about 10 years.[130] Though the commercial sector normally considers projects viable with payback periods of less than five years, city governments tend to have longer investment horizons, since their built environment lasts for decades. Other sustainable energy options may have longer payback periods but may yield harder-to-quantify benefits, such as local investments, job creation, improved competitiveness and enhanced quality of life (e.g., reduced commuting times, improved air quality and health, and more green and community space).

Financial viability requires city actors to be able to obtain sufficient funds to implement sustainable energy solutions, sustain outcomes, and maintain a positive return on investment under prevailing and projected financial cash flows. To acquire and sustain modern energy services (e.g., electricity, natural gas, or district heating), prices need to ensure cost-recovery. For energy efficiency measures to be viable, saved energy has to be as reliable as and cheaper than conventional supply options. In other words, a viable sustainable energy solution has to be a viable business proposition. As market valuations often fail to account for environmental externalities, some renewable energy solutions, such as wind electricity and solar photovoltaic systems, may still need government subsidies or regulations (feed-in tariffs) to be viable. The recent expansion of carbon financing markets should improve the financial attractiveness of sustainable energy investments by providing a new and sometimes more secure revenue stream for such projects. But many financially viable energy efficiency opportunities remain unimplemented due to various market barriers.[131]

As shown in Table 3.11, the investments most likely to be undertaken will be partly driven by economic considerations. In this context, strong analytical work can identify short- to medium-term payback measures that a city may wish to pursue. The key challenge is developing the best overall package of investments that is below an acceptable payback or other investment threshold. Access to special funding, such as concessional donor funds or carbon finance revenues, can increase overall returns while maximizing the measures in the investment package.

Social equity requires cities to address access and affordability for the poor. Artificially suppressing energy prices or providing universal subsidies are not the right ways to approach these challenges. Instead, the city government should target subsidies only to those who cannot afford to pay, with others paying full cost-recovery prices for energy services. Social equity also means that cities should link sustainable energy actions with energy equity objectives. A

Table 3.11 Indicative Economics of Sustainable Energy Options

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

good example is promoting compact fluorescent lamps in low-income or slum areas.

Environmental sensibility requires that cities be mindful of the local, regional, and global environmental impacts of their energy practices and adjust future energy plans to mitigate impacts. For example, in the City of Rizhao in Shandong Province of China, it made good business and environmental sense to adopt sustainable urban energy solutions while addressing social equity issues (Box 3.7).

Indicators and Benchmarks

Sustainable urban energy planning and practice are elusive without realistic metrics to quantify performance (using indicators) and measure progress (using benchmarks). For cities in developing countries, indicators and benchmarks do not just reveal gaps, but also inspire actions to achieve greater energy services without reducing affordability or compromising the environment, as exemplified in Rizhao City. Developing

BOX 3.7

An Extensive Solar Water Heating Program in Rizhao, China

Rizhao, a city with 350,000 people in northern China, is using solar energy for water heating and lighting. In the early 1990s, a municipal government retrofit program mandated that all buildings install solar water heaters. After fifteen years, 99 percent of households in the central district had obtained solar water heaters. Solar water heating is now ubiquitous. In total, the city has over a half million square meters of solar panels for heating water, equivalent to about 0.5 megawatts of electric water heaters. Most traffic signals and street and park lights are powered by solar cells, reducing the city's carbon emissions and local pollution. Using a solar water heater for 15 years costs about $1,934 USD (15,000 Yuan), which is less than the cost of a conventional electric heater. This shift has generated annual household savings of $120 USD in an area where per capita incomes are lower than the national average.

This achievement is the result of a convergence of three factors: a regional government policy that promotes and provides financial support for the research, development and deployment of solar water heating technologies; a new industry capitalizing on new opportunities, and city officials with the vision and the leadership to implement changes with other stakeholders.

How does it work?

The municipal government, the community and local solar panel industries had sufficient political will to adopt these practices.

The Shandong provincial government provided subsidies and funded the research and development of the solar water heater industry.

The cost of a solar water heater was reduced to that of an electric one: about $190. This represented about 4-5 percent of the annual income of an average household in Rizhao, and about 8-10 percent of a rural household's income.

Panels are simply attached to the exterior of a building. The city helps install panels on households.

The city raised awareness through community campaigns and education. Rizhao held open seminars and supported public advertising on television.

The city mandated that all new buildings incorporate solar panels and oversee the construction process to ensure proper installations.

Source: Worldwatch Institute, State of the World 2007, Bai, X. "Solar-Powered City: Rizhao, China," State of the World 2007, Worldwatch Institute, pp. 108-109.

metrics is a worthy but difficult task because cities are different as are their energy uses and levels of energy service. It is thus important to focus on a small set of key indicators that allow meaningful cross-city comparisons. In this context, industrial energy consumption and related indicators should not be included and need to be addressed separately. It is also important to keep in mind that many developing-country cities are underserved in energy (no access or cannot afford) compared to their developed counterparts. Thus, the indicators that are sensitive to distortion (for example, per capita denominated indicators) should be carefully considered. In general, cities should have two levels of sustainable energy metrics: one reflecting the long-term strategic goals of sustainable urban energy planning and practice, and the second highlighting the performance and efficiency of energy consuming sectors in cities. Table 3.12 covers a preliminary list of sustainable energy metrics or categories of metrics proposed for cities.

Barriers to Investing in Sustainable Energy in the Public Sector

As noted previously, many sustainable energy actions can be justified based solely on their cost-effectiveness. However, for various reasons, many investments are unrealized due to administrative, policy and market barriers. Key issues include: (i) government agencies are typically unresponsive to price signals since they lack commercial orientations; (ii) public procedures for equipment and service procurement are generally inflexible to new approaches; and (iii) constrained annual budgets restrict funding for capital upgrades while restrictions on public financing and typical one-year budget appropriations make amortizing costs difficult. A list of typical barriers categorized by stakeholder is summarized in Figure 3.38.

City Government Sustainable Energy Actions

The development of modern interconnected energy systems in the past century or so has gradu-

Table 3.12 Sustainable Urban Energy * Indicators and Benchmarks—Preliminary Proposal

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

* Urban energy in this case does not include industrial energy consumption.
** Indicators represent the current performance of a city.
*** Benchmarks are the same set of metrics as the indicators but represent the medium and best practices, respectively, of a set of comparable cities in terms of climate conditions.

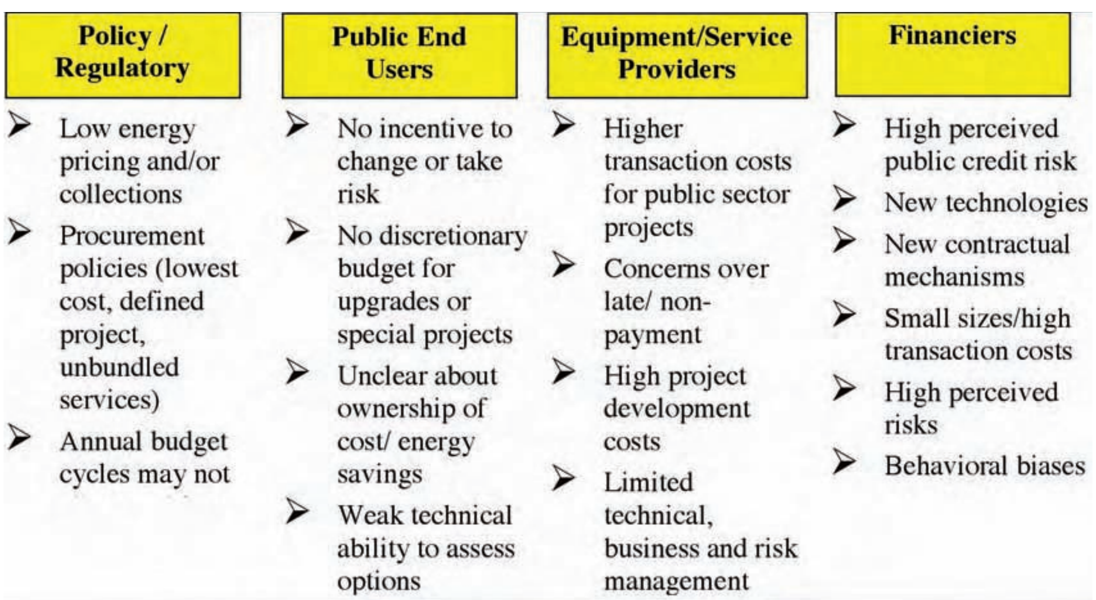


Figure 3.38 Typical Barriers to Public Sector Sustainable Energy Investments

ally reduced the capacity of cities to understand and plan for their energy needs. Cities have become passive participants in the urban energy agenda, leaving most responsibilities to regional and national governments and the private sector. To pursue a sustainable urban energy agenda, cities need to become more assertive and involved in decisions that affect energy demand and supply options. City governments need to become stronger partners of regional and national governments, and guide and mobilize private sector participation. Most importantly, cities need to act within their own authority to implement sustainable energy solutions. Cities can be effective in three areas of actions discussed below.

Energy Efficiency and Renewable Energy Solutions in the Public Sector

Energy costs often constitute a significant portion of the operational budget of city governments. In the State of California, energy is the second largest expenditure item in city government operations, after employee salaries and benefits[132]. The share of public sector consumption is particularly high in electricity and heating. Nine percent of Brazil's electricity is used by the public sector. 20 percent of Eastern Europe's electricity and heating loads are attributed to public agencies, and about 10 percent of the European Union's electricity and heating demand comes from the public sector.[133] As a first step, city governments should consider initiating sustainable energy solutions within city boundaries, as this can produce rapid benefits and is easier to implement. Common targets for improvements include: government owned buildings and facilities, water supply and wastewater treatment, public lighting/traffic lights, and municipal services, such as solid waste management, public transport, and, in cold climates, district heating.[134]

Government owned buildings and facilities. Buildings consume about one third of global energy and present significant potential for energy savings. Government buildings, particularly those in developing countries, tend to be older and use more inefficient equipment, further underlining the potential for energy efficiency gains. Measures to realize gains can focus on building envelopes (windows, insulation), electrical appliances (lighting, pumping, and heating and cooling) and office equipment (computers, copiers, and printers). Though measures are beneficial, public facilities often have rigid procurement practices that focus heavily on costs and lack discretionary budgets from which to make meaningful improvements. In addition, principal-agent relationships or split-incentives complicate investments. For example, a parent budget agency may determine a subsidiary's capital budget and even specify equipment, despite the subordinate agency's responsibility for paying monthly energy bills.

Energy efficiency programs often initially support relatively low cost and modulated measures, such as lighting retrofits, or replacement of old equipment, such as Heating, Ventilation, and Air Conditioning (HVAC) systems. In public building complexes, such as city halls, schools, and hospitals, a whole-building approach may be needed to achieve cost-effective control of the energy budget (annual energy consumption) of a building. Moreover, buildings are complex energy systems and tradeoffs are often made to optimize energy-efficiency. For example, planners must evaluate the efficiency of an HVAC system against the thermal pass-through of a building envelope, as either option reduces the effectiveness of the other. For new government buildings, adopting best practice in sustainable design and construction reduces lifecycle costs of buildings and serves as an example for the private sector. A comprehensive analysis of the financial costs and benefits of LEED[135] certified office and school buildings in the US found that a minimal upfront investment of about 2 percent of construction costs typically yields (20-year) life-cycle savings of over ten times the initial investment[136].

Recently, some governments in developing countries have experimented with retrofitting multiple municipal facilities under common authority. Though this can be more complex, it can substantially reduce transaction costs and allow for scaled-up investments. In Hungary, for example, the Ministry of Education issued a tender in 2006 for a single consortia to finance and retrofit all the schools in the country under an ESCO contract. The International Finance Corporation provided a portfolio credit guarantee to the winning bidder for up to US$250 million. To date, about US$22 million has been invested in about 200 projects.

Water supply and wastewater treatment. The operation of water and wastewater systems is often the largest outlay in municipal energy budgets. For example, Californian cities spend over 50 percent of their energy budgets on water and wastewater pumping[137]. Estimates suggest that 2-3 percent of the world's energy consumption is devoted to pumping and treating water, and that potential exists for related energy savings of more than 25 percent. In many cities, energy and water are scarce resources, and cities often introduce efficiency programs to save energy and water simultaneously in light of linkages between these sectors. In developing countries, water and wastewater systems often have poor designs, employ outdated equipment, and suffer from high non-metered water losses owing to inadequate investment and know-how. Many systems operate without adequate commercial incentives to be efficient. In light of these obstacles, the Alliance to Save Energy launched a new program called "Watergy" that demonstrates the significant benefits of increasing clean water access by reducing energy costs and water losses.[138] In Fortaleza in northeast Brazil, the Alliance to Save Energy worked with its local utility, the Companhia de Água e Esgoto do Ceara (CAGECE), to develop and implement measures to improve water distribution and access to sanitation services, while reducing operational costs and environmental impacts. CAGECE invested about R$3 million (about US$1.1 million) in various activities such as installation of an automatic control system. The utility saved 88GWh and US$2.5 million over four years. More importantly, the utility established an additional 88,000 new connections while decreasing overall energy costs.

Efforts to improve energy efficiency should consider both supply- and demand-side measures and relevant linkages. For example, as water leakage and waste is reduced, additional efficiency gains might be realized by downsizing pumping stations. Other measures should also be considered to boost efficiency, such as system redesign, pressure management, pump impeller reduction, installation of low-friction pipes and variable speed pumps, load management, power factor improvements, improved maintenance procedures, improved metering and water recycling. Wastewater treatment plants might also be made more efficient by recovering waste heat, capturing methane for power generation, and improved pumping systems.

Many cities in developing countries have pressing needs to expand water supply and wastewater treatment capacities. Reclamation of runoff water and onsite treatment of domestic wastewater are increasingly prevalent in new real estate development projects. Such practices, if properly configured within urban water and wastewater networks, can enhance overall energy efficiency while relieving pressure on scarce freshwater resources.

Public lighting. Public lighting is often considered an essential public service that enhances economic activity and improves the quality of life (e.g., by reducing crime and vehicular accidents). Street lights can be provided more effectively and extensively by using energy-efficient lighting technologies, which are now cheaper and more plentiful. However, procurement of lamps is often based on initial costs without considering impacts on recurring energy bills. To varying degrees, municipal governments possess limited capital budgets to replace lighting, lack credible information on alternatives, and in some cases fail to regularly pay electricity bills for street lighting. To illustrate the range of options available in street lighting, the cost-effectiveness of alternative systems that were considered by the State of New York in 2002 is featured in Table 3.13.

Street lamp retrofits can potentially save 30-40 percent of typical energy costs, and, depending on cost structures and available lamps, may have payback periods of less than three years. Installing time clocks and automated control systems and redesigning systems (to eliminate over-lit and under-lit areas) can achieve further energy savings. In India, the State of Tamil Nadu issued a tender for seven municipalities to be retrofitted to reduce energy use in public lighting and water pumping. Through an urban infrastructure development fund, bids were solicited that required a minimum of 30 percent in energy savings. Several competitive bids were received, an award was made, and this project has been operational since 2008.[139]

Other municipal services. There are other opportunities to realize energy savings through in municipal services, such as solid waste (e.g., waste recycling, methane recovery in landfills for power generation), transport (e.g., alternative fuel vehicles, maintenance of public transit bus fleet, establishment of rapid transit systems and congestion tolls). An especially important aim in cold climates is to improve the efficiency of district heating systems (Box 3.8).

Beyond the Public Sector: Focusing on the Built Environment

As enforcers of national, regional, and local regulations, city governments can substantially impact the adoption of sustainable energy solutions in the urban built environment. This is especially important in fast growing cities in developing countries, where inaction will only lead to future energy waste. Officials should focus primarily on the features and functions of new buildings that impact energy consumption, especially heating and cooling systems. Other factors include site plans, building layouts, building envelopes, lighting fixtures, and water heaters. Much relevant experience has been accumulated in developed countries over the past

Table 3.13 Economic Analysis Comparing Several Street Lighting Systems

	MERCURY COBRAHEAD (CONVENTIONAL)	METAL HALIDE COBRAHEAD (ENERGY-EFFICIENT)	HIGH PRESSURE SODIUM CUTOFF (ENERGY-EFFICIENT)
Lamp type	400W MV	250W MH	250W HPS
Number of luminaries	12	12	11 ***
Installed cost	$36,672	$36,240	$35,618
Annual energy cost	$2,391	$1,551	$1,419
Annual operating cost *	$2,536	$1,677	$1,601
Total annualized cost **	$6,271	$5,368	$5,229

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

30 years. Matured technologies and efficient materials can create buildings with low or near zero energy use for heating and cooling.[140] Implementing energy efficiency standards requires coordinating national, regional and city efforts, but local enforcement is most critical. China provides a good example of how energy efficiency programs can succeed in fast urbanizing developing countries. In 1995, China introduced its first mandatory energy efficiency standard for new residential buildings in cold climates. Among applicable northern Chinese cities, the compliance rate was a meager 6 percent in 2002. Since then, the national government has increased assistance to local governments to enforce compliance and conduct inspections. The rate of compliance rose to about 40 percent in 2005 and 70 percent in 2007. Compliant buildings on average lose 35 percent less heat than conventional buildings. Looking forward, the national government will soon promulgate a revised energy efficiency standard for new residential buildings in cold climates that will cut heat losses by an additional 30 percent. This time, many cities are ahead of the national government. For example, Beijing and Tianjin adopted in 2005 energy efficiency standards for buildings similar to the pending revised national standards. The provinces of Liaoning and Hebei did the same in 2007.

Many developed countries have broadened their efforts to promote sustainable buildings by incorporating other conservation strategies, such as improved management of water and waste, and steps to improve the quality of indoor environments. For example, the State of California adopted the United States' first Green Building Standards in 2008. Developing countries should take note, however, that it takes years to develop adequate capacity to enforce energy efficiency and green standards. Moreover, it is important to sequence sustainable building interventions in ways that suit local capacity and priorities.

BOX 3.8

Improving Energy Efficiency, Reducing Energy Costs, and Releasing Municipal Budgets

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

Results in four cities

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

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

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

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

The Big Picture and Altogether: Urban Spatial Development

Ultimately, individual cities and regional urban clusters must become more efficient in using natural resources, including energy. In cities, sustainable urban energy planning and practices should be integral parts of implementing resource-efficient growth, which hopefully complements sustainable development agendas at regional and national levels. To achieve intelligent resource-efficient growth, cities may need to drop expansionary urban spatial development linked to motorized transportation, and refocus development in neighborhoods to ensure that key services are within walking distance and/or the range of bicycles and public transport. Details on the impacts of urban spatial development on urban energy efficiency are discussed in Chapter 7 and in the Cities and Transport Chapter. In essence, the key message is that urban energy requirements can be reduced by increasing urban densities, which reduces the extent of major municipal infrastructure, such as roads, water and wastewater systems, power lines, and gas pipelines (etc.). Infrastructure capital, operation and maintenance costs also fall under condensed systems. Figure 3.39, for example, illustrates the general relationship between urban density and transport fuel consumption. Density also has drawbacks and limits, however, and must be planned based on existing physical, socio-economic and natural conditions.

Conclusions

As energy cuts across multiple sectors, planning and implementing sustainable energy measures

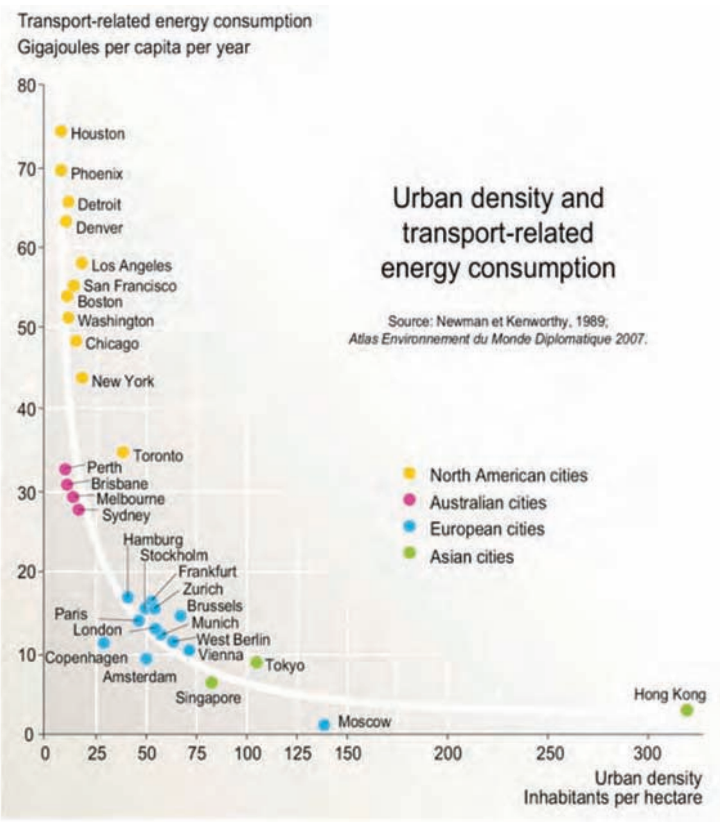


Figure 3.39 Urban Density and Transport-related Energy Consumption
Source: Adopted from Kick the Habit: A UN Guide to Climate Neutrality

in urban settings are complex. Though many energy investments can be justified based on their financial and/or economic returns, environmental concerns should be factored into project assessments. Some general recommendations for promoting sustainable energy and increasing energy efficiency and clean energy include:

- *Get the energy sector to work properly*. Energy sector restructuring, utility commercialization, pricing reform and other measures can reduce energy costs while reducing energy waste. These efforts are best led at the national level.
- *Explore options to retrofit the existing stock of infrastructure*. This can be done by auditing energy sources and organizations, changing procurement guidelines, contracting ESCOs, and devising public agency targets for energy efficiency (etc.). Access to financing is key to realizing these gains.
- *Consider options to address the new built environment*. This could entail adopting energy efficiency standards for buildings and equipment, improving city planning and design processes, strengthening land use schemes, and so forth.
- *Seek options to bundle city programs together*, such as combining procurement of equipment to negotiate better costs, combining similar services across cities, increasing influence at the national level, etc.
- *Seek ways to better incentivize public agencies and staff on sustainable energy options* by offering environmentally sustainable awards, publishing agency energy and environmental performance records, providing incentive grants, etc.
- *Create mechanisms for sharing cities experiences across the country*, through associations, case studies, newsletters, and so forth.

SECTOR NOTE 2

Cities and Water

Overview

Water is indispensible to all human activity. Ancient civilizations flourished around water sources, including ancient Egypt, China and Rome. Water shaped the destinies of great cities, like Cairo, Beijing, London, Paris, New York, Sidney, Frankfurt and Rome. On the other hand, many pioneering cities, like Babel and Sheba, diminished or disappeared because water sources dried up. Water plays an important role in economic growth, quality of life, and environment sustainability. Some people define water as a divine gift, while others view it as an economic commodity. In any case, water is a limited resource that must often be processed to become usable, and there are costs associated with its transportation, distribution and management. Water has social value, and access to sufficient water to survive is a human right. In this context, politicians and managers typically take steps to guarantee that the poor have access to an equitable share of water services, particularly in developing countries.

Water is a shared resource that plays a vital role in the development of other economic sectors. Given the importance of water, there is a need for integrated management at the sector and macro levels to ensure the resource is used in optimal and sustainable ways (i.e., Integrated Water Resources Management)

To ensure resource optimization and sustainability, governments must address key aspects of integrated water sector management and cross cutting issues between various sectors. These aspects and issues involve policies, regulations, planning activities, sector investments, financing methods, service provisions and institutional factors.

The input-output model for the water sector is shown in Figure 3.40. This figure specifies input parameters, desired outputs, relevant interventions, and undesired outputs that must be minimized. All interventions in a city should lead to desired objectives, which include: 1) accessibility for all residents including the poor; 2) adequate service quality; 3) high operational efficiency; 4) service reliability; 5) supply security and sustainability; 6) environmental preservation; and 7) service affordability. These objectives are interlinked and trade-offs must be recognized. Interventions can be related to: 1) planning; 2) water resource protection and enhancement; 3) infrastructure; 4) service delivery; and 5) management. These interventions are subject to relatively unchangeable input constraints (independent inputs) such as: 1) characteristics of water resources; 2) hydrology and hydrogeology; 3) climate and atmospheric conditions; 4) demographic and economic conditions; and 5) social norms and historical rights. Parameters that are manageable include: 1) policy, legislation, and regulations; 2) institutions; 3) physical systems technology and spatial planning; 4) stakeholders; and 5) economic and financial aspects. Undesirable impacts

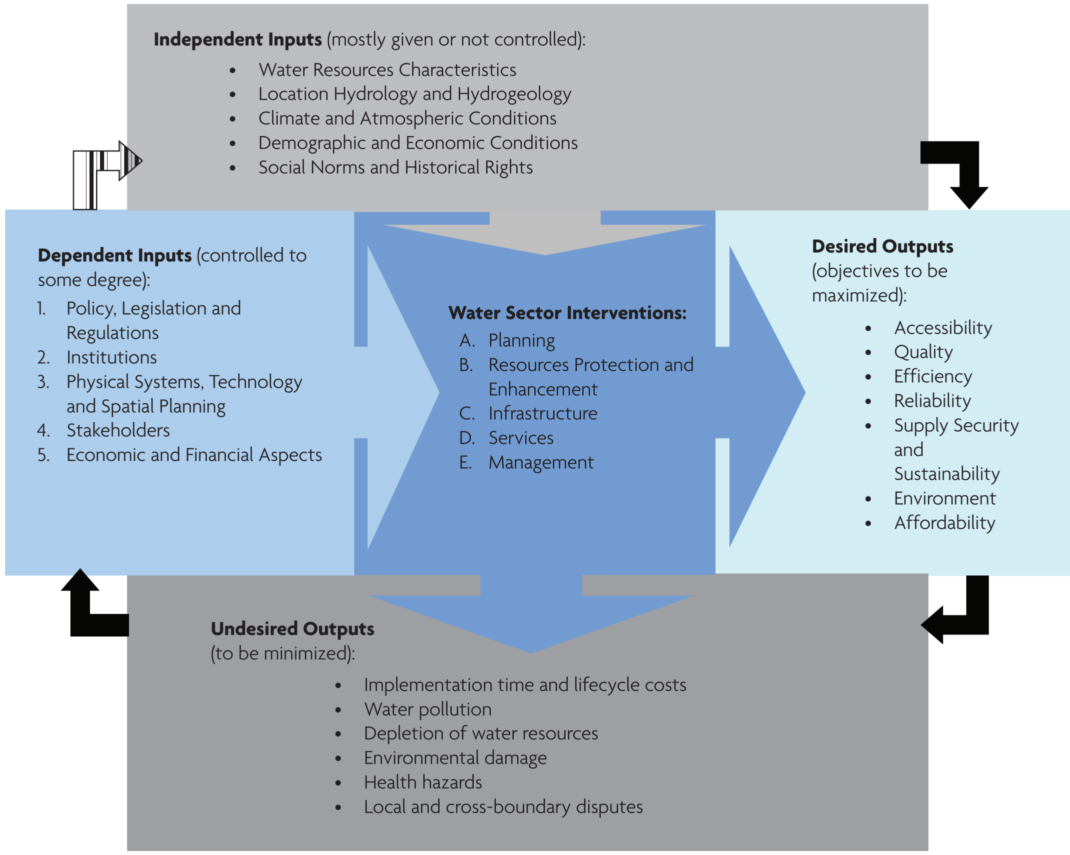


Figure 3.40 Input and Output Framework of Water Sector

should be mitigated or eliminated. These potential impacts include but are not limited to: 1) implementation time and lifecycle costs; 2) water pollution; 3) depletion of water resources; 4) environmental damage; 5) health hazards; and 6) local and cross-boundary disputes.

This sector note sheds lights on strategies for water sector management. It is designed to assist urban decision makers in putting together an optimal and well coordinated set of programs. A key challenge is the high degree of non-linear interconnections between urban sectors, including water, energy, solid waste, telecommunications, and transportation, which share many economic, environmental and political constraints. Nonetheless, optimization of net benefits amid these sectors and linkages is the defined objective.

Water Sector Policy, Legislation and Regulations

The Policy, Legislation and Regulations framework defines the rules for managing the water sector at national and local levels. The framework may expand beyond national boundaries and address cross country issues when water resources are shared or water management and protection require international cooperation. The framework strives to satisfy myriad aims: 1) ensure adequate protection of water resources; 2) develop and promote sustainable water services; 3) ensure equitable distribution and access; 4) improve health and environmental conditions; 5) enable economic growth; and 6) promote efficiency and optimization of use of water resources to enhance the viability of the sector.

As suggested in Table 3.14, water sector management systems are linked and systems and subsystems need to be connected. The three main interconnected systems include: 1) water resources, 2) water services, and 3) governance systems. Each of these main systems is composed of downstream systems and subsystems. Though management and implementation of these systems and subsystems may intersect within the water sector, some systems and subsystems may also intersect with other sectors, such as land, construction, and infrastructure operations, particularly to make decision on allocation of water resources.

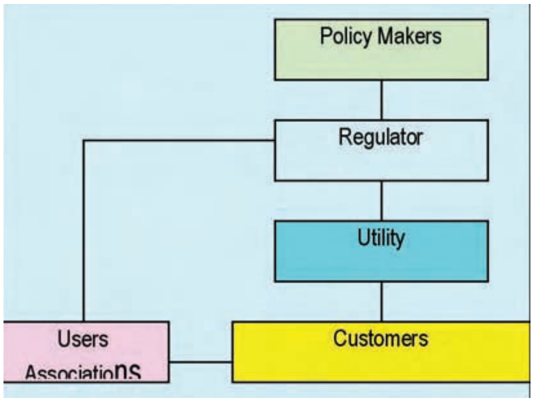


Figure 3.41 Water Sector Institutional Setup

Table 3.14 Water Sector Management Systems

I. WATER RESOURCES SYSTEMS	II. WATER SERVICES SYSTEMS	III. GOVERNANCE SYSTEMS
1. Water Resources Planning System.	**1. Water Service Planning System**.	**1. Policy Making System**
1. Financial Planning Subsystem	*1. Financial Planning Subsystem*	
2. Organization Planning Subsystem	*2. Organization Planning Subsystem*	**2. Regulatory System**
3. Physical Planning Subsystem	*3. Physical Planning Subsystem*	*1. Environmental Regulation Subsystem*
		2. Economic Regulation System
2. Water Resources Operations System	**2. Water Service Operations System**	*3. Drinking Water Quality Regulation* Subsystem
1. Construction Management Subsystem	*1. Construction Management Subsystem*	
2. Operation and Maintenance Subsystem	*2. Water Operation and Maintenance Subsystem*	**3. Accountability System**
3. Water Resources Management System	*3. Wastewater Operation and Maintenance Subsystem*	
1. Abstraction Licensing System	*4. Systems Hardware and Software Management Subsystem*	
2. Allocation System		
3. Supply and Demand Management System		
	3. Water Services Management System	
	1. Services Quality Compliance Subsystem	
	2. Effectiveness and Efficiency Subsystem	
	3. Pricing Subsystem	
	4. Commercial System	
	1. Customer Services Subsystem	
	2. Billing Subsystem	
	3. Collection Subsystem	
	5. Human Resources Management System	
	6. Management Information System	

The high degree of connectivity and interaction in these systems and subsystems calls for well developed policies, legislation and regulations at the national and local levels.

At the national level, the framework influences the minimum service standards for the quality of drinking water and wastewater treatment and disposal, in accordance with quality regulations and technical standards of water systems. Standards for allocation of water resources are normally based on environmental regulations, and prices are usually set based on economic regulations, water laws and the modalities of service providers. At the local level, the framework addresses equity and access to services, community participation in decision making, distribution and collection system layoff, physical planning, the spatial configuration of water works, and distribution system acoustic and odor control and management (Table 3.15).

Though policies and legislation are normally formulated at the central level, regulations can be imposed centrally and/or locally. In some cases, regulations may be imposed through contracts.

Institutional Context

A strong and adequate institutional setup ensures smooth and successful compliance with sector policies, legislation and regulations. Institutions ideally execute interventions to optimize gains amid sector constraints and boundary conditions. Institutions should prioritize achieving sector targets, but also interface with other sectors to ensure optimal development on a larger scale. The key institutional bodies include policymakers, regulators, service providers and customers (Figure 3.41). Regardless of the institutional arrangements, the integrity of the sector systems (Table 3.15) must be preserved and remain intact. An institutional setup should have the following: 1) integrity, 2) comprehensiveness, 3) sound division of roles and responsibilities, and 4) representation in other developmental forums.

- *Policymaker:* The policymaking function resides mainly at the central level, and national policies are normally imposed on cities.
- *Regulator*: The regulatory system is responsible for enforcing rules to guarantee com-

Table 3.15 Policies, Legislation and Regulations Framework Affecting the Water Sector

	POLICIES, LEGISLATION AND REGULATIONS FRAMEWORK
National level	• Water laws • Allocation of water resources to the domestic sector and share the province and the city • Drinking water quality standards • Wastewater treatment and disposal standards • Water works and systems standards • Tariff structure and pricing policy
Local level	• Physical planning and spatial distribution • Metering and usage charges • Billing and collection • Equity and access • Affordability • Efficiency of operations • Local environmental impacts like noise, vision and odor • Participation and community empowerment

pliance with services standards and other sector policies to ensure sustainability. This requires providing adequate services at affordable prices. The three subsystems under the regulatory function include:

- Environmental Regulation subsystem (licensing for abstraction and disposal)
- Quality Regulation subsystem (ensuring compliance with standards for drinking water, wastewater treatment, and quality of works)
- Economic Regulation subsystem (reviewing prices to ensure tariffs are proportionate to real costs, promote efficiency and conservation, and enable sustainability and affordability among the poor)

In some cases, municipalities can propose and implement regulations. However, it is important to ensure separation between a regulator and service provider to avoid conflicts of interest. The regulator ensures that customers receive services up to agreed standards to mitigate the risk that service providers underperform. Both bodies should not be under the jurisdiction of the same entity. It is equally important that the policy making body and regulator(s) be separate institutions. In the United Kingdom (UK), regulations are extensive. Environmental regulations are executed by the Environmental Agency, which is separate from the independent economic and quality regulator (Office of Water, OFWAT). This separation enhances the internal transparency and accountability of the regulatory system, as decisions are made in the open. However, regulatory agencies should coordinate closely to manage trade-offs. The prime interest of the environmental regulator is to minimize abstraction from water resources and enforce stringent standards on disposed sewage. However, the main interest of the economic regulator is to ensure that levied tariffs cover costs, which often means supporting relaxed disposal standards and maximizing the use of natural water resources before considering more expensive and non-conventional options, such as seawater desalination.

- *Service provider*: Service providers are responsible for providing water services in the city, including water treatment and distribution and associated customer relations. Water sources can be located within the city and managed by the service provider, or outside the city and managed by a different water provider. The same service provider should provide storm water collection, flood management and wastewater collection and treatment services. Consolidating these services will help to improve control of all services, and promote accountability and more efficient operations. For instance, a water supplier normally encourages customers to reduce sewage when it is the same utility that handles the sewage. Suppliers will also promote protection of water resources if they bear the cost of water treatment. Service providers can be private companies (UK, France, Germany, etc.), public utilities (Germany, South Africa, Australia) or municipalities (Cairo, Jordan, France, Germany). In some cases, "multifunction" utilities offer water, electricity and other services. The decision to combine utility services should depend on the scale of related industries and potential cost savings. Moreover, public utilities may outsource some or all of their operations to increase their efficiency.

- *Civil Society*: The civil society should be institutionalized by establishing user associations and appropriate participation channels. This helps to ensure public participation in industry development and related decision making. Policymakers and regulators often consult user associations to assess and ensure the adequacy of policies, legislation regulations, and service levels. Service providers should recognize users as genuine customers that drive industry revenue and sustainability.

Physical Systems Technology and Spatial Arrangement

Water systems are composed of four main systems for water supply, wastewater, storm water and reclaimed water. The storm water and reclaimed water systems are similar in configuration and operation to the wastewater and water supply subsystems. Figure 3.42 illustrates a typical layout of water systems. The systems include water and wastewater treatment facilities, distribution and collection networks, control valves, pumping stations, storage tanks and disinfection facilities. The systems serve distributed demand nodes. The following sections highlight the technological factors in designing water systems and the merits of proper spatial distribution of demand nodes, which are governed by land use planning.

A. Water Supply System

Demand Centers Spatial Distribution: Cities should strive to limit urban sprawl to ensure that water demand is not overly dispersed and that the extent of distribution and collection systems is minimized (costs related to distribution networks typically account for 70 percent of overall costs of a water supply system). Denser land developments help to minimize capital and operation costs. Energy consumption also typically falls, as consumption is linearly proportionate to pipe length. In addition, dense developments promote environmental protection.

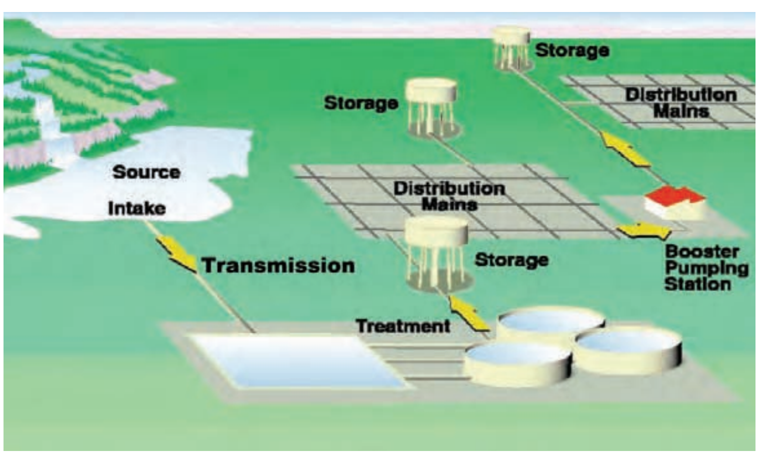


Figure 3.42 Schematic Diagram of Water System

Source: Haestad Methods, "Water Distribution Modelling—Featuring WaterCad", Haestad Press, 2001."

Distribution System Spatial Configuration: It is important to achieve highly reliable water supply services. This often entails some redundancy in the network, such as loop networks that supply a demand zone through more than one main pipe. This may involve trading higher capital costs for improved reliability and reduced energy costs. As illustrated in Box 3.9, proper system reconfiguration leads to reduced total distribution costs. To avoid substantial increases in network costs, loop networking can be operated at lower pressures, and through smaller pipes made of cheaper material than ductile iron.

Water Treatment Plant: The water treatment process can be simple. Biological treatment is preferred over chemical intensive processes. Treatment plants must be close to water resources and hopefully close to urban demand centers. To ensure the security of water supplies, the treatment plant must have space to expand to meet growing demand, and cities should consider building more than one plant from different sources (if possible).

Groundwater and Water Wells: When groundwater is viable, well fields should be developed and distributed near demand centers. This proximity leads to a simpler network and lower energy and capital costs. Distribution systems can often operate from minimal storage tanks, as the aquifer itself represents a robust and feasible storage source. Moreover, many cities (e.g., Paris) commonly use aquifers as natural storage receptacles for surface water that infiltrates from basins along river embankments and other areas. Infiltration is a natural treatment process that helps to purify water at minimal cost.

BOX 3.9

Effect of Distribution System Configuration on Energy Consumption

The schematic below represents a small town with an hourly water demand of 450 m^3. The demand is split between the nodes 2,3,4 and 5. The town is served through a fixed speed pump from a reservoir which is at elevation of 10 m. For illustration purposes, two scenarios were considered.

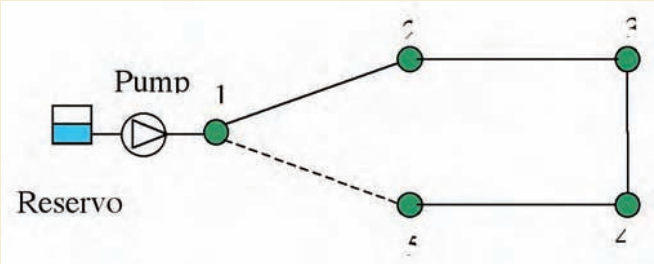
Scenario 1: Link 1-5 does not exist

Scenario 2: Link 1-5 was constructed

DISTRIBUTION SYSTEM DATA						ANALYSIS RESULTS		
Node	Demand (m^3/hr)	Elevation (m)	Pipe	Diameter (mm)	Length (m)	Node	Pressure[1] (m)	Pressure[2] (m)
1	0	10	1-2	500	1000	1	58.33	43.75
2	100	30	2-3	400	1000	2	37.02	23.39
3	50	30	3-4	400	1000	3	34.58	23.03
4	100	30	4-5	300	1000	4	27.13	22.47
5	200	25	5-1	400	1000	5	23.58	27.66

(1) node pressure for Scenario 1

(2) node pressure for Scenario 2



Results:

1. In Scenario 2, the pump was replaced by smaller one and the power demand dropped to 71.5 kW from 95.3 kW (25% drop).
2. Annual energy saving is 209 MW/hr, which can cost US$20,000 per year.
3. The capital investment to complete the loop and construct pipe 5-1 is less than US$100,000 and can be paid back in about 5 years from energy savings.
4. Further improvement can be achieved if a full optimization analysis is conducted to target the sizes of the pipes (diameters) while maintaining other hydraulic parameters like flow velocities and nodes pressures within the recommended hydraulic design limits.

* Hydraulic analysis was conducted using EPNET modeling software.

Water Pumps: Water pumps are the main energy consumers in water systems. The energy consumed is proportional to the set efficiency of the pump-motor. Normally, pumps are most efficient at their designed operating points. However, owing to load changes, pumps are often operated outside of peak efficiency and significant energy is wasted. Variable speed pumps can be modified to address this waste. Pump speed is adjusted to maximize efficiency given any particular load. Pumps may also be noisy, but this can be mitigated by introducing acoustic insulators.

Storage Tanks: Depending on the mode of operation, storage tanks can be important components of a water supply system. Storage capacity should equal one day of service. Such capacity enhances water security in case of treatment plant stoppage, leads to smaller treatment and pumping facilities, reduces capital and operation costs, and enables optimal pump scheduling and intense treatment during periods of low electricity tariffs (usually nights and off peak hours). Planners must balance potential savings with the capital costs of constructing storage tanks.

B. Storm Water Management

Storm Water Rainwater Harvesting and Flood Management: Storm water collection systems can be combined with sewage collection systems. Though this may reduce capital investment, treatment becomes difficult when wastewater and storm water are reused. As such, these systems should normally be separate, complemented by effective and innovative water storage tools. For example, rainwater can be harvested from the roofs of buildings and used for gardening, flushing toilets, and washing cars.

In general, climate change analysis predicts that East Asia will receive heavier and more intense rains. Worse, the sea is forecasted to rise about 0.5 meters by 2100 (Figure 3.43 and 3.44). Flood management systems must be designed to cope with these expected loads, and systems must be strategically located at vulnerable elevations. All new coastal cities in the region should also consider plans to locate infrastructure above the anticipated sea level.

It is often advantageous to bundle construction of road, water, sewerage and storm infrastructure. A common underground infrastructure and service corridor is a typical practice in many cities, and can reduce overall costs and ease maintenance.

C. Non-conventional Water Resources

Wastewater Reuse: Treated wastewater is a potential resource. It can be used to irrigate public parks and landscaped plots, and is rich in nutrients for plant life. Strategic use of treated wastewater can cut crop production costs and relieve stresses on fresh water resources of meeting domestic, industrial and environmental demands. Wastewater reuse is practiced in East Asia, including in China, Japan and Singapore. In situ treatment and recycling of industrial wastewater can also contribute to partially satisfying industrial water demand.

Water Desalination: Most East Asia countries are next to the sea, and desalination represents a promising process to enhance water resources. Seawater desalination has undergone significant improvements over the last two decades. Owing to technological advancements in membranes and energy recovery devices, the cost of seawater desalination in Reverse Osmosis (RO) plants dropped from around US$3.0/ m^3 to less

Figure 3.43 Area at risk from 0.5 m sea-level rise in Asia

Source: The World Bank, East Asia Environment Monitor, Adapting to Climate Change, 2007, Report No 40772

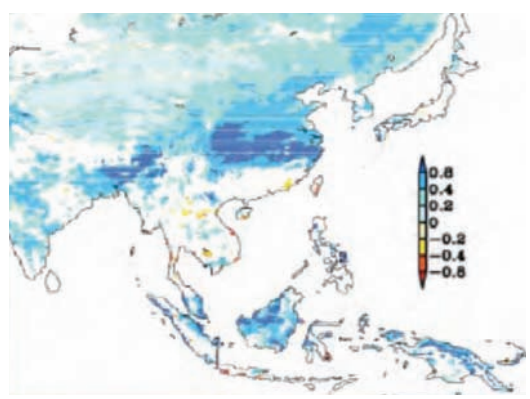


Figure 3.44 Annual mean of daily precipitation changes expected by 2100 in (mm)

Source: The World Bank, East Asia Environment Monitor, Adapting to Climate Change, 2007, Report No 40772 than US$ 0.60/ m^3. In addition, energy consumption fell from 8.0 kW.hr/ m^3 to less than 3.0 kW.hr/ m^3. Thermal desalination processes can be competitive depending on their designs and integration into power generation plants. Cogeneration plants generally improve the production of both electricity and fresh water.

RO desalination plants are more flexible and do not need to be constructed with power plants. Due to their high energy needs, RO desalination plants should be equipped with energy recovery devices, like the newly developed pressure and work exchangers that recover nearly all the energy from brine before being disposed in the sea. Alternatively, brine can be processed further to produce raw material for the sea minerals industry. Under such setups, the plant is called a "zero disposal plant." In any case, disposal of brine into the sea must be carefully executed to avoid environmental damage. Brine must be dispersed in active water to avoid increased salt concentration or increases in seawater temperature that can harm marine flora and fauna. Special nozzles are available and can be used to limit environmental damage.

D. Water Supply and Demand Management

Non-Revenue Water and Leak Reductions: Non-revenue water comprises the collective commercial and physical losses from a system. Good practice suggests that physical losses should be less than 4.4 percent, as in Singapore. Physical losses entail loss of water as an economic resource, loss of revenues to maintain sector sustainability, and energy costs to produce and transport lost water. Wasted energy unnecessarily increases greenhouse gas (GHG) emissions. GHG emissions are responsible for global warming and climate change that is already impacting water resources, flood management and developmental investments.

Leakage negatively impacts the environment, economy and ecology. Water leaks represent losses of resources and energy, and may damage infrastructure installations and ecological facilities. Leaks can be minimized and/or controlled through pressure control devices (i.e., zoning, reconfiguring online control and distribution systems), district metering, and instruments to detect leaks. Leaks are linearly proportional to pipe water pressure, thus pressure should be kept at a level minimally adequate to deliver services. For example, leaks drop by 50 percent when pipe pressure falls from 4 to 2 bars. Appropriate pressure modulation can be achieved by introducing variable speed pumps, proper pump scheduling, and pressure control valves. Construction of elevated reservoirs and appropriate configurations of distribution systems also help reduce risks of leakage. Detection equipment is available and is used by water utilities around the world.

Metering: Metering is crucial to water supply management. Metering enhances equity as consumers pay for only the water they receive, and metering promotes management of water demand. Unlike fixed fees, meter-based charges provide incentives to save and conserve water. Water meters, on the other hand, must be frequently checked and calibrated, and may need to be replaced each decade. Meters are manufactured in classes (A, B, C and D) based on their levels of accuracy at specified flows. The higher meters (i.e., C and D) are more accurate in measuring low flows at wider ranges. But class D meters are more expensive. To save costs in meter reading, remote reading technologies are often employed.

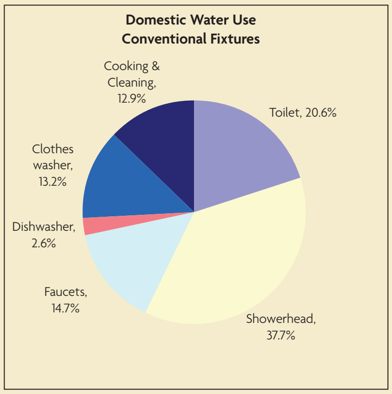
Conservation and use efficiency interventions: New technological devices have been developed and are available to promote water conservation. In households, showers, toilets and laundry facilities represent the most significant sources of water consumption. Box 3.10 illustrates experiments in Canada where water consumption was reduced by 52 percent by introducing modern fixtures, including kitchen faucet aerators, aerated shower heads, dishwashers and front-loading washing machines.

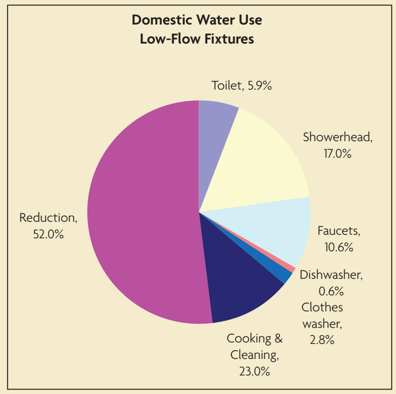
BOX 3.10

Domestic Water Consumption in Canada and Conservation

The average domestic consumption for a home in Canada is approximately 350 to 400 liters per person per day (300 l/d for indoor use, and 100 l/d for outdoor use). Canadians use considerably more water than most other nationalities. Consequently, summer water flows from mountain glaciers and annual snowpacks are diminishing. To sustain access to water, conservation in Canada is an important aim.

Domestic water is used in bathrooms (toilets, showers, and faucets), kitchens (dishwashing and food preparation), and in laundry facilities. Based on typical values, the following charts illustrate the percentages of water used for these activities using "conventional" and "low-flow" fixtures.





These values are based on a family of four people, as follows:

FIXTURE	FAMILY USE	FIXTURE WATER CONSUMPTION	LOW FLOW FIXTURE WATER CONSUMPTION
Showerhead	8 minutes / person / day	15 liters / minute	7 liters / minute
Toilets	5 flushes / person / day	13 liters / flush	6 liters / flush solids 3 liters / flush urine
Faucets	5 minutes / person / day	10 liters / minute	7 liters / minute
Kitchen (cooking & cleaning)	15 minutes / day	10 liters / minute	7 liters / minute
Conventional Dishwasher	1 use / day	33 liters / use	8 liters / use
Top-load Clothes Washer	7 uses / week	170 liters / use	36 liters / use

The toilet is the single highest source of water consumption in the home. Over 70% of water use occurs in the bathroom. Logically, toilets and showerheads represent the greatest opportunities for water reduction in the home.

Low-flow fixtures include dual flush toilets in which one button provides a 3 liter flush for urine, and a second button provides a 6 liter flush for solids. Showerheads and faucets can be designed to reduce flows without a noticeable reduction of performance. New appliances like dishwashers and front-loading clothes washers have significantly lower water needs. Using low-flow fixtures can reduce water consumption in the home by over 50%, from approximately 1200 l/d (interior use) to 600 l/d. This does not include outdoor use for landscaping.

Source: Adopted from the Living Home Website. Ref: http://www.thelivinghome.ca/index.php?option=com_content&task=view&id=98&Itemid=132

In some areas, heating and hot water infrastructure is centralized. This may result in high energy and water losses to flush out cold water in house connections. In most cases, instant heaters with shorter service pipes from gas furnaces or electric heaters are more feasible and energy efficient, and water losses from such devices are negligible.

The practice of washing cars using hoses connected to house taps should be abandoned.

"Bucket-and-towel" washing or visiting specialized commercial car wash terminals should be substituted, as these processes consume less water. Special car wash terminals may also recycle water. Street cleaning should take place in the night when roads are coolest, thus reducing evaporation.

In general, agriculture is the sector that consumes the most water. In urban areas, agricultural activities are still common in parks, along streets, and in public and residential gardens. Efficient irrigation in these areas helps to improve water use and sector sustainability. Irrigation should be properly timed to avoid peak daily temperatures and reduce evaporation and evapotranspiration losses. Efficient irrigation systems should be employed such as drip irrigation, subsurface irrigation and sprinkler irrigation.

E. Wastewater Treatment and Sludge Disposal

Location of Wastewater Treatment Plant: Wastewater treatment plants are not popular facilities. While wastewater is generated within residential centers, residents generally pressure governments to locate wastewater treatment plants far from their neighborhoods. In general, plants need to be located as close as possible to sewage generation sources, downwind of communities, and dispose wastewater downstream of neighborhoods and water works facilities when there is an intermediary river. The plant also needs to be centrally located to minimize the energy consumption of sewage transfer and effluent disposal and/or reuse. Moreover, there are often trade-offs between these conflicting interests.

Process of Wastewater Treatment: There is a wide range of sewage treatment processes. As much as possible, priority should be given to biological treatment processes to avoid use of hazardous chemicals. It is also important to treat domestic and industrial sewage separately. Moreover, legislation is needed to prohibit non-biodegradable domestic detergents and the disposal of hazardous wastes, such as heavy metals, pesticides, hydrocarbons and medical wastes, into city sewers. Awareness campaigns and public participation are essential to these efforts. Activated sludge treatment plants are common around the world and lauded for their efficiency and relatively compact sizes. However, their treatment processes are energy intensive. Treatment plants with extended lagoons consume much less energy and are cheaper to construct, though they need more land.

Sludge management: In addition to treated effluent, wastewater treatment plants produce sludge, which is composed of biomass and settled biological material. If the biological content has been appropriately digested, sludge can be a valuable resource for composting or fertilizing or generating methane. Generated methane can be captured and used as an energy resource. Commonly, treatment plants are equipped with gas turbines and generators that use methane to produce electricity. The generated electricity can be sufficient to cover most of the electric demand of treatment, and/or can be sold to the distribution grid. Special legislation can encourage plants operators to sell electricity or subsidize production costs through Carbon Finance funds. These funds promote technologies that reduce GHG emissions such as carbon dioxide, which is linked to global warming and climate change.

In traditional plants, sludge was often discarded in the sea or dumped into solid waste landfills. These practices are falling out of favor as they risk harming the marine environment and polluting groundwater.

F. Energy Efficiency

Energy is often the dominant factor that determines the cost of water and wastewater services. Energy needs can vary from less than one kW/hr to many kW/hrs per cubic meter of treated water. The amount of required energy depends on these factors:

- the distance and elevation of water sources relative to service areas;
- topography of service areas
- the depth of groundwater aquifers (if applicable);
- locations of wastewater treatment and disposal facilities;
- energy consumption in water production and wastewater treatment facilities;
- energy recovery ratios at wastewater treatment plants via sludge digestion;
- energy recovery ratios at desalination plants;
- levels of technical and commercial water losses;
- configuration and design of the water distribution and wastewater collection systems; and
- modes of operation of the water distribution system.

There is a strong and direct relationship between water use and energy savings. This linkage lent itself to the expression "Watergy." Box 3.11 summarizes the scope of Watergy within the water sector, such as through demand management, supply management and the synergy between the two in terms of system design and operation.

Box 3.12 illustrates a case study from Brazil. The case study reveals that automating the water supply system and providing online control saved 22 GWh/year, equivalent to USS$2.5 million. The control system cost only US$1.1 million.

BOX 3.11

Combined Water and Energy Activities in the Water Supply Management

Watergy Efficiency
Is cost-effectively delivering water services, while minimizing water and energy use

Supply-Side Efficiency Measures

Water supply systems offer multiple opportunities to reduce water and energy waste directly, while better serving customer needs.

- Leak and loss reduction
- Operations and maintenance
- Pumping systems
- Primary/secondary wastewater treatment

Demand-Side Efficiency Measures
Consumers
Residential/Industrial

Reducing demand by helping the consumer use water more efficiently decreases the required water supply, saving both energy and water.

- Water-efficient household appliances
- Low-flow toilets
- Low-flow showerheads
- Industrial water reuse
- Leak and water waste reduction

Comprehensive Demand / Supply Side Approach Synergies

Looking at a water system comprehensively and ensuring efficiency projects are designed in tandem creates even greater efficiency opportunities.

- Right-sizing pump systems after reducing consumer demand
- Avoiding wastewater treatment by promoting reuse and reducing demand

Source: Watergy, 2007

BOX 3.12

WATERGY Case Study

FORTALEZA, BRAZIL

CHALLENGES

The importance of this project was highlighted during BrazilÐs energy crisis in 2000 and 2001. 70% of BrazilÐs generated energy comes from hydropower, thus droughts and energy shortages are inextricably linked. During droughts in 2000 and 2001, all consumers were required to reduce energy consumption by 20%. Since 2001, the Alliance to Save Energy has worked with the Companhia de Água e Esgoto do Ceara (CAGECE) in northeast Brazil to develop and implement measures to promote efficient use of water and energy. This partnership aimed to improve the distribution of water and access to sanitation services, while reducing operational costs and environmental impacts. The partnership reduced CAGECEÐs energy use and serve as good practice for other national projects, which is important as BrazilÐs water and sanitation sector represents 2.3% of the nationÐs energy consumption.

BACKGROUND

The designs of water distribution systems are based on population projections from statistical and historical data over a 20 or 30 year planning horizon. As such, many systems are over-designed, particularly the sizes of storage, treatment and distribution facilities. Over-design entails energy consumption much greater than needed to provide for adequate demand, especially in booster stations. Design criteria affect not only pumping stations, but also the size of pipes, capacity of reservoirs, and the construction of treatment facilities and booster stations. Moreover, water systems need to be able to expand to satisfy increasing demand, but not while sacrificing efficient use of energy.

OBJECTIVES

The focus of the partnership between the Alliance and CAGECE was to develop a methodology that provided CAGECE with the tools and the know-how to produce initiatives that resulted in savings and rational use of energy and distributed water. As the work progressed, it became clear that the model would be useful to other water and sanitation companies in Brazil exploring ways to increase efficiency.

APPROACH

An automated water distribution system allows operators to obtain strategic data and control equipment in real time. The automation of the system in the Fortaleza Metropolitan Region allows for correction of deficiencies, particularly those linked to over-design. Along with CAGECE's efforts, Alliance actions in 2002 included:

- Establishing a baseline of energy consumed and water distributed for CAGECE.
- Implementing efficiency measures that led to a reduction in operational energy consumption
- Developing a financing proposal with the Government of Brazil's Fight Against Electricity Waste Program (PROCEL) to implement energy efficiency projects with CAGECE's operational staff. The technical support provided by the Alliance resulted in the development of energy efficiency projects, cost/benefit analysis, and specifications of equipment that could be financed.
- Arranging for R$5 million in financing for energy efficiency projects to CAGECE. These projects included automation of operations, rewinding and replacement of motors, maximizing existing pump systems efficiency, and increasing storage capacity to allow the shutdown of pumps during peak hours.
- Creating an operations procedures manual to serve as a reference for daily performance to operations crews and CAGECE management.

Key Results

- Energy saved: 88 GWh over 4 years
- Households newly connected to water while water consumption remained constant: 88,000
- $2.5 million saved per year under an investment of $1.1 million.
- Standardization of operational procedures and increased reliability of operational data
- Ability to act in real time with system control devices
- CO_2 Emissions Avoided: 220,000 tons/year

Source: Alliance Save Energy and Watergy, Energy Efficiency. (Under USAID funded project)

Stakeholders

The stakeholder dynamic illustrated in Figure 3.45 is important to the water sector. This dynamic includes interfaces between customers, service providers, municipalities, regulators, and policymakers. As the water industry is often highly monopolistic, transparency, accountability and public participation are needed. These factors allow strategic decisions to be made using top-down and bottom up approaches. For instance, tariffs ensure sector sustainability by furnishing revenues to finance sector management expenses. Tariffs are usually set at the municipality level, which represents local government, though in some models tariffs are

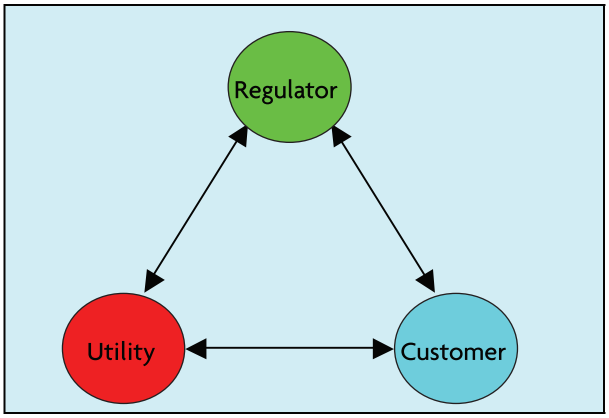


Figure 3.45 Stakeholders Dynamics and Accountability Triangle

set by central government. Reviews of prices are carried out when tariffs expire. Thus, there is a continual need to thoroughly analyze the real costs of service delivery, including the scarcity "rent value" of water resources. The regulator is responsible for conducting price reviews. Calculations of real costs are expected to cover: 1) the shadow price of water; 2) cost of treatment to specified standards; and 3) costs of distribution and delivery. The shadow price of water is governed by demands of all users, and thus the policy affecting resource allocation will affect various end users. Cost of treatment is influenced by the quality of the raw water and relevant national standards.

Customers should participate in setting standards. This requires a process of consultation and participation to ensure that the economy can afford maintaining these quality standards and that service providers can achieve these standards. Often, costly capital investment programs are needed, and private sector participation may be required. All costs should be checked against international good practice. The economic regulator needs to set thresholds for operational efficiencies and incorporate these into setting and reviewing prices.

The tariff structure should include incentives to improve services and enhance efficiency, conservation, equity, and social and environmental protection. Progressive block tariffs are appropriate demand management tools to achieve these targets. Poor households with low consumption rates fall in the first blocks, which are usually under-priced and subsidized by other consumers who are wealthy and can afford services. The regulators must continuously interact with customers and service providers to ensure that services comply with standards.

Economic and Financial Aspects

In general, water supply costs range from US$0.2 to US$1.0 per cubic meter, while wastewater collection and treatment costs US$0.5 to US$1.0 per cubic meter. Normally, wastewater services cost twice as much as water supply services. In some cases, water can reach US$10 per cubic meter when sold by vendors. Given these relatively high rates, leakage or customer abuse leads to real economic costs. As shown in Figure 3.46, reducing losses from 50 percent to 15 percent and cutting demand in half from water conservation practices can produce net water savings for a city of 400,000 inhabitants of around 71 percent. This is equivalent to about 61.8×10^6 m^3 of water per year. As a new city needs 25.8×10^6 m^3 of water per year, this means another city of about 1,000,000 inhabitants can be served at the same cost.

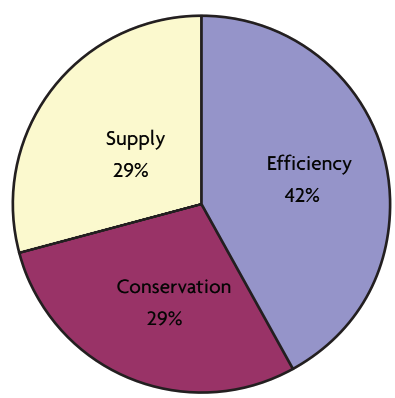


Figure 3.46 Savings in Water Supply
(due to reducing non-revenue water from 50% to 15% and efficiency gain of 50% from conservation)

Similarly, assuming that an urban water supply and sewage system consumes energy equal to 2.0 kW.hr per cubic meter of supplied water, annual urban energy consumption will fall from 175 to 52 GW.hr and follow the same trend depicted in Figure 3.46. Annual energy savings would total 123 GW.hr, which is sufficient to supply a city of more than 120,000 inhabitants with 1000 kW/hr per capita per year. This electricity savings would also cut CO_2 emissions by 307,000 tons/year. These benefits can increase more than threefold when water and wastewater services are more energy intensive, such as when using desalination plants or serving demand centers at higher elevations than water treatment facilities.

As in other infrastructure sectors, attainting economies of scale is important. For instance, the costs of producing fresh water at desalination plants ranges between US$3.0 at smaller (1,000 m^3/day) capacity plants to a much less US$0.60 at larger (30,000 m^3/day) facilities. The same benefits of scale apply to other water facilities and wastewater treatment plants. Given clear cost savings, cities might consider building joint plants that serve more than one city area.

It is also recommended that construction works be synchronized between sectors, and that joint facilities like common underground corridors be used for water, wastewater, storm water, electricity and telecommunication infrastructure.

Conclusion

To a large degree, all sectors regulate or modify natural resources, serve mostly common customers, require sources of funding, deliver services managed by the public and private sector, and face the challenge of higher costs from urban sprawl and associated widely distributed infrastructure. Moreover, a high level of synergy is possible between sectors to boost overall efficiency. Urban policymakers and planners might consider the following options depending on their situations:

- Establish a common regulator for more than one service, like water, electricity, and telecommunications
- Develop similar policy principles for tariff structures, standards, and resource allocation among sectors
- Establish multifunction utilities as feasible.
- Enable investments by supporting incentives, policies and enforcement of laws and legal systems to protect investments and improve revenue collection (i.e., willingness to pay)
- Increase the efficiency of construction management by coordinating construction activities, developing unified procurement systems and land use plans, and sharing access roads
- Develop cross-compatible customer charters delineating principles for service, and share customer complaint centers to minimize costs
- Consider cross-sector economic and sustainability gains related to the following:
  - Cogeneration (electricity and seawater desalination, irrigation, and hydro-power generation)
  - Performance incentives
  - Conservation
  - Efficiency
- Enable a balanced environment for public private partnerships. All linked sectors need to be feasible to encourage the private sector to invest in the water sector. These sectors need sufficient tariffs and incentives for infrastructure services.
- Encourage proper land use and distribution of infrastructure facilities.

SECTOR NOTE 3

Cities and Transport

Overview

The reasons that cities should care about the transport sector are myriad and complex: transport produces important benefits (principally mobility and accessibility) and enables the economic and social activity that sustains urban life. At the same time, transport consumes significant shares of land, energy, time, and other resources, and generates specific undesired outputs such as pollution and accidents. This chapter addresses urban transport issues, particularly those in fast-growing cities that face challenges and various investment options.

Transport is not an end per se, but rather a means to one or multiple ends such as access to jobs, markets, and other social or economic opportunities. For this reason, it is difficult to create a single objective recognizing all relevant constraints and tradeoffs. An urban transport system requires many inputs —some more controllable than others—and produces numerous outputs—some desirable and others undesirable—which influence the inputs. These are described and illustrated below in Figure 3.47.

"Independent inputs", which are mostly given or not controllable, include: 1) demographic and economic conditions (i.e., population, income, and types of industries), 2) geographic constraints (e.g., rivers, lakes, coastline, mountains, etc.), 3) climatic and atmospheric conditions, and 4) social norms and historical practices. Among other things, these inputs influence land development patterns (i.e., distribution of land uses and densities), the shape of the city (i.e., linear, circular, semi-circular), and the spatial and temporal travel patterns (e.g., radial, circumferential, and polycentric patterns; and trip trends at different daily hours, weekdays, seasons, etc.).

The "dependent inputs" over which decision-makers retain some degree of control, and the focus of this chapter, include: 1) policy, legislation and regulations, 2) institutions, 3) physical systems, technology and spatial planning, 4) stakeholder dynamics, and 5) economic and financial factors. All these inputs should be considered when analyzing problems and potential interventions. Urban transport interventions, including for passengers and freight, involve one or more of the following:

- **Land use and travel demand**—interventions that influence travel behavior including origins and destinations (O-D), purposes, modes, frequencies, and trip distances.
- **Infrastructure and services**—interventions that enhance the supply or capacity of infrastructure and services such as roads, public transport, traffic management, and other investments.
- **Vehicle fleet and fuel supply**—interventions that alter the number, composition, technologies, or use of vehicles and fuels.

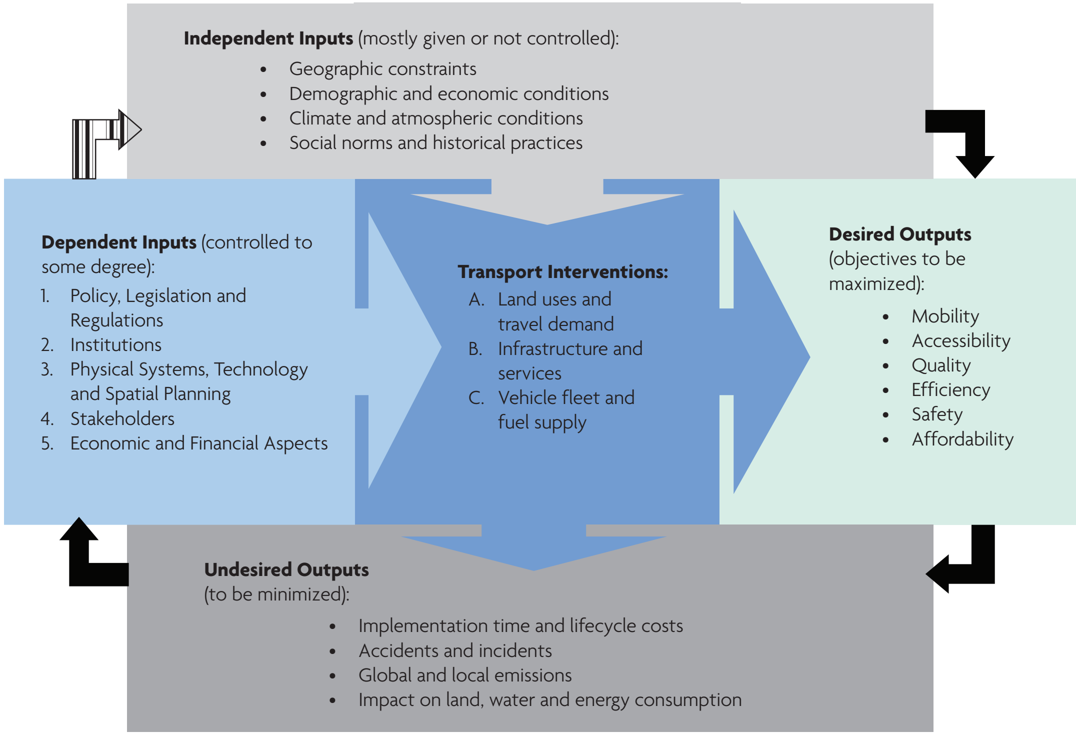


Figure 3.47 Input and Output Framework for Transport Interventions

The "desired outputs" noted in Table 3.16 can be used to define Project Development Objectives (PDO) and program indicators for Monitoring and Evaluation (M&E).[141] Improving ***undesired outputs*** or outcomes is important to ensure sustainable transport interventions. For example, international experience suggests that high shares of private vehicles and low urban densities boost fuel consumption (i.e., energy per capita), which increases travel expenditures, infrastructure investment, and emissions of local pollutants (NOx, SOx, CO, PM) and global pollutants (CO2 and other greenhouse gases, GHG). Table 3.17 provides sample transport sector outcomes in several cities around the world. The spatial, physical and technological factors contributing to these outcomes are described in later sections.

Sustainable transport interventions should be linked to a continuous and comprehensive planning process that involves incremental implementation, or a "building block" approach. The selection and sequencing of interventions should depend on "enabling" conditions and the co-implementation of complementary measures. In other words, maximizing mobility and accessibility can be achieved only if reasonable levels of safety, economic viability, and financial sustainability have been ensured. In this context, the World Bank Transport Strategy emphasizes that clean, safe, and affordable infrastructure and services represent the main aims of urban transport users. This chapter describes sustainable transport interventions under each of the five controllable inputs listed earlier, distinguishing between enabling conditions (Stage I) and additional measures (Stage II) that are substitute or complementary.

Policy, Legislative and Regulatory Framework

Urban transport is shaped directly or indirectly by policies, legislation, and regulations at the national, sub-national (regional or

Table 3.16 Typical Objectives or Desired Outputs of Transport Interventions

	DESCRIPTION	EXAMPLE INDICATOR(S)
Mobility	Amount and type of travel (both passenger and freight)	Number of trips by mode, passenger or ton-kilometers, change in travel times or delivery
Accessibility	Connectivity between desired origins and destinations; ability to reach desired goods, services and activities	Number of jobs within in a 1-hour radius, retail area within a 10-minute walk of a station
Quality	Quality of travel between origin and destination	Reliability (e.g., travel time variability, failures), comfort, convenience and equity
Efficiency	How resources are used and the environment impacted, including: • Local and global emissions • Energy consumption and efficiency • Impact on land and water	• Emissions of NOx, SOx, CO, PM, or CO2 • Quantity of fuel consumed per unit of mobility or economic welfare created • Amount of noise, runoff, sediments, dust, and other impacts to health and welfare
Safety	The safety and security of the transport system	Minimizing intentional and unintentional incidents, fatalities, injuries, property damage
Affordability	Economic and financial sustainability from various perspectives, including: • Users (by income group) • Government and general public • Operators and others	• Travel expenditure in relation to income • Implementation time and capital costs • Operating, maintenance, and disposal costs • Other social and economic impacts of the investment (e.g. poverty reduction)

Table 3.17 Different Urban Transport Outcomes from Several Cities

City	Population Density per ha	% walking + cycling + transit	Journey cost (% of GDP)	Annual travel (km/cap)	Energy (Mj/cap)
Houston	9	5	14.1	25,600	86,000
Melbourne	14	26	-	13,100	-
Sydney	19	25	11	-	30,000
Paris	48	56	6.7	7,250	15,500
Munich	56	60	5.8	8,850	17,500
London	59	51	7.1	-	14,500
Tokyo	88	68	5	9,900	11,500
Singapore	94	48	-	7,850	-
Hong Kong	320	82	5	5,000	6,500

Source: UITP (2001) Cities Database as cited in GTZ Sustainable Transport Sourcebook (2004), "Land Use and Urban Transport"

metropolitan), and local levels. Table 3.18 provides a summary of typical considerations at each policy level. It also distinguishes enabling conditions from more advanced policy measures that build on them.

Sustainable transport policies at the national level require (1) institutions, (2) processes, and (3) financial mechanisms that prioritize public transport (PT) and non-motorized transport (NMT) while discouraging private vehicle use. A lack of any of these elements can undermine a policy's impacts. For example, China's National Government adopted policies to prioritize PT and ensure people-oriented projects, but local impacts have been shaped by other factors, including capacity-building and financial mechanisms. Funding for transport investments, and occasionally operation and maintenance, may be financed by vehicle and fuel taxes, bonds, and government-

Table 3.18 Policies, Legislation and Regulations Affecting the Transport Sector

LEVEL	STAGE I: ENABLING CONDITIONS	STAGE II: ADDITIONAL MEASURES
National	Vehicle and fuel standards and taxes Roadway design standards Environmental protection and management laws	Sustainable transport policies Energy policies and targets Universal design and participatory rules Capacity-building and research
Regional/ Metropolitan	Urban expansion and land management policies Public transport provision and regulation	Integrated transport improvement and land use plans Financial mechanisms (road pricing)* Vehicular restrictions
Local	Zoning and taxation Traffic and parking regulations	Road space allocation Financial mechanisms (value capture)

backed loans. Funding of transport infrastructure typically requires participation from national or sub-national governments, while local governments typically provide operations and maintenance with or without private sector participation.

A fuel tax is arguably one of the most important and effective fiscal measures as it directly levies users for consumption, but it is often politically difficult to pass or sustain. Fuel tax revenue is usually collected by national governments, and then redistributed to fund roadway and transport investments. Most oil-importing countries impose a tax on transportation fuels, but policies vary widely. In the United States, gasoline is taxed roughly US$0.12 per liter, but it is taxed several times higher in European countries. The additional revenue collected in Europe has funded an arguably more sustainable mix of high-quality transport infrastructure and services, while encouraging less dependence on automobiles. Opponents argue that a fuel tax is socially and economically regressive as middle and lower-income groups spend a higher share of their total income on fuel. For these and other reasons, national governments commonly adopt other taxes to raise revenue, including vehicle, registration and licensing taxes. A carbon tax is analogous to a fuel tax since GHG emissions are directly related to fuel consumption.

Many countries mandate road, vehicle, and fuel standards to promote safety, efficiency, and quality. The United States, for example, requires automobile manufacturers to meet fuel efficiency targets under the Corporate Average Fuel Efficiency (CAFE) law passed in 1975, but standards in many European and Asian countries are stricter, as illustrated in Figure 3.48. Several countries also require that domestically sourced ethanol be blended into fuels, but the efficiency of the ethanol production process is highly dependent on the source of the fuel. Corn is the main fuel source in the United States. However, corn is inferior to sugar cane, which is being used in a successful ethanol program in Brazil, because corn is a major food crop that requires more resources to produce.

Other considerations at the national level include environmental protection laws, energy policies, and participatory regulations. Environmental laws often require a detailed review process to characterize and mitigate project impacts on air, soil, water, and the environment (i.e., impacts such as noise or visual intrusion). These rules influence transport policies or projects at the sub-national level. For example, air quality regulations linked to federal transport funding in the United States have driven cities and states to implement vehicle inspection and maintenance programs that mandate emissions and safety standards for motor vehicles. National policies also include targets for energy efficiency or independence. China, for example, has targeted a 20 percent reduction in energy intensity in all sectors by 2020. In transport, this will require a reduction in consumed energy per unit of GDP (or other measure). Meeting this target will require changes in travel behavior, project design, and implemented technologies. In this context, national research and development efforts should focus not only on evaluating and piloting advanced technologies, but also training and educating transport professionals. In addition, national governments have also addressed equity concerns through rules on 1) universal designs to accommodate all users, including people with disabilities and special needs (e.g., Americans with Disabilities Act in the United States), and 2) public participation and transparent reviews that give stakeholders ample opportunities to influence planning (such as the U.S. Government's National Environmental Policy Act and subsequent rules requiring Environmental Impact Statements).

A fundamental challenge to achieving equitable and efficient transport is charging users the full, long-run marginal costs of travel and parking, including externalities (i.e., the undesired outputs in Figure 3.47). Many innovative "time and price" instruments, supported by relevant technologies, have been piloted in cities in the last few years. These instruments can raise additional revenue for public transport and alternative investments. For example, London, Stockholm, and Singapore have implemented congestion and road pricing schemes that require drivers to pay tolls when entering defined central areas during certain hours of the day. In 2008, Milan (Italy) went a step further and applied a "polluter pays" principle—charging vehicles entering the central city for their expected emissions. Advanced parking management, which includes centralized control and varied rates based on hour of the day, is another example of an innovative revenue tool.

Urban expansion and land management policies are basic considerations at the metropolitan level. Regional transport investment programs that support 'sprawl' or physical de-

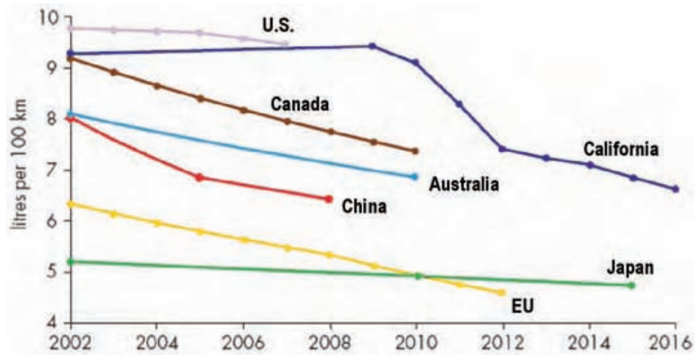


Figure 3.48 Average New Vehicle Fuel Economy Standards
Source: IEA World Energy Outlook, 2007

centralization in dense cities can have counterproductive effects, such as encouraging more vehicular traffic and congestion. The integration of transport and land development planning should consider macro-level urban spatial and land use patterns, site plans, transport network characteristics, travel patterns, user costs, and environmental impacts. In the United States, integrated transport, air quality, and land use plans for metropolitan and statewide transport programs are updated at least once every four years. There is a strong consensus that compact cities with a single or a few large, dominant centers or central business districts (CBD) are best-suited for traditional fixed-route, fixed-schedule public transport systems. Lower-density, homogeneous cities with many dispersed, weak centers are better served by individual modes. There is less agreement on the specific instruments that may be used to influence conditions, but they may include: 1) road pricing; 2) incremental taxation of land and property benefiting from transport investments; and 3) land development regulations on density requirements (floor-to-area ratios), lot sizes, building set-backs, traffic rules, and parking and zoning.

Metropolitan and local governments are typically responsible for public transport services and planning, which should be linked to demand, available resources, and urban characteristics. Cities typically establish policy-based criteria to define network coverage, distance between stops, and service frequencies. Network coverage is often defined as the percent of the population within walking or biking distance of a PT stop. In Bogotá, Colombia, for example, the master plan established that the percent of residents within 500 meters of a station or stop under the Transmilenio BRT and bus system should reach 50 percent in Phase 1 and 80 percent in Phase 2. Along with service decisions, many cities also enact policies regulating PT fares and subsidies.

The allocation of existing and planned road space among pedestrian; motorized, non-motorized, and public transport; and parked vehicles represents one of the most potent, low-cost ways that local governments can promote equitable transport management.[142] The goals of allocating street space may be diverse, such as protecting walkers and cyclists, ensuring safe movement of people, and facilitating public transport via transit-only lanes. One option for reallocation is constructing dedicated lanes for high-performance rapid bus transit (e.g., the BRT presented in Box 3.17) on arterial roads. In many large cities, transport demand can justify reallocating one or more lanes to buses. Yet local authorities often find this difficult. Unfortunately, due to public pressure, motor vehicle mobility is often emphasized at the expense of non-motorized and public transport.

Institutional Context

Efficient and stable institutions are an essential part of an urban transport system. These institutions can be characterized by their functions and scopes, including jurisdictions and modes. Institutional scopes can vary from a special city district (e.g., CBD), a major corridor, or a vast multi-jurisdictional region. Institutional functions include: 1) planning, including strategic, policy, investment, and financial planning; 2) implementation and service provision, including operations and maintenance by public and private entities; and 3) management and regulation. In Table 3.19, good practices are presented for two different institutional scenarios: a single jurisdiction with un-integrated modes, and multiple jurisdictions with multiple modes.

Difficult institutional issues often include planning, physical and operational integration, public transport reform, and fare policies (including subsidies). At a basic level, city

Table 3.19 Transport Institutional Functions and Jurisdictions

SCOPE: / FUNCTION:	STAGE I: (ONE JURISDICTION, EACH MODE SEPARATELY)	STAGE II: (MULTIPLE JURISDICTIONS, INTEGRATED MODES)
Planning and financing	• Roadway investment and maintenance plans • PT network planning • Pedestrian and bicycle access and facilities	• Coordinated metropolitan planning and decision-making – Service and accessibility standards – Prioritizing and budgeting – Financial mechanisms
Implementation and service provision	• Physical integration (intermodal terminals) • Electronic fare system with pre-payment	• Integrated transport strategy (physical, operations, fare policy, land use, emissions) • Private sector participation – Joint development – Concessions and management contracts
Management and regulation	Separate management of: • Road access • Regulation of PT and taxis • Traffic and parking management • Freight	• Centralized control and multi-modal optimization with: – Real-time information systems – Signal priority and coordination

transport institutions create forums for discussion and coordination between road planners, economic planners, public transport operators, traffic management officials, and police. In China, many cities have "leading groups" chaired by city officials. At an advanced level, transport institutions can represent forums for joint decision-making and priority-setting across multiple jurisdictions and multiple modes. Some good examples of this include Madrid (*Consorcio de Madrid*), Paris (STIF), London (Transport for London), Vancouver (TransLink), and Singapore (Land Transport Authority). Good examples also exist in emerging countries. Box 3.13 summarizes the essential "pillars" of sustainable transport institutions based on international experience in Latin America and other regions.

Ideally, there should be one metropolitan authority overseeing all transport issues and modes, particularly in regions with multiple jurisdictions. This authority should plan multiple modes, set priorities, and coordinate decisions on investments, taking into account land and environmental plans and the concerns of the public, civil society, and private sectors. The authority should oversee strategic policies and management of modes, including parking, taxis, public transport, highways, and arterial roads. The regulation and reform of public transport is challenging as it must balance the roles of the public and private sectors and respond to local conditions. An excerpt from recent World Bank operational guide illustrates challenges: "*Institutional approaches to providing public transport services range from a single publicly-owned monopoly operator at one extreme, to numerous weakly regulated or un-regulated small-scale, privately owned providers at the other. In some cities, a range of approaches coexist. The first extreme tends toward inefficient operations and uneconomic fares both of which map into high subsidies. It may also produce poor services, especially when the subsidy mechanism fails and operators are starved for funds. The other extreme may produce good services at zero public expenditure, but more often provides poor service with high accident and pollution costs. When this regulatory set-up is matched by low fares constrained by regulation or unfettered competition, service levels and quality fall and externalities rise.*"[143]

BOX 3.13

Four Pillars of Sustainable Urban Transport Institutions

Before financing major urban transport projects, decision-makers should attempt to put in place the basic elements that ensure long-term sustainability of the sector. Specifically, policymakers should incorporate a four-point agenda into any urban transport strategy:

Create a regional transport coordination commission in charge of coordinating policies among federal, state, and municipal governments, giving highest priority to major urban transport investments in the metropolitan region and promoting modal integration; this will help improve the sector's economic efficiency and long-term sustainability.

Adopt a strategy for integrated land use, urban transport, and air quality that provides a framework for community and decision-makers to evaluate future urban transport investments and policies.

Enact into law formal financing mechanisms to ensure that long-run variable costs of urban transport systems are covered by operating and non-operating revenues and by appropriate user charges.

Promote private sector participation in the operation, maintenance, and construction of urban transport systems to lessen the financial burden on the government (through, for example, concessions or management contracts).

Adapted from: Rebelo, J. (1996). "Essentials for Sustainable Urban Transport in Brazil's Large Metropolitan Areas." World Bank Working Paper Series 1633.

Physical Systems, Technology and Spatial Planning

The design of systems, technologies, and spatial plans should be driven by current or near-term transport demand and a longer-term credible and transparent transport plan. The transport plan is the product of a continuous, comprehensive, and inclusive process. Spatial planning should consider future land uses and existing travel and freight demand. Physical systems and technologies include the supply of infrastructure and services for passengers and freight. Technologies also include fuels, vehicles, and equipment used to deliver infrastructure and services. Table 3.20 provides a framework for these types of transport interventions. Table 3.21 summarizes physical, technological, and spatial interventions at basic and advanced levels.

International experience suggests that sustainable transport investment strategies need to: 1) prioritize public transport and other essential mode; 2) encourage non-motorized trips; 3) ensure that users of private automobiles internalize the costs they impose; and 4) include urban plans and incentives to support compact cities. The strategies should aim to achieve realistic results at different points in time: 1) in the short term, by improving fuel efficiency of existing vehicle fleets; 2) in the medium term, by facilitating a shift away from private car use; and 3) continuously, by supporting the development of compact cities built around public transport corridors that reduce demand. There are four outcomes of sustainable transport interventions: 1) managed demand, 2) enhanced supplies, 3) shifted modes, and 4) improved performance. The following sections describe specific interventions and expected outcomes.

Table 3.20 Framework of Transport Interventions

	A. SPATIAL PLANNING	B. PHYSICAL SYSTEMS	C. TECHNOLOGIES
3.1 Land uses and travel demand	Macro or master planning	Micro-design (e.g., Transit-Oriented Development (TOD))	Travel demand management (TDM)
3.2 Infrastructure and services	Location-efficient planning	Mobility and freight management (roads, public transport (PT), non-motorized transport (NMT), traffic management (TM), other facilities)	Intelligent Transportation Systems (ITS)
3.2 Vehicle fleet and fuel supply	Fleet management and efficiency programs	Standards, inspection and maintenance programs	Alternative fuels and advanced technologies

Table 3.21 Basic and Advanced Transport Interventions

	STAGE I: ENABLING CONDITIONS AND MEASURES	STAGE II: ADDITIONAL MEASURES
Land uses and travel demand	• Micro-design: – Urban densities – Road patterns and design – Intersections and crossings – Basic pedestrian and bicycle facilities – Parking and access management • Macro plans: – Origin-destination surveys and calibrated transport model – City structure and development pattern	• Micro-design: – Mixed land uses – Building design and orientation – Transit-Oriented Development (TOD) (Box 3.14). • Macro plans: – Development along high-quality public transport corridors – High-density, mixed-use nodes around public transport facilities – Reserving rights-of-way for future corridors – Energy use and emissions – Travel Demand Management (TDM) (Box 3.15 and 3.16)
Infrastructure and services	• Road network development • Public transport • Traffic management, including road safety measures	• Integrated PT and TM network • Bus Rapid Transit (BRT) (Box 3.17) • Intelligent Transport Systems • Freight management
Vehicle fleet and fuel supply	• Cleaner fuels (low-sulfur diesel) • Inspection and maintenance programs	• Alternative fuels • Advanced vehicle technologies

3.1 Land Uses and Travel Demand [144]

The transport plan should recognize the effects of transport interventions on future land development and travel demand. The interaction between transport supplies and land use is a complex, two-way relationship. Existing land uses and developments are "served" by transport infrastructure and services, which in turn "induce" certain types of land development and travel patterns.

Spatial planning is one of the most important factors influencing the demand, mode choice, and financing of urban transport investments. In turn, sustainable development can be the most important goal of transport investments, particularly public transport. Land development planning should include two complementary approaches: a "macro" or top-down approach, and a "micro" or bottom-up approach. The macro approach entails viewing the city or region from "10,000 meters" with a time horizon of more than one decade. Strategic planning and alternative analysis are initial steps in the macro approach that allow selection of appropriate modes and a city's alignment. The micro approach is more focused geographically (i.e., on blocks or corridors) and anthropogenically. It also has a shorter time horizon (<10 years) and requires more detailed preliminary designs.

At the macro level, the major determinants of travel demand include the distribution and character of land use. Transport investments can positively influence the distribution and character of land use by creating accessible and visible development nodes. For example, properly located public transport stations can be focal points for development, thus increasing public transport demand, reducing inefficient land consumption ("sprawl") and creating NMT opportunities. Other macro level planning issues include:

High-density, mixed-uses around PT—PT traditionally serves the city center and major activity centers, and particularly work-related travel. The locations of activity centers and job sites affect the designs and effectiveness of public transport. Traditionally, jobs are concentrated in the city center, but cheaper land or perverse incentives can attract development and jobs to urban peripheries where there is little or no infrastructure. Development in the urban periphery reduces economies of scale for public transport, making it more difficult to operate without substantial subsidies. Developing dense developments around public transport is therefore critical.

High-quality PT corridors—Focusing development along high-capacity, high-quality PT corridors is important, particularly to prevent unplanned development elsewhere. Such a strategy can be pursued in cities in China, but it has not yet been practiced effectively except in Hong Kong. In Singapore and Stockholm, urban rail and mass transit have been used effectively to supply high-quality PT. Bus Rapid Transit (BRT) is another innovative and cost-effective PT approach that was developed and is now widely applied in Latin America. Road infrastructure also plays a critical role. For example, the ring road model in Chinese cities induces higher private vehicle use and leads to dispersed development that is difficult to serve with PT.

City structure and development pattern—Radial city development and structures best facilitate high-capacity rail and bus systems provided that major job and activity sites are located in urban centers or along arteries (radial lines from the center, see Figure 3.49 below). Curitiba, Brazil is a good example of a radial, transit-oriented city in the developing world with a high-capacity BRT system serving five high-density corridors. These arteries were planned, and rights-of-way were reserved, decades before they were fully developed. This degree of urban foresight required a long-term vision and institutions that had sufficient capacity and political independence. Ring road or circumferential development places fewer constraints on

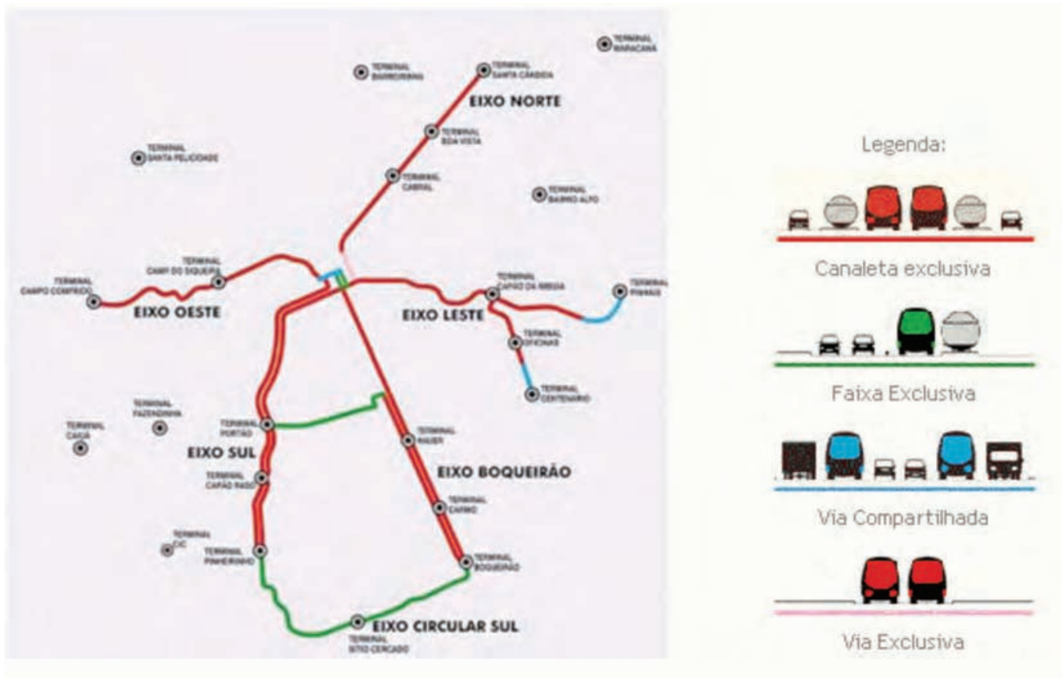


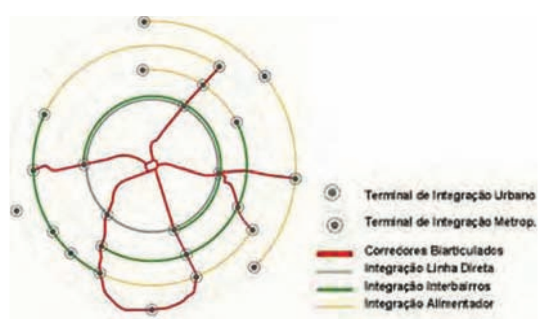
Figure 3.49 Structure of Curitiba's Integrated Public Transport Network
Source: URBS Website. http://www.urbs.curitiba.pr.gov.br/PORTAL/rit/index.php?pagina=terminais

land development, but encourages dispersed and inefficient land consumption. Urban development based on satellite cities is also less than ideal. It takes many years for a satellite city to become self-sustaining, and costly new connections to the city center and other poles are needed.

Land management—Developing large lots in primary and secondary markets for high-rise developments is important. Migration and urbanization trends in East Asian cities should be directed toward radial corridors rather than ring road development. Singapore, Hong Kong and South Korean cities provide good examples of effective land management. On the other hand, weak land use policies combined with large lots, high private vehicle use, and low fuel prices favor urban sprawl and decentralization. In many cities in North America in the second half of the 20th Century, these factors decreased the effectiveness of PT services, and created a "vicious cycle" that reinforced dependence on automobiles.

Financing mechanisms—It is important to be able to efficiently capture and transfer revenue derived from infrastructure through, for example, a value-based property tax. This approach was institutionalized in Tokyo, Hong Kong, and Singapore. In China, a significant share of city revenues comes from land sales or long-term leases, which provide incentives to expand city boundaries and oversupply land, exacerbating sprawl.

Tools and resources for macro planning include household travel surveys on origins and destinations (O-D), and transport models that use survey information for calibration.



Micro approaches have a narrower geographic and human focus. They also have a shorter time horizon (<10 years) than strategic planning, and have more detailed preliminary designs. Micro-design is largely analogous to the principles of Transit-Oriented Design or Development (TOD, Box 3.14) and is summarized below:

Land use distribution (space and time)—All functions in large cities cannot be centralized, and relative locations of developments and transport linkages determine travel demand and mode choice. Mixed land uses are important because they influence how far one has to travel to visit a store and get to work or school. Convenient foot and bicycle access (< 10 minutes) should be provided from residential housing to shops, services, and recreation, complemented by PT facilities for work trips.

Urban densities—Population densities and job locations affect transit and land use plans, but are not the only considerations. As described earlier, lower urban densities tend to boost car use, negatively impacting multi-modal sector plans. On the other hand, high densities without adequate planning and services can impede the quality of life for residents. The photo below depicts a sprawled residential development typical in developed countries.

Design and orientation of buildings—Large street offsets, parking lots, fences, and greenbelts

Figure 3.50 Colorado, USA
Source: Google Earth

Figure 3.51 Pedestrian-friendly Street of Curitiba, Brazil
Source: IPPUC

around buildings became much more common in the second half of the 20th century owing to concerns about safety, security, noise, and pollution. But these elements can discourage walking and bicycling because they impose barriers and make trips more circuitous. Thoughtful design is critical.

Road patterns and design—Traffic volumes on local streets influence the quality of life in residential areas. Road designs influence driving behavior, traffic speeds, and safety. Certain road patterns have low accessibility and connectivity (e.g., dead end streets and cul-de-sacs). Speed limits should be conservative and enforced rigorously in dense residential and commercial areas using signs, police, cameras, and speed humps.

Intersections and crossings—Local access roads wider than 5 meters, equivalent to approximately 2 lanes, tend to discourage crossing. Intersections with more than one lane in each direction may require traffic channelization (i.e., sidewalks, curbs, pedestrian islands, markings) and signals. Most congestion on arterials in dense areas is caused by limited throughput at intersections rather than the dimensions of the intermediary road sections. Road width can often be reduced or limited to 2–3 lanes in each direction, and include channelization and modal separation, while minimally impacting travel times.

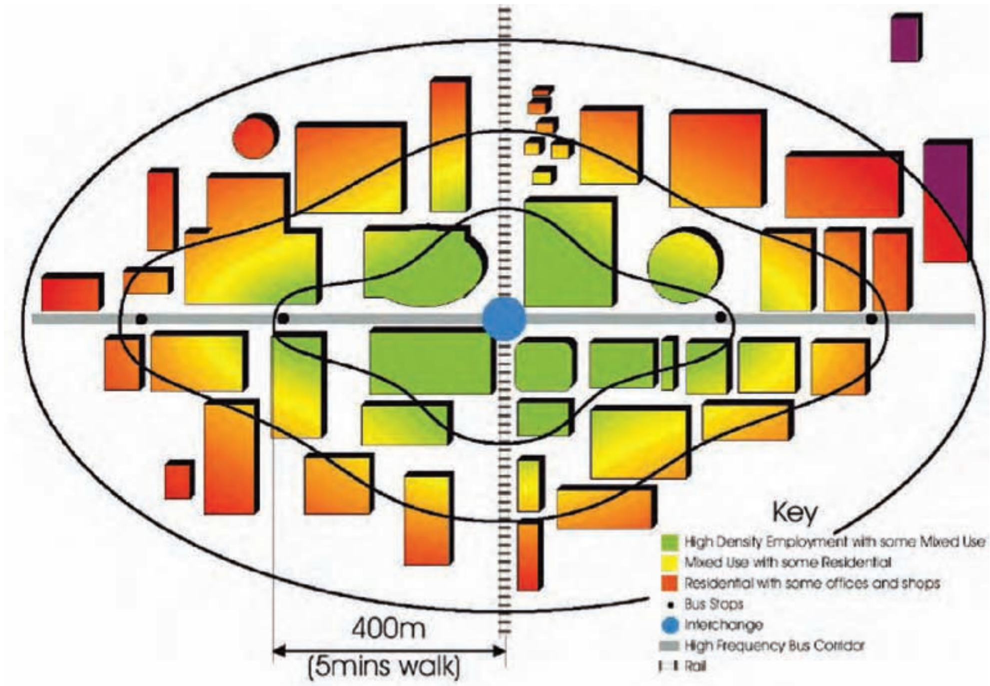


Figure 3.52 Example of Micro-Design and Walking Isochrones
Source: Buchanan (2001), as citied in GTZ Sustainable Transport Sourcebook (2004), "Land Use and Urban Transport"

Pedestrian and bicycle environment—Encouraging walking and bicycling by prioritizing non-motorized over motorized vehicle access (and parking) is a key objective for the urban environment. It is also important to provide pathways or greenways in city blocks, major complexes that are safe and shaded, and pervious surfaces that can absorb run-off water.

Parking and access management—Surface, underground, and on-street parking in cities is limited because of the high cost of land and construction. Where available, parking facilities should target multiple uses (e.g., office parking on weekdays, event parking at night, and fair or market parking on weekends) and be designed to minimize walking distances and impervious surfaces.

Spatial or land use planning should strive to optimize resources by reducing unnecessary motorized travel and encouraging trips on the most appropriate modes and routes at the most appropriate times. However, land use planning alone has a limited impact on the use of private vehicles (ITDP, 2004). Travel demand management (TDM), preferably linked to PT, and other major investments in infrastructure and services are needed. Common TDM activities include adequately pricing roads, restricting vehicle use by time or location (e.g., car-free Sundays), establishing high-occupancy or priority lanes, ridesharing and carpooling, and promoting telecommuting and flextime. Box 3.15 describes innovative TDM and emissions approaches adopted by Milan's EcoPass project. Box 3.16 describes Beijing's TDM and PT approaches linked to its tremendous urban growth and the 2008 Olympics.

3.2 Infrastructure and Services

Effective spatial planning considers the location of infrastructure and services relative to demand and other transport supplies in the region. Location efficiency, or Transport-Efficient Development (TED),[145] aims to optimize the location of transport investments and new major activity centers by maximizing benefits and minimizing environmental externalities such as energy use. Information gathering and

BOX 3.14

Transit-Oriented Development (TOD)

TOD is characterized by:

- Development near and functionally related to transit stations and terminals and served by high-quality public transport (BRT, metros, etc.)
- Compact, mixed use developments that encourage, by design, walking, cycling and transit use by residents, employees, shoppers and visitors

The ingredients of a successful TOD include strategic (macro) and design (micro) elements, such as:

- Strong development climate
- Master plans for multi-use, high intensity developments with implementation plans
- Transport investments that promote:
- Easy and direct pedestrian, bicycle and PT access (as pictured in the Eco-block above)
- Good signage and a pleasant environment to attract significant pedestrian flows
- High regional accessibility to major job and activity centers
- Short, direct connections between transport modes and transit facilities
- Bicycle lanes and parking facilities that feed stations
- Attractive facilities that are well-integrated with surroundings (public spaces, street furniture, etc.)
- Safe and secure designs, including adequate lighting
- Effective parking management around stations
- Environmentally-friendly technology options, such as a shared fleet of alternative (electric) vehicles located in neighborhoods

Research shows that the impacts of TOD are realized in the long-term and depend on the quality of related micro-designs, and the rate of an area's demographic and economic growth:

Figure above: Eco-block concept in China proposed by University of California Berkeley, Prof. Harrison S. Fraker Jr. http://bie.berkeley.edu/ecoblocks

- Research by Lund, Cervero and Wilson (2004) on residential and commercial sites in major cities of California (USA) showed that TOD factors, particularly proximity to urban and commuter rail stations, increased ridership on rail and buses as much as 3 to 4 times than in control sites.
- Cervero and Day (2005 and 2008) surveyed households relocating to suburban TOD and non-TOD sites in Beijing and Shanghai to assess impacts on travel behavior. TOD sites had significant positive impacts:
- Increased public transport ridership
- Improved access to regional jobs (as measured by employment locations within a radius equivalent to one hour to travel time)
- Reduced commuter times per household worker

Photos (Source: WMATA): The picture on the left shows a high-quality public transport corridor between Arlington, Virginia and Washington DC with an underground Metrorail (orange line) and feeder bus system. The corridor exhibits many elements of good macro-level planning and TOD, including higher densities around high-quality public transport (underground metrorail) in an otherwise car-oriented environment. Twenty years of mixed-use development around stations (such as Clarendon, pictured on the right) has made the corridor a good example of urban form.

BOX 3.15

Emission-Based Road Pricing in Milan, Italy

In January 2008, Milan introduced EcoPass, a program designed to restrict access to the city center during certain hours of the day by charging the most heavily polluting vehicles. This is the first urban environmental policy in the region where the transport sector applied the European Union's "polluter pays" principle. Strong results have been achieved to-date through this innovative congestion charging scheme:

- Traffic was reduced 19 percent during the enforcement period and 8 percent overall
- The speed of PT rose by 11 percent and PT ridership increased by 10 percent
- CO_2 emissions fell by 12 percent and particulate matter by 19 percent

For more information, see http://www.comune.milano.it/dseserver/ecopass/index.html

BOX 3.16

Beijing TDM and the Legacy of the Olympic Games

Transport operations during Beijing's 2008 Olympics required not only massive infrastructure investments, but also a new paradigm for TDM and unprecedented interagency coordination and public cooperation. According to transport officials, Beijing spent over 100 billion RMB (approximately US$14 billion) in the past five years on transport infrastructure and services. Temporary TDM measures included prohibiting half of Beijing's private vehicles from driving on city roads on alternating days based on the last digit of license plates (50% restriction). One-third of the capital's more than 3 million vehicles was removed from roads, though the city exempted government, emergency, public transport, taxi and Olympics-related vehicles from the restriction. Movement of freight vehicles was also restricted, and logistic distribution centers and tolls on inbound routes were implemented to further reduce traffic in the city center. The government also suspended activities at hundreds of factories and construction sites in and around Beijing. As a result, the city's notoriously poor air quality in August and September 2008 was the best in over ten years.

Congestion, notoriously severe in Beijing, was significantly reduced despite the Olympics-related traffic and the more than 260 km of lanes on arterials and ring roads reserved for Olympics, press, and government vehicles. According to transport officials, the share of commuters riding public transport rose by 35 to 45 percent due largely to restrictions on car use, expansion of the public transport network, and a recent reduction of bus and subway fares. In the past year, the city opened three subway lines, a light rail line from downtown to the airport, new bus lines, and a new Beijing-Tianjin intercity express railway. Beijing's transit network now includes more than 200 km of rail and 45 km of rapid bus lines. The improvements have diversified commuting options for millions of residents, but more investment is needed.

Returning to a pre-Olympic transport paradigm and ignoring long-term demand will quickly overwhelm Beijing's new infrastructure. Beijing's population of 18 million is growing by roughly half a million a year. Car ownership is not just as a symbol of status, but increasingly a necessary convenience. The number of motor vehicles is growing by over 10 percent per year, and more than 20 percent among private cars. International comparisons are few but instructive. London, Paris, Tokyo and New York experienced rapid growth in car use and ownership in the 20th Century, but motorization in Beijing appears to be progressing more rapidly than in any time in history. It took Tokyo 20 years (1962 to 1982) to increase its motor vehicles from one to three million, but this increase took place in only 10 years (1997 to 2007) in Beijing. New cars in Beijing have never been more efficient, but travel demand will overwhelm road capacity despite the rapid and ongoing expansion of the network.

Public opinion surveys after the Olympics showed that Beijing residents are now more aware of sustainable transport and air quality issues. While about 70 percent of residents were willing to live with certain car restrictions to sustain reductions in air quality and congestion, most car owners opposed the scope of restrictions on vehicle use. Car owners remained a minority, but this may change as more than 1,000 vehicles are added to Beijing's roads every day. Moreover, officials grappled with questions on which measures should be kept and to what degree. The Olympic experiment presented a unique opportunity to implement changes, but it also heightened public expectations.

After the Olympics, the Government announced that private cars will be allowed in the city, which includes the area within BeijingĐs Fifth Ring Road, on four out of five weekdays (20% restriction). As before, the last digit of license plates will determine the restricted day. This policy started in October 2008 and will undergo

BOX 3.16 (continued)

a six-month trial. Similar one-day restrictions have been in place for many years in mega-cities such as Mexico City and São Paulo. Evidence suggests that these restrictions become less effective over time as unused road capacity is taken up by other vehicles. More importantly, some people find ways to circumvent the rule. For example, some residents buy a cheap, older vehicle that can be legally driven on certain days. To mitigate against non-compliance, these approaches are often combined with vehicle inspection, maintenance, and scrappage programs.

Looking forward, Beijing transport officials are supporting a shift from "investment scale-up," where infrastructure investment consumes a large share of GDP, to "optimized operations." New infrastructure and technologies (e.g., Intelligent Transport Systems) will remain important, but effective planning and demand management will be sought to ensure long-term success. Among the most important proposed initiatives are:

- Harmonizing land use and transportation— including efficiently designing and locating activity centers and transit-oriented developments, improving accessibility for pedestrians and bicyclists, and adopting other policies and strategies
- Appropriate pricing and tolling—including for road use, vehicle registration, fuel, parking, and public transport (to encourage improved travel behavior and financial sustainability)

Photo (by Sam Zimmerman): Beijing's Third Ring Road at peak hour before the 2008 Olympics

- Efficiently allocating resources among modes and along integrated corridors— In Beijing, as in many of the largest cities, buses will continue to be workhorse vehicles; investments in measures to support buses are usually very cost-effective
- Adopting the latest, proven technologies for vehicles and fuels
- Improving institutional system and planning processes

modeling are crucial to TED. The type of land development is also important, as these types affect economies of scale and determine the physical constraints that make certain systems, technologies, or spatial plans more or less viable. Table 3.22 delineates the characteristics, opportunities, and challenges of common land developments.

Table 3.22 Type of Development and Implications for Transport

DEVELOPMENT	CHARACTERISTICS	OPPORTUNITIES	CHALLENGES
Greenfield (Urban Expansion)	Site of former agricultural or other non-urban land, usually on the edge of cities	• Application of best land use practices • Reserving rights-of-way (ROW) for future corridors • Smaller resettlement requirement	• No existing demand or services • Requires costly new infrastructure
Greyfield (Redevelopment)	Site of existing or former residential, institutional, commercial or industrial establishments	• Can capitalize on existing demand and services • Benefit of upgrading obsolete facilities or land uses (parking lots) • Easier to get public support	• Redesigning existing facilities and services to serve new demand • Resettlement and appropriation • Potential contamination site (brownfield)
Infill Development	Open site available within already developed area or next to other built sites and existing services	• Can capitalize on existing demand and services	• Rarely available or more costly • Reduction of open/green spaces

Though transport interventions typically influence limited spatial dimensions (e.g., radial or circumferential corridors can form a network or a grid), demand normally has a wider scope (e.g., block, district, city, and region, over time). The time dimension is also important as some interventions require many years and can be implemented incrementally. Urban planners normally strive to achieve a spatially balanced flow of passengers (encouraging trips in both directions on a road or rapid transit corridor) and to reduce peak demand, which is the most costly to serve.

Mobility management includes a range of transport interventions that enhance supplies and induce modal shifts. Road development is perhaps the most common type of mobility management intervention, but is best practiced to balance transport projects with other types of investment such as PT, NMT, freight management, and traffic management and road safety (TM/RS). Table 3.23 provides a summary of the most common

Table 3.23 Mobility Infrastructure Hierarchy

INFRASTRUCTURE	GENERAL CHARACTERISTICS	FUNCTIONS
Good practice dictates a balanced network of the following:		
Urban Highways and Ring Roads	• Highest speeds • Controlled access, with grade-separation and interchanges • Highest cost and lowest network density (<0.2 km/sq. km)	• Longest distance trips • Divert through traffic, particularly trucks • Evacuation routes • Encourage dispersed land development patterns
Primary Roads or Arterials	• Medium-high speed • Sidewalks and signalized crossings at every intersection • High cost and medium network density	• Major thoroughfare and inter-district trips • Access to highway networks and major activity centers
Secondary Roads	• Limited on-street parking • Sidewalks and pedestrian crossings at major intersections • Medium cost and medium network density	• Intra-district trips • Access to primary roads; high-density commercial, office residential and institutional developments
Local Roads or Collectors/ Distributors	• Low speeds and un-signalized intersections • Limited on-street parking • Sidewalks • Low cost and high network density	• Access to major roads • Motorized and non-motorized access to commercial developments and residential areas
Best practices also include:		
Traffic Management and Road Safety	• Centralized and coordinated signals and cameras • Channelization (islands) and pedestrian signals at intersections • Analysis of accidents and incidents	• Adapt to current conditions and give priority to special vehicles • Incident management and enforcement • Target road safety investments
Public Transport Facilities	• Dedicated or exclusive lanes • Intersection priority • Stations and terminals, park-and-ride facilities	• Give priority movement to PT • Maximize the coverage of the network while minimizing the burden of transfers
Bicycle Ways	• Crossings at major intersections • Amenities (secure bicycle parking, shade, etc.)	• Recreation (parkway) • Feeders to PT facilities • Commuter routes
Pedestrian Streets or Areas	• Downtown or shopping areas with high pedestrian traffic • Amenities (shade, benches, etc.) • No surface parking	• No vehicular access to buildings • Feeders to PT facilities • Public spaces for events
Freight Facilities	• Multi-modal terminals • Designated loading and parking	• Optimize operations by better matching vehicles and freight

types of mobility infrastructure by function and characteristic.

Balancing transport investments is important because it influences current and future mode shares and the sustainability of the system. For example, providing free or ample parking for private vehicles can severely reduce the viability of public transport. Moreover, maintaining or increasing the mode share of public transport and non-motorized modes becomes more difficult as the fleet and infrastructure for private vehicles grows. It is also important to note that new infrastructure, particularly for private vehicles, can induce a "rebound effect" or new demand due to increased capacity.

Public transport is a particularly important type of mobility intervention in the urban context. Table 3.24 summarizes the main elements of a PT network by function, capacity, and characteristic. At a basic level, most elements are applied but not in a coordinated or balanced way. Best practices recommend creating an integrated network that is scaled to demand. As the full cost of private vehicle travel is not internalized in most cities, individual decisions to use a private vehicle instead of PT can be based on inaccurate costs. PT systems require specific land development patterns to be successful. Some corridors are better suited for rapid transit, including rail, metro, or BRT. At the least, cities need sufficient available or "redevelopable" land around potential stations, and good pedestrian and bus access.

Intelligent Transportation Systems (ITS) aim to increase the capacity or efficiency of infrastructure by harnessing appropriate technology. ITS has the potential to improve highway operations by 1) mitigating congestion, 2) managing speeds, and 3) smoothing traffic flows. Spe-

Table 3.24 Elements of a Public Transport Network

SERVICE TYPES/MODES	FUNCTION	CAPACITY	CONDITIONS	REQUIREMENTS
Feeder or Circulators (collectors and distributors)	Shortest trips (usually 1–3 km) within district or neighborhood	Low Small buses (7–20 meters, 20–40 passengers)	Lowest population density but with defined nodes	Local streets, low costs
Local (Bus)	Medium trips (3-8km) from district to city or district to district	Intermediate schedules if more than minute headways	Medium density nodes or corridors	Arterial roads, bus stops and other facilities
Commuter Express Bus or Suburban Rail	Long trips (>20km) from regional suburbs to city center or district	Intermediate	Few origins with limited destinations	Highways or arterials, bus stops and other facilities
Surface Mass Transit—Bus Rapid Transit (BRT) or Light Rail Transit (LRT)	All trips from district to city (usually 5–20 km)	Intermediate-High: ridership: 100K-300K daily, 10K–30K in peak hour	High population density: 5,000–10,000/sq.km	Exclusive lane(s) on major arterials, 10-20m of right-of-way, stations and terminals, intermediate investment (typically US$1-10 million per km depending on infrastructure)
Grade-Separated Mass Transit (Elevated or Underground)	All trips from district to city (usually 5–20 km)	High: ridership: 200K-500K daily, 20K-50K in peak hour	Highest population density: >15,000/sq.km	Underground or elevated stations and terminals, highest investment (typically US$50–200 million depending on infrastructure)
Intercity (Bus or Rail)	Longest trips from region to region	Medium to High	Limited origins & destinations	Intermodal stations and terminals

Note: For further information, see the World Bank PPIAF-funded course material, "Introduction to Public Transport Planning and Reform."

BOX 3.17

Bus Rapid Transit (BRT)

Photo: D. Hidalgo, P. Custodio, and P. Graftieaux (2007). "A Critical Look at Major Bus Improvements in Latin America and Asia." World Bank Report and presentation at http://go.worldbank.org/W8FO3NQ680

BRT is an integrated system of high-quality bus interventions that can be implemented incrementally and catalyze more substantive reform. Among the key elements of a BRT system are:

- Exclusive or segregated busways
- Stations with level boarding and pre-payment of fares
- Large vehicles with multiple doors
- Advanced service and operations plan including for trucks and feeders
- Electronic and integrated fare collection system
- Intelligent Transportation Systems including centralized control and effective management of passenger information
- Marketing and branding to reinforce a distinct image

BRT has been shown to improve the level of service by reducing waiting, boarding, and travel times, and by offering modern, comfortable, and convenient services more cost-effectively than rail investments. PT services under BRT have increased viability relative to other, more polluting, energy intensive modes.

Milestones in the evolution of BRT include the following:

- Since the 1970s, Curitiba (Brazil) has been a pioneer in developing BRT as part of a long-term vision and implementation strategy that included reserving rights-of-way for structural axes (major city PT corridors), and building institutions with high technical capacity that have endured political changes.
- The Transmilenio BRT in Bogoto, Colombia has achieved myriad milestones: 1) very high-capacity of up to 35,000 passengers per hour per direction, 2) a shorter implementation period as part of an urban redevelopment plan, and 3) recognition as the first PT system approved under the Clean Development Mechanism (CDM) for sale of carbon credits.
- The Colombian National Urban Transport Program is a framework for technical collaboration and financing of BRTs in 7 participating cities to replicate and scale up the success of Transmilenio. The National Government has financed most infrastructure investments, while cities oversee operations of private concessionaires that earn profits based on system efficiency. Pereira, which is pictured above, was the first city to implement a scaled-down version of the Transmilenio system featuring 1) one-way streets in a narrow downtown area; and 2) improved solutions for feeders including an electronic fare system.
- Seoul (South Korea) and Santiago (Chile) both chose to implement ambitious PT reforms and investments that included: 1) BRT-type corridors, 2) integration of bus networks into express-trunk-feeders, 3) integrated smartcard systems, and 4) centralized controls. The main lessons-learned from Transmilenio was that a realistic or incremental implementation plan (with pilots) is critical.
- BRT can complement other PT investments. Several Asian cities have taken steps to discourage private car use and strengthen public transport by improving the bus system and building or expanding urban rail systems. Such cities include Singapore, Hong Kong, Tokyo, and Seoul. (ITDP, 2004).

For more information about relevant costs, benefits, and lessons learned, the material below is recommended:

- "BRT Planning Guide" (2007) by GTZ and ITDP
- "BRT Implementation Guidelines" (2006), TCRP Report 90.
- "Characteristics of BRT for Decision-Making" (2004), US Federal Transit Administration

Source: Alliance Save Energy and Watergy, Energy Efficiency

cific measures for each of these strategies are described in the bubbles in Figure 3.53. In California, each strategy has reduced fuel consumption and on-road CO_2 emissions by 5–10 percent. Mitigating congestion and smoothing traffic boosts average travel speeds closer to the optimal 35 mph (roughly 55 kph). Managing speed entails increasing vehicular speed to more efficient levels (below 65 mph or 100 kph). This scenario, however, assumes a congested environment and no "rebound effect." These strategies correspond to the ITS "market packages" pictured in Figure 3.54, namely freeway management and emergency management. For a complete database of ITS costs, benefits and lessons learned, please visit http://www.benefitcost.its.dot.gov/.

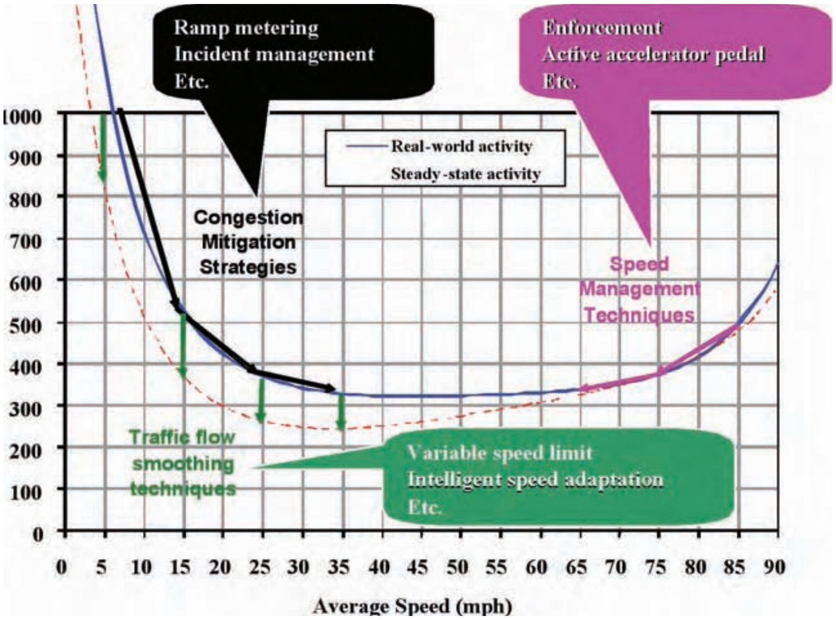


Figure 3.53 Benefit of Select ITS Highway Applications Under Speed Conditions
Source: Matthew Barth, Center for Environmental Research and Technology, UC Riverside

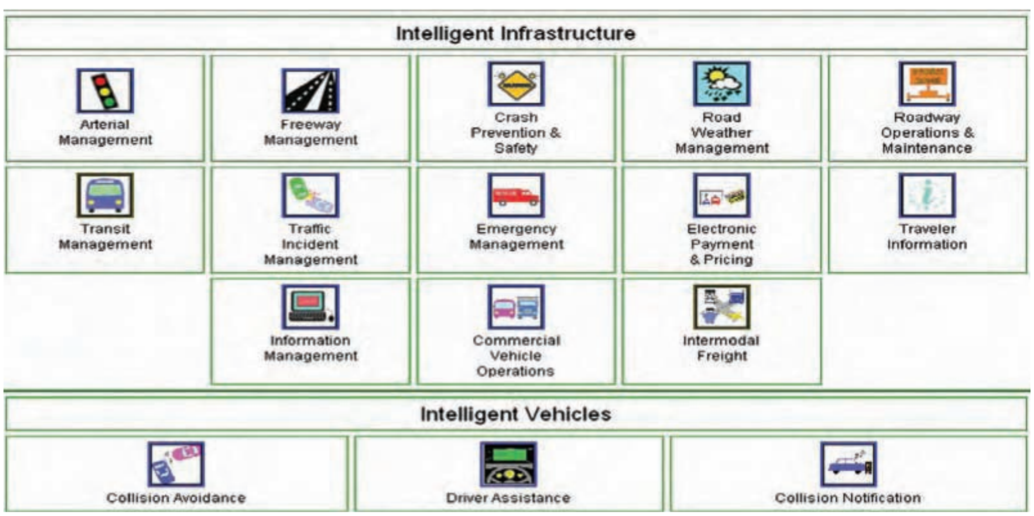


Figure 3.54 Classification of ITS Market Packages
Source: US Department of Transportation and http://www.iteris.com/itsarch/

3.3 Vehicle Fleet and Fuel Supply

Technological interventions targeting vehicle and fuel savings should normally be implemented together to ensure performance and cost effectiveness. There is usually little point in investing in advanced vehicle technologies without complementary fuel measures (and vice versa). For example, filters that capture dangerous particulate matter in exhaust will not work effectively without ultra-low sulfur diesel fuel, and these filters can be counterproductive in not properly installed. It is also important that basic steps are implemented before pursuing advanced technologies. These steps could include adopting minimum fuel and economy standards for new vehicles, and banning the most polluting vehicles (such as those with highly inefficient 2-stroke engines). In many countries, periodic inspection and maintenance schemes are common to compel repair of the most polluting vehicles or their removal from roads. Table 3.25 provides a partial overview of common vehicle and fuel technologies and practices and illustrative examples.[146] However, only a few advanced interventions are suggested because they are highly dependent of the local contexts.

Good management and operational practices are also essential. For example, a highly sophisticated hydrogen fuel cell bus would provide little benefit if the bus carries few passengers or the primary fuel source used to produce the clean hydrogen was something more polluting than standard diesel. Table 3.26 provides estimates of CO2 emissions from various vehicle types based on realistic assumptions of occupancy, maintenance, and primary energy sources.

Table 3.25 Summary of Select Vehicle and Fuel Interventions

	VEHICLES	FUELS
Stage I: Enabling Conditions	• Minimum safety and efficiency standards for new vehicles • Ban existing 2-stroke engines	• Minimum fuel quality standards (unleaded, low-sulfur, reformulated fuel, etc.)
Stage I: Additional Measures	• Emissions control equipment – Catalytic converters for gasoline – Particle traps for diesel • Inspection, maintenance and scrappage requirements	• Alternative and bio-fuels where appropriate and cost-effective, including – Natural gas – Ethanol • Reduce leakages and inefficiencies in the vehicle and distribution system
Stage II: Additional Measures	• Advanced technologies for managed/shared fleets – Eco-driving options and idle reduction – Hybrid-electric – Plug-in electric	• Renewable alternative fuels with distribution network where appropriate – Solar – Wind

Table 3.26 CO2 Emissions from a Range of Vehicle Types and Modes

	LOAD FACTOR (AVERAGE OCCUPANCY)	CO_2 EQUIVALENT EMISSIONS PER PASSENGER KM (FULL ENERGY CYCLE)
Car (gasoline)	2.5	130–170
Car (diesel)	2.5	85–120
Car (natural gas)	2.5	100–135
Car (electric)*	2.0	30–100
Scooter (two-stroke)	1.5	69–90
Scooter (four-stroke)	1.5	40–60
Minibus (gasoline)	12.0	50–70
Minibus (diesel)	12.0	40–60
Bus (diesel)	40.0	20–30
Bus (natural gas)	40.0	25–35
Rail transit**	75% full	20–50

Source:Sperling and Salon, 2002
Adapted from ITDP, 2008
Note: All numbers in this table are estimates and approximations, and are best treated as illustrative.
* Ranges are due largely to varying mixes of carbon and non-carbon energy sources (ranging from about 20% to 80% coal), and also the assumption that the battery electric vehicle will tend to be somewhat smaller than conventional cars.
** Assumes heavy urban rail technology ("Metro") powered by electricity generated from a mix of coal, natural gas, and hydropower, with high passenger use (75% of seats filled on average).

Stakeholder Dynamics

Incentives for the public sector, private sector, and citizen stakeholders need to be aligned and coordinated. Table 3.27 outlines the various stakeholders. Their main interests are described below:

- *Decision-makers*: Elected and appointed officials (typically with 4-5 year terms) gauge the political and economic feasibilities of innovative urban projects. Innovative projects are often linked to city goals, efforts to boost the quality of life, and major special events that can catalyze transformative change (such as Olympic Games in Beijing, Box 3.16). The key questions are: What will be the projects' impacts on key interests? Are impacts reversible if something goes wrong? Are projects implementable during a "window of opportunity" and are they sustainable beyond the current term?
- *Users or the riding public*: The interests of this group include maximizing personal mobility and the accessibility, quality, safety, and affordability of services, and minimizing personal expenses. Interests can be measured from user surveys. International experience shows that users value participatory processes and the principles of universal accessibility.
- *Public*: The public (including non-users) is generally interested in the performance and cost-effectiveness of investments. Public opinion surveys (including household surveys) can form part of a transparent vetting process that also publishes public information on web sites and through other media and channels.
- *Transport Planners and Operators*: Transport officials usually strive to ensure the financial and social sustainability of infrastructure and services. Subsidies may be required for some services or in areas where affordability is a main concern.

Table 3.27 Basic and Advanced Stakeholder Interests

	STAGE I: ENABLING CONDITIONS OR MEASURES	STAGE II: ADDITIONAL MEASURES
Decision-makers	• Windows of (political) opportunity • Economic feasibility	• Special events and larger vision • Quality of life issues
Users	• User surveys (on-board, intercept)	• Participatory process • Universal accessibility
Public	• Public opinion surveys	• Transparent process
Operators	• Financial sustainability	• Social sustainability

- *Business community*: Transport infrastructure lubricates a city's economic engine, and business leaders are often keenly interested in the development of key projects.

Economic and Financial Aspects

Best practice dictates that feasibility or planning studies for transport projects thoroughly analyze viable alternatives. Analyses should consider investment lifecycle costs and time horizons. Studies of PT corridors often assess BRT and urban rail alternatives. BRT has a slightly lower capacity and shorter lifecycle as buses and busways do not last as long as rail cars and tracks. However, BRT is considerably faster and cheaper to build than rail if rights-of-way are available. BRT is also more flexible and can be implemented incrementally and more easily altered. Table 3.28 summarizes the key aspects of economic and financial assessments of transport projects.

Table 3.28 Economic and Financial Aspects

	STAGE I: ENABLING MEASURES	STAGE II: ADDITIONAL MEASURES
Economic	• Feasibility or planning study • Cost-benefit analysis (primary benefits)	• Alternatives analysis • Evaluation of primary and secondary benefits
Financial	• Financial analysis	• Innovative financing options

Economic analysis of transport alternatives typically employs cost-benefit analysis and calculation of a rate of return.[147] For World Bank-financed projects, the economic and financial indicators are usually linked to PDOs and the M&E framework. These indicators include calculations of Net Present Value (NPV) and an Internal Economic Rate of Return (IERR), which are typically estimated over the life of the project, and include the following elements:

- Costs:
  - Capital (fixed or up-front investment costs)
  - Operating (variable or operational, maintenance, disposal costs)
- Benefits (listed from primary to secondary benefits):
  - Travel time savings: quantified using transport models, including demand forecasts and mode choices. This value theoretically captures most of the potential gains in land values from improved transport services and accessibility.
  - Vehicle operating cost savings: quantified based on the wear and tear on vehicles, and fuel savings.
  - Road safety benefits: sometimes quantified in terms of avoided injuries, fatalities, and property damages using statistical values from local data sources.
  - Air quality benefits: sometimes quantified based on estimates of the economic and health impacts of reduced emissions of local pollutants.
  - Greenhouse gas (GHG) emissions: this factor is directly related to fuel consumption and is sometimes quantified, particularly to evaluate the possibility of selling carbon credits (see innovative financing section below). GHG emissions are usually normalized by person or unit of economic welfare (such as GDP). Issues related to estimating transport-derived GHGs are discussed.
  - Other impacts of infrastructure on employment and poverty are sometimes considered. However, the broader, long-term economic impacts of integrated transport systems and technologies (e.g., impacts on the small business market and technology exports) are rarely quantified.
- Sensitivity analyses to assess the viability of investments under different scenarios, based on variations in at least three variables:
  - Costs (i.e., increases in the capital or operating costs)
  - Start state (i.e., to account for costs of delays)
  - Revenue or demand variation (i.e., less than expected traffic volumes or ridership)

Forecasts of demand and mode choice are critical elements of an economic analysis. Theoretically, an individual will choose an available mode or service that maximizes utility and/or minimizes total cost. As shown in Figure 3.55, utility comprises several variables including total travel time and total travel cost. Travel time can be monetized into a value of time (VOT) for different users, and travel purposes can be measured through surveys. Monetary estimates of time are valid only to the extent that there is a real tradeoff between time and money. Another limitation of mode choice models is the valuation of other qualitative aspects of travel, such as comfort, safety, and convenience. Some of these factors can be monetized using surveying techniques to estimate willingness-to-pay (WTP).

Any large sustainable transport investment is a long-term financial commitment that requires fiscal discipline and institutional capacity to manage it over the long-term. Examples include urban rail or metro investments that can cost hundreds of millions of dollars to construct and millions per year to op-

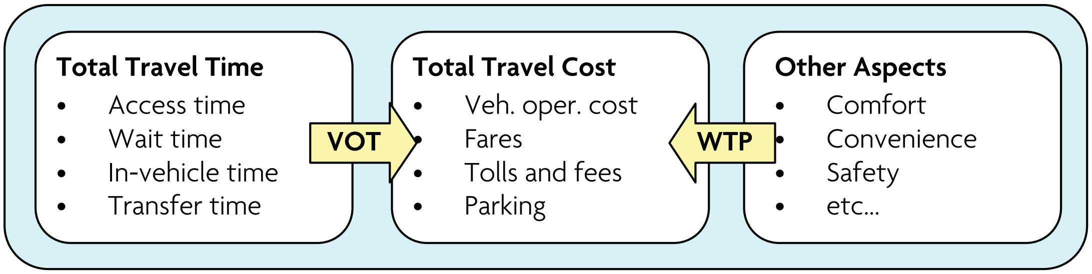


Figure 3.55 Elements of Utility in Mode Choice Models

erate. The government finances public transport infrastructure in many cities, and services are often subsidized even when operated by the private sector. This is because local conditions often do not allow profitable operations while still fulfilling social objectives. Financial indicators for transport projects depend on the type of project (i.e., investment, reform, or public-private partnership) and should measure liquidity (working capital ratio), performance (operating ratio for PT companies), and financial sustainability (debt service coverage ratio).

There are many innovative financing options that can be considered:

- *Public-private partnerships* (PPP) are frameworks for joint investment planning (and asset ownership or revenue sharing) between public and private sectors. PPP is usually selected because of: 1) fiscal constraints on public funds; or 2) the rigor and efficiency brought by the private sector. One example is using public land as a direct "payment" to private partners in return for construction of PT facilities and stations (etc.). PPP is not always the lowest-cost option; therefore, an appropriate allocation of risks (e.g., construction, economic, and traffic risks) and accurate estimations of value are important. Good PPP examples include public transportation terminals financed by the private sector, such as those in Japan and Brazil. Terminals also represent good locations for leased retail space and other public services
- *Land development and value capture* include techniques where the public entity sells surplus land to developers ("joint developers") or develops land around transport investments. A good example is Hong Kong's public transport system.
- *Tax increment financing* provides a dedicated stream of land taxes to finance projects.
- *Carbon financing* involves the sale of greenhouse gas emission credits to finance capital or operating costs. One example is the CDM-approved methodology used in Bogota's Transmilenio.
- *Other tolls and fees* can be imposed to specifically fund projects. For example, impact fees have been used in some parts of the United States to tax developers for the expected impacts of developing the transport network.

Figure 3.56 Photo of Terminal Carmo in Curitiba with Adjacent Shops and "Citizenship Street"
Source: IPPUC

Integration Opportunities

There are a number of analytical resources and modeling tools used in transport that are potentially applicable to other sectors. There are summarized below:

- *Macro planning tools include household and user surveys of travel O-D*. These surveys should be executed at least once every 7-10 years and survey all modes (walking, bicycling, private vehicle use, public transport modes of various types, taxis, and trucks) aggregated by travel purpose and income level.
- *The O-D data can be used to develop and calibrate a four-step metropolitan transport model*, which encompasses: 1) trip generation, 2) trip distribution, 3) mode choice, and 4) network assignment. Officials can employ this model to support decisions on major transport policies or investments in a metropolitan transport plan. "Carbon footprint" and GHG analyses also require recent O-D survey data (preferably less than 7 years old) and a calibrated transport model. A common pitfall in developing such a model is underestimating or ignoring shorter, non-motorized trips within zones, and overestimating longer trips on major corridors. Freight modes must also be accurately considered, especially in large and fast-growing cities where trucks have significant impacts.
- *Emissions inventories*: There are at least two ways to estimate urban transport emissions. A "bottom-up" approach entails collecting data on vehicle fleets including number, type, average fuel efficiency, and annual vehicle-kilometers traveled (VKT). This information can be substituted or supplemented by motorized trip tables and average distances from O-D studies. A "top-down" approach analyzes the amount of fuel sold or consumed in an area. The latter approach is often used to check the data in the former, but the two approaches are normally difficult to reconcile for urban emissions.
- Important micro-design tools include site plans, station area plans, and zoning ordinances.

There are also important bottlenecks in sustainable transport planning and potential solutions, such as the following:

- *Road space allocation*—Traffic engineers tend to focus on vehicle volumes on roadway segments and intersections. Investments often thus optimize networks for moving vehicles rather than people or goods. By considering vehicle occupancy and appropriately valuing passengers on high-capacity vehicles such as buses, one can easily argue for increased priorities for high occupancy vehicles on streets and intersections. These concepts are illustrated in Figure 3.57.
- Energy consumption can be incorporated in a city's master planning process if modal OD and fuel consumption data are systematically captured. This data can be harnessed to develop multi-sector spatial plans and policies for energy use and climate change mitigation and adaptation (i.e., infrastructure standards and codes, emergency procedures).
- Public transport provisions, regulations, fares, subsidies, and service levels directly impact a city's finances. In PPPs, involvement of private companies, and their associated exposure to risks, typically progresses from management and operations to ownership of fleets, facilities, and infrastructure. Multiple options are available to allocate risks between public and private partners; the choice depends partly on the extent of development of legal systems and market institutions in a city and country.

Figure 3.57 Road Consumed by Equivalent Passengers in Cars, Bicycles and Bus
Source: Muenster, Germany as cited in GTZ Sustainable Transport Sourcebook (2004), "Land Use and Urban Transport"

Regulatory changes in urban transport are often linked and aligned to complementary reforms in the water and energy sectors, including in urban utilities and national enterprises.

In sum, there are numerous approaches that integrate transport and other sectors that can improve the urban ecological and economic environment. Table 3.29 summarizes cross-sector integration opportunities.

Table 3.29 Summary of Cross-Sector Integration Opportunities

DIMENSIONS	URBAN	ENERGY	WATER	SOLID WASTE
Policy, Legislative and Regulatory	• Land use zoning for residential, commercial, institutional properties	• Energy and emissions inventories and targets • Fuel security • Air quality standards for drainage	• Roadway design standards	• Litter prevention programs • Materials recycling programs
Institutional Context	• Metropolitan coordinating institutions	• Reform and regulation • Conservation programs	• Reform and regulation • Conservation programs	• Reform and regulation • Conservation programs • Enforcement programs
Physical Systems, Technology and Spatial Planning	• Master Planning of NMT facilities, accessibility, amenities and urban furniture, • Public spaces	• Fuel and vehicle standards • Inspection and maintenance • Location efficiency • Fleet management and efficiency programs	• Stormwater runoff • Production and disposal of infrastructure, vehicles, systems	• Production and disposal of infrastructure, vehicles, systems • Location of collection and disposal facilities
Stakeholder Dynamics	• Special events to change behaviors and spur investment			
Economic and Financial Aspects	• Saving from coordination	• Savings from coordinated utility development (power lines, lighting)	• Savings from coordinated road construction	• Saving from coordination

SECTOR NOTE 4

Cities and Solid Waste

Overview

Waste management is often viewed as an end stage in a product's life cycle. However, it also provides opportunities to renew materials' useful life by recycling, composting, and recovering energy through thermal processes such as incineration or methane capture from landfills. The energy released from thermal treatment or methane combustion can then be used to generate electricity or other power, creating a synergistic loop. The desired aims of a waste management system can be summarized thus:

> "Waste management should fundamentally protect public health; while also maximizing material and energy resource use efficiency and protecting the natural ecology."

Figure 3.58 delineates the main inputs, interventions, and outputs of a waste management system. Inputs can be either independent or dependent based on their degree of controllability. For example, geography normally represent an independent input over which authorities have little if any control, while policy frameworks are dependent as cities do influence legislation. Outputs can work toward the aims above, or be undesirable, such as higher than expected air and water pollution.

Why is waste management important?

Effective waste management is critical to the ecological and economic vitality of urban areas. Fundamentally, a properly designed and operated waste management system provides:

- *Protection of Public Health*. Inadequately collected waste and poor disposal are breeding grounds for disease-carrying vermin such as rodents and insects. vIn addition, bacteria like salmonella and shigella thrive in food waste, which accounts for over half of the municipal waste in developing countries.[148]
- *Ecological Protection*. An effective system will regulate or prohibit harmful practices, such as open burning and improper waste disposal, to protect local and regional ecologies and mitigate impacts on air, land, and water.
- *Effective Budget Management*. Efficient solid waste management is very important to the fiscal health of a city because solid waste management in medium-sized cities can reach 40 to 50 percent of total municipal budgets.[149]
- *Employment*. Waste management provides significant formal employment from collection to disposal. Informal employment may also be important, such as waste collectors who recover materials for recycling prior to collection at disposal sites.
- *Aesthetics*. Effective systems protect cities' visual and sensory appeal by ensuring that waste is effectively managed and that practices do not unduly impact residents and visitors.

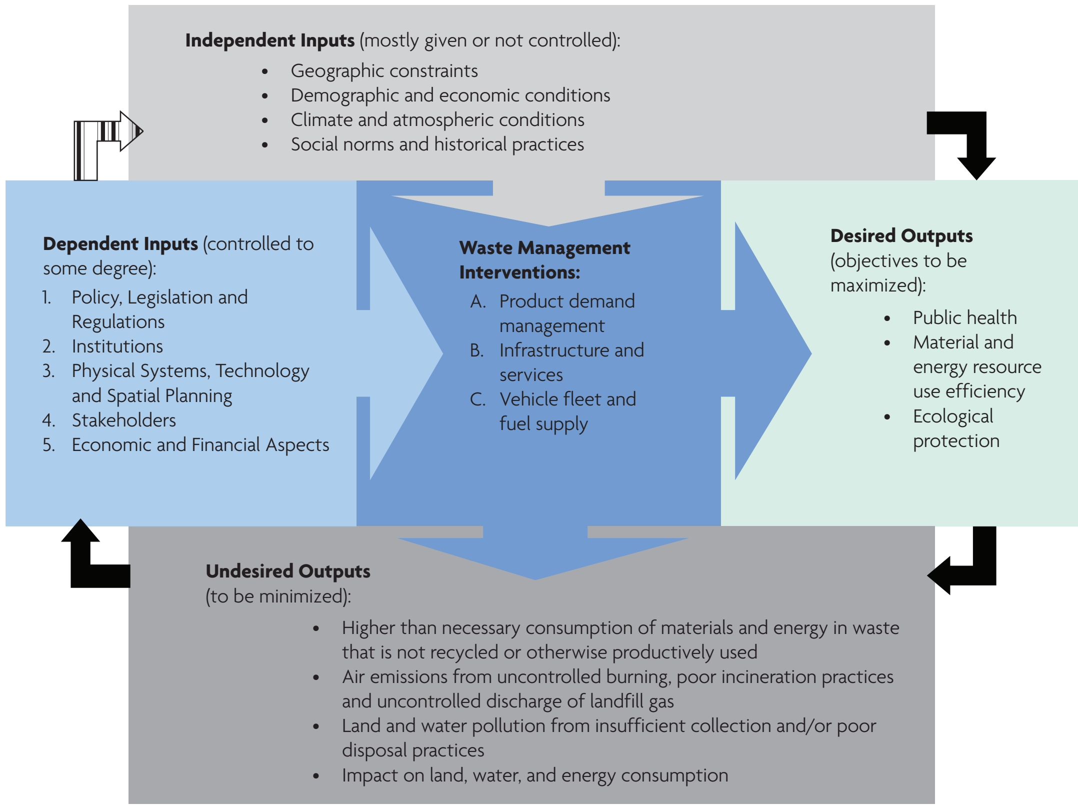


Figure 3.58 Input and Output Framework for a Waste Management System

What comprises solid waste?

Most people rightly attribute significant portions of municipal solid waste to residents and commercial operations. However, municipal solid waste includes other sources, some of which have special waste management needs:

- *Medical Facilities*. Hospitals and clinics generate solid waste. Medical facilities also generate infectious waste and occasionally radioactive waste. In general, infectious and radioactive wastes must be separately managed from other medical waste, although infectious waste that has been rendered non-infectious through incineration and autoclave or microwave treatment can be discarded in municipal landfills.

- *Industry*: Municipal landfills can receive industrial waste, but hazardous waste must be managed separately.

- *Construction and Demolition Debris*. This waste comprises discards from new building construction and renovation of older facilities, and residue from structures that are torn down. Much of this debris can be recovered for recycling, which could minimally include clean fill if problem materials are extracted such as wood with lead paint and asbestos.

- *Slaughterhouses*. These facilities produce animal waste and various excreta that must be properly managed.

- *Sewage Treatment Plants*. The residue of sewage treatment—sludge—can be discarded in a landfill in limited quantities to maintain the stability of disposal sites if mechanically dewatered. This is because sludge typically has high moisture content (70–80 percent). Alternatively, dewatered sludge can be applied to land as a soil conditioner. Dried sludge, which is more suitable for storage and longer distance transport to agricultural areas, can also be applied to land. Sludge can further be used as compost. Such uses require that sludge meets regulatory standards on pollutants such as metals. Biological digestion of sludge at treatment plants can reduce volatile organics by more than 50 percent. Such digestion reduces the amount of sludge that must be treated or discarded. The digestion process, which is anaerobic, also produces gas that may be up to 60 percent methane, which can be used as an energy source.

- *Combustion Residue*. This comprises ash from waste incineration or combustion of solid fuels in central facilities or in households (i.e., ash generated from cooking and heating).

What are the characteristics of waste?

The options for urban solid waste management partly depend on the quantity and composition of discarded waste.

Generation. The total quantity of discarded waste depends on the per capita generation rate, which is highly correlated to residential income. Cities with higher incomes tend to generate more waste than similar sized cities with lower incomes. People with higher incomes purchase more goods and services, which results in more waste. Table 3.30 illustrates the relationships between between income level, per capita waste generation, and total urban generated waste. Assuming a consistent population of one million residents, a low income city would generate 500 tons of waste per day, but this would more than triple to 1,600 tons per day in a high income city.

Table 3.30 Waste Generation Rates

INCOME LEVEL	GENERATION RATE (KG / CAPITA / DAY)	WASTE QUANTITY * (TONS / DAY)
Low	0.5	500
Middle	0.7	700
High	1.6	1,600

* Assumed population of 1.0 million.

Composition. The composition of waste also varies by income level, as illustrated in Table 3.31. Food waste tends to be highest among lower income earners. As income increases, food waste generally falls as consumers purchase more prepared foods relative to fresh food. Fresh food results in more waste from peels, pits, and other residue.

Waste composition helps to determine the appropriate approaches to waste management. A city with a high level of food waste, for example, should provide more frequent collection to minimize the potential to attract vermin, which can transmit diseases to residents. Aerobic composting is also suggested for areas with high food waste, which decays rapidly in compost operations given its high moisture content.

Conversely, areas with high food waste are not good candidates for incineration systems. Waste will only auto-combust if the moisture content is less than 50 percent, which means that a supplemental fuel is need to burn food waste due to its higher moisture content. This factor is exacerbated during rainy seasons.

What are the common approaches to waste management?

Options for managing waste have been ranked in a number of forums. A universally accepted pyramid of choices is provided in Figure 3.59. Under this schema, waste prevention is the preferred option at the top of the pyramid and

Table 3.31 Waste Composition by Income

MATERIAL	INCOME LEVEL LOW	MIDDLE	HIGH
Food	40–85%	20–65%	20–50%
Paper	1–10%	15–40%	15–40%
Recyclables	4–25%	5–26%	11–43%
Miscellaneous	15–50%	15–50%	5–20%
Moisture	40–80%	40–60%	20–30%

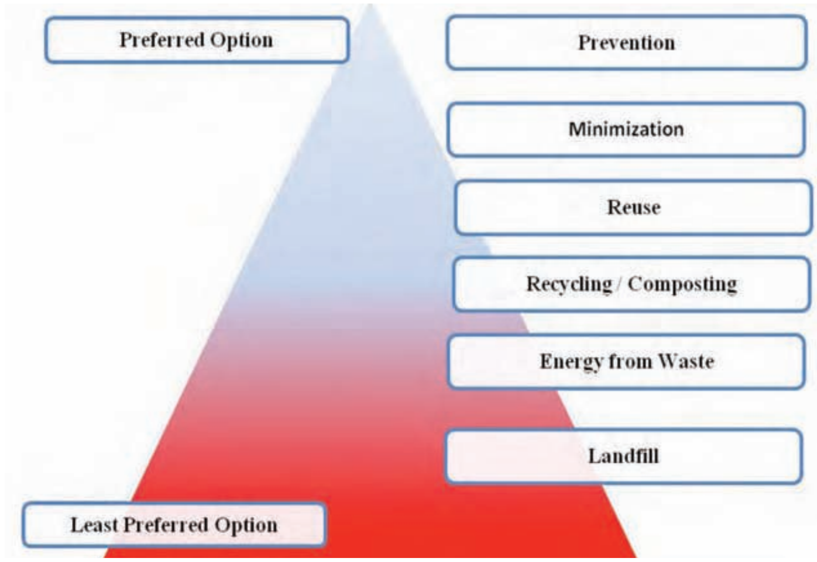


Figure 3.59 Waste Hierarchy
Most Favored Options at the top of the Pyramid Declining to the Least Favored at the Bottom

waste disposal the least favored option forming the pyramid's foundation. Waste prevention and minimization are equivalent to waste reduction, and involve:

> '...prevention of wastes at their source by redesigning products or changing patterns of production and consumption'.[150]

Waste reduction (i.e., prevention and minimization) comprises demand management practices such as creating durable products with longer lives. Reuse implies products that can be used more than once, unlike "disposable" or single-use products such as diapers and soft drink containers. The recycling option includes composting. Energy recovery includes technologies such as methane capture that harness waste or byproducts to generate useable energy.

What are the key dimensions influencing a waste management system?

Policy, Legislative, and Regulatory Dimensions

Policy Dimension. National and local governments must be committed to improving their urban environments to protect the health of residents. Additionally, governments, especially at the national level, should emphasize demand management to control the quantity of generated waste. Demand management includes programs to reduce waste, encourage reuse, and recycle.

In Japan, for example, the city of Yokohama took action to reduce demand for waste treatment (incineration) and disposal. In 2003, the city launched its G30 Plan (G = garbage; 30 = 30 percent reduction in waste generation by FY2010). The program targeted residents, businesses and government, and focused on the 3Rs: Reduction, Reuse and Recycling. The program has exceeded its goals. In FY2007, waste was reduced by 38.7 percent, or 0.1 million tons per year. The reduced waste enabled officials to close two incinerators, yielding savings in operational expenditure (OPEX) of US$30 million per year. After subtracting the US$24 million of OPEX costs for the additionally required operations, such as separating waste and subcontracting recycling, the city realized net savings of US$6 million per year. The closing of the two incinerators also obviated the need for US$ 1.1 billion in capital expenditures (CAPEX) that would have been required to renovate the incinerators.

At the local level, effective wastewater management and air pollution control are needed to address risks. In cities with open drains, for example, uncollected waste dumped into drains can block or hinder water flow, which can cause severe flooding during high rainfall. As waste disposal sites are often in low lying areas near waterways or wetlands, inappropriately designed landfills or discarded waste can also contaminate surface and ground water, with concomitant risks on drinking water and residents that live downstream.

Even when disposal sites are not near water bodies, ground water can still be contaminated. Leachate, which includes contaminated rain water and waste with high moisture content such as discarded food, can percolate through soil under an inadequately designed disposal site and pollute ground water. Leachate can be controlled by lining the bottom of a disposal site with clay and/or a synthetic material such as high density polyethylene. These materials inhibit the flow of leachate, which can then be collected through pipes on top of the liner, and treated.

The combustion of solid waste, whether in an incinerator or a fire at an open dump, can add particulates (smoke) to the atmosphere and other toxic and non-toxic air pollutants. Emissions from incineration can be controlled, but a comprehensive emissions control system can be nearly as expensive as a combustion system.

Government policies need to address disposal of other types of wastes, such as infectious medical waste, hazardous waste, sewage sludge, residue from livestock slaughterhouses in urban areas, and residue from energy production facilities, especially those using solid fuel such as coal and/or biomass. These wastes should be managed separately from municipal waste, and may require treatment prior to disposal, such as to render medical waste non-infectious.

Whenever possible, policies should be benchmarked against those in other cities in the region and in developing and developed countries. Benchmarking helps to evaluate the expected effects of policies through analysis of past practices and lessons learned.

Legislative Dimension. Appropriate laws at all levels of government are important to the development and operation of the waste management sector. Legislation supporting a viable waste management framework should be instituted, if they are not already in place.

Environmental protection and solid waste management measures are often complementary. For example, improved waste management is often a component of environmental legislation to protect water sources and reduce air pollution. Appropriate siting and operation of landfills strengthen efforts to protect water sources. In addition, air quality can be improved by reducing open burning of waste, installing air pollution control equipment at incinerators, and eliminating poor operational practices.

Regulatory Dimension. Enactment of suitable national and local legislation should be followed by passage of appropriate regulations and enforcement of waste management laws. In this context, multiple regulations should be considered and approved by governments based on waste management requirements and the existing environmental and waste management policy framework. Measures to consider are noted below.

- **Waste classification and standards for collection, treatment, and disposal.** Regulatory definitions are important tools for setting standards for waste management practices. For example, management programs for infectious medical waste should be much more rigorous than for non-infectious medical waste. Further, treatment standards for different types of infectious medical waste such as sharps and body parts can differ in terms of sterilization and destruction. The type of waste also influences the ways waste is disposed. Infectious waste, for example, which may undergo incineration, autoclave, and microwave treatment, might be buried in a disposal site with a secure perimeter that restricts access.

- Provision of **cost recovery mechanisms,** such as user fees, should be considered and tied to the amount of disposed waste. For example, if waste is collected from households or taken to a staffed collection point, the generators of waste could be charged per container or bag. A lesser charge could be levied for recyclable and compostable materials to encourage reductions in waste. Other mechanism to cover the cost of waste management services, such as product charges (e.g., packaging taxes) and carbon finance to reduce greenhouse gas (GHG) emissions are addressed in a later section.
- A systematic program for **monitoring and measuring solid waste services** can be a valuable tool to evaluate the performance of a public or private waste management system. The program should be developed based on appropriate metrics and benchmarks that provide a basis for evaluation of the performance trends. A performance database should be considered and include historic data whenever possible. Benchmark information from other cities in the metropolitan area, region, and country could be added to this database. Evaluations of trends may suggest positive or negative performance or slower advances than anticipated by municipal officials. By evaluating trends, the program will be in a position to effectively respond to shortfalls or poor performance.
- **Local and regional planning tools for waste management.** Regional collaboration should be actively pursued to promote the most comprehensive solutions to waste management, and to achieve economies-of-scale. Though a city might be capable of achieving suitable economies-of-scale without pursuing regional solutions, a regional approach may enhance the benefits of a project by expanding its scope beyond the urban area.

An important but often overlooked aspect of regulation is enforcement by an independent government agency. Enforcement is critical to implementing regulations and ensuring ongoing regulatory compliance. An effective enforcement program requires that enforcement agencies have the tools to address regulatory deviations. An enforcement agency or program should have the capacity to levy fines and other mechanisms to encourage compliance by punishing non-compliance.

Institutional Context

An effective policy, legislative, and regulatory framework should be combined with institutional measures to eliminate gaps and overlaps in the operational structure of the waste management sector.

Government. An effective program should involve ongoing, senior level coordination among municipal and national government officials and agencies. Local government programs should involve more than just those directly involved in the city, but also those from the metropolitan area to encourage regional cooperation. In the waste management sector, treatment and disposal programs are areas where regional cooperation could achieve efficiencies and economies-of-scale. Efforts are also encouraged to strengthen regional coordination in strategic planning.

Operational Structure. In many cities, a public agency provides solid waste services, which can be an efficient means of achieving a community's public health and environmental goals. However, promoting competition in delivering waste management services can often improve efficiency and services.

Promoting private sector participation (PSP) is an option to achieving competition in the waste management marketplace. PSP may make particular sense in certain areas, such as waste collection and disposal (e.g., landfill construction and operations), but can be considered for all services. Ancillary activities can also be considered for PSP. Vehicle maintenance, for example, might be contracted to a private sector provider, possibly with the contractual participation of vehicle fleets from other sectors. Moreover, an effective PSP program should leverage a competitive environment in which private companies can provide sound pricing and quality services. To assist in assessing PSP options, relevant metric and benchmark information can be collected on service levels and market trends in the city and in other cities with mixes of public and private service providers.

It is important, however, that waste management service decisions consider ongoing and planned efforts to reduce waste. Doing so can minimize potential conflicts, such as awarding a contract to operate an incinerator or landfill, and then realizing the contract is no longer needed due to waste reduction programs.

A combination of metrics and benchmarks can be used to monitor system performance as the sector is modified (Box 3.18). For example, collection metrics might include uncollected waste in designated areas, quantities of waste gathered per collection vehicle (requires scales at disposal site or other locations), and average number of daily trips per collection vehicle. It is advised to consider developing system-wide benchmarks rather than benchmarks for individual vehicles as aggregate benchmarks strengthen comparisons with other cities and are more useful in evaluating sector-wide interventions.

To strengthen waste management, small and medium sized enterprises (SMEs) can be tapped to provide targeted waste collection and recycling services. SMEs often offer better services in areas inaccessible to collection trucks. Additionally, recycling can promote informal and creative employment opportunities, such as waste picking. Recovered materials are also valuable to primary industries, which use them to produce new products, thereby stimulating the local economy and providing income to additional workers.

It is important that any PSP alternatives pursued by local governments are supported by proven procurement methods, particularly those successfully tested in other cities and regions. Among other things, procurement methods should address tendering (including transparency of the procurement process), contract design, and contract management, including accountability.

BOX 3.18

Performance Metrics

Specific waste management metrics in cities vary depending on the services provided. A waste collection operation might include the factors noted below. Waste collection is a good sample subsector as it is an integral part of a waste management system.

- Population served.
- Annual waste quantity collected.
- Annual recyclables quantity collected.
- Annual total of waste and recyclables collected.
- Annual collection cost.
- Collection cost per ton.
- Collection routes per week.
- Total stops serviced per week (times a truck stops to collect waste).
- Average stops per route.
- Average tons collected per stop.
- Cost per stop.
- Population served per stop.
- Cost per individual resident.

Common indicators for greenhouse gas projects might include:

Average system greenhouse gas emissions per ton of collected waste transported to a transfer station, treatment facility or disposal site.

Average system greenhouse gas emissions per ton of collected waste recycled, incinerated, or landfilled with or without gas recovery.

These indicators can be employed to calculate a collection cost benchmark that can be used to assess economic efficiency vis-à-vis other programs, and track performance.

Physical Systems, Technology, and Spatial Concerns

The physical, technological and spatial aspects of waste programs depend on factors unique to each city. It is initially critical to define the physical parameters of the existing waste management system, its employed technologies, and spatial requirements. A second step is to assess alternative options that fit the guidelines of the program.

Spatial Characteristics. Understanding the physical nature of a city is critical to developing a clear definition of existing and potential directions. Baseline factors that need to be defined include:

- Population.
- Surface area (population density).
- Terrain/topography of a city and its surroundings
- Per capita income
- Mix and location of economic activities, including:
  - Industrial (types)
  - Transport (freight consolidation, warehousing)
  - Commercial (types)
  - Special institutions (types, such a medical facilities that generate infectious wastes)
  - Residential (multifamily, single family)

Waste Characteristics. After establishing the factors that affect waste generation and waste management operations, it is important to understand the characteristics of generated waste in a target city. The two critical characteristics are waste quantity and composition.

Quantity. Quantity is critical for sizing the waste management system. As the population or economy of a city grows, per capita waste and total waste tend to increase (Table 3.30). Reliable data on the quantity of waste being generated and managed in different urban areas are important to properly size the system, plan equipment purchases, and determine the services needed to manage a city's waste.

Composition. As noted, low income cities tend to produce substantial organic discards, mainly food waste. Food waste has a high moisture content, which can affect a waste stream's suitability for alternative treatment processes. Systems that must treat high shares of food waste lend themselves to composting rather than incineration, as food waste will not generally auto-combust.

Waste System Components. The processes used to manage solid waste could include:

- **Waste storage at households or commercial establishments**, or at selected collection points that serve a number of these groups.
- **Vehicle collection**, which entails defining pickup frequency, equipment, and crew size. Besides truck collection, **underground pneumatic collection** might offer advantages in urban areas with narrow streets that impede truck collection. Under this scenario, waste is drawn by vacuum pressure to a collection point where it is deposited into a container. A pneumatic system includes trash receiving stations, an underground piping system, a vacuum blower that pulls waste through pipes, air filters for particulates and odor, and a facility where collected material can be stored until it is hauled to a treatment or disposal facility. Pneumatic systems have been used in some smaller urban areas in Japan and Sweden, and in large complexes such as airports, shopping centers, and hospitals. In many developing countries, particularly in slums, waste collection in urban areas with narrow streets can be accomplished through innovative solutions. For instance, local residents and the poor can be directly involved in waste collection (Box 3.19).
- **Formal and informal (i.e., waste picking) recycling**. Recycling may take place at collection points, treatment facilities and/or disposal sites. In Curitiba (Box 3.20), the city generated employment and formalized informal activities through an innovative recycling program.

BOX 3.19

Innovative Waste Collection Approach

In Curitiba, Brazil, a "Green Exchange" program was started in slum areas inaccessible to waste collection vehicles. To encourage the poor and slum dwellers to clean areas and improve public health, the city started to offer bus tickets and vegetables to people who brought garbage to neighborhood centers. In addition, children were allowed to exchange recyclables for school supplies, chocolate, toys, and show tickets. The city purchases vegetables at discounted prices from farmers who have trouble selling abundant products. Through this program, the city saves the costs of arranging waste collection in slum areas, which often have inadequate roads, and helps farmers to unload excess produce. The program also helps to improve nutrition, transport accessibility, and entertainment opportunities among the poor. Most importantly, slums have become cleaner with less litter, less disease, and less garbage dumped in sensitive areas such as rivers.

Citizens bringing their Garbage
Source IPPUC

BOX 3.20

Recycling Program Involving Citizens

Curitiba's "Garbage that is not Garbage" program encourages people to separate discards into recyclable and non-recyclable waste. To raise awareness of this program, children are educated to understand the importance of waste separation and environmental protection. Campaign mascots are created and school activities are conducted. One to three times a week, trucks collect paper, cardboard, metal, plastic, and glass that have been sorted at homes. This recycling saves the environmental equivalent of 1,200 trees a day,and local parks contain displays on the numbers of trees saved. Money raised from selling recyclables supports social programs, and the city employs the homeless and those in alcohol rehabilitation in its garbage separation plant. Recycling leads to other benefits. For instance, recycled fiber is used to produce asphalt for road construction. Tire recycling has removed piles of discarded tires, which can attract mosquitoes that transmit dengue disease. Proper tire collection has decreased dengue disease by 99.7 percent.[b] Nearly 70 percent of residents participate in Curitiba's recycling program. 13 percent of

"Garbage that is not Garbage" Recycling Program
Source IPPUC

Curitiba's waste is recycled, which greatly exceeds the 5 percent and 1 percent recycling rates in Porto Alegre and Sao Paulo, respectively, where education on waste dissemination has not translated into significant impacts.[c]

a. Figure from Rabinovitch, J. and Leitmann, J. (1993). *Environment Innovation and Management in Curitiba, Brazil.* UNDP/UNCHS/World Bank.
b. Figure from DVD (2007) *A Convenient Truth: Urban Solutions from Curitiba, Brazil.*
c. Figure from Hattori, K. (2004) 人間都市クリチバ (Human City Curitiba). Kyoto: Gakugei Shuppan Sha.

- **Collection at transfer stations** to consolidate waste for transport to treatment and long-term disposal facilities.
- **Treatment facilities including organic waste composting** (Figure 3.60) or **incineration with or without energy recovery**. The heat released during combustion or other thermal processes can be used to generate electricity, process energy, or in co-generation. However, given the high mois-

Figure 3.60 Waste Sorting Plant and Windrow Composting Operation (Cairo, Egypt)

ture content in much municipal solid waste in Asia, officials there should be cautious in pursuing thermal processes that depend on auto-combustion. As noted, waste needs to have a moisture content of less than 50 percent to auto-combust. Though a supplemental fuel such as coal can heat waste to evaporate water and compel combustion, this fuel increases energy needs, costs, and pollution. Municipal officials should also avoid treatment processes that are not commercially proven.

- **Disposal sites for direct and residual wastes from households and commercial establishments and treatment facilities**. Disposal sites range from open and modified dumps (at the lower end of environmental and public health protection) to safer engineered landfills. Disposal sites, especially engineered landfills, create anaerobic conditions as organic waste decomposes.

A byproduct of anaerobic decomposition is landfill gas (LFG). LFG, which is typically about 50 percent methane (a greenhouse gas) may be recovered and used for energy or burned (flared).[151] The recovery and combustion of LFG is potentially eligible for carbon finance if a project meets the conditions of the Clean Development Mechanism (CDM), which is a provision of the Kyoto Protocol.

A recovery system that uses LFG to generate electricity is shown in Figure 3.62. The complex includes blowers (vacuum pumps) to extract gas from the landfill, combustion generators for power production, and a flare to burn excess LFG.

Figure 3.61 Landfill Compactor Operating on a Landfill

Figure 3.62 Central Electricity Generation Facility and Flare for Landfill Gas (Tianjin, China)

Source: Peterson, Charles; Zarina Azizova; Qi Wenjie; Liu Baorui; Jane Huang. "Landfill Gas Capture and Electricity Generation and the Clean Development Mechanism (CDM): Shuangkou Landfill; Tianjin, China" 12th Annual Landfill Methane Outreach Program (LMOP) Conference. Baltimore, MD, USA. January 2009

Stakeholder Dynamics

Urban residents, workers, and visitors generate waste in their daily lives by preparing meals, transacting business, and participating in activities that use of goods and services. Successful waste management interventions depend on the cooperation and participation of these stakeholders in the waste management system.

Involvement of stakeholders in a waste management program should be ongoing. It is important that stakeholders are interested in the program and that their suggestions and ideas are considered as the program evolves.

A stakeholder participation program should provide a thorough plan for soliciting and tracking comments and reporting on relevant actions. Periodic meetings should be organized during a program's lifespan to engage stakeholders. In addition, an independent call center should be considered to enable stakeholders to register comments (questions, complaints, praise) on the waste management system.

Public meetings, call centers, and other communication mechanisms should track the nature of contacts and efforts should be made to monitor actions to resolve issues, questions, and complaints. The stakeholder program should monitor the time needed to resolve issues. Summary information on comments, issues, actions, and performance should be presented to stakeholders on a regular basis (often quarterly). Yokohama, for example, was successful in involving stakeholders in waste reduction activities through strong public campaigns and efforts to raise awareness.

BOX 3.21

Waste Reduction through Stakeholder Engagement

Yokohama's G30 Plan identifies the responsibilities of stakeholders, including households, businesses, and the city government, to achieve waste reduction through the "3Rs" (reduce, reuse, and recycle), a polluter-pays-principle, and extended-producer-responsibility.[a] The plan provides a mechanism for an integrated approach to reduce waste with detailed action programs. For example, citizens must separate their waste into 15 categories and dispose of it at designated places and times based on the relevant waste category. Businesses are requested to provide products and services that create less waste, and to implement the 3Rs. The city, as one of the largest generators of waste, is committed to reducing waste and working together with citizens and business.

To raise awareness of the G30 approach, the city conducted environmental education and promotional activities and requested public action to achieve the G30 goal. To promote waste separation, the city conducted more than 11,000 seminars for the public and neighborhood community associations to explain waste reduction methods,[b] including how to separate waste. The city also sponsored 470 campaigns at all railway stations, and about 2,200 awareness campaigns at local waste disposal points (among other places).[c] Campaign activities were also held at supermarkets, local shopping streets, and at various events. The logo for G30 has been printed on city publications and vehicles, and displayed at city events.

As a result of these efforts, Yokohama achieved its 30 percent waste reduction target for the FY2001-FY2010 period in FY2005. In FY2007, the city had reduced waste by 38.7 percent, despite an increase in population of 165,875 since 2001.

Reduction of total amount of waste (FY2001–FY2007)	623,000 ton (–38.7%)
Economic Benefit	US$1.1 billion capital costs saved by incinerator closure US$6 million operational costs saved by incinerator closure Life of landfill sites extended
CO_2 reduction (FY2001-FY2007)	840,000 ton

a. City of Yokohama (2003) Yokohama G30 Plan. (横浜市：横浜市一般廃棄物処理基本計画、横浜G30プラン) <http://www.city.yokohama.jp/me/pcpb/keikaku/kei1.html> (accessed February 2009)

b. 80 percent of the population participates in neighborhood community associations; City of Yokohama (2008) Proposal for Eco-Model Cities. (横浜市：環境モデル都市提案書-様式１) <http://www.city.yokohama.jp/me/kankyou/ondan/model/> (accessed February 2009)

c. City of Yokohama Resources & Wastes Circulation Bureau (2006) Yokohama G30 Plan –Verification and Next Steps. (横浜市資源循環局：横浜G30プラン「検証と今後の展開」について) <http://www.city.yokohama.jp/me/pcpb/keikaku/G30rolling/> (accessed February 2009)

Economic and Financial Aspects

Three economic and financial factors influencing the waste management sector are institutional capacity, financial sustainability, and the cost efficiency of service delivery.

Institutional Capacity. The important element here is the capacity of the municipal financial management team, whose success depends on effectively tracking and managing cash inflows from cost recovery instruments (see below). The financial team also needs to successfully manage cash outflows. Cash outflows are incurred for CAPEX and OPEX.

Complementing cost recovery instruments, budget allocations are normally needed to support CAPEX and OPEX. Budget allocations usually come from local governments, but also provincial and national agencies. International donor assistance may also be a source of revenue, especially for capital investments.

Financial Sustainability. The financial sustainability of a program depends on its ability to generate sufficient cash flow to cover a program's expenditures through various measures.

User Charges. A common way to generate cost recovery is to charge users for received services. From a fairness perspective, users should be charged based of the quantities of discarded waste. However, this can be administratively challenging even if households and commercial operations receive services directly. Because waste pick-up in many cities targets multiple households and commercial operations, charges may be based on other factors, such as floor space or percentages of electrical bills. Such approaches do not provide economic incentives to waste generators to increase recycling or reduce waste. Nonetheless, such imperfect proxies at least provide a basis for recovery of all or a share of system costs.

Product Charges. A second option to recover costs that might stimulate recycling or waste reduction is applying a charge on products in the waste stream. This "polluter pays" principle has been applied in some European countries through a packaging tax, whose revenue helps to pay for waste management. This concept has yet to be applied in East Asia, but it might be a workable solution and a step forward.

Carbon Finance. Carbon finance, a program designed to support greenhouse gas reductions through waste management and other technologies, may generate revenue to cover program costs. Carbon finance procedures are detailed in the Kyoto Protocol's CDM provision (Box 3.22). The CDM enables industrial countries that have ratified the Kyoto Protocol to purchase emission reductions to meet their Protocol targets from projects in developing countries.

In the waste management sector, emissions can be reduced by capturing and using LFG, composting organic waste, and incinerating waste. Box 3.23 details an example of an LFG capture project in Tianjin, China. As the organic fraction of solid waste decomposes in a landfill, anaerobic conditions lead to production of methane, a combustible greenhouse gas that has 21 times the global warming potential of carbon dioxide.

Efforts are underway to devise a replacement accord for the Kyoto Protocol, which expires at the end of 2012. The current situation presents short-term uncertainty concerning the future form of carbon finance. However, many projects with expected preparation times of up two years or longer are still being developed.

About 15 percent of GHG is methane attributable to anthropogenic sources. More than 23 percent of GHG is methane and other non-CO_2 gases from anthropogenic sources. Methane emissions from municipal waste disposal sites account for 12 percent of global methane emissions, or an estimated 730 million tons of carbon dioxide equivalent (tCO_2e). Globally, municipal waste disposal sites are the fourth largest contributor of non-CO_2 GHGs. Although proportionately small, non-CO_2 GHGs have a much greater effect on global warming relative to carbon dioxide.

In November 2008, there were 1,587 registered CDM projects. Registration is the final step

BOX 3.22

CDM and Waste Management

Kyoto Protocol. One of the earlier efforts to address global warming was the formation of the Inter-governmental Panel on Climate Change (IPCC) by the World Meteorological Organization (WMO) and the United Nations Environment Programme (UNEP) in 1988. The IPCC compiles published scientific and technical literature on global warming, its potential impacts, and options for adaptation and mitigation.

A further effort to stabilize green house gas emissions was the 1994 establishment of a voluntary program under the United Nations Framework Conventional on Climate Change (UNFCCC, http://unfccc.int), following the Earth Summit in Rio de Janeiro, Brazil. Failure of the voluntary program to achieve its desired results led to the legally binding Kyoto Protocol. The Kyoto Protocol became effective in February 2005.

Clean Development Mechanism. The CDM (http://cdm.unfccc.int/index.html), a provision of the Kyoto Protocol, allows industrialized countries listed in Annex 1 of the Protocol to purchase emission reduction credits from developing countries to meet their established emission reduction targets. More specifically, Annex 1 countries generate credits by supporting projects that reduce emissions in developing countries, sometimes through new technologies in waste management. Emission reductions under CDM programs can be traded among buyers in Annex 1 countries. Since emission reductions are tied to performance, carbon finance programs are a source of operational revenue rather than capital investment.

A range of methodologies has been approved by the CDM Executive Board to help determine eligible projects, including those in waste management. A common feature of all methodologies is the requirement to establish baseline emissions that would have occurred in the absence of a CDM project. In waste management, a common baseline assumes waste disposal exclusively in landfills, and calculations of associated greenhouse gas emissions based on this assumption.

CDM interventions must also be "additional." That is, they must create additional emission reductions that would not have been achieved without the project. Assessment of project "additionality" is based on any of the following conditions. First, investment analysis can demonstrate that the internal rate of return for a project without carbon finance revenue would be insufficient to justify the project from being implemented and maintained. Additionality can also be demonstrated by showing that employed technology is not used in the country where the project is located, or that the proposed CDM project is not common practice in the host country.

Methane. The most frequent greenhouse gas associated with waste management is methane, which is generated amid anaerobic conditions in waste disposal sites. Methane has a global warming potential that is 21 times greater than carbon dioxide.

Waste management programs offer several options to generate emission reductions. Two common options are capturing and using methane in landfills and avoiding methane by composting organic waste. Emission reduction credits may be earned by incinerating waste with or without energy recovery. The World Bank is also developing a methodology to earn emission reduction credits from recycling.

Waste Management Methodologies. Since landfill disposal is the baseline for assessing emission reductions, estimates of potential emission reductions can be calculated using a first order decay (FOD) model, which relies on multiple variables and default values. Critical variables include the composition rates of organics in a waste stream (food, other putrescibles, paper/textiles, and wood), and average annual precipitation and temperature. Areas with higher precipitation and temperature normally have higher decomposition rates based on data from the recent IPCC guidelines (see http://www.ipcc-nggip.iges.or.jp/public/2006gl/vol5.html).

For LPG projects, estimates can provide reasonable forecasts of emission reductions, but monitoring equipment is needed to track actual gas flow and composition, which permits calculations of combustion efficiency and methane captured and destroyed. The combustion of captured methane in a flare or to produce energy (commonly electricity) releases carbon dioxide. However, since carbon dioxide is from biomass, it is considered carbon neutral. Methane avoidance projects such as aerobic composting depend entirely on calculated emission reductions, as there is no way to measure methane that is not produced.

There are two common types of methodologies for waste management projects (LPG and methane avoidance). The specific methodologies for both large and small scale (less than 60,000 tons of carbon dioxide equivalent (tCO_2e per year)) are provided in Box 3.23.

Emission reductions can be gained by displacing conventional (fossil fuel) power generation sources on the electricity grid. Methane recovered from gas capture programs is used to generate electricity. The methodology listed below is for a small-scale power generation project (less than 15 Megawatts (MW).

in the development of a CDM project prior to start-up of operations. An independent validator must annually verify achieved emission reductions. Registered projects cover a range of activities designed to reduce GHG emissions, including LFG capture. LFG projects account for about 5 percent of registered CDM projects, most of which use captured methane for energy recovery (typically electricity). Projects without suitable access to energy markets and/or modest gas flow rates flare the recovered methane. In China, LFG projects recover energy and flare only as a back-up, as the Designated National Authority (the entity responsible for CDM oversight in a country) encourages electrical generation.

Cost Efficient Service. Another economic factor in waste management is promoting cost efficient delivery of services through appropriate capital investments and operations.

Capital Investment. Investment in equipment is an important first step in this process. Designation of appropriate equipment begins before procurement when sector managers decide on relevant specifications. It is important to attain a balance between capital expenditures for equipment, their operation and maintenance costs, and useful lifespans, which are influenced by operating environments. Reforms to the waste management system can also have beneficial effects on capital and operating expenditures, as evident in Yokohama.

Following procurement of capital assets, a sound program of preventative and scheduled maintenance should be established to maximize value. Preventative maintenance helps to avoid unscheduled downtime, which has a monetary cost. It is important to keep a supply room well stocked with lubricants, supplies, and spare parts, in line with recommendations from equipment manufacturers.

Operations Services. Supporting PSP and reengineered public operations can improve the cost efficiency of services in the waste management sector. In either case, it is important to establish goals and metrics to track performance. In addition, historical data and lessons from other cities and regions can be collected to compare options and devise strategies.

BOX 3.23

Landfill Gas Capture and Use—Tianjin, China

Tianjin's Shuangkou landfill, the first modern landfill built in Tianjin, conforms to China's standards, which mandate a bottom liner and a system for leachate collection and treatment. Design and construction of the landfill began in 1999, and the site began receiving waste in 2001. The landfill was financed by the World Bank as part of a broader loan program for Tianjin.

A daily average of about 1,300 tons of household waste is delivered to the landfill. The 60 hectare landfill has a capacity of 8.5 million cubic meters, equivalent to 7.4 million tons of waste and about 15 years of life at the current rate of infill. At closure, the depth of waste will be about 34 meters.

Decomposition of waste in the anaerobic conditions of a landfill generates methane. The methane is collected in pipes from a series of wells that were drilled where waste was deposited. Additional wells will be drilled as waste is deposited in new areas. The captured gas is transported in pipes to a central facility where it is burned to produce electricity that is sold to the North China Power Grid. A flare is used when there is excess methane or when the generators are out of service, such as during maintenance. The recovery system began operations in June 2008.

Landfill gas is about 50 percent methane, with the balance composed of carbon dioxide and other gases. Combustion of the methane during power generation or flaring destroys the methane. Under the agreement signed with the World Bank, the Tianjin Clean Environment and Environmental Engineering Co. Ltd (TCEEE) will sell 635,000 tCO_2e of greenhouse gas emission reductions, which is 70 percent of the expected reductions during the first seven years of operation. The World Bank has an option to purchase an additional 470,000 tCO_2e.

TCEEE. Formed in August 2005, the TCEEE is part of the Tianjin Construction Commission. TCEEE was authorized by the Construction Commission and Environmental Sanitation Commission, both under the municipality of Tianjin, to implement the Shuangkou landfill gas recovery and utilization project as project developer, operator, and seller of emissions reductions. Operation of the Shuangkou landfill is managed by the Tianjin Solid Waste Treatment Centre, a division of the Environmental Sanitation Commission.

World Bank. The World Bank is a trustee for 12 funds and facilities for which it negotiates long-term purchase agreements and manages relations with associated projects. In the case of the Tianjin landfill gas recovery program, the World Bank is the trustee for the Spanish Carbon Fund.

Project Registration. The Tianjin project was registered with the CDM Executive Board on August 27, 2008, which means the project has been able to earn Certified Emission Reductions (CERs) since that date. For specific information on the project, please visit the following link.

Managing Spatial Structure of the Cities

Introduction

Cities enjoy high productivity because their large consumer and labor markets drive increasing returns to scale. Theoretical and empirical literature correlating the wealth of cities to urban spatial concentration is abundant and no longer controversial. National data show that the economic output of large cities is much higher than is suggested by their shares of population. The World Bank's 2009 World Development Report "Reshaping Economic Geography" and the 2009 Report of the Commission on Growth and Development "Urbanization and Growth" summarize and document the theoretical and empirical arguments justifying the economic advantages of concentrating economic activities in large cities. Moreover, it is widely accepted that effective urban management and the spatial structure of cities are crucial to their success.

Cities in the 21st century will need to confront myriad development challenges from rapid growth in income, population, and built-up areas. However, developing "one size fits all" models or forms of urban development is unrealistic given the diversity in urban culture, history, economy, climate, and topography.

Nonetheless, cities face two fundamental spatial challenges as they absorb new populations and manage urban transitions: 1) maintaining mobility; and 2) enabling the provision of affordable land and shelter for existing and new citizens.

Mobility is important because the productivity of large labor markets is important for cities, and lack of mobility fragments labor markets and decreases productivity.

Affordability is crucial because poor rural migrants often transition to middle class citizens in cities. A city should have the capacity to shelter migrants during this transition. Ignoring migrants' needs for adequate shelter impedes assimilation in the formal economy, and has a high social cost.

Maintaining mobility

Maximizing the economic advantages of spatial concentration hinges on workers' capacity to find work anywhere in a city, and employers' ability to select workers among a large and dispersed pool of labor. Maintaining mobility of people and goods within a metropolitan area is one of the conditions to realizing economic benefits. Congestion acts as a tax on city productivity because it impairs the free movement of goods and people. In 2000, congestion in 75 metropolitan areas in the United States caused fuel and time losses valued at US$ 67.5 billion.[152] These losses exceeded the value of Kenya's 2008 Gross Domestic Product of US$ 61.83 billion.[153] When cities are unable to maintain mobility, the "tax" of severe congestion might surpass the economic benefits of spatial concentration. In the long-run, a city that cannot sustain mobility is bound to decay economically.

Maintaining mobility of people and goods should be a prime objective of land use planning and infrastructure investments. Mobility has two aspects:

I. Location mobility for firms and households

II. Workers and consumers' commuting mobility

Location mobility for firms and households

Location is important for residences and workplaces. People and firms should be able to buy or rent residences or business facilities anywhere in a city under as few restrictions as possible. The traditional principle of locating low income housing close to industrial areas in distant suburbs is based on a 19th century vision of labor. The service sector in a modern city employs more unskilled labor than factories. Poor people should have access to all areas of a city, and zoning plans should not segregate low income housing into pre-designated areas.

Real estate transaction costs should be as low as possible to ensure that households and firms can select the best locations they can afford, and move quickly to better locations when economic circumstances or external conditions change.[154] Tying housing subsidies for poor households to low income housing projects prevents mobility and tends to increase unemployment.

Zoning should not segregate land uses arbitrarily, as this restricts firm and household mobility. Zoning in modern cities should segregate only those economic activities that create real hazards and nuisances. Zoning should not apply inherited and arbitrary categories that needlessly curtail mixed use development.

Workers and consumers' commuting mobility

In all but the largest cities, workers and consumers should be able to reach any point in the metropolitan area within an hour. Ideally, multimodal transport systems can ensure sufficient mobility. However, urban planners often favor one transport mode at the expense of others. For instance, in cities where underground metros are being built, the high capital costs of the metro often divert needed funds from other modes of transport, such as buses. In other cities, cars are heavily subsidized by low gasoline prices, free parking, and street designs. In both cases, less mobility is the result.

Though planners in the last decade have tried to privilege one mode of transport over others, planners must acknowledge that: 1) every city needs a multimode transport system; and 2) consumer safety, affordability, and convenience are the main aims of transport modes.

Choosing a dominant transport mode or other modes in a multimodal system should be linked to a city's spatial structure. City managers should not arbitrarily select a city's dominant transport mode, whether transit, car, or bicycle. Consumers decide for themselves which transport mode is the most convenient in terms of speed, comfort, and cost, considering among other things a city's spatial structure. City managers, however, can influence a city's spatial structure through regulations and infrastructure investments. In high density, mainly monocentric cities, mass transit can be an efficient choice for commuters. However, in low density polycentric cities, cars, motorcycles, and taxis are often the most convenient travel modes.

Mobility, spatial structures and transport networks

Land developments and transport options determine the patterns of daily commuter trips to and from work. As household income rises, non-commuting trips to shop, pick up children, visit family, or undertake recreation become more important. The proportion of commuting trips over other trips thus decreases. Figure 3.63 illustrates the most usual trip patterns in metropolitan areas.

In monocentric cities (Figure 3.63-A) where most jobs and amenities are concentrated in

Central Business Districts (CBDs), transit is the most convenient transport mode, as most commuters travel from suburbs to the CBD. Trip origins might be dispersed, but the CBD is the most common destination. Small collector buses can bring commuters to radials, where Bus Rapid Transit (BRT) or underground metros can usher them at high speed to the CBD. Monocentric cities are usually dense (i.e., above 100 people per hectare).

In low density, polycentric cities (Figure 3.63-B), few jobs and amenities are in the city center and most trips are from suburb to suburb. There is a high number of possible travel routes, but few passengers per route. The trips have dispersed origins and dispersed destinations. In this type of city, individual transportation modes or collective taxis are more convenient. Mass transit is difficult and expensive to operate because of the multiplicity of destinations and the limited passengers per route. Polycentric cities usually have low densities as car use does not favor concentration in any specific area.

Figure 3.63-C illustrates the so-called "urban village model" that is often included in urban master plans, but is difficult to produce in the real world. In this model, the city includes many centers, and commuters travel only to the center closest to their residences. Under this model, everyone could walk or bicycle to work, even in a large metropolis. For this model to work, urban planners must be able to perfectly match residences and workplaces. However, this notion often contradicts the economic justification for large cities. Employers in large cities do not select employees based on where they live, and specialized workers do not select jobs based solely on proximity to residences. Moreover, the "urban village model" implies a systematic fragmentation of labor markets which is not economically sustainable in the real world.

In certain suburbs of Stockholm, urban regulations permit developers to build new residential units only when they can prove a corresponding number of jobs in the neighborhood. However, the five satellite towns around Seoul offer examples of problems with urban village

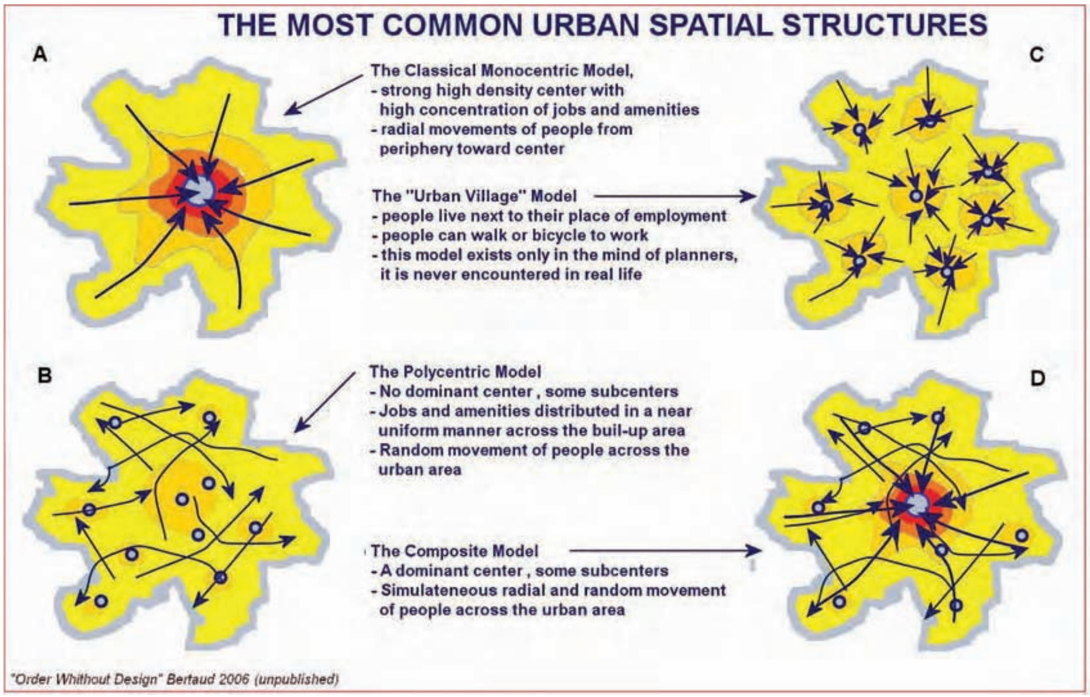


Figure 3.63 Spatial Structures and Trips Pattern

layouts. When the towns were built, jobs and inhabitants were carefully balanced and the satellite communities were expected to be self contained in housing and employment. However, recent surveys show that most people living in the new satellite towns now commute to work to the main city, while most jobs in the satellite towns are taken by citizens from the main city.

The "composite model" in Figure 3.63-D is the most common urban spatial structure. This model includes a dominant center, but a large number of jobs are in the suburbs. Under this model, most trips from the suburbs to the CBD use mass transit, while trips from suburb to suburb use individual cars, motorcycles, or collective taxis.

The composite model might be an intermediary stage in the progressive transformation of a monocentric city into a less dense and polycentric one. As population grows and the urban built-up area expands, the city center becomes more congested and loses its attractiveness, which was based on easy access and communication stemming from spatial concentration.

As a city grows, CBD decay from congestion is avoidable. Good traffic management, timely transit investments, strict parking regulations, urban environment investments (pedestrian streets), and land use reforms permitting vertical expansion contribute to reinforcing the city center and its attractiveness to new business and urban commuters. In New York, Singapore, and Shanghai, such measures have been reasonably successful. However, coordinating policies between investments and regulations is often difficult. Such coordination has to be executed consistently over long periods to enhance the viability of city centers.

One way to reduce non-commuting (non-work related) trips while enhancing the vibrancy of a city is to develop mixed use neighborhoods that employ intelligent urban design. Within these neighborhoods, planners can provide greater commercial street frontage, often with wide sidewalks and attractive window space, supporting an array of cafes, cleaners, grocery stores, hardware stores, restaurants, and other local shops. Such a strategy encourages local commerce, supports walking and biking trips, and enhances urban safety and attractiveness. Moreover, shorter non-work trips result as services are located close to households.

Failure to expand traditional city centers through infrastructure and amenities weakens transit systems in the long run, as jobs in city centers stagnate or fall as additional jobs are created in suburban areas.

City structure is path dependent. Once a city becomes mainly polycentric, it is nearly impossible to return to a monocentric structure. Monocentric cities, however, can become polycentric if traditional centers decay. The inability to manage traffic and operate an efficient transit system is a main factor that explains the decay of traditional CBDs.

THE SUBSTANTIAL SPACE REQUIRED BY CAR TRAFFIC AND PARKING MAKE TRANSIT INDISPENSABLE AS A MAIN TRANSPORT MODE TO DENSE CITY CENTERS

Transit is viable as a dominant mode only when servicing a dense business or commercial core. Not surprisingly, a car dominant mode of transport is incompatible with dense city centers. Cars occupy a large and incompressible amount of space when moving or parked. In addition, cars require more street space as their speeds increase.

Unfortunately, many city managers consider public parking in downtown areas as a municipal responsibility that should be subsidized. The subsidies constituted by free or quasi-free parking in downtown areas are not trivial. A car parked on or off street uses about 14 m^2 of costly real estate, which could be rented or bought at market prices. The private parking spaces provided at the bottom of the Marina Towers in Chicago (Figure 3.64) suggest that car parking is and should be considered commercial real estate, and not a public good provided by the municipality.

The graph in Figure 3.65 shows the area of street space per person for select neighborhoods in different cities. The street area as a percent of total area varies from neighborhood to neighborhood (in the case studies shown on the graph, from 11 percent to 50 percent). The densities (i.e., the land area per person) vary between neighborhoods (in the case studies, from 18 to 1.65 people per hectare). Residential density is used throughout, as it is usually the only available density measure. However, for the two New York neighborhoods (Wall Street and MidTown), job density is also provided.

The graph shows the street area one car requires for on street parking (red dotted line) and for running at 15 and 30 kms per hour. The graph shows that at certain densities, a parked car uses more space than the street space available per person. In Midtown, New York City, the available street space per worker is about 0.70 m^2. A parked car requires a much larger 14

Figure 3.64 Parking Space as Real Estate in Marina Towers in Chicago

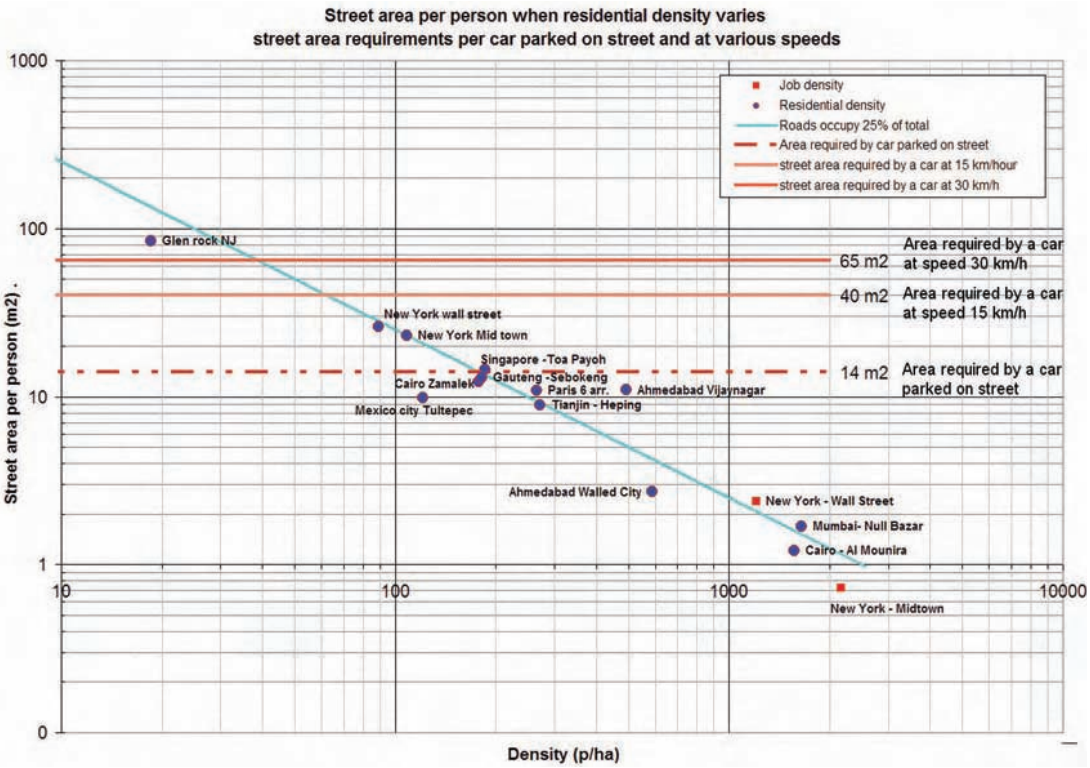


Figure 3.65 Car Space Requirements and Densities

m^2,[155] and a car driving at 15 km an hour requires about 40 m^2! If every worker were driving a car to work, 3 hectares of parking would be needed for each hectare of land, which would require about 6 floors devoted solely to parking. By contrast, Glen Rock New Jersey, a suburb of New York City, has enough street space to allow every resident to drive a car simultaneously at more than 30 km an hour.

New York City is not unique. Many urban neighborhoods in developing countries have residential densities similar to Midtown Manhattan's densities. Null Bazar in Mumbai, for instance, has a residential density of 1,600 people per hectare, which is similar to that in downtown Mumbai. The Al Mounira neighborhood in Cairo has a similar density. Limited street space in these neighborhoods limits car ownership to around 40 cars per 1,000 people.

In these dense cities, transit is and will be the only way to provide adequate mobility. Some streets can be widened in strategic areas, but never enough to allow cars to be the main mode of transportation. The failure to provide convenient transit services in dense cities will result in less mobility for a large share of the population. Without adequate mobility, labor markets in large cities will become fragmented, and these cities will be less productive.

WHY DOES A CITY'S SPATIAL STRUCTURE MATTER?

Low density polycentric cities may be viable—but are they efficient and socially desirable? These cities are viable only when household income is sufficiently high to allow people to buy and operate cars, and when suburban densities stay low (below 50 p/ha). Moreover, those who cannot afford or drive cars, such as the poor and older citizens, may be dislocated from job opportunities under this model, yet have little recourse to adequate transit alternatives.

Energy costs are more important to individual transport options than for transit. When energy prices increase, low density polycentric cities reliant on car transportation see transport costs increase in nearly the same proportion. Most low density, polycentric cities in the United States were built when energy prices stayed mostly below US$50 per barrel of oil in real terms. It is uncertain, absent a rapid technological breakthrough, that these cities could maintain a unified labor market if the price of a barrel of oil was, say, US$200 over a sustained period.

The spatial structure of cities is at the nexus of three fundamental urban objectives: mobility, affordability, and transport-related energy efficiency. In low and middle income cities, maintaining a dominantly monocentric structure is a precondition for maintaining workers' mobility, a high share of transit trips, and adequate revenue when the prices of energy spike.

The spatial distribution of populations in Jakarta and Gauteng (Figure 3.65) illustrates different urban spatial structures and their consequences for transit operation. The "classical" profile of Jakarta, which has high residential densities close to the city center, facilitates operation of a transit system (trains and BRT) that is convenient to users. By contrast, the dispersion of relatively high population densities in Gauteng explains the dominance of individual cars among high and middle income households, and collective taxis among low income households. The dispersed structure of Gauteng is partly attributable to the city's history of apartheid. Subsidies are offered to low income households in distant settlements, but these subsidies cannot be readily used for transportation. Suppliers may have derived benefits from building these settlements on a large scale, but the settlements do not provide convenient access to work.

However, transit should not be considered the only means of transportation. Delivering freight necessarily involves cars and trucks, and cars will always comprise some share of commuting trips. The challenge is to maintain a balance between modes to minimize vulnerability under hikes in energy prices, and to reduce con-

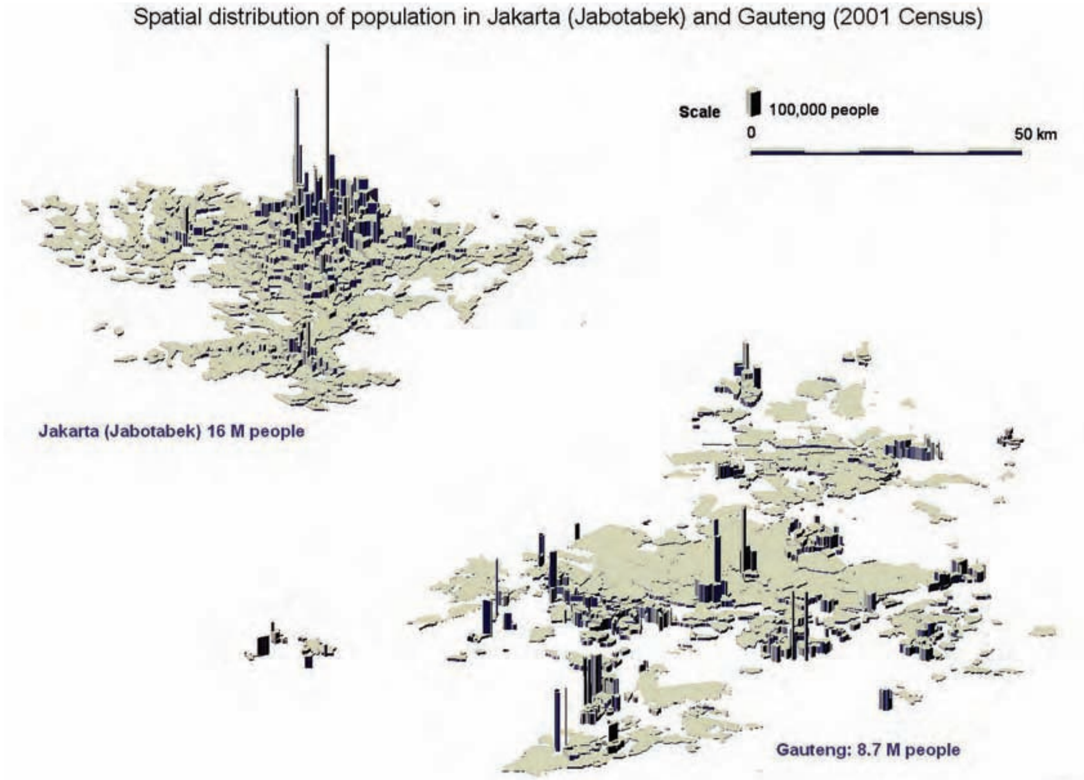


Figure 3.65 3D representation of the Spatial Distribution of Population in Gauteng and in Metropolitan Jakarta

gestion and pollution harnessing available technology.

Cities have complex structures that continuously evolve. Technology also evolves, sometime unpredictably. The Tata Nano and research in China to develop a low-cost, electric car may reverse certain of the assumptions above, but likely not all of them. Moreover, ***individual cars, because of their space requirements, will always be incompatible with high density city centers, such as those in Cairo, Mumbai, Shanghai*. *Mexico City, and New York City.***

Spatial structures, regulations and markets

Urban spatial structures matter. However, governments are not the sole actors that influence spatial structures. For example, the real estate market plays a fundamental role in determining urban form. Typically, a government's sphere of action is limited to infrastructure, land use regulations, and taxation. The sections below address how governments can use market forces to influence the shapes of cities.

The interaction of market forces with government taxation, transport investments, and land and tenure regulations is complex. This interaction impacts spatial layouts. Table 3.32 summarizes the impacts of government measures on spatially-linked market factors (i.e., land supply and prices in city centers and suburbs) and spatial development (i.e, dispersion and concentration of population and jobs).

It is neither good nor bad *per se* whether government actions favor concentration or dispersion. Assessing value depends on a city's long range policy and its starting point. Job dispersion would be negative in a city that has invested heavily in a radial transit system, as many jobs would be out of reach of the transit system. However, dispersion might be a positive in a city that mostly relies on minibuses and cars, as dis-

Table 3.32 Impact of Government Actions on Land Markets, the Size of the Informal Sector and the Spatial Structure of Cities

Government Action	Market reaction				Impact on size of informal sector	Spatial impact			
sector	Land supply		Land price			Dispersion		Concentration	
	center	suburbs	center	suburbs		Population	Jobs	Population	Jobs
1- Transport infrastrucure									
Improving or/and building radial roads		(+)	(+)	(-)	(-)			(+)	(+)
Building ring roads		(+ +)	(-)	(-)	(-)	(+)	(+)		
Building transit in radial pattern		(+)	(+ +)	(-)	(-)			(+)	(+ +)
Building transit in grid pattern		(+)	(-)	(-)	(-)	(+)	(+)		
2 - Land use Regulations									
Low Floor area ratio			(+ +)	(+ +)	(+ +)	(+)	(+)		
High minimum plot area		(-)		(+)	(+ +)	(+)			
high standard of land development		(-)		(+)	(+ +)	(+)			
Long approval process for building permits	(-)	(- -)	(+ +)	(+ +)	(+ +)			(+)	(+)
Restrictive zoning practices	(-)	(- -)		(+ +)	(+ + +)				
Setting up an urban growth boundary (UGB)		(- -)		(+ +)	(+ +)	(?)		(?)	
3 - Land tenure									
Large government land holding	(- -)	(- -)	(+ +)	(+ +)	(+ +)	(+)	(+)		
Rent control	(-)		(+ +)		(+ + +)				
Restriction on land transactions in periphery		(- -)	(+ +)	(+ +)	(+ + +)			(+)	(+)
High stamp duty on land transactions		(-)			(+ + +)				

Increase	(+)
decrease	(-)

persion would likely relieve congestion and provide cheaper land for housing and businesses.

The government actions in Table 3.32 are often implemented with insufficient consideration of long-range objectives and impacts on land and overall urban form. For instance, the goal of building ring roads is usually to alleviate congestion by allowing through traffic to bypass city centers. However, little thought is typically given to considering impacts on land supplies and prices along ring roads and in other affected areas.

Because local governments often support urban regulations and investments focused on short-term objectives, government actions and goals can contradict each other. For instance, in Bangalore, the local government has financed a BRT that tends to concentrate jobs in the city center. At the same time, the government limits the floor area in the central business district (CBD) to a ratio lower than in the suburbs, thus preventing the concentration of jobs that justified the BRT.

This type of policy contradiction between two branches of local government—transport and land use planning—is typical. Transport engineers desire high job and population densities along transit routes to ensure a high number of transit passengers. Planners facing congestion in city centers find it easier to mandate decreased densities to alleviate congestion.

Though regulations significantly impact city shape, market forces have the most influence on urban spatial structures in the long-run. Market forces particularly affect the spatial distribution of densities. In a monocentric city, land prices fall as one moves away from the city center. In polycentric cities, land prices tend to decrease from the centers of built-up areas, though usually at lower paces than in monocentric cities.

Where land prices are high, households and firms tend to consume less land. Population and job densities thus tend to be higher in CBDs or other urban centers, and lower in suburbs.

In Bangalore, the regulatory floor area ratio (FAR) is lower in the city center than in the suburbs. However, population densities are higher in the center than in the suburbs because of the high cost of land. Households living in Bangalore's city center consume much less floor space than they would consume if the city's FAR was higher. In Bangalore's case, FAR regulation has been unable to counteract market forces in shaping urban structures.

The density profiles of most large cities suggest that the traditional monocentric city model is still a good predictor of density patterns despite most cities becoming increasingly polycentric. These profiles demonstrate that markets remain the most important force for allocating land despite price distortions from direct and indirect subsidies, and ill conceived land use regulations. The profiles of population densities of 12 cities on four continents noted in Fig-

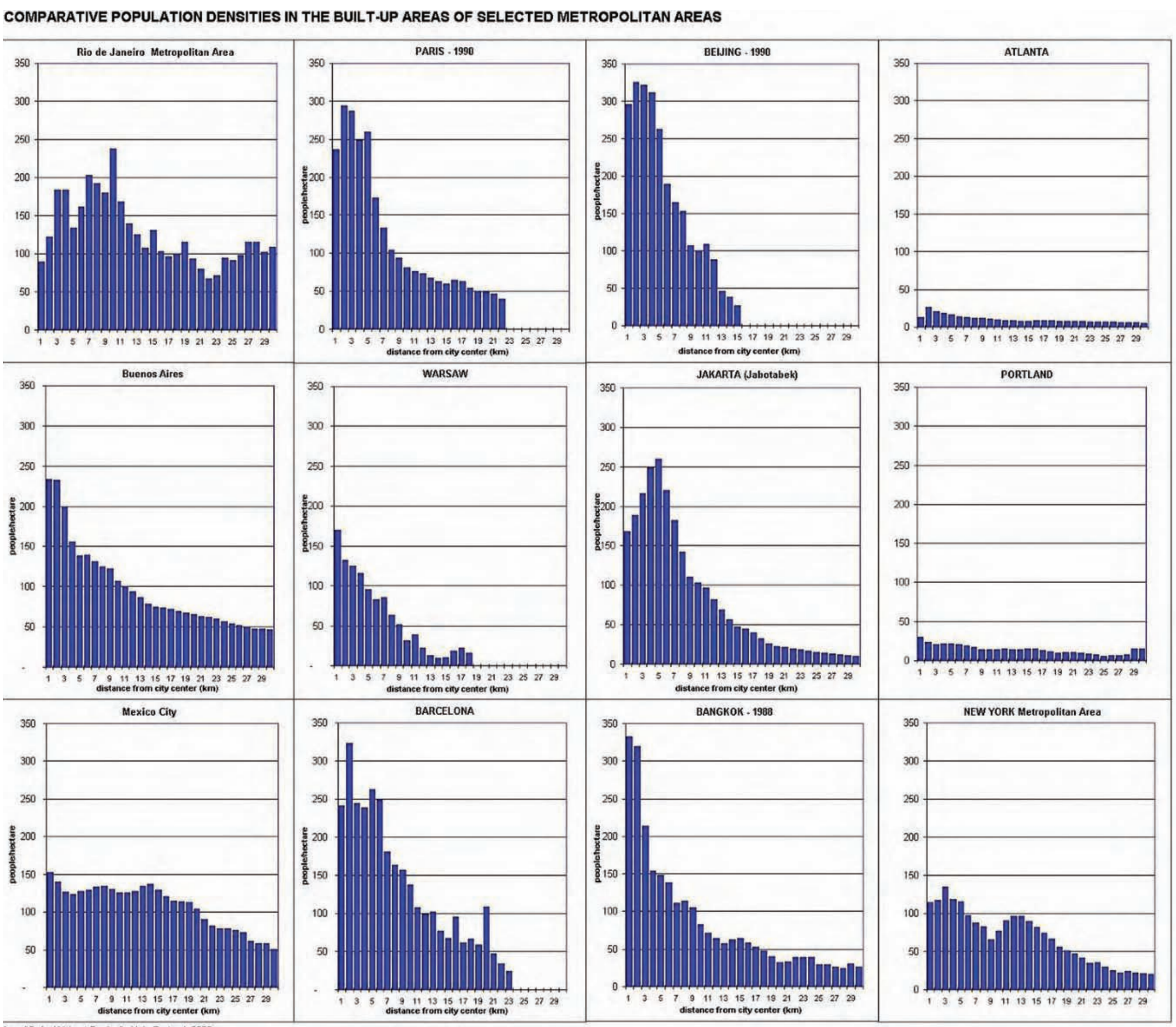


Figure 3.66 Profile of Built up Densities in 9 Large Metropolises

ure 3.66 show that despite these cities' economic and cultural differences, markets played important roles in shaping the distributions of populations around their centers. All the cities shown in Figure 3.66 closely follow the negatively sloped gradient predicted by the classical monocentric urban model.

Moreover, the spatial structure of most cities tends to follow these trends:

- Over the long run, average densities decrease
- traditional CBDs tend to lose primacy (with notable exceptions)
- the evolution of spatial structure is often adversely affected by household mobility

Average densities fall over the long run for these reasons: (1) improvements to transport networks (i.e., length and speed) increase land supplies more rapidly than can be used by growing populations; (2) increases in household income and decreases in household size allow people to consume more land and floor space; and (3) diversification and specialization of economic activities require more land and floor space.

In China, for instance, cities managers have become increasingly alarmed by growing per capita land consumption, and they have taken measures to curb "sprawl" by making land development more difficult or expensive, or by imposing quotas on land development. Many cities in other countries have taken measures to constrain the supply of land by delineating boundaries for urban growth, or establishing quotas for land development that boost the prices of land and housing, which often adversely affect urban dispersion.

It is not possible to establish optimal per capita rates of urban density or land consumption that are completely consistent over time. Land is an input in the production of floor space. Where land is expensive, developers (regulations permitting) will substitute capital for land by increasing FARs and densities. Where land is cheap, such as in suburbs, substituting capital for land is not justified and FARs and densities are low. A financially optimum density could be temporarily achieved during an area's development provided that the prices of inputs (i.e., land and construction) are not too distorted by regulations or subsidies. Without price distortions and externalities, a financially optimum density would equal the economically optimum density. However, the prices of land, capital, and other inputs will eventually change, possibly in different directions, and the new optimum density will shift from the optimum achieved during development. When the new optimum density differs substantially from actual density, land will be redeveloped.

The periodic recycling of land into new densities is indispensable to maintain land use efficiency and urban productivity. Unfortunately, many land use regulations, such as rent control to maximum FAR, tend to prevent the recycling of land.

Traditionally, CBDs become larger as cities develop. The inability of local governments to manage traffic in CBDs and to maintain mobility often results in deterioration of the CBD (Mexico City) or in the progressive abandonment of the CBD (San Salvador, El Salvador). As a result, jobs disperse into new locations, and transit networks are unable to adequately link residential areas to these areas. Minibuses and collective taxis gradually become more efficient ways to reach dispersed locations.

Coordination between Land Use and Transit the example of Singapore

Though most dense, monocentric cities have become progressively less dense and polycentric, a few cities have kept a large share of jobs and amenities in CBDs despite population growth (e.g., New York City, Tianjin, and Shanghai; Singapore has also pursued this strategy and its transit network is illustrated in Map 3.9). These cities maintained consistent land use and transport policies that extended the CBD area, increased FARs, and expanded radially oriented concentric transit networks serving the CBD. In addition, these cities included amenities such as theaters, pedestrian streets, and museums within or near city centers. These approaches are important to develop dense cities, particularly in Asia where urban built-up densities are often above 100 people per hectare. These strategies also facilitate efficient transit operations in the densest urban areas.

In these "neo monocentric cities," trips between suburbs might continue to grow. Suburb to suburb trips will be made by cars or collective taxis. In Singapore, car ownership is strictly controlled, an elaborate high tech congestion pricing system is in operation, and land and transit policies are consistent. Nonetheless, private car trips as a share of all trips grew from 37.0 to 41.6 percent between 1990 and 2000, while transit ridership fell from 55.0 to 52.4 percent.

Singapore's example shows that cities with high transit investment and good coordination among land and transit policies may nonetheless experience growth in car trips, although more slowly than in cities that do not pursue these strategies. In this context, cities should continue efforts to reduce car traffic and congestion along with programs to increase transit share. In the long-run, traffic and congestion can drive jobs and people to other areas, increasing trip length and making transit less viable.

Land and Housing Affordability

Ensuring that developed land and floor space are affordable to various income groups is a major challenge, particularly in large cities in rapidly urbanizing countries. Cities in countries with sizeable rural populations must accommodate annual migrations of rural citizens with incomes below urban averages. Local governments should carefully monitor land supplies and audit land development regulations to ensure that such regulations do not establish

Map 3.9 Singapore metro network is centered on an expanding CBD

thresholds below which low or middle income households are unable to buy or rent legal dwellings.

Infrastructure and land use regulations have an impact on the supply and price of land and floor space. This important role is not always understood by city managers

Variations in the supply of land and floor space typically drive variations in rents and land prices. The supply of land and floor space is highly dependent on primary infrastructure, transport networks, and land use regulations, which are usually under the jurisdiction of local governments. Unfortunately, local governments often ignore the links between land supply and land prices and rents. Unfamiliar with supply and demand, local officials often attribute high prices to "speculation," without realizing that bottlenecks in land supply and FARs are fueling high prices. When facing significant increases in land prices and rents, officials often fail to increase land supplies or FARs. Instead, they try to control prices by imposing higher transactions costs or tightening rent control legislation. These actions result in higher land and housing prices, which in turn generate more regulations in a vicious inflationary spiral.

Because government actions have such important impacts on real estate markets and urban spatial structures, it is worthwhile examining the direct and indirect impacts of infrastructure investments and land use regulations.

The aims of land use regulations are to avoid externalities linked to changes in land use. Preventing a negative externality is beneficial. However, regulations also have costs. Unintended side effects may increase the costs of many regulations beyond their supposed benefits. Many land use regulations are not tested for their impacts and may create social costs by artificially increasing the costs of developed land and floor space.

In reality, most regulations are not formulated to correct explicit externalities, but reflect officials' utopian visions on what constitutes appropriate urban design. This explains why most land use regulations entail higher land consumption than had land use been driven by consumer demand. Normative regulations establish arbitrary and enduring consumption thresholds for land and floor space (e.g., minimum plot sizes, maximum floor area ratios), and systematically fail to adapt to changing incomes, technologies, and land and construction prices. In poor countries, regulations often impose minimum fixed values on variables like plot size, apartment size, and floor area ratios. In utility and affordability equations for housing and other land uses, these variables should not have fixed minimum values and should be dependent variables linked to independent variables, such as the price of land, rate of interest, and the cost of construction.

Land use regulations for a given city may fill several volumes. However, only four types of regulations are really important. These regulations should be carefully audited owing to their impacts on land demand and affordability:

i. regulations establishing minimum plot sizes and minimum apartment sizes (explicitly or implicitly)

ii. regulations limiting floor area ratios

iii. zoning plans limiting the type and intensity of urban land use

iv. land subdivision regulations establishing permissible ratios of developable and salable land in new greenfield developments

Regulations on minimum plot sizes and apartment sizes

The goals of mandating minimum plot sizes are to prevent excessive densities and ensure a high quality urban environment. Households in all cultures tend to maximize the land and floor area they consume taking into account trade offs between location and local real estate costs. For example, poor households may opt to live in dense, inner city slums rather than in low density, legal subdivisions at urban peripheries. These decisions are completely rational as households are simply trying to maximize welfare. Minimum plot size regulations contradict these rational decisions, and impose different trade offs: either live in a legal subdivision in distant suburbs, or in an illegal slum closer to job opportunities. The trade off is no longer between distance and density, but legality and illegality! Not surprisingly, many households select the illegal solution.

Minimum plot size regulations establish a *de facto* cost threshold below which it is illegal to develop land. Though the minimum plot size may be fixed, the cost threshold often varies temporally and spatially. For instance, a minimum plot size of 200 square meters may be affordable up to 3 km from the city center to 90 percent of households in a certain year. However, economic changes in a different year may mean that only half of households may be able to purchase such a plot, pushing other households into the distant periphery or illegal dwellings. The problems associated with minimum plot size regulations in a major African city, Addis Ababa, are illustrated in Figure 3.67.

Addis Ababa's minimum plot size was 75 m^2 in 2002. Most poor households living close to the center (Kebbele housing) occupy on average about 35m^2 of land, which includes communal courtyards and passageways. Figure 3.67 illustrates the impact of the minimum plot size regulation on housing affordability, assuming a suburban location where land is cheaper. Due to the regulation, 75 percent of households cannot afford, with or without financing, to satisfy the minimum standards, as represented by the

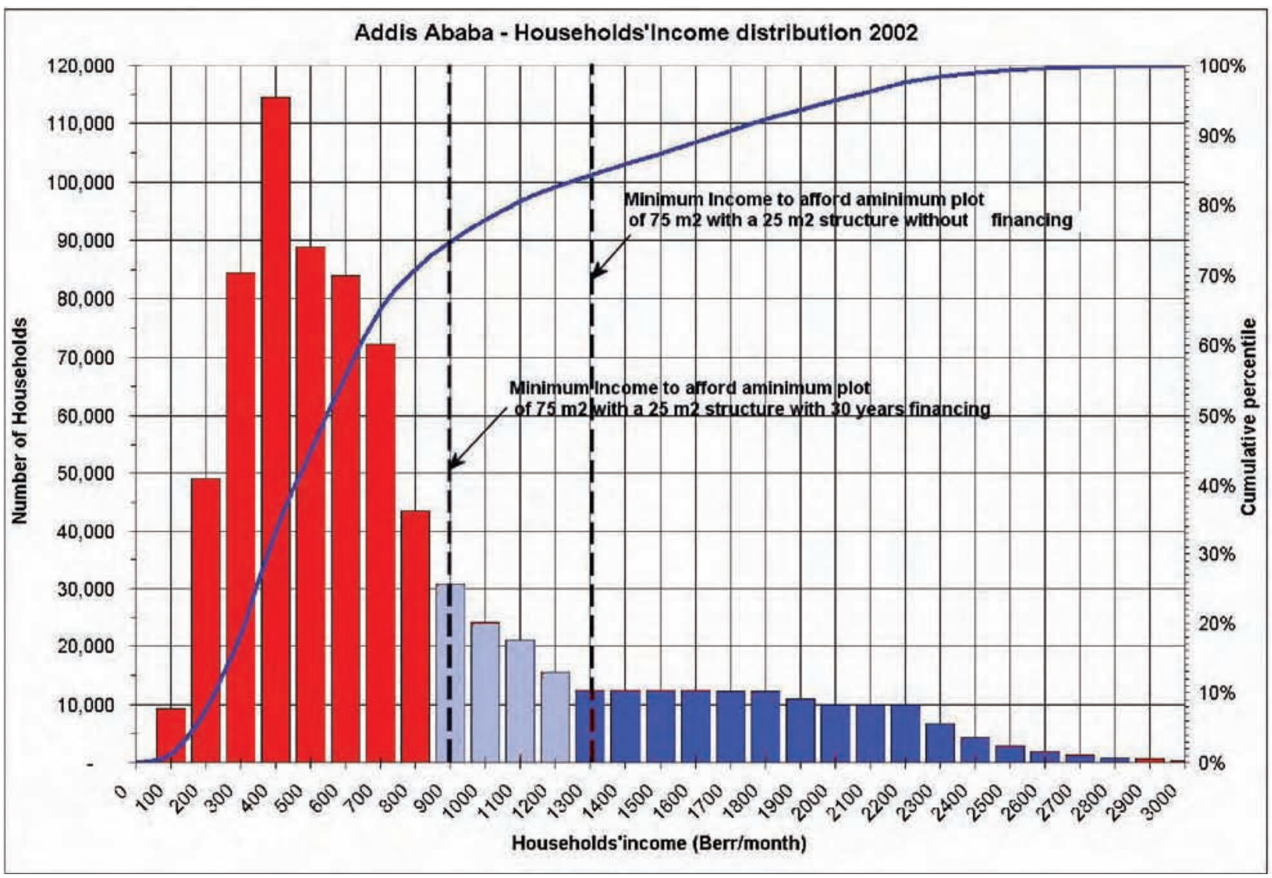


Figure 3.67 Addis Ababa -Affordability of Minimum Plot Size in Suburban Areas

Figure's red bars. With a 30-year financing package, only a quarter of the households can afford a house of 25 m^2 on a minimum plot size of 75 m^2. Without financing, such a structure and plot are affordable to only 18 percent of the households in Addis, represented by the dark blue bars in the Figure.

The government, aware of this affordability challenge, developed a subsidized housing finance scheme for formal developers who develop land adhering to minimum regulatory standards. Even with a subsidized loan, 75 percent of households cannot afford the minimum standards in Addis Ababa. Not surprisingly, about 75 percent of households in Addis are living in informal housing.

A similar study done in Kanpur in the State of Uttar Pradesh in India in 1988 showed that a 100 m^2 minimum plot size was unaffordable to 87 percent of the population.

The best solution is to repeal households' minimum standards for land and floor space, and to replace these standards by minimum standards for developed *parcels* of land, without specifying how many households may subdivide and live on the parcel. In this way, infrastructure issues related to small, unequally sized land parcels would be solved. In other words, water and sewer connections would be shared by the households living on a regulated parcel, but the number of households sharing a parcel would be left to the users based on affordability.

This shared parcel design is common in many informal and sometimes formal settlements around the world. Informal houses in Kabul are usually built in a large lot of around 300 m^2, served by one street entrance. The number of houses built around a lot's central courtyard depends on household income, and may vary from one in affluent areas to 20 in the poorest areas. If economic circumstances change, land and floor space per household will adjust as the number of households rises or falls, without any change in infrastructure or street layout.

In South Africa, the courtyards of many detached formal houses are subdivided into informal "backyard shacks" rented to lower income members of the community. Informal subdivisions of this type are often discouraged by municipalities, or by the housing institutions that have developed a settlement.

The argument against lot subdivision is that increased density risks overloading infrastructure. This may be a genuine risk, despite the fact that lower income households consume only a fraction of the water and electricity consumed by higher income residences. In any case, it is normally easier and cheaper to upgrade infrastructure in such subdivisions than to develop new land at urban fringes to accommodate new households. In addition, it is difficult to develop land for those renting backyard shacks.

Figure 3.68 shows Sebokeng, a formally subsidized low income settlement in a southern suburb of Gauteng, South Africa. The beneficiaries of this subsidized housing project have built and rented one room houses in their backyards. This approach is probably the most efficient way to provide land and housing to the low income population in this area. This process should be encouraged rather than discouraged. It provides additional income for the plot owner while allowing renters to share community facilities, including schools, with higher income residents. As a result of these practices, the density of the neighborhood rose about 50 percent compared to the original design, but infrastructure should be sufficient. If not, it remains less expensive to run an additional water pipe along the road than to develop new land for the renters.

Regulations limiting floor area ratios (FAR)

Regulations limiting FARs are designed to reduce externalities by limiting densities and the bulk of buildings. Negative externalities are created by the shadows of taller buildings and the increased traffic and utility consumption implicit in higher densities. There is no optimum FAR that can be calculated for an entire city.

Sebokeng sample density

Total area	17.51	ha
formal stands and houses	431	units
people per formal house	5	people
Total population	2,155	people
Design density	**123**	**p/ha**

Back yard shacks	0.8	per stand
Total backyard shacks	345	units
People per backyard shack	3	people
people in backyard shacks	1,034	people
Total real density	**182**	**p/ha**

Figure 3.68 South Africa - Sharing of larger plot by lower income households

However, it is possible to calculate, for given prices of land and construction, a FAR that produces the lowest cost of construction per square meter. In many cities such as Mumbai, FAR values are much too low, leading to urban decay in the city center and favoring sprawl.

Zoning plans

Zoning plans aim to separate incompatible land uses and prevent development in environmentally sensitive areas. In addition, plans typically contain regulations for each zone that limit the intensity of land use, including regulations on plot coverage, maximum heights, setbacks, FARs, etc.

Zoning is an important tool to preserve sensitive areas, and can be employed to mandate green areas that absorb excess water and runoff. However, zoning plans often do not clearly establish their objectives or the externalities they are designed to correct. Though zoning can be a useful tool, it must not obstruct the provision of affordable land and shelter in rapidly urbanizing cities.

Land subdivision regulations (LSRs)

LSRs are mostly employed for new greenfield developments. LSRs establish the standards for, *inter alia*, roads, block lengths, open spaces, and areas to be reserved for community facilities. The percentage of post-development salable land is arguably the most important parameter set by LSRs. Unfortunately, this parameter is seldom explicit, and has to be derived from other LSR parameters. In many countries, the percentage of such salable land, including residential and commercial lots, is below 50 percent. This figure should be higher, which requires new developments to be land intensive. Typically, LSRs are established for all new urban greenfield developments, and do not consider location or land prices.

Implicitly, LSRs also set maximum densities, but these are seldom explicitly calculated by regulators. Maximum densities are seldom compatible with land prices and developments that are affordable to low income households.

By imposing ill conceived standards, LSRs are often responsible for an exceedingly high proportion of informal sector settlements, as in Cairo, India, and Mexico. LSRs should be tested using land and infrastructure price models to establish the minimum household income that can afford a minimum standard plot in a new greenfield development.

Unlocking land supply and allowing a higher intensity of use is a key factor to increase the supply of affordable housing

Regulatory constraints affecting land supply are often ignored by governments that are otherwise eager to increase the supply of affordable housing. Subsidized interest rates are often the main tools employed to create affordable housing. However, when regulatory constraints, like the one described above, prevent elasticity of supplies, more and cheaper housing is not the result, but housing inflation.

Unlocking land supply is a prerequisite to stimulating housing demand. An audit of land use regulations should be conducted at least every 2 years. The audit should calculate the cost of building a house or apartment under current minimum standards in various areas of a city, incorporating current market prices for developed land and construction. The cost of this "minimum" house should be compared with the incomes of various socio-economic groups. The results of the audit should be drawn on a map that clearly shows the parts of a city where legally developed land and shelter are affordable to different income groups. Land use regulations should then be amended through an iterative process so that housing in sizable urban areas is affordable to unskilled migrants. ***The two key aims are to open the supply of land through regulatory reform and primary infrastructure investments, and to allow poor households to consume as little land and floor space as needed in areas that are convenient for finding employment.*** The low cost housing issue is at the nexus of mobility and affordability objectives.

A Plan for Active Management of Constantly Evolving Urban Spatial Structures

Methodology and training for urban planners / urban managers

Urban managers should change their urban planning methodologies. Rather than collect data once each decade to devise a development plan that often faces a long approval process, managers should constantly monitor urban demographic and physical changes and real estate prices. Infrastructure investments and regulations should also be adjusted on a continual basis.

Understanding the ways that markets work is essential to those who make decisions on infrastructure investments and regulations. Because acquiring economic knowledge constitutes a departure from the traditional role of urban planners, academic requirements should be modified. All urban planners should have some formal training in urban economics regardless of their original fields.

Reorganization of Urban Planning Departments

Urban planning units should be involved in actively managing cities. Planning units cannot substitute for line agencies that design and maintain infrastructure such as roads and water treatment plants, but they should have a say in new infrastructure investments that affect mobility and land supplies.

Planning units should have monitoring and operational departments. The monitoring department should constantly collect and analyze data on the evolution of the city. Whenever possible, data should include spatial and demographic dimensions, such as coordinates and census identifiers. Data and indicators should include, *inter alia*, real estate prices, household income, building permit issuance, car ownership, commuting time, transport mode shares, and urban densities A synthesis of data should be issued annually, and describe trends in mobility and affordability.

The work of the operational planning department should be guided by clear goals set by the mayor or the city council. The operational department should build on the monitoring report to propose complementary actions with clear objectives and targets, including infrastructure investments and regulatory changes. After proposed actions are approved by the city government, program design and implementation should be passed to traditional municipal line agencies (i.e., public works department, water supply utility, transit company, etc.).

Cities with decision processes fragmented across many departments that pursue their own agendas tend to produce undesired outcomes, including inconsistency and even incoherence. Clear objectives and targets are key factors in successful urban planning.

World Bank Group's Financial Instruments and Multi-Donor Funds

The World Bank Group offers subnational governments two options: 1) IBRD/IDA financing and risk management products *with* a sovereign guarantee on the same terms as national governments; or 2) financing *without* a sovereign guarantee on commercial terms through the joint IFC-World Bank Subnational Finance program. Multi-donor funds are also available to subnationals. Below is a list of major financial instruments relevant to financing Eco² programs at the municipal level.

1. World Bank IBRD Loan/IDA Credit

These include: A) Specific Investment Loans; and B) Subnational Development Policy Lending.

Table 3.33 World Bank IBRD Load/ IDA Credit: Specific Investment Loans (SILs)

A) Specific Investment Loans (SILs) are a major financial instrument of IBRD and IDA. They are disbursed to middle-income countries as loans (in the case of IBRD) and to the world's 78 poorest countries on concessional terms (for IDA credits).

ELIGIBILITY	FUNDING OBJECTIVES	INDICATIVE AMOUNT/TERMS[a]
Eligible entities are subnationals of developing countries that are IBRD/IDA member countries *Application: Municipalities apply through IBRD/IDA representatives at national governments*	Financing a broad range of investment activities aimed at creating physical and social infrastructure They finance: 1) both stand-alone projects with specific pre-determined investment components and programmatic investment activities; and 2) technical assistance activities related to investment projects and their sector reforms. *For Eco² program:* 1) infrastructure services necessary for sustainable urban development, such as water supply, wastewater management, power generation and distribution, solid waste management, roads, public transport, etc.; and 2) National Eco² Fund programs (see Part 1; Chapter 3)	IBRD Flexible Loan: *Variable Spread Option:* LIBOR-0.5% *Fixed Spread Option*: LIBOR+1.00% (–1.45%) based on average payment maturity (10 years or less/ 10-14 years/ greater than 14 years) and currency (USD, EUR, JPY). Local Currency Loan is available for Currency Conversion Option. IDA Credit: No interest rate

Note: Rates are as of May 1, 2009 and are subject to change. For updated information, please see treasury.worldbank.org.

Table 3.34 World Bank IBRD Load/ IDA Credit: Subnational Development Policy Lending (DPL)

B) Subnational Development Policy Lending (DPL): Development Policy operations provide untied, direct budget support to governments for policy and institutional reforms aimed at achieving a set of specific development results. DPLs consist of series of typically two to three single-tranche loans (i.e., DPL 1, DPL 2, and so on), which can be released against the delivery of policy and institutional reforms. The World Bank may provide DPLs to a member country's national government, or to a subnational division of a member country, which includes state and provincial governments with legislative and budget authority.

ELIGIBILITY	FUNDING OBJECTIVES	INDICATIVE AMOUNT/TERMS
Eligible entities are jurisdictions with legislative autonomy and independent budgetary authority immediately below the national government, including states, provinces, and other entities with similar status (e.g., Republics and regions of Russian Federation and the federal districts (capital cities) of federal countries in Latin America). Normally, municipalities and countries subject to state or provincial legislation and oversight are not eligible. (C.f., countries that have experience with SDPL include Argentina, Bolivia, Brazil, India, Mexico, Pakistan, Russia, and Ukraine.) Countries must be IBRD/IDA member countries.	Supporting sector reforms through 1) developing specific policies and policy instruments, 2) enforcing policy implementation with legal instruments, and 3) developing institutional capacities for effective implementation *For the Eco² program*: DPLs could address major policy and institutional reforms required for sustainable urban development, particularly in the areas of resource efficiency and energy saving.	IBRD Flexible Loan: same as above IDA Credit: same as above *Disbursement*: Loans provided directly to state or local government or agency, with a sovereign guarantee, or to the country with proceeds on-lent to the subnational unit. IDA credits provided to countries which onlend the proceeds.

2. World Bank Group Financing

This includes A) Subnational Finance by the World Bank and IFC, B) financing and services by IFC, and C) guarantees by MIGA.

Table 3.35 World Bank Group Financing: Joint IFC-World Bank Subnational Finance

A) Joint IFC-World Bank Subnational Finance: This provides eligible states, provinces, municipalities, and their enterprises with financing and access to capital markets, without sovereign guarantees, for investment in essential public services.

ELIGIBILITY	FUNDING OBJECTIVES	INDICATIVE AMOUNT/TERMS
Eligible applicants are: 1) State, Municipal, Provincial, Regional, or Local Governments and their enterprises (including water and sanitation utilities), 2) Financial Intermediaries supporting local infrastructure, 3) Nationally-owned Enterprises operating in natural monopoly, infrastructure sectors (selectively), and 4) Public-Private Partnership entities (to cover commitments of the public partner). Eligible projects must 1) be located in a developing country that is a member of IFC; 2) be in the public sector; 3) be technically, environmentally, and socially sound; and 4) benefit the local economy. Eligible sectors are water, wastewater, solid waste, transportation, social infrastructure (e.g. health and education), power, gas distribution, and district heating, and other essential public services.	Strengthening the borrowers' ability to deliver key infrastructure services such as water, wastewater management, transportation, gas, and electricity, and improving their efficiency and accountability as service providers. Investment selection criteria include a. Financial: Predictability of cash flows to service debt without sovereign guarantee b. Socio-economic: Robust economic base c. Institutional: Operational efficiency d. Regulatory: Functional system e. Development Impact: Essentiality of investment and strong economic benefits.	Products are commercially priced, tailored to client's needs, and can be delivered in 3-6 months. All products are provided without sovereign guarantee, and may be available in local currency. Products: a. Lending Instruments: Senior loans, Subordinated loans and Convertible loans b. Credit Enhancement: Partial credit guarantees, risk sharing facilities and Securitizations c. Equity and Quasi Equity: Equity and Other hybrid instruments For details, please see www.ifc.org/subnationalfinance.

Table 3.36 World Bank Group Financing: Financing and Services (IFC)

B) Financing and Services (IFC): IFC finances investment in the private sector in developing countries.

ELIGIBILITY	FUNDING OBJECTIVES	INDICATIVE AMOUNT/TERMS
Eligible projects must: 1) be located in a developing country that is a member of IFC, 2) be in the private sector, 3) be technically sound, 4) have good prospects of being profitable, 5) benefit the local economy, and 6) be environmentally and socially sound, satisfying IFC standards and those of the host country.	*For Eco² projects:* Components such as private infrastructure, including industrial zones and development of energy efficiency industries, such as energy efficient buildings and Light-Emitting Diodes are suitable. IFC offers also guarantees to local banks that invest in Energy Services Companies (ESCOs).	Products: Financing and Services: a) Financial products (traditional and largest service of IFC): loans, equity finance, and quasi-equity, financial risk management products and intermediary finance to finance private sector projects in developing countries. b) Advisory services: areas including privatization, business-related public policy, and industry-specific issues for private businesses and governments in developing countries. c) Resource mobilization: the loan participation program, which arranges syndicated loans from banks, and structured finance transactions for companies in developing countries to tap into international capital markets. For details, please see www.ifc.org IFC typically does not invest in project sizes less than 20 million dollars. However, IFC works with local banks and leasing companies to finance projects smaller than that.

Table 3.37 World Bank Group Financing: Guarantee (MIGA)

C) Guarantee (MIGA): MIGA promotes developmentally beneficial foreign direct investment into emerging economies by insuring investments against political risks, such as expropriation, breach of contract, and war and civil disturbance; resolving investment disputes; and helping developing countries attract private investment.

ELIGIBILITY	FUNDING OBJECTIVES	INDICATIVE AMOUNT/ TERMS
Eligible applicants: 1) Nationals of a MIGA member country other than the country in which the investment is to be made 2) Juridical persons if they are either incorporated in and have their principal place of business in a MIGA member country, or if they are majority-owned by nationals of MIGA member countries 3) State-owned corporations if they operate on a commercial basis investing in MIGA member countries other than the country where they are incorporated 4) Nationals of the host country or juridical persons incorporated in said host country or whose capital is majority-owned by its nationals, provided that the invested assets are transferred from outside the host country	Offering political risk insurance against losses relating to currency transfer restrictions, expropriation, war and civil disturbance, and breach of contract for projects in a broad range of sectors (e.g., power, water, wastewater, transport and green infrastructure, energy, telecommunications, and finance) in developing countries that are MIGA member countries. MIGA can cover expropriation and Breach of Contract by a sub-national entity. MIGA's contribution to reducing the adverse impact of climate change focuses on supporting green infrastructure investments in developing countries which build renewable energy capacity, encouraging resource conservation and distribution efficiency, improving sanitation, and offsetting GHG emissions.	Per project insurance: Up to US$200 million (if necessary, more can be arranged through syndication of insurance) Duration up to 15 years (20 years if justified.) Guarantee premiums based on country and project risk. Rates for the SIP guarantee (3 coverages): 0.45%–1.75% basis points per year Types of foreign investments include: a) equity interests, b) shareholder loans, c) shareholder loans guaranties and d) other investments, such as technical assistance, management contracts, franchising, and licensing agreements. For details, please see www.miga.org

3. Multi Donor Funds

These funds include A) Climate Investment Funds, which consist of the **Clean Technology Fund (CTF)** and the **Strategic Climate Fund (SCF)** (which consists of 3 programs, including Scaling-Up Renewable Energy in Low Income Countries), and B) the Global Environmental Facility.

Table 3.38 Multi Donor Funds: Climate Investment Funds

A) Climate Investment Funds[a]

A-1. Clean Technology Fund (CTF): In keeping with Multilateral Development Bank (MDB) practice, investment projects and programs may include financing for policy and institutional reforms and regulatory frameworks.

ELIGIBILITY	FUNDING OBJECTIVES	INDICATIVE AMOUNT/TERMS
Eligible entities are subnationals in developing countries with (1) Official Development Assistance -eligibility (according to OECD/DAC guidelines); and (2) an active MDB country program.[b] Application: Municipalities apply through their countries, which express interest and request a joint mission of World Bank and a regional development bank for the preparation of a country CTF investment plan. Egypt, Mexico, and Turkey have developed a CTF investment plan, the "business plan" of the MDBs, developed under the leadership of the government, to assist a country with CTF co-financing in implementing its national development strategies/ programs that include low carbon objectives. They were cleared by the CTF Trust Fund Committee in January 2009.	Promoting scaled-up financing for demonstration, deployment, and transfer of low-carbon technologies with a significant potential for long term GHG emissions savings including programs in 1) power sector (renewable energy and highly efficient technologies to reduce carbon intensity), 2) transport sector (efficiency and modal shifts) and 3) energy efficiency (buildings, industry, and agriculture) Programs/projects selection criteria: a. Potential for long-term GHG emission savings b. Demonstration of potential c. Development impact d. Implementation potential	Indicative total amount: about $US 5.2 billion was pledged in September 2008. Indicative project number: 15–20 Investment Plans CTF would seek to provide through MDBs: a. concessional financing in the near-to-medium term to meet investment needs to support rapid deployment of low carbon technologies; b. concessional financing at scale, blended with MDB financing, as well as bilateral and other sources of finance, to provide incentives for low carbon development; c. a range of financial products to leverage greater private sector investments; and d. financial instruments integrated into existing aid architecture for development finance and policy dialogue. Products and terms: a. Concessional Loans have 2 options: a-1. Harder Concessional Maturity: 20 years/Grace Period: 10 years/ Principal Repayments Year 11–20: 10%/ Grant Element: -45%/ 0.75% service charge a-2. Softer Concessional Maturity: 40 years/ Grace Period: 10 years/ Principal Repayments Year 11–20: 2%/ Principal Repayments Years 20–40: 4%/ Grant Element: –71%/ 0.25% service charge b. Grant: up to US$1 million (for CTF preparation) c. Guarantees: partial credit guarantee and partial risk guarantee MDBs lend to a) national governments, b) national governments for on-lending to subnational entities, or c) subnational entities

(Table continues on the following page.)

Table 3.38 Multi Donor Funds: Climate Investment Funds (continued)

A-2. Strategic Climate Fund (SCF): This fund is broader and more flexible in scope and serves as an overarching fund (US$900 million) that can support various programs to test innovative approaches to climate change. SCF consists of three programs: Pilot Program for Climate Resilience, Forest Investment Program (FIP), and Scaling-Up Renewable Energy Program for Low Income Countries (SREP). It will provide financing to pilot new development approaches or to scale-up activities aimed at a specific climate change challenges through these targeted programs.

ELIGIBILITY	FUNDING OBJECTIVES	INDICATIVE AMOUNT/ TERMS
Pilot Program for Climate Resilience (PPCR): the first program included in the SCF		
Municipalities in Bangladesh, Bolivia, Cambodia, Mozambique, Nepal, Niger, Tajikistan, and Zambia	Supporting scaled-up action and transformational change in integrating climate resilience in national development planning of a few highly vulnerable countries.	Indicative total amount: about US$500 million Grants and concessional lending for technical assistance and program of public and private sector investments
Program for Scaling-Up Renewable Energy in Low Income Countries (SREP): Helping low income countries make a transformational change to low carbon energy pathways by optimally exploiting their renewable energy potential to offset fossil-based energy supply.		
Under Design	Demonstrating the economic, social, and environmental viability of low carbon development pathways in the energy sector by creating new economic opportunities and increasing energy access through the use of renewable energy.	Indicative total amount: about US$250 million (being sought)

a. For details, please see www.worldbank.org/cif

b. An "active" program means where an MDB has a lending program and/or on-going policy dialogue with the country.

Table 3.39 Multi Donor Funds: Global Environment Facility

B) Global Environment Facility: A global partnership among 178 countries, international institutions, non-governmental organizations (NGOs), and the private sector to address global environmental issues while supporting national sustainable development initiatives. It provides grants for projects related to six focal areas: biodiversity, climate change, international waters, land degradation, the ozone layer, and persistent organic pollutants. The GEF works with three implementing agencies, including the World Bank and seven executing agencies. The active portfolio of World Bank-implemented GEF projects at the end of 2007 is 219 projects with total net GEF Grant amount commitments of US$1.6 billion. In terms of approval, the GEF grant amount approved by the World Bank Board in FY2007 was US$220 million (22 projects).

ELIGIBILITY	FUNDING OBJECTIVES	INDICATIVE AMOUNT/ TERMS
Eligible countries: A country shall be an eligible recipient of GEF grants if it is eligible to borrow from the World Bank (IBRD and/or IDA) or if it is an eligible recipient of UNDP technical assistance through its country Indicative Planning Figure (IPF). An eligible project must 1) be undertaken in an eligible country; 2) be consistent with national priorities and the GEF operational strategy; 3) address one or more of the GEF focal areas, improving the global environment or advancing the prospect of reducing risks to it; 4) seek GEF financing only for the agreed incremental costs on measures to achieve global environmental benefits; 5) involve the public in project design and implementation; 6) be endorsed by the government(s) of the country(ies) in which it will be implemented Application: Municipalities in member countries apply in consultation with Country Operational Focal Point.	Providing grants for projects related to six focal areas: biodiversity, climate change, international waters, land degradation, the ozone layer, and persistent organic pollutants.	Per project size: Full-sized project: Grant over US$1 million Medium-sized project: Grant up to US$1 million Enabling Activities: Grant up to $0.5 million in GEF financing, but varies across focal areas For details, please see www.gefweb.org/

4. Market Based Instruments

These instruments, which are relevant for Eco², include A) Carbon Finance, which consists of 11 funds and 1 facility including the Carbon Partnership Facility. The World Bank Carbon Finance Unit (CFU) uses funds contributed by governments and private companies in OECD countries to purchase project-based GHG emission reductions in developing countries and countries with economies in transition. The GHG emission reductions are purchased through one of the CFU's carbon funds on behalf of the contributor, and within the framework of the Kyoto Protocol's Clean Development Mechanism (CDM) or Joint Implementation (JI). Unlike other World Bank financial instruments, the CFU does not lend or grant resources to projects, but rather contracts to purchase emission reductions similar to a commercial transaction, paying for them annually or periodically once the emission reductions have been verified by a third party auditor. The selling of emission reductions—or carbon finance—has been shown to increase the bankability of projects, by adding an additional revenue stream in hard currency, which reduces the risks of commercial lending or grant finance. Thus, carbon finance provides a means of leveraging new private and public investment into projects that reduce GHG emissions, thereby mitigating climate change while contributing to sustainable development. Currently, the CFU has eleven carbon funds that are primarily for fulfilling commitments under the Kyoto Protocol by 2012.

Table 3.40 Market Based Instruments: Carbon Finance, Carbon Partnership Facility (CPF)

A) Carbon Finance, Carbon Partnership Facility (CPF): A new generation of Carbon Finance that is being developed to scale-up emission reductions and their purchase over longer term beyond the regulatory period of the Kyoto Protocol, which ends in 2012. Its objective and business model are based on the need to prepare large-scale, potentially higher-risk investments with long lead times, which require durable partnerships between buyers and sellers and significant capacity building for program development. It is also based on the need to support long-term investments in an uncertain market environment, possibly spanning several market cycles. "Learning by doing" approaches will be an essential aspect of the Carbon Partnership Facility, as the program moves from individual projects to programmatic approaches, including methodologies for such approaches. It is expected that CPF's size would be €5 billion for 2012-2016 period.

ELIGIBILITY	FUNDING OBJECTIVES	INDICATIVE AMOUNT/ TERMS
Eligible entities: Seller participants should 1) be public or private entities committed to develop one or more emission reduction (ER) programs and sell a portion of the ERs to the Carbon Fund, one of the trust funds under CPF, and 2) be acceptable by the Bank in accordance with established criteria. Buyer participants should 1) be public or private entities committed to contribute to the Carbon Fund. For the first tranche of the Carbon Fund, €35 million is the minimum required contribution from a public or private entity (a group of entities can form a pool/consortium to participate as a group).	Facilitating the development of low-carbon investments with a long-term impact on mitigating GHG emissions in the framework of the UNFCCC and/or the Kyoto Protocol, and/or any future agreement under the UNFCCC, and/or any other regime as deemed appropriate by the Trustee in consultation with the Participants by 1) providing sellers with certainty of a significant and long-term revenues stream, and by 2) providing buyers with opportunities to receive relatively certain future large stream of carbon credits.	Indicative total amount: Fist Tranche of the CPF Carbon Fund to become operational with a minimum capitalization of €200 million, and could grow to about €400 million. Expected to become operational in latter half of CY2009. Over time the Carbon Fund is targeted to grow to several € billion. Indicative per project size: several million tons of ER/program over 10-15 years. Price of ERs: will be based on a transparent CPF pricing approach, based on market prices; may allow (to be confirmed) for upside and downside sharing between buyers and sellers. First Trance of the CPF Carbon Fund is denominated in €. Subsequent tranches could be denominated in other currencies as well. For details, please see http://web.worldbank.org/WBSITE/EXTERNAL/TOPICS/ENVIRONMENT/EXTCARBONFINANCE/0,,menuPK:4125909~pagePK:64168427~piPK:64168435~theSitePK:4125853,00.html

(Table continues on the following page.)

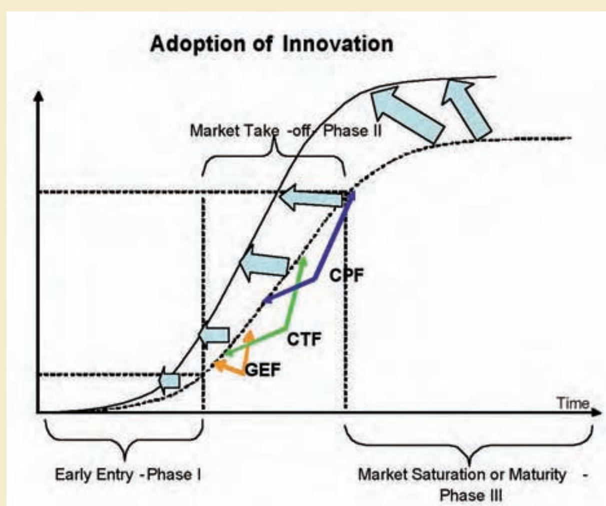
Table 3.40 Market Based Instruments: Carbon Finance, Carbon Partnership Facility (CPF) (continued)

ELIGIBILITY	FUNDING OBJECTIVES	INDICATIVE AMOUNT/ TERMS
Eligibility of an ER programs includes 1) reduction of 6 GHG covered under the Kyoto Protocol or under any future climate change regime 2) demonstration of value added to the programs by World Bank's involvement (e.g. power sector development, energy efficiency, gas flaring, transport sector, and urban development programs.); 3) suitability for scaling up, i.e., can be replicated as part of a larger program or in another country; Prioritized programs are 1) aligned with Country Assistance Strategy/ Country Partnership Strategy and UN Framework Convention on Climate Change/Kyoto Protocol, 2) built on World Bank lending pipeline and other operations, 3) commercially available technology, 4) expected to have significant ER (preferably several million tons over 10-15 years intermediaries)		

BOX 3.24

Using Different Climate Change Funds Simultaneously or Sequentially

The major climate change mitigation financial instruments available at the World Bank Group are the Global Environment Fund (GEF), the Clean Technology Fund (CTF) of Climate Investment Funds (CIF), and the Carbon Partnership Facility (CPF). These tools share the similar objective of reducing the growth of greenhouse gas emissions by creating the favorable market conditions for GHG reduction, and they are compatible with each other. Therefore, they can be pieced together to serve the same project as long as their coverage does not overlap. GEF focuses on barrier removal by providing grant funding for innovative projects in energy efficiency, renewable energies, and sustainable transportation to establish conditions for market transformation. CTF focuses on investment support to fill financing gap by providing grants, concessional finance, and guarantees to scale-up markets. By supporting to reduce the cost of investments or guarantees, CTF aims to reduce the costs of risks. CPF, a new type of carbon fund, provides performance rewards or output-based revenue sources to create incentives for carbon-reducing investments.



Note: Projects need to be planned to avoid double/ triple counting of the same quantities of GHG among GEF, CTF, and CPF

BOX 3.25

Citywide GHG Emission Reduction and Carbon Finance

Emissions in urban areas are from a wide range of sources, including transportation, electrical, and thermal energy consumption in buildings and industries, water and wastewater management, municipal waste, and various public services. Under the Clean Development Mechanism (CDM), there are around twenty methodologies relevant to an urban authority, with the waste sector being the most addressed. Methodologies enable the projects to measure GHG reductions in comparison with the baselines or the 'business-as-usual' trends for specific sources of emissions, and monitor emission reductions. However, as the GHG impact of individual sources, such as a single waste site or street-lighting is very small, many of these projects are unable to access carbon finance due to high transaction costs. Furthermore, sectors such as buildings are not effectively addressed by current methodologies.

The Carbon Finance Unit of the World Bank is developing a framework methodology that attempts to aggregate the GHG impact of all individual sources in a single administrative area, allowing for simplification and streamlining of measurement and monitoring approaches, as well as enabling development of a city-wide program for GHG mitigation. For a typical existing city, the proposed baseline is the current and projected future service provision. For a new city, the baseline could be common practice in the region. Emission sources are categorized into waste, transport, and energy use sectors. These emissions can be reduced from a range of activities. In the waste sector, methane avoidance, biogas generation, and recycling facilities are key sources. Increasing the share of public transport can have a significant GHG mitigation benefits. Energy efficiency opportunities include, buildings, lighting in public areas such as street-lights, water pumping, district heating, and integrated planning for heating-cooling supplies. Significant emission reductions are also achieved by using energy from renewable sources such as wind, solar, and geothermal.

GHG emission reductions at the city level can be realized in each sector either through projects or through regulatory and incentive-based initiatives that facilitate the participation of private sector and the general public. A typical program at the city level would be managed by a city authority. Projects may be implemented by city authorities, either through public-private partnerships or by contractors. GHG mitigation projects are implemented in the above-mentioned three sectors (waste, transport, and energy) over a period of time and generate emission reduction credits based on their performance. Depending on the acceptance of a citywide aggregated methodology, emission reduction credits can be traded and sold, either for use by industrialized countries to meet a part of their emission reduction targets under the Kyoto Protocol, or into the voluntary market for use by industries, governments, or cities themselves.

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PART THREE

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96. Australian Bureau of Statistics, "Regional Population Growth, Australia, 2006–07," released on March 31, 2008
97. Australian Bureau of Statistics, "Regional Population Growth, Australia, 2006–07," released on March 31, 2008
98. *Our Shared Vision: Living in Brisbane 2026*, p. 40
99. *Our Shared Vision: Living in Brisbane 2026*, p. 2. The state of Queensland will have to accommodate one million new residents over the next two decades, 25 percent of whom will arrive in Brisbane.
100. Brisbane City Council, *Brisbane: Long Term Infrastructure Plan* (Brisbane City Council, 2007), p. 41. The state of Queensland has experienced a 53 percent increase in electricity consumption and an 8 percent annual increase in peak load growth.
101. Brisbane City Council, *Brisbane: Long Term Infrastructure Plan* (Brisbane City Council, 2007), p. 41
102. Brisbane City Council, *Climate Change and Energy Taskforce Report: A Call for Action* (March 12, 2007), pp. 16–28
103. Brisbane City Council, *CitySmart* http://www.brisbane.qld.gov.au/BCC:CITY_SMART:1042909255:pc=PC_2645
104. Tony Dingle, "'Gloria Soame': The Spread of Suburbia in Post-War Australia," in Richard Harris and Peter J. Larkheim, eds., *Changing Suburbs: Foundation, Form and Function* (Routledge, 1999), p. 189
105. Peter Newman, "Transport: Reducing Automobile Dependence," in David Satterthwaite, ed., *The Earthscan Reader in Sustainable Cities* (Earthscan Publications Ltd., 1999), p. 192
106. *Urban Renewal Brisbane*, http://www.brisbane.qld.gov.au/BCC:BASE:306686453:pc=PC_1745#TOD
107. Brisbane City Council, *Climate Change and Energy Taskforce Report*, p. 24
108. Brisbane City Council, *Urban Renewal Brisbane* http://www.brisbane.qld.gov.au/BCC:BASE::pc=PC_1726
109. Brisbane City Council, *Know Your Kreek- Moggill Creek* http://www.brisbane.qld.gov.au/BCC:BASE::pc=PC_3127
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112. Case Study description extracted from: 'Wicked', 'messy' and 'clumsy': Long-term Frameworks for Sustainability, Bob Frame, Sustainability and Society, Manaaki Whenua - Landcare Research, New Zealand

113. The NZ Government is in the process of restructuring Auckland's local government and will replace the existing 7 local councils and one regional council with one super council and 20–30 local community boards.
114. World Energy Outlook 2008, International Energy Agency (IEA). This paper adopts IEA's definition of cities as a general and interchangeable reference for urban areas, which may be large metropolitan city-regions, such as New York City, or small urban settlements that have only a few thousand people. The exact definition of urban areas varies by country.
115. www.nyc.gov/planyc and http://www.paris.fr/portail/Environnement/Portal.lut?page_id=8412
116. For example, grid-based electricity supply and prices are generally regulated by regional or national governments.
117. USAID Energy Update, Issue 2, April/May 2005.
118. C40 Cities, Lighting Best Practices (http://www.c40cities.org/bestpractices/lighting/vaxjo_streetlight.jsp).
119. Cost of Pollution in China, 2007, the World Bank.
120. In general, building energy codes are regulated at regional (province or state) or national levels depending on the country. But compliance is completely dependent on local and city-level enforcement.
121. Refer to California Green Building Standards Code, State of California, USA, 2008
122. Energy efficiency-enhanced alternatives are often more expensive upfront, requiring higher capital investment. But the lifecycle costs of more energy-efficient alternatives are generally lower than those of business-as-usual practices because of lowered recurring cost such as energy bills.
123. Electric lighting is a good example. On average, about 70 percent of the energy content of coal is already lost (through conversion, transmission and distribution) by the time electricity reaches a light bulb. A compact fluorescent lamp can deliver the same amount of lighting service (i.e., brightness per square meter) using about 20 percent of the electricity of an incandescent lamp.
124. Passive houses using ultra low energy for space cooling and heating are already demonstrated in Europe and the United States. http://www.nytimes.com/2008/12/27/world/europe/27house.html?ref=world&pagewanted=all
125. (IEA, 2008)
126. (IEA, 2008)
127. International Local Government GHG Emissions Analysis Protocol, http://www.iclei.org
128. There are also distributed energy resources (DER) in urban areas. They are parallel and stand-alone electric generation units located within the electric distribution system at or near the end user, for example a micro gas turbine system, a wind turbine system, a fuel cell, or a rooftop photovoltaic system. Distributed generation can be beneficial to both electricity consumers and, if the properly integrated, the electric utility.
129. (PLANYC 2030)
130. C40 Cities, Buildings Best Practices (http://www.c40cities.org/bestpractices/buildings/melbourne_eco.jsp).
131. Market barriers to energy efficiency investments refer to factors, usually social and institutional, that prevent the realization of the full economic potential of energy efficiency opportunities. They are offered to explain the difference between observed actual energy efficiency choices and decisions, and those predicted by economic theory. Some common market barriers include misplaced incentives, lack of access to financing, high transaction costs, regulatory distortion on pricing, and lack of information or misinformation.
132. (Lantsberg, 2005)
133. Sources: Ringel 2007, Bharvirkar et al. 2008, BEG 2006, McGrory et al. 2006, Borg et al. 2003, Harris et al. 2005, Meyer and Johnson 2008, PROST 2003.
134. District heating systems are the only modern urban energy infrastructure which is entirely city-bound. The ownership structure has undergone significant changes. But city governments still have large influence on the development and management of district heating systems.
135. LEED—Leadership in Energy and Environmental Design—is a green building rating system, developed by the U.S. Green Building Council. It provides a suite of criteria for environmentally sustainable construction. The main financial benefits of meeting LEED criteria include lower costs of energy, water, and waste disposal.
136. (Kats, 2003)
137. (Lantsberg, 2005)
138. See the Alliance to Save Energy's 2007 Watergy Handbook for a discussion on the barriers and opportunities for tapping water and energy efficiency in water utilities: http://www.watergy.net/resources/publications/watergy.pdf.

139. ESMAP (forthcoming). "Public Procurement of Energy Efficiency Services." 2009
140. No Furnaces but Heat Aplenty in 'Passive Houses', New York Times, December 26, 2008
141. It is good practice and the policy of World Bank-financed projects to require ex-ante identification of PDOs and continuous monitoring of M&E indicators with respect to future targets in a "results framework."
142. World Bank (2008). "A Framework for Urban Transport Projects." Operational Guidance,TP-15.
143. Ibid.
144. Discussions related to public transport, micro-design and macro-level approaches are based on presentations at the World Bank 2008 Urban Rail Workshop in Beijing (publication forthcoming) and discussions with World Bank experts Sam Zimmerman and Shomik Mehndiratta.
145. Zegras, C., Y. Chen and J. Grutter (2009). "Potentials and Challenges for Using Clean Development Mechanism for Transport-Efficient Development: A Case Study of Nanchang, China." TRB Annual Meeting.
146. A more comprehensive review is available in World Bank publications, including "Vehicular Air Pollution: Setting Priorities" (2001). A review of economic instruments such as fuel taxes and efficiency incentives can be found in "Fiscal policy instruments for reducing congestion and atmospheric emissions in the transport sector" (2008).
147. For more detailed information, the reader is referred to the World Bank's guidance available on its web site. *Notes on Economic Evaluation of Transport Projects*: (TRN-5) provides the context within which we use economic evaluation in the transport sector, (TRN-6 to TRN—10) provide criteria for selection a particular evaluation technique or approach; (TRN-11 to TRN-17) address the selection of values of various inputs to the evaluation, and (TRN-18 to TRN-26) deal with specific problematic issues in economic evaluation.
148. http://www.straight.com/article-102902/rats-yes-but-bacteria-love-garbage-strikes-too
149. Pagiola, S. et al. Generating Public Sector Resources to Finance Sustainable Development, Revenue and Incentive Effects. World Bank Technical Paper No. 538, Environment Series.
150. Peterson, Charles. What Does 'Waste Reduction' Mean? http://www.p2pays.org/ref/10/09702.pdf
151. Note: Natural gas is composed of about 99% methane.
152. Downs, Anthony. Still Stuck in Traffic, 2004, Brookings Institution Press, Washington DC.
153. CIA World Fact book
154. Lowering real estate transaction costs includes decreasing stamp duties and excessive capital gain taxes.
155. A Tata Nano would require only slightly less space.