Policy Focus Report • Lincoln Institute of Land Policy

Urban Planning Tools for Climate Change Mitigation

PATRICK M. CONDON, DUNCAN CAVENS, AND NICOLE MILLER

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Policy Focus Report Series

The policy focus report series is published by the Lincoln Institute of Land Policy to address timely public policy issues relating to land use, land markets, and property taxation. Each report is designed to bridge the gap between theory and practice by combining research findings, case studies, and contributions from scholars in a variety of academic disciplines, and from professional practitioners, local officials, and citizens in diverse communities.

About this Report

The Lincoln Institute of Land Policy and the Design Centre for Sustainability at the University of British Columbia have been engaged in surveying existing tools that support land use policy and decision making in the context of climate change mitigation and urban planning at local and regional levels. To date, two international workshops have been held in Vancouver, an area at the forefront of mitigation policy for greenhouse gas (GHG) emissions. The meetings brought together many of North America's leaders in tool development, policy implementation, and urban development regulation. The first event in October 2007 identified specific needs, and the second meeting in April 2008 formulated a research agenda with a focus on emerging climate change mitigation policy and practice.

This report draws from those workshops and reviews the relationship between urban planning and GHG emissions as a key component of climate change, provides characteristics of GHG decision support tools, and evaluates the strengths and limitations of a cross section of existing tools using those characteristics. Four case studies illustrate how selected tools are utilized at various stages of the planning and development process.

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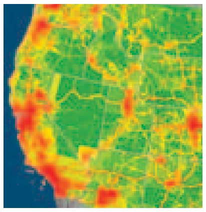
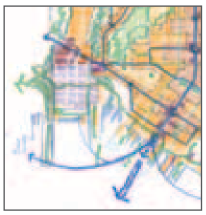
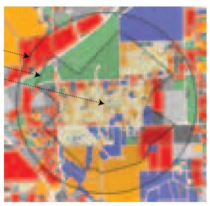
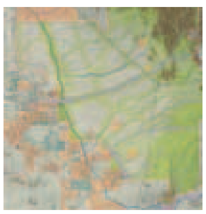
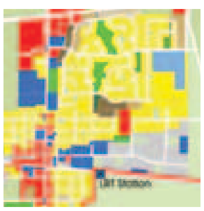
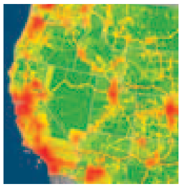
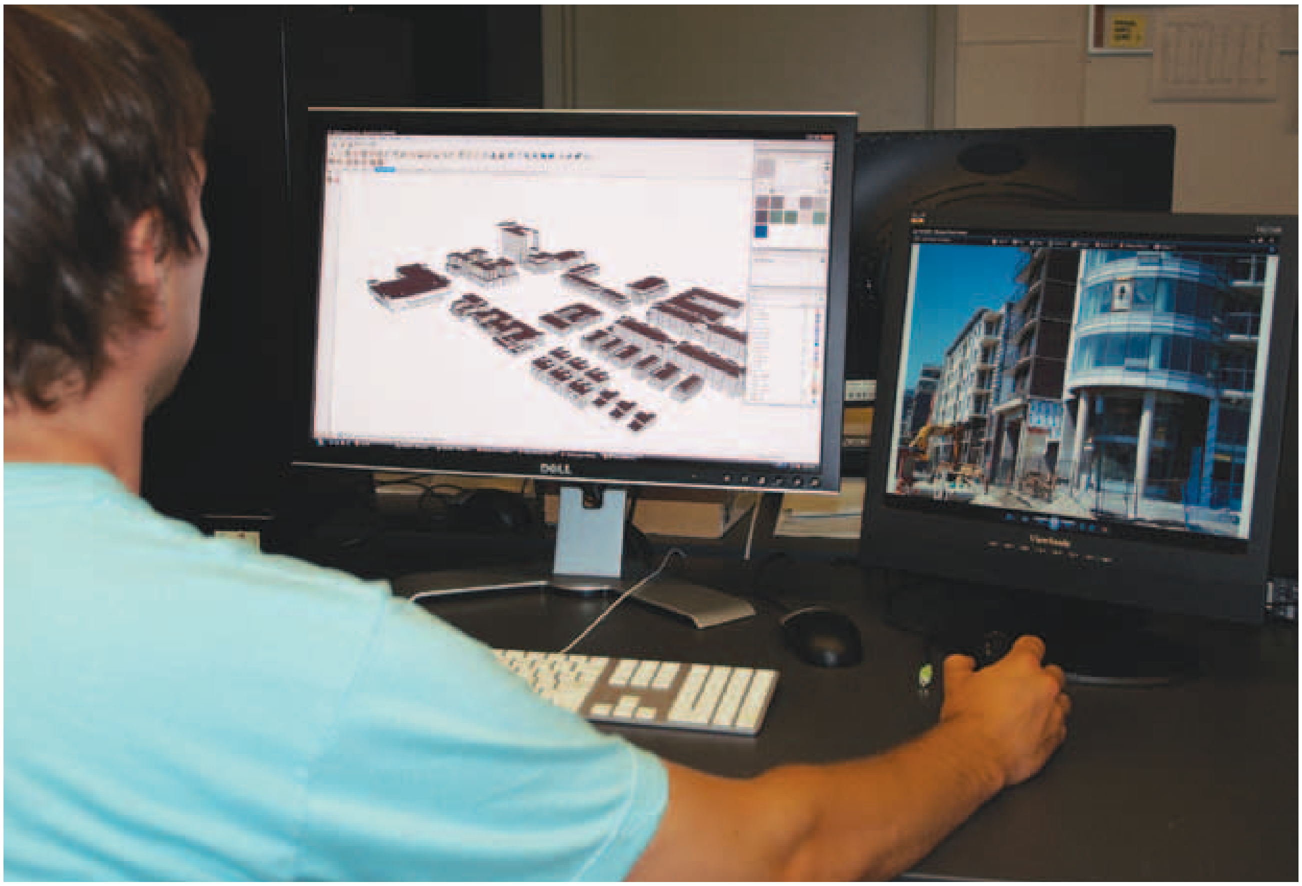








Executive Summary



The scale of intervention required to reduce and adapt to the effects of climate change will require action at all levels of government and society. International accords to limit overall carbon emissions will involve national governments. Setting carbon emission targets and standards by industry or sector, or fuel efficiency standards for vehicles, traditionally falls within the purview of federal and state or provincial governments.

Some state governments are beginning to require local governments to meet greenhouse gas (GHG) reduction targets in relatively short periods of time. However, it is at the local level that most decisions about urban form are made—by public officials, practitioners, and citizens in cities, counties, metropolitan organizations, and special service districts. Yet urban planners and local decision makers generally lack the tools and means needed to make informed choices about the climate change implications of local growth and redevelopment decisions, or to measure their effects.

Policy makers and regulators at all urban scales, as well as their political constituents and stakeholders, need decision support tools that illustrate the GHG implications of urban form so they can make sound, locally relevant land use decisions. While a wide spectrum of tools currently exists, few have the capacity to work simultaneously at both the regional and local scale, or to capture the multiple consequences of regulatory decisions. They generally lack the capacity to model the land use–GHG relationship in a way that easily and in real time informs the policy process.

This report focuses on the present state of tools to model and evaluate the relative climate change benefits of alternative development approaches in cities, ranging from the project to the neighborhood to the metropolitan scale. Four case studies illustrate how selected tools are already being used in the urban planning and development process in the United States and Canada.

While no one tool can yet address all of the desiderata identified by officials and experts, the potential to build on the strengths of existing tools is promising. Continued tool development will serve to enhance connections among various tools, create new methods of evaluating urban form and GHG emissions, and establish test cases through which new tools can be applied and refined.

An ideal tool or integrated suite of tools should have the following characteristics.

- ***Comprehensive:*** able to capture the GHG contributions of all relevant sectors, including buildings and transportation, and support the consideration of additional criteria related to the economy and livability.
- ***Three-dimensional:*** grounded in the physical realities of the urban spaces they seek to model, and able to provide vivid and accurate descriptions of the consequences of future community design.
- ***Multi-scalar:*** able to connect top-down (from regional to block scale) with bottom-up analysis and respond to the interactions between incremental site-scale decisions and regional and higher-level decisions on GHG emissions.
- ***Policy-relevant:*** supportive of the way policy is made and implemented, in terms that are direct and useful to decision makers.
- ***Iterative:*** capable of testing alternative scenarios in real time, including within multi-stakeholder decision processes and planning charrette environments, to produce results that can be evaluated rapidly and incorporated into plan modifications for improved outcomes.
- ***Additive:*** able to build on and link to existing models and related applications.
- ***Accessible:*** intelligible to a wide range of stakeholders, using a common language and interface with transparent outputs.
- ***Affordable:*** relatively inexpensive to acquire and easy to use by staff and consultants to obtain useful results.

To produce such a tool or suite of tools may appear daunting, but the need is great to support effective planning and regulatory decisions, and to set and adjust policy. We are poised to make planning and policy decisions at the international, national, state, provincial, regional, and local levels that will have potentially enormous consequences. This report can guide public officials and proponents of development projects in making better informed decisions with respect to climate change impacts, and can help tool developers and modelers identify critical needs as they design the next generation of planning support tools.

CHAPTER 1

The Relationship Between Climate Change and Urban Planning

Los Angeles, California

Climate change is among the most important issues of our time. Rising global temperatures, largely the product of human activity, are likely to have severe—and potentially catastrophic—effects on both the earth's natural systems and human society. Sea level rise and dramatic changes in weather patterns, predicted as a consequence of sustained global warming, could accelerate the disruption of economic systems, dislocation of coastal communities and port facilities, shortages of food and water supplies, increases in disease, additional health and safety risks from natural hazards, and large-scale population migration. Secondary effects may include the potential for civil unrest and war.

Unprecedented human intervention will be required in the coming decades to reduce the extent of climate change and thereby avoid its worst potential consequences (referred to as mitigation), or make changes to accommodate those effects that are unavoidable (adaptation). Much of the mitigation policy discussion to date has centered on reducing greenhouse gas (GHG) emissions through fuel substitution and fuel efficiency for vehicles and on energy efficiency for buildings and industries.

At the same time, there is a growing acknowledgement by scientists and policy analysts that a substantial part of the global warming challenge may be met through the design and development of cities. The form and function of human settlements can either reduce or increase the demand for energy, and can also influence how energy is produced, distributed, and used. As world population and economic activity increase, urban form factors may play as important a role as reduced fuel use in diminishing the extent of avoidable climate change.

The scale of intervention required to reduce and adapt to the effects of climate change will require action at all levels of government and society. International accords to limit overall carbon emissions will involve national governments. Setting carbon emission targets and standards by industry or sector, or fuel efficiency standards for vehicles, falls within the traditional purview of federal and state or provincial governments.

Some state governments are beginning to require local governments to meet GHG reduction targets in relatively short periods of time. A 2008 Washington State Senate Bill on Climate Action mandates emission reporting and requires GHG reductions of 25 percent below 1990 levels by 2035 and 50 percent by 2050 (State of Washington 2008). Similarly, the California Global Warming Emissions Cap sets a statewide GHG cap for 2020 based on 1990 emissions levels (State of California 2006), while the B.C. Greenhouse Gas Reduction Targets Act requires emissions reductions of at least 33 percent below 2007 levels by 2020, and 80 percent below 2007 levels by 2050 (Province of British Columbia 2007).

Despite these state-level efforts, most decisions about urban form are made at the local level—by public officials, practitioners, and citizens in cities, counties, metropolitan organizations, and special service districts. Yet urban planners and local decision makers generally lack the tools and means needed to make informed choices about the climate change implications of local growth and redevelopment decisions, or to measure the effects of those decisions.

THE CHALLENGE OF CLIMATE CHANGE

Over the past 60 years, average annual global temperatures have been rising to levels unprecedented in the past 100,000 years. Scientists believe this is due primarily to human activity, and that the burning of carbon fuels has been the principal contributor to the overproduction of GHGs that create a blanket in the earth's atmosphere, trapping the warmth of the sun. Because greenhouse gases accumulate rather than dissipate over time, the earth's atmospheric temperature has been rising and will rise further, likely producing two primary phenomena over the next several decades that could have enormous consequences for natural systems and human settlements.

1. The melting of land-based ice masses could result in long-term sea level rise, potentially submerging vast amounts of coastal land.
2. Changes in global and local weather patterns and dynamics could result in substantially higher incidences of flooding, drought, wildfires, and landslides.

Most scientists now predict that temperatures will rise even faster over the next 40 years than recently, due in part to the accumulation of GHGs in the earth's atmosphere, and in part to rapidly growing populations and economies in Asia and South America. They believe that some amount of global temperature rise is now inevitable (on the order of 1 to 2 degrees Celsius by 2050) and will result in increases in sea level and changes in weather patterns with concomitant impacts on food supply, natural hazards, and economic activity.

This phenomenon will require aggressive adaptation strategies to address the unavoidable results of climate change. Among the measures to be considered are limiting development in flood-prone areas, enhancing flood control systems, ramping up water and soil conservation measures, rationing water, and improving inoculation rates for infectious diseases.

Further global climate change (another 2 degrees Celsius or more) and its most catastrophic effects are avoidable through aggressive mitigation strategies. In the last three years a scientific and policy consensus has emerged around an overall objective for mitigation: to reduce annual GHG production to a level that is 80 percent below 1990 levels by the year 2050 (roughly equivalent to 1955 U.S. levels). This objective is now endorsed by a number of states in the United States, and serves as the benchmark for several new regulatory schemes.

Mitigation actions generally fall into two categories: altering the supply source of energy, and reducing the demand for energy. Since changing the supply source—shifting from carbon-based to alternative fuels and energy sources—will take decades, even under aggressive carbon taxation scenarios, strategies to reduce demand are extremely important. Increasing the fuel efficiency of vehicles and machinery and the energy efficiency of buildings are two paths to reducing demand, but more profound measures involve shifts in societal behavior and settlement patterns.

THE RELEVANCE OF URBAN FORM

Some analysis indicates that planning and urban design measures can substantially reduce the number and distance of vehicle trips by organizing human activity in compact communities with a range of housing types, providing reliable transit to and from employment, and placing services within easy walking distance of home. For example, Ewing et al. (2008) found that miles driven are reduced by between 20 and 40 percent in compact urban developments compared to miles driven in the auto-dependent suburbs that have predominated in North America over the last 60 years.

Transportation activity of all forms contributes about 33 percent of energy-related GHG production in the United States, and single-occupant automobile travel makes up about half of that activity (figure 1). The vast majority of vehicles now burn carbon fuels and will continue to do so for some time (even with aggressive fuel substitution and efficiency measures), so strategies that reduce travel by limiting suburban expansion and encouraging more compact, walkable, full-spectrum living and working environments can potentially make a significant contribution to overall climate change mitigation.

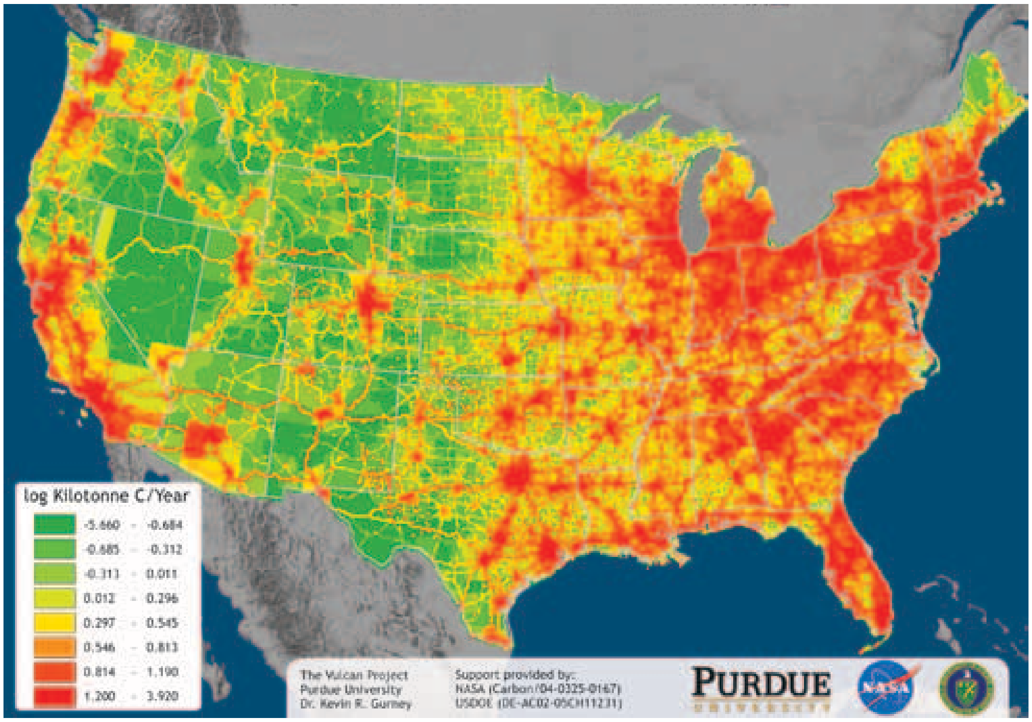
A GHG reduction of up to 10 percent may result from a change in land use approach alone, and additional reductions will result from employing other strategies such as transit investment, fuel pricing, and parking charges (Ewing et al. 2008). By one estimate, approximately two-thirds of all development in 2050 will be new or will have been redeveloped since 2007, suggesting that combined land use and transportation strategies could be quite powerful in mitigating the increases in GHGs (Nelson 2006).

The Portland (Oregon) metropolitan area, for example, has deliberately contained growth and provided transit options over the past several decades to protect surrounding farm and forest land. These policies have reduced per capita vehicle trips by about 17 percent since 1990 and kept overall GHG levels at about 1990 levels despite a 16 percent growth in population (Metro Regional Government 2000). Assuming the area maintains its commitment to "growing in, not out," population growth could actually produce further per capita carbon savings in trip reduction by spawning a fuller array of services and housing types in close proximity and by making alternative transportation investments feasible in more locations throughout the metropolitan landscape.

Additional carbon reductions could come from exploiting other aspects of city making and redevelopment. Using the critical mass of buildings and activities at the district scale, it is possible to develop practical and efficient heating and cooling systems (district energy systems). This approach shows great promise in reducing the carbon footprint of urban development, although the potential costs and benefits of broad-scale application have not yet been quantified sufficiently. Other energy conservation benefits may result from common-wall and vertical living structures typical of multifamily urban locations, as well as more efficient recycling of solid waste.

While the impact of more compact land use on building energy consumption has been studied less extensively than its impacts on transportation energy consumption, several analyses have begun to explore this

FIGURE 1
Total Emissions of Fossil Fuel Carbon Dioxide, 2002



Source: www.purdue.edu/eas/carbon/vulcan/plots.php

The pattern of higher carbon dioxide emissions relates closely to highways and urbanized areas.

relationship. Norman et al. (2006), for example, report that per capita energy consumption and GHG emissions are 2 to 2.5 times higher in low-density developments than in high-density areas.

Urban design also offers the potential for cities to claim some of the attributes now associated primarily with rural living, including green infrastructure, such as natural systems that handle storm water and reduce heating loads, and localized food production that reduces shipping, storage, and packaging needs. These and other strategies that exploit the nontransportation aspects of urban form may contribute significantly to overall GHG mitigation, but a more rigorous quantification of the potential benefits is needed to augment the estimates already provided in the transportation sector.

TOOLS AND FRAMEWORKS FOR URBAN PLANNERS AND POLICY MAKERS

Local governments have several ways of influencing climate change mitigation. As purchasers (and sometimes producers) of power, they can influence the conversion of energy to noncarbon sources. They can also influence resident and local business behavior through education, tax, and fee policy, and other economic incentives or disincentives. However, the greatest influence of local governments is evident in their decisions on urban form, primarily through urban planning and land use regulation.

Local planning guides both infrastructure investment and development regulation, the arenas where decisions can be made about mixed-use, walkable neighborhoods, alter-

Portland, Oregon

native transportation approaches and investments, district energy, green infrastructure, urban farming and farmers markets, and a host of other decisions that can either advance or hinder climate change mitigation.

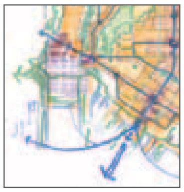
Policy makers and regulators at all urban scales, as well as their political constituents and stakeholders, need decision support tools that illustrate the GHG implications of urban form so they can make sound, locally relevant land use decisions. While a wide spectrum of tools currently exists, few have the capacity to work simultaneously at both the regional and local scale, or to capture the multiple consequences of regulatory decisions. They generally lack the capacity to model the land use–GHG relationship in a way that easily and in real time informs the policy process.

Four key factors could ultimately help planners and local government officials in these efforts.

1. Articulating the "big math"—what portion of the 80 percent of 1990 GHG levels by 2050 should be attributed to urban form, and how much (what ranges) might be achieved by the major components of urban form and other local strategies?
2. Documenting and examining the development status of tools and models for estimating and measuring the climate change effects of alternative development strategies and scenarios at the neighborhood, city, and metropolitan level.
3. Defining ways to deepen and broaden the menu of local approaches to climate change mitigation within the urban form arena and to access information about experiences in other jurisdictions.
4. Examining possible governance structures to make more effective climate change policies and investments. Cities and special service districts are either too small or too narrowly focused to act alone and be successful, yet most metropolitan areas lack effective regional governments.

This report focuses on the second issue: the present state of tools to model and evaluate the relative climate change benefits of alternative development approaches in cities, ranging from the project to the neighborhood to the metropolitan scale. It summarizes the relationship between urban form and climate change, particularly in the mitigation arena, and presents four case studies that illustrate how selected tools are already being used in the urban planning and development process.

This chapter was written primarily by Gil Kelley.



CHAPTER 2

Characteristics of Modeling and Support Tools

Charrette in North Vancouver, British Columbia

Existing urban design modeling tools and GHG-related decision support tools can be categorized according to four characteristics: scope, methodology, scale, and support for policy making. These categories help us compare the capacity of available tools, understand how they might complement each other, and identify gaps in information and decision-making support processes.

SCOPE

Single-sector Emissions Sources

Existing decision support tools differ in how many sectors of the urban fabric they can measure in terms of emissions sources. Many are designed to do a detailed job on just one sector, such as the GHG consequences of certain policy changes, technologically based efficiency enhancements, or changes in transportation mode splits. Tools utilizing a single-sector approach provide important quantitative baseline emissions data and help track progress toward reduction targets, but this information is usually not robust enough to guide a systems-based, all-inclusive approach to assessing and implementing low-carbon land use policies.

Multi-sector Emissions Sources

Tools that encompass multiple emissions sources may simply quantify total emissions from multiple sectors, such as buildings, transportation, waste, and agriculture, or they may represent the more complex relationships among these sectors. Tools with the capacity to go beyond this quantification can reflect a spectrum of issues, such as transportation demand, mode and mix, or energy use in buildings resulting from the shape or arrangement of the urban fabric.

These are precisely the kinds of issues that planners need to understand and address in their communities. Multi-sector comparisons provide critical information that allows decision makers to target emissions sources strategically for the greatest reduction potential. This type of analysis comes with a cost, however, resulting in greater complexity and reduced certainty due to the interactions of many variables remaining in play.

METHODOLOGY

Available GHG tools can also be organized according to their methodological approaches: spatial/nonspatial, top-down/bottom-up, simulation/end-state, and observation-based/process-based. It is also possible for a single tool to employ more than one approach.

Spatial/Nonspatial Methodologies

Decision support tools that use a spatial methodology model the relationships among urban elements. This is important because the physical organization of a city—the arrangement of its elements in space—greatly impacts its carbon footprint. For example, the proximity of one's residence to employment, transit, and commercial services, as well as the road network configuration among these destinations, directly affects transportation choice and travel patterns.

Spatial tools are particularly useful for modeling the transportation impacts of different scenarios, and for analyzing building performance (e.g., solar access, wind mitigation from surrounding buildings, and vegetation) and determining feasible locations for community energy systems using minimum density thresholds. A nonspatial methodology presents data findings in numerical format and does not take into account the analysis of the physical arrangement of an urban area. While nonspatial tools are less data-intensive and quicker to prepare, spatial methods are, at least in theory, more effective in supporting local government planning for reduced GHG emissions.

Another advantage of using a spatial methodology is that it allows for visual representations of results, often using GIS technology and 3-D modeling software that make it easier for lay persons to understand the physical implications of alternative strategies on GHG production. Furthermore, spatial methodologies can provide more compelling visual outputs, allowing decision makers, stakeholders, and constituents to imagine and understand the on-the-ground impacts of policy choices.

Top-down/Bottom-up Methodologies

Tools using top-down methodologies operate at a broad geographical scale, typically designed to support development of plans at the municipal or regional level. In contrast, tools using a bottom-up approach focus analysis on local, site-level projects. However, few tools effectively blend both approaches to assess or provide information on GHG emissions across scales.

Simulation/End-state Methodologies

The methods used by existing tools to model future impacts on urban form can be categorized as either simulation or end-state assessments. Simulation methodologies begin with two primary data inputs: current land use conditions, and a set of specific rules or parameters defining how present conditions will develop over time, including behavioral patterns, technologies, and government policies. The modeling tool combines these two sets of data to forecast and simulate the outcome that would result over a given time period.

End-state assessment methodologies start with data describing future land use and behavioral patterns—in other words, the desired scenario to be achieved at a specific point in time. Performance is assessed using data provided in the scenario, and the changes required to achieve the desired end state can then be back-cast from ideal future conditions.

Simulation tools have one key limitation: they are often constrained by present-day assumptions regarding technological capabilities and behavioral proclivities that are embedded, often unconsciously, in the data used to forecast future scenarios. As a result, the scenarios often fail to consider or reflect technological advancements or broad behavioral shifts resulting from evolving societal preferences or the sensitivity of individuals to price signals.

Simulation methods are also highly complex and time consuming, often requiring months to model future scenarios. Conversely, end-state assessment methods can be much simpler and faster in providing appropriate levels of data, thus allowing policy makers and other users to break free of current assumptions and norms. At the same time, they sometimes sacrifice grounding in real-world cases and the resulting richness of data that those cases often provide.

Observation-based / Process-based Methodologies

Simulation methodologies can be further broken down into observation-based and process-based approaches. The key difference is in how the underlying models are calibrated. Tools with an observation-based simulation method use empirical data to establish the parameters of the model, such as the impact of density on the proportion of nonvehicular trips. Statistical techniques can establish general relationships between two parameters without measuring the direct relationships among individual components. Process-based simulation methods explicitly model the choices or interactions of individual agents or components within a described system.

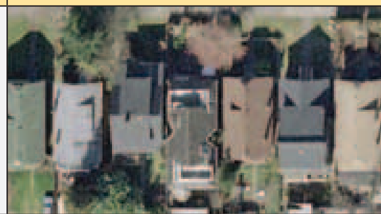
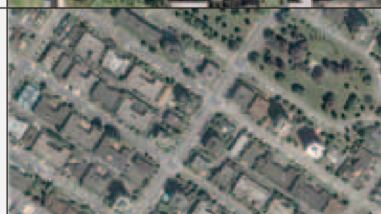
One difficulty with observation approaches is that they are generally unable to function outside the range of typically observed phenomena. A further pitfall is their assumption that data can be extrapolated accurately from one locale to another. For example, the impact of increased street connectivity on transportation-based GHG emissions in a large, temperate metropolitan area may not be the same as in a small, northern community with a different climate, scale, and set of cultural preferences.

SCALE

GHG assessment tools are also categorized according to the geographical scale or scales at which they operate, including individual buildings, parcels, blocks, neighborhoods, municipalities, regions, and bioregions. Most existing GHG tools operate at a single scale, measure and model impacts and performance of specific individual buildings, or utilize future land use scenarios at the regional level. Some tools offer a more flexible framework applicable at a variety of municipal and regional scales.

GHG emissions are influenced by decisions made at all scales—from individual projects at the site scale to infrastructure projects at the regional scale (figure 2). For example, community or master plans at the municipal scale might include increased density targets that could potentially impact ridership on regional and local transit; increase the viability of utilities at the neighborhood or municipal scales; and increase or reduce average energy requirements for building heating and cooling at the parcel

FIGURE 2
Scales of Urban Form and Policy Instruments to Impact GHG Emissions

	Scale	Urban Form	Common Policies
Scales	Building, parcel		Building codes, zoning bylaws, development guidelines
	Block, neighborhood, district		Local area plans, concept plans, community visions, development guidelines
	Municipality		Municipal development plans, comprehensive plans
	Region, bioregion, megaregion		Regional growth strategies, regional visions, regional transportation plans

Source: Design Centre for Sustainability, University of British Columbia

scale. Due to these interconnections, tools with capacity to operate fluidly across multiple geographical scales are the most desirable way to inform low-carbon land use planning decisions at all scales, albeit the most conceptually and practically challenging (figure 3).

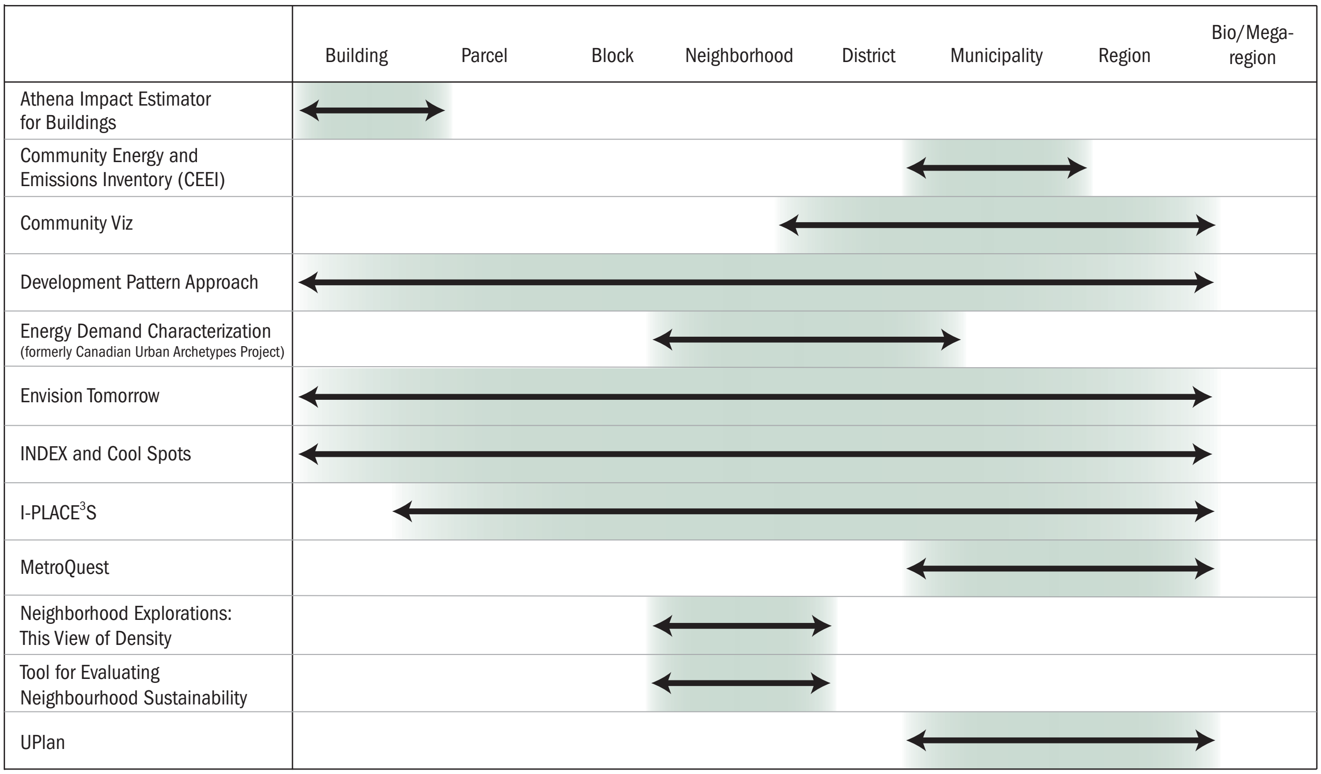
SUPPORT FOR POLICY MAKING

Currently available GHG tools can also be classified according to the specific stage or stages of the policy-making cycle that they support, inform, and influence. In a democracy, particularly in the United States and Canada where most physical planning decisions are made at the local level by bodies responsible to public opinion, the processes of land use planning do not always fit neatly into a linear policy-making cycle. Furthermore, it is now apparent that reducing GHG emissions resulting from city design cannot be addressed exclusively through technological change, behavioral change, transportation policy, road configuration, building design, economic development strategy, or fair housing policy alone; the solutions require coordinated action in all of these realms.

The increasingly widespread use of the design charrette in land use planning illustrates one response to this complexity (Kwartler and Longo 2008). A charrette is an intensive design and policy formulation event that brings together diverse stakeholders to produce through collaborative interaction a plan for a sustainable community (Condon 2007). It typically follows a multistage process.

- In-depth research on issues important to the community to inform workshop decision making;
- Two to four preliminary workshops to identify community goals and objectives and to set performance targets;

FIGURE 3
Scales of Existing Tools



Source: Design Centre for Sustainability, University of British Columbia

- Collaborative design during the charrette itself, including facilitated stakeholder discussion and selection of strategies to achieve performance targets combined with designer-only sessions during which discussion outputs are translated into rough drawings;
- Production of final drawings and development of the final public presentation and subsequent report;
- Translating the final presentation into a final concept plan that describes the ideas and goals generated at the charrette; and
- Development of implementation plans and technical documents such as design guidelines that describe the concept plan in regulatory terms.

The theory underpinning charrettes is that, given the complexity of sustainability factors, there is no possibility for linear, single-issue processes to manage them. The alternative is synthetic, holistic, and inclusive integration of all issues that pertain to real-world problems of city design, in a collaborative and interdisciplinary setting (Condon 2007). Successful charrettes and other multiparty roundtable processes take advantage of all the information and decision support tools available. The challenge is to integrate the information and tools in a form that fluidly intersects the decision-making discourse.

The following five-step policy cycle model accurately reflects the way that collaboratively produced sustainable community design decisions are made, and integrates the existing tools into the stages to which they are best suited (Hessing et al. 2005).

1. *Information gathering.* Research and assembly of data helps to describe past and present conditions and project the impacts of various land use decisions.
2. *Interpretation.* Analysis of the assembled data explains relationships between policy

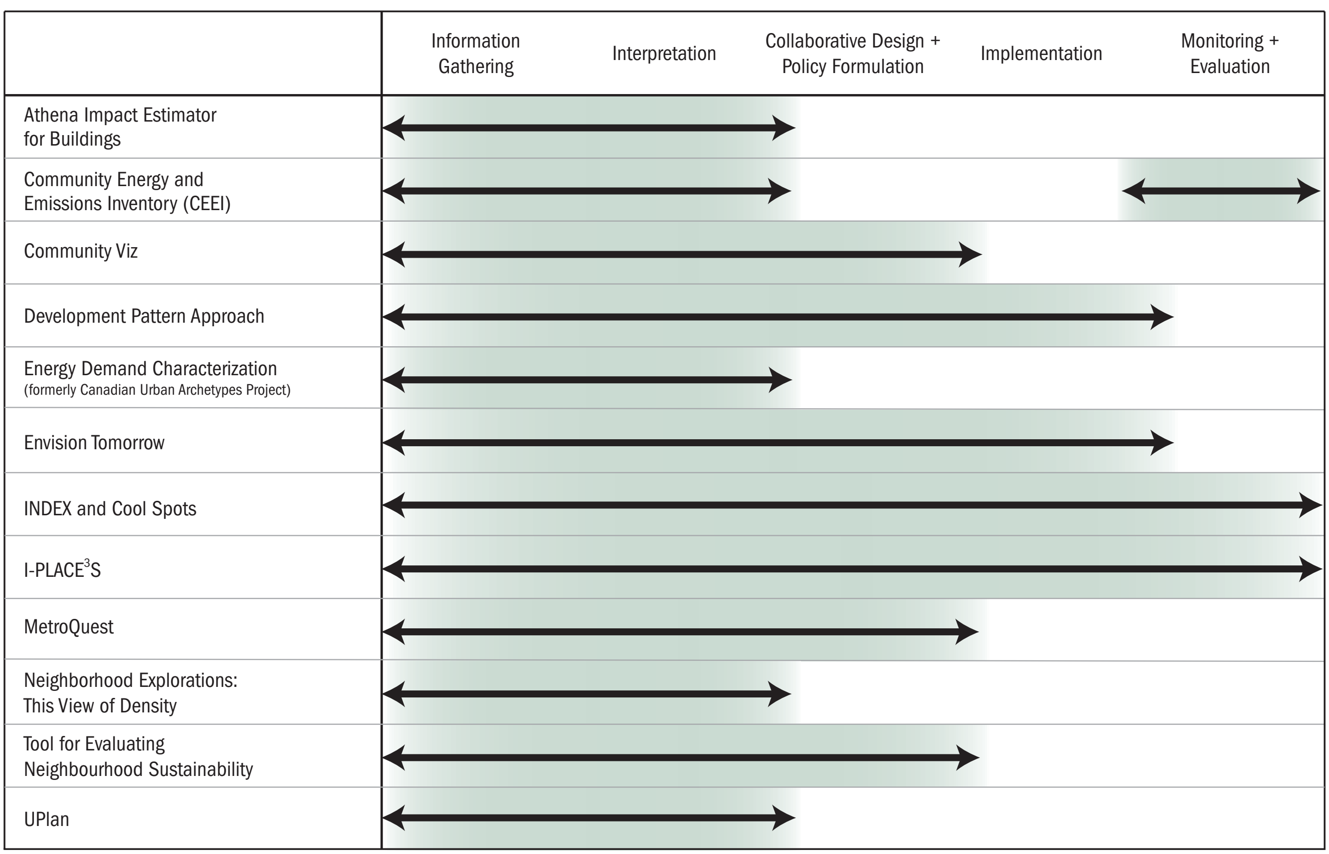
decisions and data, and informs design and policy formulation.

3. *Collaborative design and policy formulation*. Charrette-style decision-making methods bring together diverse stakeholders to participate in a collaborative design process. The impacts, costs, and benefits of proposed policy options are assessed using design, and consensus is achieved on the formulation of land use strategies and policies.
4. *Implementation*. The policy decision achieved during the previous stage is carried out using a variety of tools, such as bylaw amendments or development permit guidelines.
5. *Monitoring and evaluation*. The results and effectiveness of the policy decision are assessed, and revisions made if necessary.

Most available tools quantify the GHG implications of different strategies and/or scenarios. They best serve the information gathering stage of the policy-making process. Fewer tools are available to fully support the interpretation and collaborative design and policy formulation stages of land use decision making. Additionally, existing tools are often unresponsive to later implementation, monitoring, and evaluation demands, as well as ongoing public education and outreach needs.

A small number of tools have begun to address the process-driven, cross-scale needs of policy makers (figure 4). Lessons from these applications, if incorporated into tool development, will undoubtedly enhance them.

FIGURE 4
Policy Cycle Impact of Existing Tools



Source: Design Centre for Sustainability, University of British Columbia

CHAPTER 3
Existing Tools to Assess GHG Emissions

INDEX digital charrette in Elburn, Illinois

A broad cross section of existing tools and other tools still under development illustrates the scope of GHG calculations, the methodologies employed, the scale at which they are used, and how they support policy decisions. While this inventory is far from exhaustive, it represents the range of tools currently available and compares their various features and functions (table 1).

Athena Impact Estimator for Buildings
Developed by the Athena Institute, a non-profit organization located in both the United States and Canada, this software tool uses a life-cycle assessment method to provide cradle-to-grave building evaluation. Outputs displayed in summary tables and graphs include data on embodied energy, GHG consequences, solid waste emissions, and pollutants to air and water. This tool models building performance only, and does not evaluate issues beyond the envelope.

Community Energy and Emissions Inventory (*CEEI*)
Sponsored by the British Columbia Ministry of Environment, this initiative is a data collection, analysis, and reporting system. Using data from sources including utilities, the Insurance Corporation of B.C., and the Recycling Council of B.C., the system generates baseline inventories and periodic reports of community energy consumption and GHG emissions for on-road transportation, buildings, and the solid waste sector.

TABLE 1
Comparisons of Tool Features

Tool	Scope	Methodology	Scale	Policy Support
Athena Impact Estimator for Buildings	single-sector; building energy on a lifecycle basis	nonspatial; spreadsheet-based	individual buildings	information gathering
Community Energy and Emissions Inventory (CEEI)	multi-sector; buildings, transportation, community waste, and land use change	nonspatial; observation-based; end-state assessment of current conditions	municipal; regional	information gathering
CommunityViz	multi-sector; various user-selected sustainability indicators	spatial; observation-based	neighborhood; regional	information gathering; interpretation; collaboration
The Development Pattern Approach (DPA)	multi-sector; buildings, transportation, renewable energy, and other sustainability indicators	spatial; observation-based; end-state evaluations	parcel; neighborhood; district; municipal; regional	information gathering; interpretation; collaboration; implementation
Energy Demand Characterization (formerly the Canadian Urban Archetypes Project)	multi-sector; transportation and building energy	nonspatial; observation-based and survey-based case studies	neighborhood (approximately 300 residential units)	information gathering; interpretation
Envision Tomorrow	multi-sector; various sustainability indicators including building and transportation energy and emissions	spatial; observation-based; end-state evaluations	parcel; neighborhood; district; municipal; regional	information gathering; interpretation; collaboration; implementation
INDEX and Cool Spots	multi-sector; various sustainability indicators including building and transportation energy and emissions	spatial; observation-based; end-state assessment	parcel; neighborhood; municipal; regional	information gathering; interpretation; collaboration
I-PLACE³S	multi-sector; population, transportation, and employment patterns	spatial; observation-based; end-state assessment	parcel; neighborhood; municipal; regional	information gathering; interpretation; collaboration
MetroQuest	multi-sector; various sustainability indicators including building and transportation energy	spatial; end-state assessment	municipal; regional	information gathering; interpretation; collaboration
Neighborhood Explorations: This View of Density	single-sector; transportation	non-spatial; observation-based; end-state assessment spreadsheet	neighborhood	information gathering
Tool for Evaluating Neighbourhood Sustainability	single-sector; transportation	nonspatial; observation-based; end-state evaluation spreadsheet	neighborhood	information gathering; interpretation; potential for collaborative use
UPlan	multi-sector; urban growth model; emissions	spatial; process-based simulation	municipal; regional	information gathering

Community Viz

This collection of GIS-based 3-D visualization and decision support tools for planning and resource management was developed by the Orton Family Foundation in Vermont. It is managed by Placeways, LCC, a company in Colorado that was formed by a group of former CommunityViz employees. The tool allows users to build land use planning scenarios to analyze and communicate environmental, economic, and social impacts in real time. The tool can be adapted for many purposes through user modification, including GHG calculations.

Development Pattern Approach (DPA)
This project is under development at the University of British Columbia Design Centre for Sustainability's Neighbourhoods Lab. The DPA is a suite of methods for modeling urban development scenarios and quantifying their performance against a variety of sustainability indicators. It uses archetypical patterns of urban form to represent current and future urban conditions that can be queried by a suite of submodels (e.g., building energy, transportation) that measure different urban characteristics, including GHG production associated with certain neighborhood and district configurations.

Energy Demand Characterization (formerly the Canadian Urban Archetypes Project)
This project is under development at CANMET Energy Technology Centre within Natural Resources Canada. The project offers municipalities, urban planners, and developers a reference library of archetypes illustrating energy and consumption in the areas of transportation, residential building energy use, water, and waste for a range of urban form types and resident lifestyle patterns.

Envision Tomorrow
This suite of urban and regional planning tools can model land use decisions from the site to regional scales. It can evaluate the feasibility and implications of different styles and mixes of development on energy use, water use, and carbon footprints.

INDEX and Cool Spots
INDEX is a GIS-based software that compares energy use, costs, air pollution, GHG emissions, and other indicators to current conditions, business-as-usual, and alternative planning scenarios at neighborhood to regional scales. INDEX is utilized in the Cool Spots planning technique that was developed in 2007 by Criterion Planners as a way to organize and prioritize neighborhood-scale climate action measures.

I-PLACE^{3}S
This Web-based modeling platform was developed by the California Energy Commission (CEC), the California Department of Transportation, and the U.S. Department of Energy; it is administered by the Sacramento Area Council of Governments (SACOG). It evaluates planning scenario impacts from multiple issues at the parcel, neighborhood, and regional scales.

MetroQuest
This real-time, interactive planning support tool was created by the Sustainable Development Research Institute at the University of British Columbia and is managed by Envision Sustainability Tools, a company based in Vancouver. Using an archetype methodology and GIS-based visual communication, MetroQuest builds, compares, and evaluates alternative 40-year scenario simulations at municipal and regional scales.
It captures a range of issues including land use planning, infrastructure spending, transportation, and air quality. GHG can be computed from transportation information, but this module is not yet available within the tool.

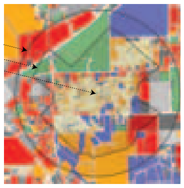
Neighborhood Explorations: This View of Density
This Web-based tool compares area of land used, roads and sidewalks, water use, local shopping, transit service, vehicles, parking, mileage, fuel use, gasoline cost, volatile organic compounds (VOCs), and GHGs in table format for ten specific San Francisco

neighborhoods with residential densities ranging from 3 to 500 households per residential acre. The tool allows users to generate customized neighborhood profiles by entering residential density, cost of gasoline, and vehicle mileage.

Tool for Evaluating Neighbourhood Sustainability
Developed by the Canadian Mortgage and Housing Corporation, this is a spreadsheet-based model for estimating annual per-household GHG emissions from personal travel based on neighborhood design features. Characteristics include density, land use, number of bedrooms, frequency of transit service, and intersection density. It allows users to test a variety of development proposals by manipulating and adjusting locational and neighborhood design variables. The tool is also capable of establishing the relative GHG emissions difference between two or more neighborhoods in large metropolitan areas.

UPlan
UPlan is maintained by the Information Center for the Environment at the University of California, Davis. Modeling future regional land use patterns based on fine-grained grid data inputs, the application allows users to overlay projections with environmental data to calculate fiscal costs, as well as impacts on storm water runoff, water quality, wildlife habitat, and GHG emissions. Outputs include maps and Excel-based tables.

Source: MetroQuest (www.metroquest.com).



CHAPTER 4

Case Studies: Applications of Selected Tools in Planning Projects

The applications of four different tools or sets of tools in a variety of case study projects illustrate how these tools have been used in real-world planning situations. They offer a representative sample of available tools, and the results produced when they are applied to an actual site. Each description presents the tool and its operational characteristics, the project site, the methodology employed, some conclusions, and the case study consultant.

The rail transit station in the project site

INDEX: Designing a Cool Spot Neighborhood

Elburn, Illinois

The Tool

INDEX is planning support software introduced by Criterion Planners in 1994 as a land use/transportation modeling tool to evaluate scenarios using goal-derived indicator scores. INDEX is an ArcMap GIS extension designed with the following features.

- *User-friendly and portable.* With a user interface designed for nontechnical audiences, the tool is operated on laptops at public meetings.
- *Iterative and fast.* Scenarios can be sketched and scored in real time to enable rapid iteration to preferred outcomes.
- *Transparent.* All inputs and calculations are documented to explain the basis of results, and major input parameters are user-defined.

- *Scalable.* The tool performs its calculations at the building and parcel level, and scenarios can be assembled for blocks, neighborhoods, communities, and regions. Lower-level scenarios nest within larger-scale scenarios.
- *Linkable.* Scenarios can be exported to transportation demand, storm water, developer pro forma, and fiscal impact models, among others.
- *Comprehensive.* A menu of 94 indicators addresses demographics, land use, housing, employment, recreation, transportation, water, energy, and GHG emissions.
- *Affordable.* The cost of acquiring and applying the tool is comparable to typical local government GIS applications.

The tool has been applied in the United States at approximately 700 locations in 37 states, as well as in Australia, Canada, China, Japan, and Spain. In the United States, the software is licensed to 175 user organizations, including municipal and regional planning agencies, urban design consultants, and educational institutions (Brail 2008). Current representative applications include regional transit planning in Portland, Oregon;

FIGURE 5
Existing Land Use Plan, Elburn, Illinois

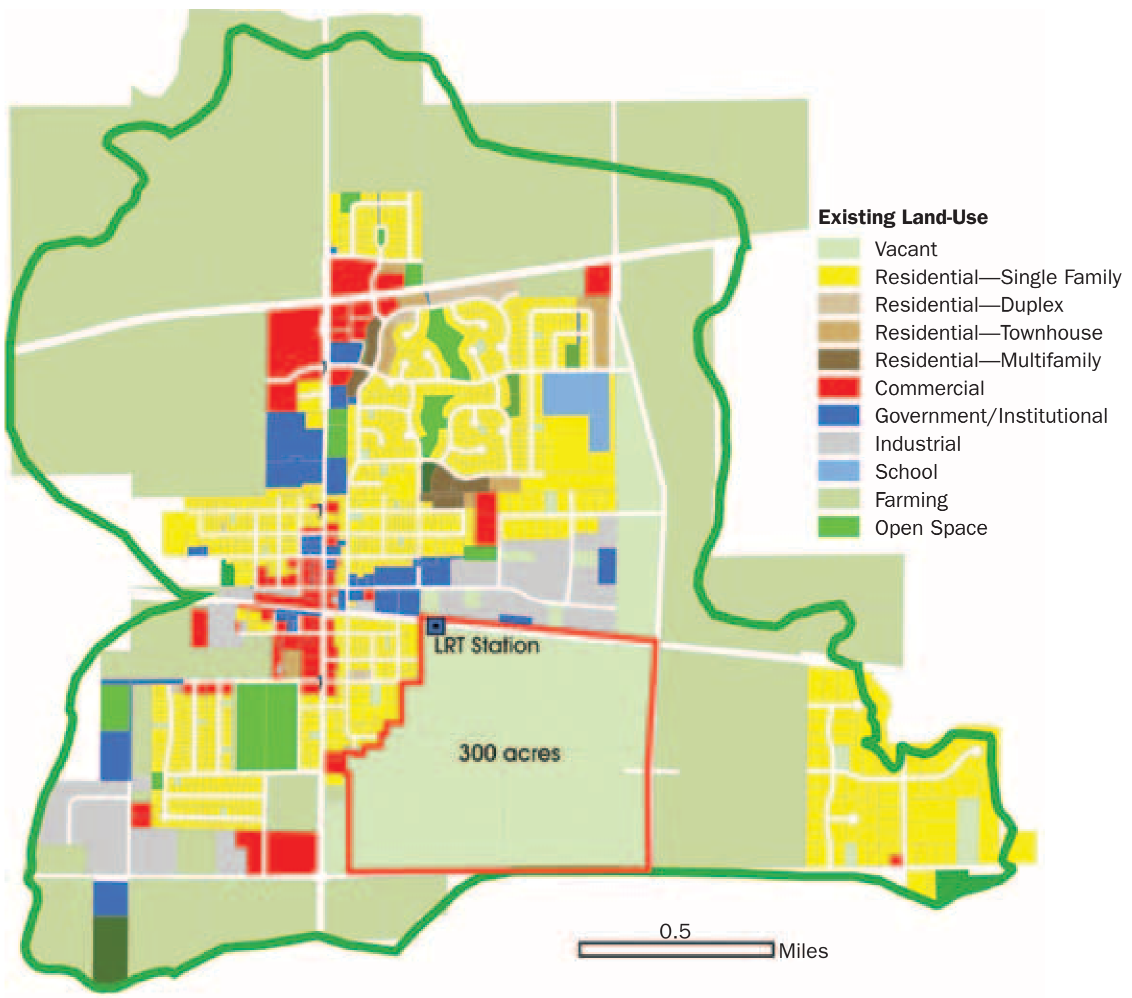


FIGURE 6
Land Use Palette for Scenario Sketching

DU=Dwelling Units
MW= Megawatts

redevelopment planning of the Mall of America neighborhood near Minneapolis, Minnesota; preparation of a regional "growing cooler" framework for Baltimore, Maryland; identification of potential Cool Spots for Albuquerque; and a downtown climate change action plan for Lafayette, California.

The Project

Elburn, Illinois, is a Chicago suburb of approximately 4,000 residents with a commuter rail transit connection to the center city. A 300-acre site adjacent to the rail transit station is the community's focus area for future growth. It presents a significant opportunity for a climate-friendly Cool Spot design (figure 5).

Since 2007, a series of INDEX digital charrettes have been conducted to evaluate Cool Spot opportunities in the station area. The objective of the charrettes has been identification of alternative land use/transportation designs that lower the station area's GHG emissions, while also meeting the community's overall comprehensive planning goals. The charrettes were preceded by the following set-up tasks.

- *Calibrate local energy and carbon characteristics.* Fuel shares and carbon content for local building and transportation energy supplies were specified.
- *Benchmark existing citywide land use and transportation conditions.* A comprehensive set of indicators was scored for the entire community to create a frame of reference for setting station area goals (table 2).
- *Formulate measurable goals.* Using citywide benchmark scores, goal-relevant indicators and desired scores were selected for evaluating and ranking station area scenarios.
- *Create palettes of land use and transportation features.* Station area land uses and transportation facilities were defined and assembled into palettes for scenario sketching (figure 6).

TABLE 2
Indicators for Existing Benchmarks and Project Objectives

INDEX Indicators	Units	Citywide Existing	Station Area Objectives	Station Area Design Scenarios		
				A	B	C
Demographics						
Population	residents	3,324		6,868	5,882	7,441
Employment	employees	948		3,151	5,893	3,551
Land-Use						
Use Mix	0-1 scale	0.19	0.50 or more	0.40	0.57	0.36
Use Balance	0-1 scale	0.71	0.90 or more	0.87	0.89	0.81
Housing						
Dwelling Unit Count	total DU	1,306		3,276	2,895	3,664
Single-Family Dwelling Density	DU/net acre	2.60	14.00 or more	16.00	14.62	16.00
Multi-Family Dwelling Density	DU/net acre	8.22	28.00 or more	26.61	26.39	28.65
Single-Family Dwelling Share	% total DU	76.6		38.5	10.9	12.5
Multi-Family Dwelling Share	% total DU	21.3		61.5	89.1	87.5
Amenities Proximity	avg walk ft to closest grocery	4,952	2,000 or less	1,906	3,048	3,110
Transit Proximity to Housing	avg walk ft to closest stop	2,909	1,000 or less	952	928	1,146
Employment						
Jobs to Housing Balance	jobs/DU	0.73	0.90 to 1.10	0.96	2.04	0.97
Employment Density	emps/net acre	21.04	70.00 or more	49.92	52.82	60.09
Commercial Building Density	avg FAR	0.20	0.65 or more	0.54	0.56	0.59
Transit Proximity to Employment	avg walk ft to closest stop	1,384	1,000 or less	731	959	1,087
Recreation						
Park/Schoolyard Space Supply	acres/1000 persons	19.8	3.0 to 8.0	4.0	4.9	5.9
Park/Schoolyard Proximity to Housing	avg walk ft to closest park/schoolyard	2,144	1,000 or less	1,725	1,319	1,165
Travel						
Street Segment Length	avg ft	658	300 or less	315	399	452
Street Network Density	centerline mi/sq mi	6.8		27.6	24.8	18.9
Transit Service Coverage	stops/sq mi	1.0	10.0 or more	22.6	18.1	13.6
Transit-Oriented Residential Density	DU/net acre w/i 1/4 mi of stops	4.03	28.00 or more	21.90	23.71	27.95
Transit-Oriented Employment Density	emps/net acre w/i 1/4 mi of stops	15.78		49.92	51.52	61.32
Pedestrian Network Coverage	% of streets w/sidewalks	91.9	100.0 or more	99.7	99.7	100.0
Street Route Directness	walk distance/straightline ratio	1.84	1.40 or less	1.38	1.33	1.36
Bicycle Network Coverage	% street centerlines w/bike route	33.16	50.00 or more	44.29	49.41	27.67
Home Based VMT Produced	mi/day/capita	25.0		20.6	20.9	20.2
Non-Home Based VMT Attracted	mi/day/emp	15.0		12.4	12.5	12.1
Climate Change						
Residential Building Energy Use	MMBtu/yr/capita	50.92		45.51	41.69	41.84
Residential Vehicle Energy Use	MMBtu/yr/capita	41.51		34.18	34.66	33.59
Residential Total Energy Use	MMBtu/yr/capita	92.42		79.69	76.35	75.43
Non-Residential Building Energy Use	MMBtu/yr/emp	45.66		43.34	42.47	11.85
Non-Home Based Vehicle Energy Use	MMBtu/yr/emp	24.90		20.51	20.80	20.15
Non-Residential Total Energy Use	MMBtu/yr/emp	70.56		63.85	63.26	32.00
Residential Building CO2 Emissions	lbs/capita/yr	6,462		4,561	4,735	3,634
Residential Vehicle CO2 Emissions	lbs/capita/yr	6,340		5,221	5,294	5,130
Residential Total CO2 Emissions	lbs/capita/yr	12,802		9,781	10,029	8,764
Non-Residential Building CO2 Emissions	lbs/emp/yr	7,286		4,343	4,823	1,029
Non-Home Based Vehicle CO2 Emissions	lbs/emp/yr	3,804		3,132	3,176	3,078
Non-Residential Total CO2 Emissions	lbs/emp/yr	11,090		7,476	7,999	4,107

FIGURE 7
Station Area Scenarios, Elburn, Illinois

Digital charrettes are normally four- to six-hour sessions involving as many as 100 people. Tables of eight to ten people use INDEX on a laptop to sketch and evaluate scenarios. For the Elburn transit station, participants performed the following tasks.

- Design street cross-sections and draw their locations.
- Paint land uses and locate specific amenities, such as a grocery store.
- Draw bus routes and locate stops.
- Draw bike routes.
- Select a wind power share for the neighborhood's electric supply.
- Protect existing wetlands and wildlife habitat on a portion of the site.

Figure 7 shows three scenarios developed during the charrettes, while figure 8 ranks these scenarios according to GHG reduction and the extent to which they meet community planning goals. The final iteration, Scenario C, achieves the greatest reduction in GHG emissions, and also accomplishes the strongest response to the community's goals. This GHG superiority is achieved with both high housing and employment densities that reduce air conditioning demands, auto trips, and trip lengths; and 30 percent of total electricity sourced from emission-free wind power. Scenario C also excels in terms of other community planning goals, including its large amount of park space that satisfies recreation objectives.

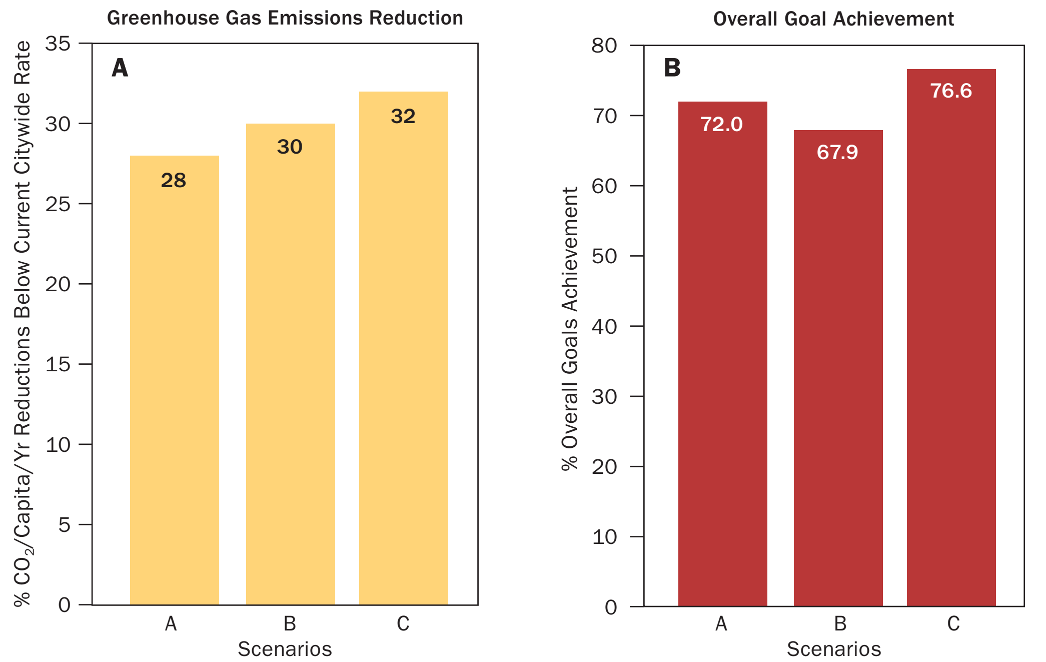
The GHG emission levels calculated for Elburn's three scenarios are consistent with research on the climate change impacts of urban form, as well as Criterion's modeling of LEED for Neighborhood Development (ND) projects. Criterion's ND certification review of 40 neighborhood projects in the United States and Canada indicates that per capita GHG emission reductions of 25 to 33 percent appear to be consistently achievable with strong multimodal travel environments and compact, mixed land use designs that embody the principles of smart growth and New Urbanism.

The Methodology

INDEX's GHG estimation process translates development scenarios into energy use and GHG emissions (figure 9). Energy

FIGURE 8

Scenario Rankings by GHG Emissions Reduction and Overall Goal Achievement



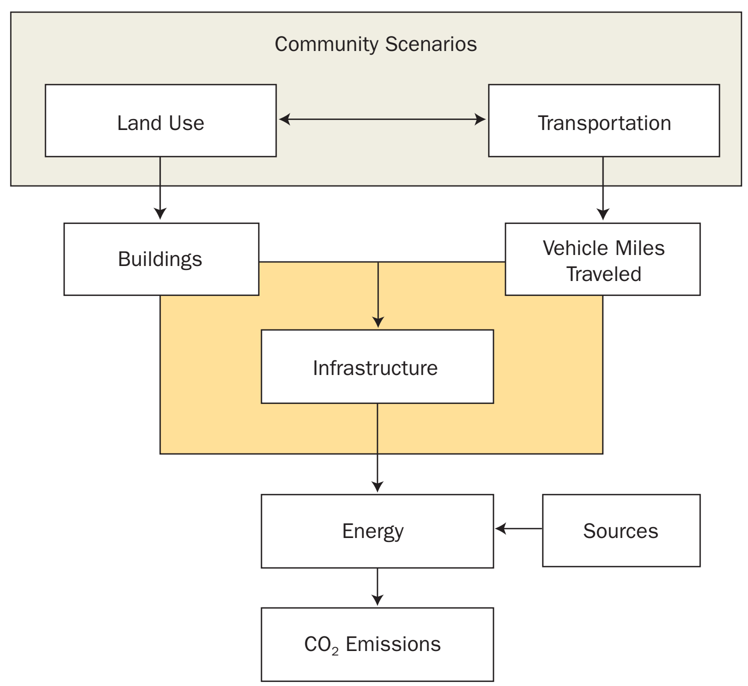
demands are set for each building type using climate-adjusted values for building square footage. The building values are then assigned to land use types, and these are aggregated into total building energy loads based on the amounts of land area "painted" with land uses. Infrastructure energy use (e.g., streetlights, utility pumps) can be added optionally.

Vehicle trips (VT) and vehicle miles traveled (VMT) are estimated based on common urban design variables such as density, interconnectivity, and availability of transit. As scenarios alter land use density and diversity, street and pedestrian networks, and regional accessibility, the elasticities estimate the resulting changes in baseline VT and VMT. VMT is converted into energy use based on vehicle types, fuel shares, and emission rates adjusted for VT effects.

To arrive at net energy use and GHG emissions, building energy and transportation

FIGURE 9

Estimation of GHG Emissions Using INDEX



energy are combined into total gross energy demand, and then credits are given optionally for clean electricity and fuel shares, embodied energy savings from building reuse, and carbon sequestration in local forestry. Once GHG emissions have been estimated and indicators scored for other goals, such as open space preservation and affordable housing, the tool ranks all the scenarios according to both individual goal achievement and overall achievement of community goals weighted by their relative importance.

Conclusions

As an integrated land use/transportation planning technique for reducing GHG emissions, Cool Spots is able to quantify the emissions of alternative community scenarios in real time at public meetings. In so doing, it assists stakeholders in assembling climate-friendly urban development plans.

Advances are occurring in GHG calculation methods and computer technology that will enable wider adoption of digital sketch planning techniques for climate protection. Touch-screen interfaces, 3-D visualization software, and smaller, distributed user devices will make charrettes easier to conduct and more engaging for participants, which will increase future participation and support for resulting plans.

To help foster such processes, however, communities need to make greater investments in data that describe land use, transportation, and energy conditions at the building and neighborhood levels; and the planning profession needs to encourage students and practitioners to acquire relevant modeling and charrette skills. Recent state legislation, such as California Senate Bill 375 and Florida House Bill 697, is beginning to mandate GHG considerations in community planning that will accelerate these trends. Eventually, GHG assessment of proposed urban development is likely to become standard practice comparable to the types of impact studies usually prepared for traffic, schools, and other community issues.

Case Study Consultant

Established in 1979, Criterion Planners is an urban and regional planning consultancy based in Portland, Oregon, specializing in community planning for energy efficiency. The firm has assisted local, state, and federal agencies with climate change action planning since 1993, including preparation of the Chula Vista, California global warming reduction plan that received the Environmental Protection Agency's 2003 Climate Protection Award.

Though mostly auto-oriented, the White Center business district has "good bones."

I-PLACE^{3}S: Initiating Health and Climate Enhancements

King County, Washington

The Tool

I-PLACE^{3}S is a Web-based, publicly available modeling platform for scenario planning that is capable of working with detailed data at scales from the neighborhood to multi-county regions. Developed by the California Energy Commission (CEC), the California Department of Transportation, and the U.S. Department of Energy, I-PLACE^{3}S is administered by the Sacramento Area Council of Governments (SACOG). It evaluates the impact of alternative development approaches or transportation investments on a range of indicators including population, employment, transportation patterns, energy use, and cost efficiency.

The visual and interactive nature of I-PLACE^{3}S mapping analysis makes scenario development and testing accessible to nontechnical users in public workshops and other settings. Because it is Web-based, I-PLACE^{3}S requires no specialized hardware or software, has only one dataset to maintain and update, and is capable of performing analysis on extremely large datasets (more than 750,000 records) within a several-second timeframe. Furthermore, I-PLACE^{3}S can incorporate data from and provide feedback into regional travel models to illustrate regional transportation benefits of local-level land use change.

The robust functionality of I-PLACE^{3}S allows the tool to take into account study area demographics (particularly important for any public health analysis), and to measure the built environment within walking distance of each study area parcel. Designed for flexibility, I-PLACE^{3}S can be expanded by adding new or updated modules and can be customized to meet the needs of individual organizations. New additions are then made available to all users, enabling synergy and cost savings.

The Project

The King County HealthScape initiative seeks to improve public health and environmental sustainability through community design. As part of this initiative, the I-PLACE³S scenario planning model was expanded to evaluate the transportation impacts of different land development alternatives, including GHG emissions. For King County and the cities within it, the enhanced version of I-PLACE³S can inform a number of processes (figure 10).

Statistical relationships generated by an analysis of King County data on the built environment, transport, physical activity, GHG, and air pollution were programmed into I-PLACE³S. The resulting version of the application was tested on the 98th Street corridor in White Center, an unincorporated urban area. The community has an interconnected street network and a mix of commercial, employment, and residential land uses enlivened by new immigrants from Asia, Africa, and South America.

The Methodology

The statistical relationships used to enhance I-PLACE³S for the King County project were generated by linear regression analyses. A previous county-wide analysis of the relationship between CO_2 and specific land use characteristics was rerun using up-to-date data from the 2006 Puget Sound Regional Council (PSRC) Household Travel Survey and the Neighborhood Quality of Life Survey (NQLS) project. Land use patterns around each household location were measured and correlated to travel, air pollution,

FIGURE 10
Parcel Map of Land Use Types in White Center, Washington

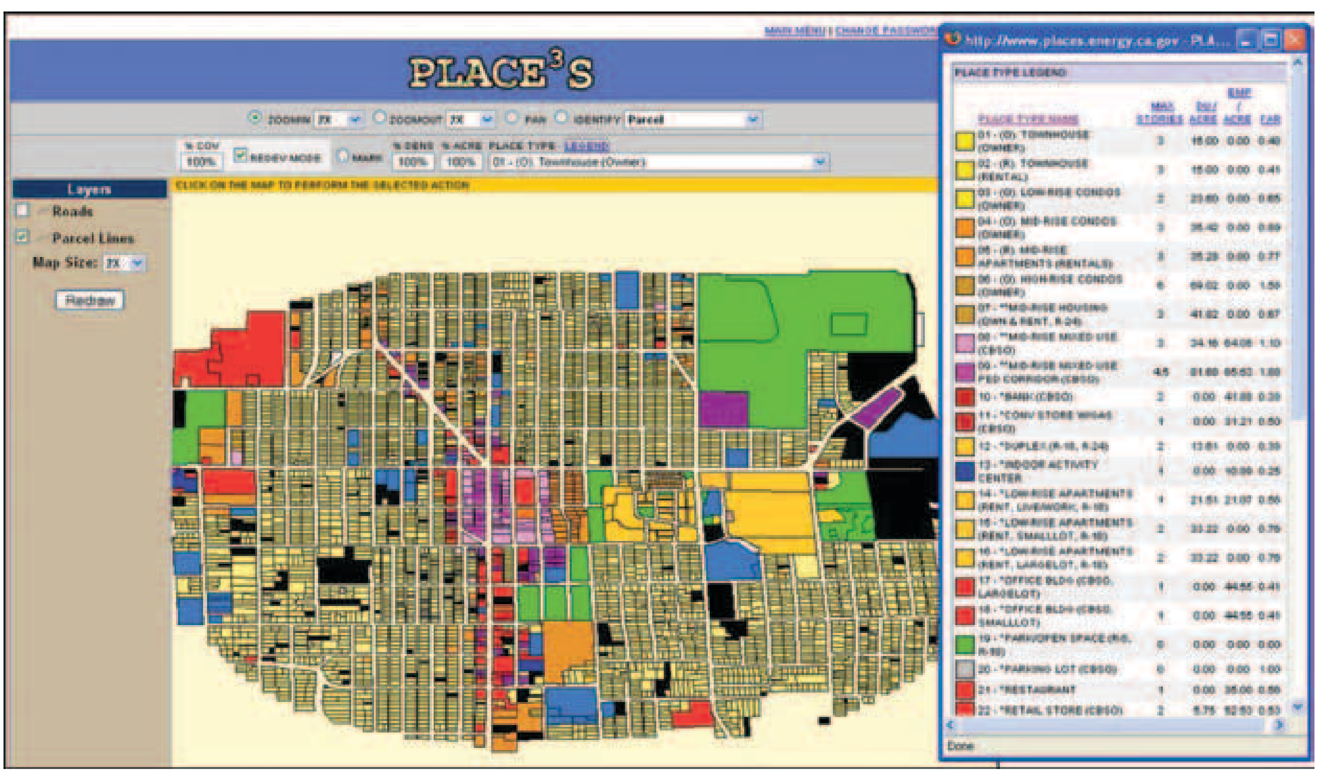
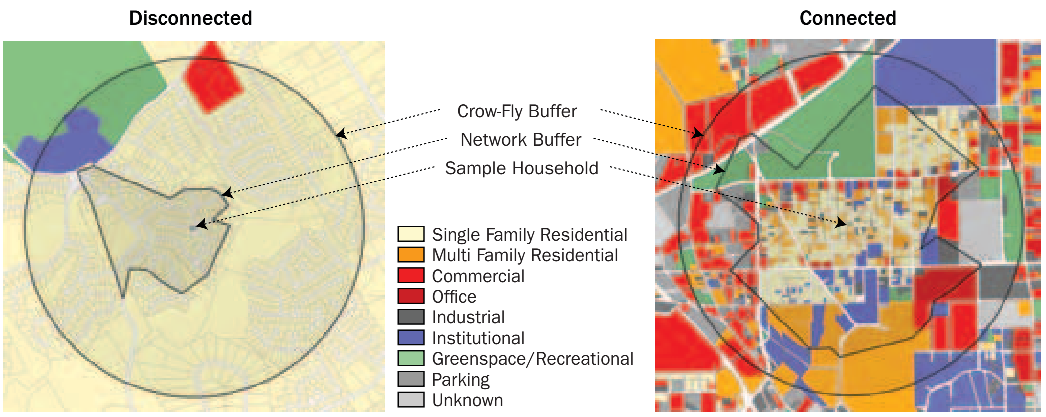


FIGURE 11

Comparative Measurements of Land Use Patterns in Single-use and Mixed-use Neighborhoods



carbon dioxide, physical activity, and body mass index (BMI).

Figure 11 contrasts a household located in a typical low-density, disconnected, single-use neighborhood on the left with another in a compact, connected, mixed-use neighborhood on the right. The circle represents a 1 kilometer radius (the crow-fly buffer) from each household. The analysis measured land use patterns within the smaller, asymmetrical 1 kilometer network buffer, which replicates the area people can access within a six- to ten-minute walk. The connected neighborhood has many more nearby destinations due to the higher densities, mixed land use pattern, and interconnected street networks.

This set of neighborhood-scale urban form measures was supplemented in the analysis by other regional-scale measures such as transit service levels and driving times to address the impacts of regional location and transit service on CO_2 emissions. Demographic and household characteristics, such as income, number of workers, and number of cars for each household, were also taken into account.

Transport-related CO_2 estimates were generated from the PSRC travel survey trip data by calculating CO_2 emissions for each link of each trip based on the road facility type (e.g., for each trip, the distance traveled on local streets, arterials, and freeways), time of day (which determined congestion and thereby travel speed), "cold starts," and vehicle occupancy. This approach provided a more detailed estimate than could be attained using a simple average speed for individual trips.

The estimated emissions for each trip link were then summed at the trip level and linked to the urban form characteristics (including net residential density, retail floor-area ratio, intersection density, land use mix, and park/retail/transit access) within the 1 kilometer walk-shed of each household.

The regression equations produced by this analysis were programmed into I-PLACE^{3}S, enabling the user to estimate how different built environment scenarios affect transport-related CO_2. I-PLACE^{3}S calculates total and per capita CO_2 at the parcel level for each scenario being evaluated.

White Center is one of the few remaining unincorporated urban areas in King County, so officials are strongly interested in making it a more pedestrian-friendly community.

The Greenbridge Hope VI housing development

Zoning in the 98th Street corridor has been changed to increase allowable densities and to both allow and encourage mixed-use development. A direct pedestrian walkway connecting the Greenbridge Hope VI public housing development to the center's commercial district is also being built.

I-PLACE³S estimated that at full build-out these changes would reduce daily household CO_2 from transport from 14.17 to 13.94 kilograms (kg), adding up to a daily reduction of 575 kg for what is a very small study area (about 200 parcels). Additional transit service in the area would reduce per-household CO_2 emissions further, to 12.9 kg per day.

Conclusions

More compact regions featuring walkable, mixed-use centers connected by fast and reliable transit service can lead to large reductions in per capita vehicle miles and hours of travel. Local and regional government agencies therefore have several options to reduce GHG emissions from transportation: expansion or upgrading of transit service by transit agencies; growth management and regional-scale development patterns by state or regional agencies; and neighborhood design through rezoning by local municipalities.

Geographically flexible and versatile applications such as I-PLACE³S can support each of the above options. In its current enhanced version, this tool can inform planning, zoning, development review, and transit/transportation investments, as well as Health Impact Assessment (HIA) in King County. Research results from other urban regions can also be incorporated into I-PLACE³S, creating a tool that is more broadly applicable across the United States and Canada.

Its future expansion to allow estimation of CO_2 generated from building energy operation, in addition to transport, would make a household carbon footprint possible. This would require obtaining data on building energy use from the local utilities in King County and other urban areas.

Planners and developers have "an unprecedented opportunity to shape the landscape" as they expand the built environment to meet growing population needs over the next 25 years (Nelson 2006). Tools such as the enhanced version of I-PLACE³S that provide quantitative, locally relevant evidence about the GHG–urban form relationship will help to ensure that new development minimizes the carbon footprint.

Case Study Consultant

Urban Design *4* Health (UD*4*H) is a leader in the application of research assessing how transportation and community design impacts environmental and health-related outcomes to practice-based decision-making contexts. With a demonstrated track record of applying evidence to real-world decisions at the neighborhood, municipal, regional, and national levels, UD*4*H focuses on informing policy and planning decisions. Using a "pracademic" approach, UD*4*H provides evidence-based advice to its clients on the environmental, health, mobility, and social implications of contrasting fiscal and regulatory strategies.

A view of the Superstition Mountains from part of the study area

Envision Tomorrow: Using Prototype Buildings and Scenario Modeling to Measure Carbon Footprint

Superstition Vistas, Arizona

The Tool

Envision Tomorrow, a suite of urban and regional planning tools developed by Fregonese Associates, is used to model land use decisions at a range of scales. At the site level, this tool can be used to identify financially feasible development opportunities and pinpoint ways to adjust existing land use regulations to encourage new development.

At the neighborhood scale, various mixes of buildings and other attributes (e.g., streets, parkland) can be compiled to evaluate the implications of different styles of development. These buildings and development types can be used to create land use scenarios at the district, city, county, and regional scales. The Envision Tomorrow tool also includes the ability to model the energy use, water use, and carbon footprint of potential development at the building, district, and regional scenario levels.

Building Prototypes. Development of Envision Tomorrow began with a tool called the Return on Investment (ROI) model that tests the physical and financial feasibility of hypothetical development projects. The ROI model can be used to develop building prototypes ranging from single-family homes and mixed-use buildings to regional retail malls and office buildings. It can also measure housing and employment densities, floor-area ratios, impervious surfaces, construction costs, financial feasibility, tax revenue, and other key attributes.

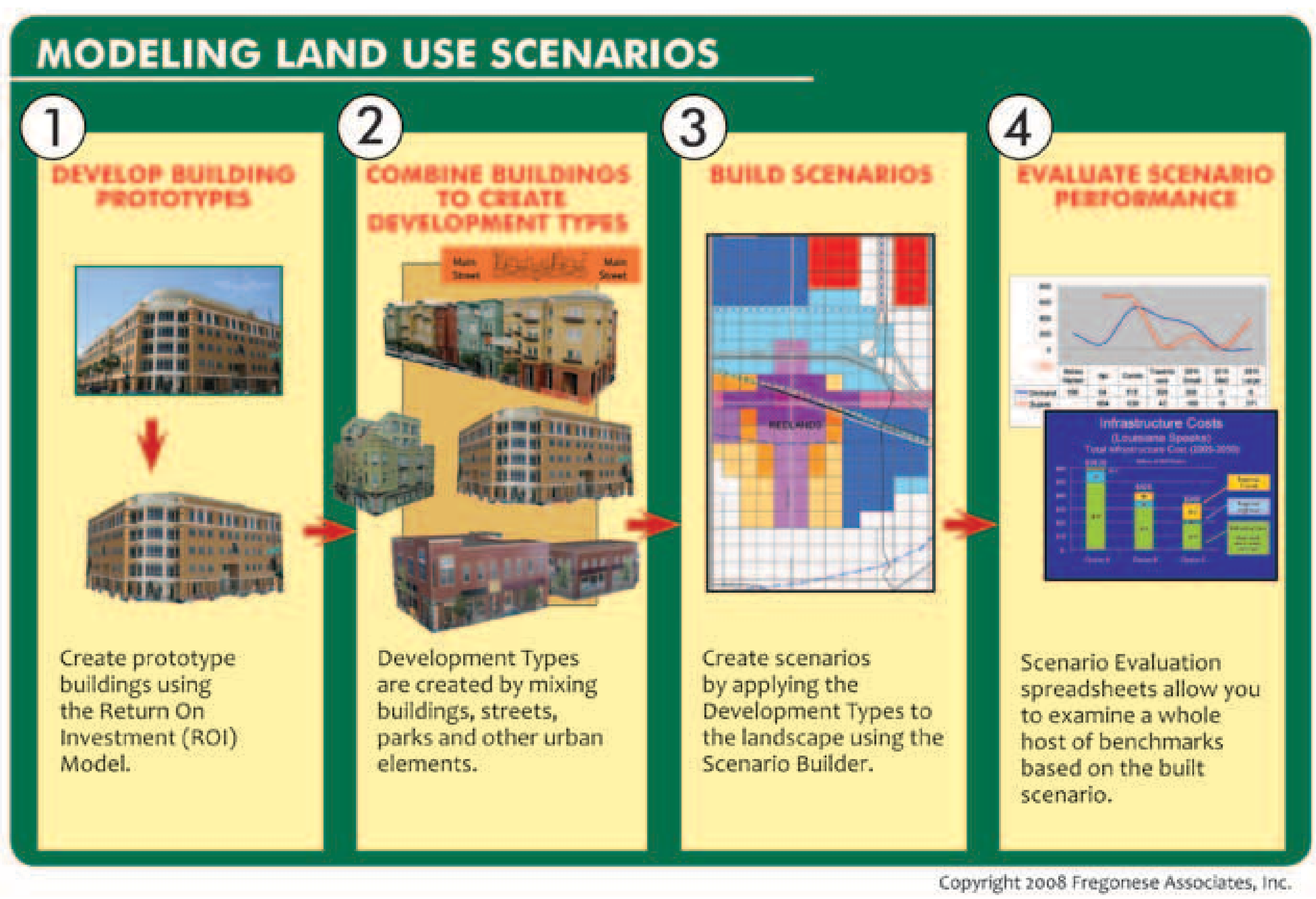
These building types can then be aggregated and combined to form development types—collections of buildings, streets, parks, and civic areas.

Scenario Builder and Scenarios. The tool also includes a Scenario Builder—an ArcMap GIS-based modeling and evaluation application capable of combining different development types into a future growth scenario (figure 12). Ranging from the neighborhood to the regional scale, these scenarios are stories about what might be, not forecasts or predictions. They are possible futures based on what already exists, evident trends, and the values and preferences of the participants. The essential requirement of any scenario is plausibility, within the realm of what exists and what is now known or can be reasonably conceived.

The Project

The Superstition Vistas project seeks to demonstrate opportunities for sustainable development in the Phoenix area that could be an international model for energy- and water-efficient development with a low carbon footprint. The 275-square-mile site at the eastern edge of the Phoenix metropolitan area spreads from the Superstition Mountains Wilderness Area south to Florence, and from the Pinal County line to the eastern edge of Florence Junction (figure 13). This

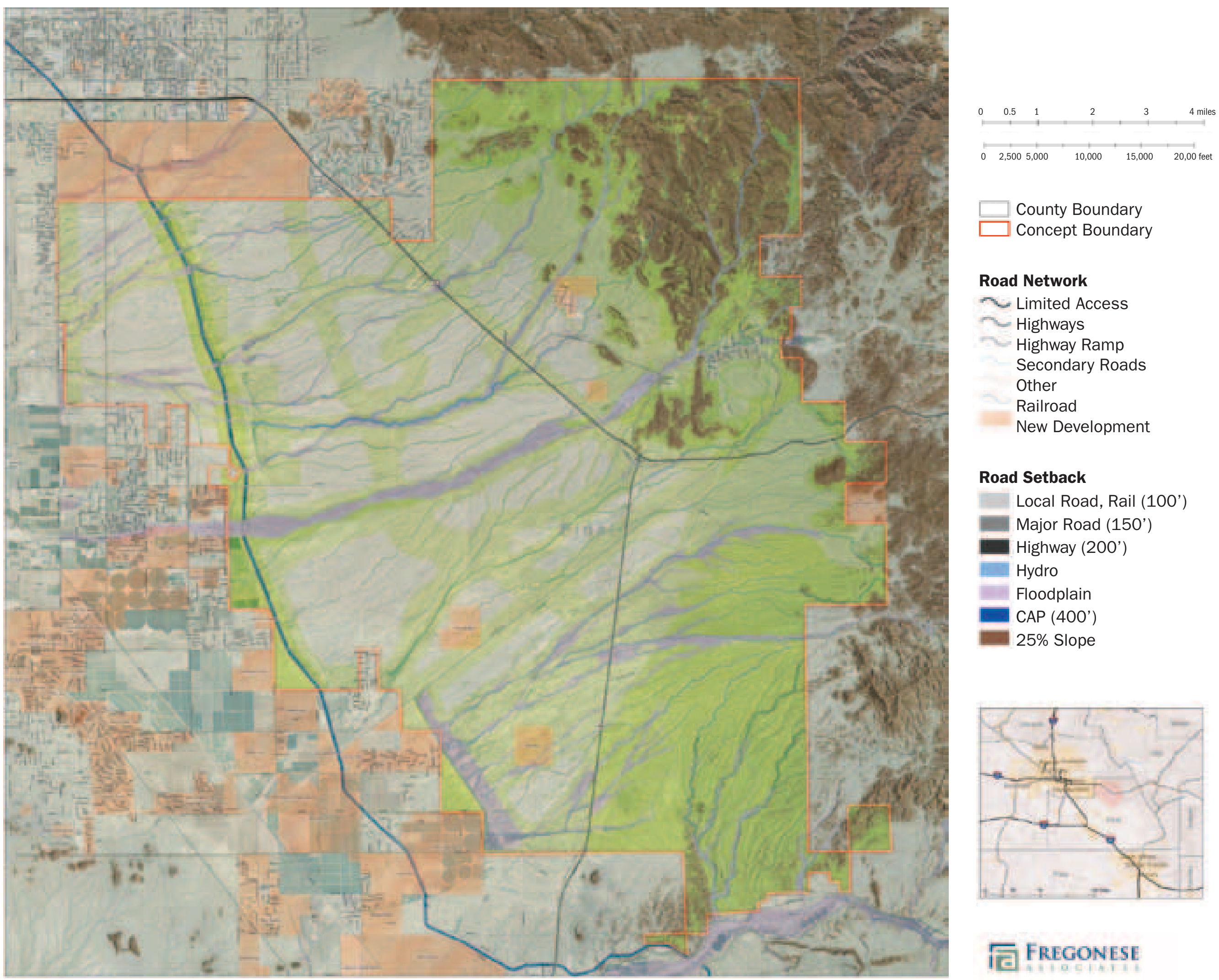
FIGURE 12
Steps for Modeling Land Use Scenarios



state trust land is owned and managed by the Arizona State Land Department for the benefit of school children. Proceeds from land sales are set aside and may be expended only for educational purposes.

Anticipating that the project area may eventually house more than one million people, the East Valley Partnership (EVP) commissioned a study in 2007 to explore ways to maximize long-term urban development sustainability while generating long-term value for education. The EVP, the project's client, is a coalition of civic, business, educational, and political leaders from the East Valley of the Phoenix metropolitan area. The EVP advocates in areas such as economic development, education, transportation, and infrastructure. The Sonoran Institute, another key partner in the project, sums up the area's potential as the "singular most significant planning opportunity in the United States" (Dougherty 2009).

FIGURE 13
Boundaries of the Superstition Vistas Project Area



The Methodology

The Envision Tomorrow scenario modeling process is based on a development pattern methodology, which grew out of the ROI model that incorporates inputs, including construction and land expenses, expected rents, and sales prices, to evaluate a project financially. Combinations of varied building prototypes, along with other urban attributes such as streets, parks, and public amenities, were then created to form a variety of development types, including urban cores, traditional downtowns, town centers, business parks, neighborhood retail, traditional neighborhoods, and residential subdivisions.

The business park development type, for example, is comprised of a mix of office buildings and retail space, and includes acreage dedicated to right-of-way, parks, and public facilities. These development types serve as the building blocks for creating large-scale regional scenarios. Each of the 20 development types used in the Superstition Vistas project were created using up to 12 building types.

Expanding on this basic building prototype approach, the project incorporated energy performance data into 12 prototype buildings, ranging from single-family homes to large mixed-use buildings and industrial and office complexes. This involved the development of a base energy use assumption, along with three levels of improvement representing 30 percent, 50 percent, and 80 percent reductions in energy use for four different scenarios (figure 14).

Estimates of carbon dioxide emissions were developed, as well as energy use from electricity and natural gas. In each case, both the additional costs and energy savings were estimated, allowing the team to understand the potential GHG emission implications of different scenario designs in the project.

The Envision Tomorrow user builds land use and transportation scenarios that represent a range of possible futures, essentially by digitally painting the study landscape with a range of possible development patterns based on the results of public involvement, the current trend, and coordinated land use and transportation strategies. The scenarios created can range from business-as-usual to compact development in which growth is concentrated in centers or along corridors.

FIGURE 14
Incremental Improvement Costs After Energy Reductions from Baseline

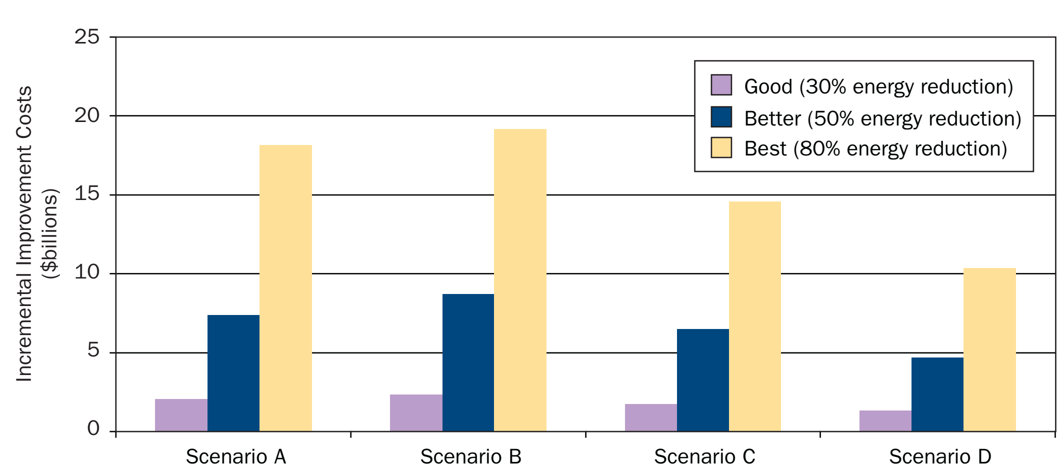
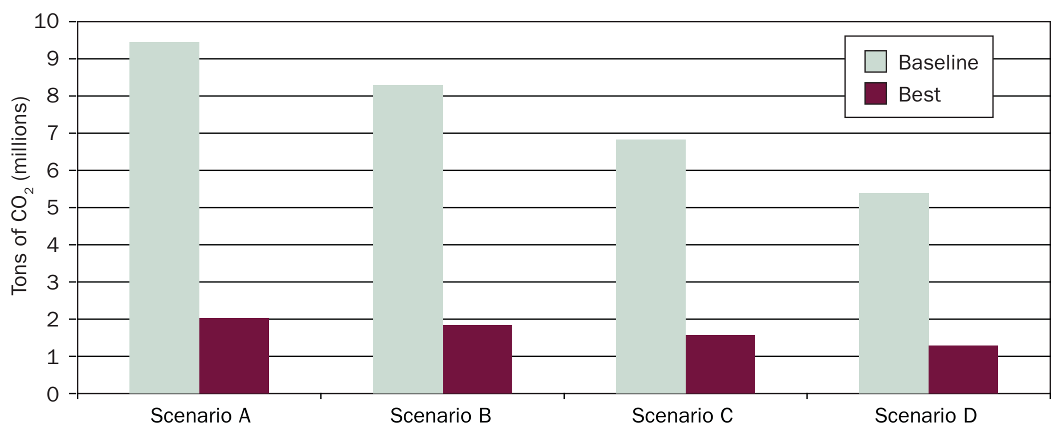


FIGURE 15
Total Carbon Footprint of Annual Building and Transportation Emissions



Outputs from the Scenario Builder can be fed easily into the traditional four-step transportation model. In the case of Superstition Vistas, the Pinal County transportation model was used to calculate traditional transportation outputs along with estimates of the carbon emissions from motorized vehicles (figure 15).

The final scenarios are subjected to a series of tests to evaluate their individual impact on the study area's housing mix, transportation network, environmental features, open space, natural areas, and economic development. Sustainability performance measures are prioritized in these evaluations. Furthermore, using the building prototype as a methodological foundation enables measurement of indicators that were previously difficult to calculate, such as the increased value and probable rent levels for residential and commercial buildings, the amount of water consumed, the number of retail employees, and even the total area of rooftops or parking lots.

Conclusions

Through the application of the Envision Tomorrow's development type methodology in Superstition Vistas and other projects, a number of patterns and design lessons have emerged. While this work is in its preliminary stages, it appears that the concept of using building prototypes to model large-scale scenarios is a powerful one that can be used in a variety of applications.

- *Building in a "greener" fashion is a key strategy.* In the past many land use scenarios have focused on efficient land use that reduces transportation expenditures. This is effective, but the impact of developing buildings to a greater level of energy efficiency is often several times more efficient in reducing greenhouse gas emissions and energy consumption.
- *The combination of multimodal land use and transportation design and building improvements can have a huge impact on carbon emissions.* Preliminary results from the Superstition Vistas work indicate reductions of 50 to 60 percent in carbon emissions are possible with good design and current technologies.
- *Developing higher density building forms can reduce their carbon impact while accommodating the same population forecast.* The end result is that on a per capita basis the buildings consume less energy and have a smaller carbon footprint, even without any investment in energy efficiency. In the case

of Superstition Vistas, the more compact scenarios reduced carbon emissions by 20 to 25 percent, even without any improvements in building technology.

- *The costs of improving energy efficiency vary widely among the prototype buildings.* Some building types may have considerably higher costs than others to achieve comparable improvements; this is important to consider when designing policy recommendations. If it is very expensive to achieve energy reductions in some building types, the funds might be better spent in developing carbon neutral energy generation, rather than in energy conservation.
- *Achieving a better jobs/housing balance is a key to reducing transportation-related carbon emissions.* A low carbon footprint from transportation sources is difficult to achieve without a successful economic development program. Additionally, the housing stock has to be affordable for the local workforce, otherwise commuters will be forced to travel longer distances from areas that are affordable, thus increasing carbon emissions from transportation.

Case Study Consultant

Fregonese Associates in Portland, Oregon, has been creating and applying development types as a way to model future growth and development since the early 1990s. This approach achieves effective simulation of building scale and density, pedestrian-friendliness, and transit-orientation while working at a neighborhood, citywide, or regional scale. Evolving from the early development types first used in Portland Metro's 2040 process, Envision Tomorrow can be used to create a range of land use scenarios quickly, and at a number of different scales.

Development Pattern Approach: Measuring GHG Impacts of Land Use Decisions

City of North Vancouver, British Columbia

The Tool

A Development Pattern Approach (DPA) methodology was applied during this collaborative process to evaluate the energy and GHG implications of various urban form scenarios, both baseline conditions and future visions, and to support informed stakeholder decision making.

Development patterns are discrete and replicable representations of specific elements of urban form that can be combined spatially and quantitatively into cities or regions. They can be used to approximate present-day land use conditions, or create desired future scenarios. The urban form characteristics include land use mix, development densities, street patterns, housing types, building geometries, commercial and residential floor areas, and block and parcel configurations (figure 16). Beyond this, development patterns represent several distinct functions of urban form: corridors, nodes, and fabric (the areas of land existing between a network of corridors and nodes).

In this North Vancouver project, the Development Pattern Approach was expanded to allow for calculation and mapping of GHG emissions. The development patterns were used as inputs to two models that measured the scenarios' building- and transportation-related GHG consequences.

They also were used to build representations of the present (2007) development scenario, as well as the 100-year development scenario produced by stakeholders and project participants. This allowed researchers to estimate GHG emissions for both scenarios, and produce spatial and visual GHG maps representing emissions intensity across the city. In turn, this enabled visual comparisons between the city's current conditions and future alternatives, helping stakeholders incorporate low-GHG land use decisions into the concept plan (figure 17).

Current and simulated views illustrate the intersection of Londsdale Avenue and 8th Street in 2007, 2050, and 2107.

The Project

The 100 Year Sustainability Vision was a multistage project conducted in the City of North Vancouver in 2007–2008 to develop

FIGURE 16

Parcel, Street, and Open Space Cases in a Development Pattern

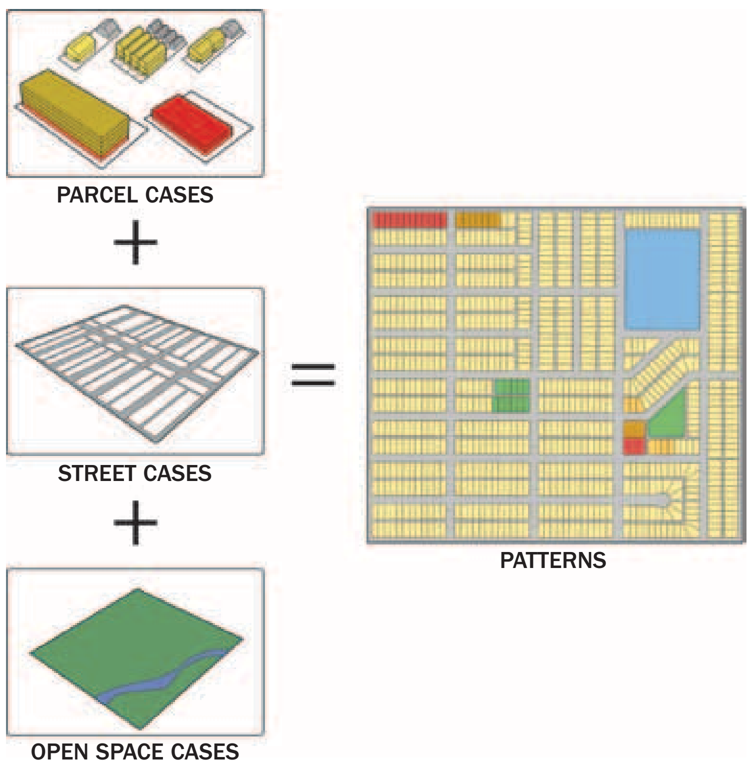
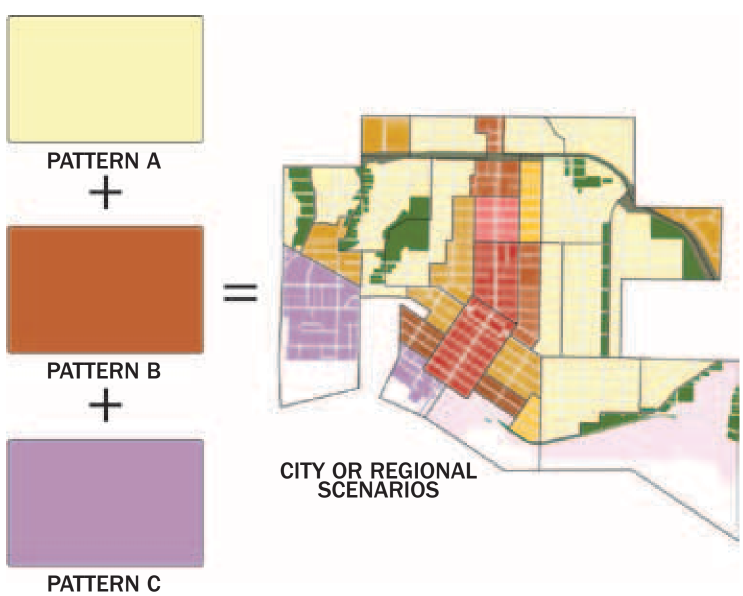


FIGURE 17

Development Patterns Assembled into Scenarios



a long-term sustainable concept plan to accommodate significant population growth while creating a vibrant, diverse, and highly livable community able to provide for social and economic needs within a carbon neutral environment. Guided by the Province of British Columbia's recently introduced Greenhouse Gas Reduction Targets Act, the project also aimed to create a plan to reduce GHG by 80 percent below 2007 levels by 2050, and to achieve zero net emissions by 2107.

The collaborative project engaged local and regional community stakeholders, city staff, utilities representatives, researchers, and others in a planning process over several months, culminating in a four-day intensive design charrette. During this process, stakeholders worked with project researchers to assess alternative development scenarios and generate a long-term, low-GHG vision for the city (figures 18 and 19).

The Methodology

The development patterns used in this project were constructed from information contained in a database created and maintained by the ElementsLAB research group within the Design Centre for Sustainability at the University of British Columbia. This database contains a comprehensive collection of parcel-scale examples of streets, open spaces, and buildings across a range of densities and forms.

Each of these examples contains visual and quantitative information, including three-dimensional digital models, site plans, and data on floor-area ratios, uses, parcel coverage, and number of residential units. These street, open space, and building cases can be assembled using spreadsheets, GIS, or other spatial modeling platforms such as Google SketchUp to generate development patterns. Replacing one case for another can quickly generate variations of patterns; for

FIGURE 18

Initial Sketch Digitized for a GIS Development Pattern Map

FIGURE 19

Development Patterns as Assigned in GIS During the Charrette

example, a single-family house case might be replaced by a duplex within a pattern to explore the impacts of densification.

To model the energy demand and GHG emissions from the buildings in the scenarios, building energy profiles—quantitative descriptions of energy consumption by end use and energy source—were created for each type of building used in the development patterns: single-family detached houses; duplexes; row houses; low-rise apartments; high-rise apartments; commercial buildings; institutional buildings; and industrial buildings.

The model used to calculate energy consumption was very simple: using a per unit (for residential buildings) or per square meter (for other buildings) annual energy demand estimation, total energy demand was derived for the entire development pattern. The data used to calculate energy consumption was derived from current aggregate figures for the entire region, while future energy consumption was calculated by taking into consideration changes in building technologies, energy source, and changes in user behavior.

The model used to calculate transportation demand and associated emissions is presently coarse and under further development. Transportation-related GHG calculations in this project were limited to trips that begin or end at a residential unit within the project area. While this definition does not capture all transportation GHG emissions (in particular, it misses the considerable GHG emissions of people traveling from other locations to the project area to shop or work), it was deemed suitable for the purposes of the charrette process, which was targeted at the ability of the local government to reduce resident-based emissions.

The transportation-related GHG emissions for each development pattern were modeled as a product of the types of units (different unit types generate different numbers of trips/day, with stacked and attached units generating fewer than larger single-family units), total trip length, vehicle efficiency/fuel assumptions, and mode split.

Conclusions

The City of North Vancouver's 100 Year Sustainability Vision project is one of the first municipal-level projects in British Columbia to consider how specific land use, building form, transportation, and infrastructure decisions will contribute to reducing energy consumption and GHG emissions, while supporting other environmental, social, and economic goals.

The development pattern method for quantifying and spatializing GHG emissions used by this project created a standardized and consistent means of measuring and comparing alternative land use scenarios—from current conditions for which a wide variety of data exists to a 100-year future about which relatively little is known. Rather than making time-consuming, parcel-by-parcel design decisions, project participants were able to assign general land use patterns to all areas of the city, while adding greater amounts of detail to sensitive or otherwise important areas (figures 20 and 21).

Additionally, the quantitative and design-based results of the project suggest that the DPA methodology has significant potential to inform decision making on urban form and GHG emission reductions during a fast-paced, collaborative planning process. Development patterns support iterative decision making. Using this approach to discuss and evaluate urban form decisions during the design charrette allowed for live feedback from researchers using GIS analysis on performance issues such as population and job targets, thereby informing iterative revisions of the 100-year vision to be adjusted during the four-day charrette.

FIGURE 20

Spatialization of Energy Demand per Unit for 2007 Baseline

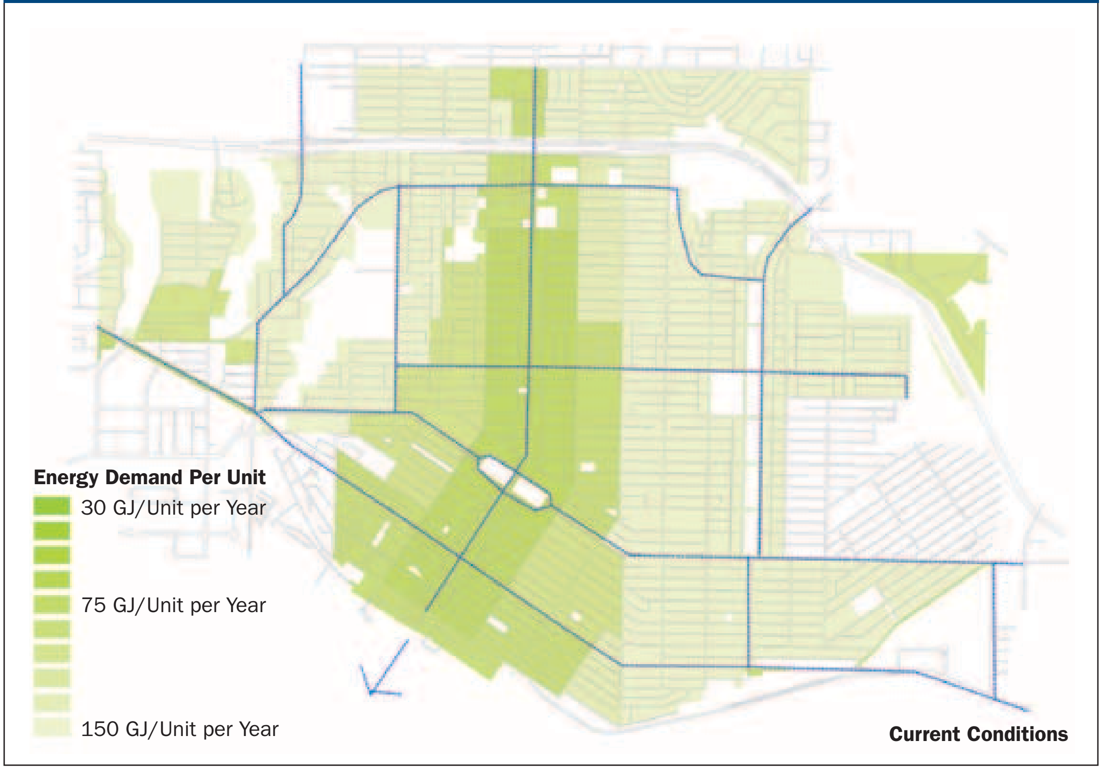
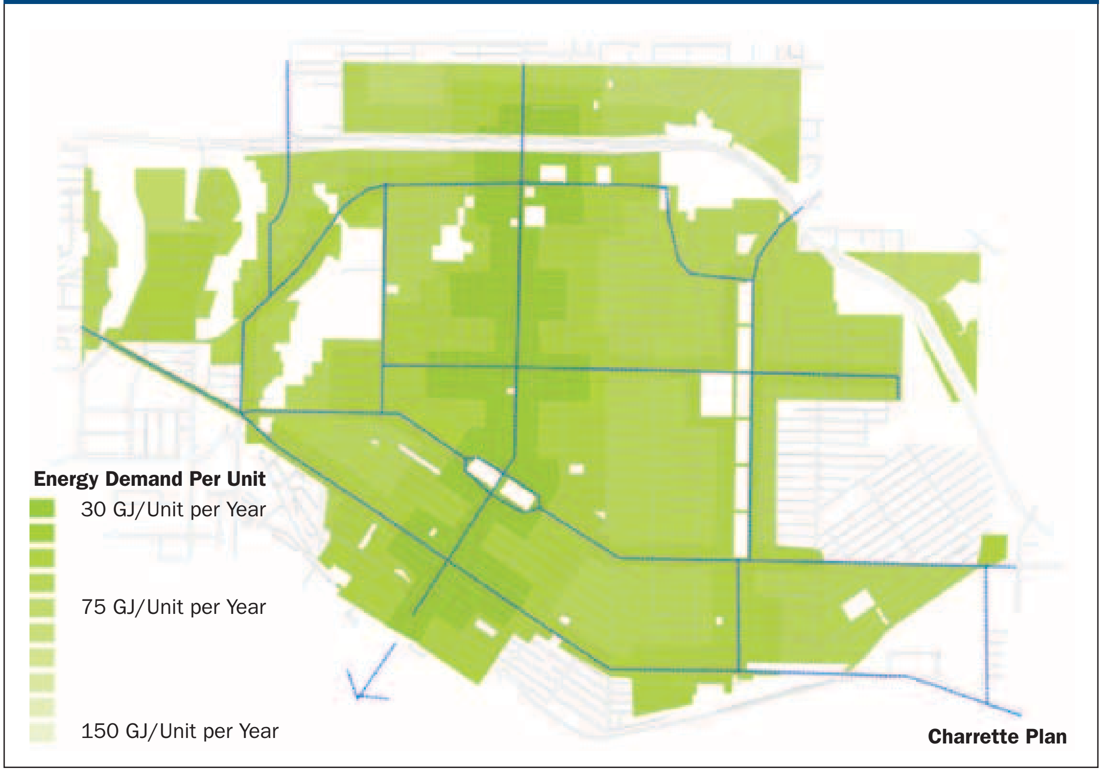


FIGURE 21

Spatialization of Energy Demand per Unit for Charrette Scenario



Because development patterns use the same types of planning data commonly available to local governments, the concept plan developed during the charrette is readily translatable to future policy and implementation processes, such as density targets, land use designations, and building design guidelines.

This project represents a first attempt to address the complex issues of GHG emissions accounting and reductions, urban design, long-term decision making, land use and transportation planning, and collaborative planning processes. While the results of this project are encouraging, additional research will be required to improve the development pattern methodology. Ongoing work to improve the approach includes:

- adding additional detail to the underlying building cases to allow development patterns to take into account parcel-level variations in building design, vintage, or mechanical systems;
- linking the DPA method with existing transportation models, including University of Toronto's TASHA model (Roorda, Miller, and Habib 2008) and MATSIM (Balmer et al. 2008) in order to improve the validity of the transportation-related GHG estimates;
- improving the representation of block-level considerations such as building orientation and shading that may further affect building energy consumption;
- developing proxy measures for patterns to represent renewable energy potential; and
- improving the level of automation in the software components to allow faster turn-around during charrette events.

In spite of these needed changes, the Development Pattern Approach represents a significant step forward in providing a modeling tool that can both evaluate GHG implications of different planning scenarios and be integrated into charrettes, workshops, and other typical planning processes.

Case Study Consultant

The University of British Columbia's Design Centre for Sustainability is an academic leader in applying sustainability concepts to the development of land, cities, and communities. DCS has led a range of research and on-the-ground projects incorporating background research, processes, and tools for shifting community planning and design toward a consideration of sustainability as a matter of course, rather than exception. The City of North Vancouver project was the fifth case study of the DCS Sustainability by Design program, a multiyear collaborative effort to produce a visual representation of what the Greater Vancouver region might look like in 2050, at neighborhood-, district-, and region-wide scales.

CHAPTER 5

Conclusions and Recommendations

Providence, Rhode Island

Cities and other urbanized areas are home to more than half of the world's population and have generated the lion's share of GHG emissions. A better understanding of the links between urban form and GHG emissions is essential to create successful climate change mitigation strategies.

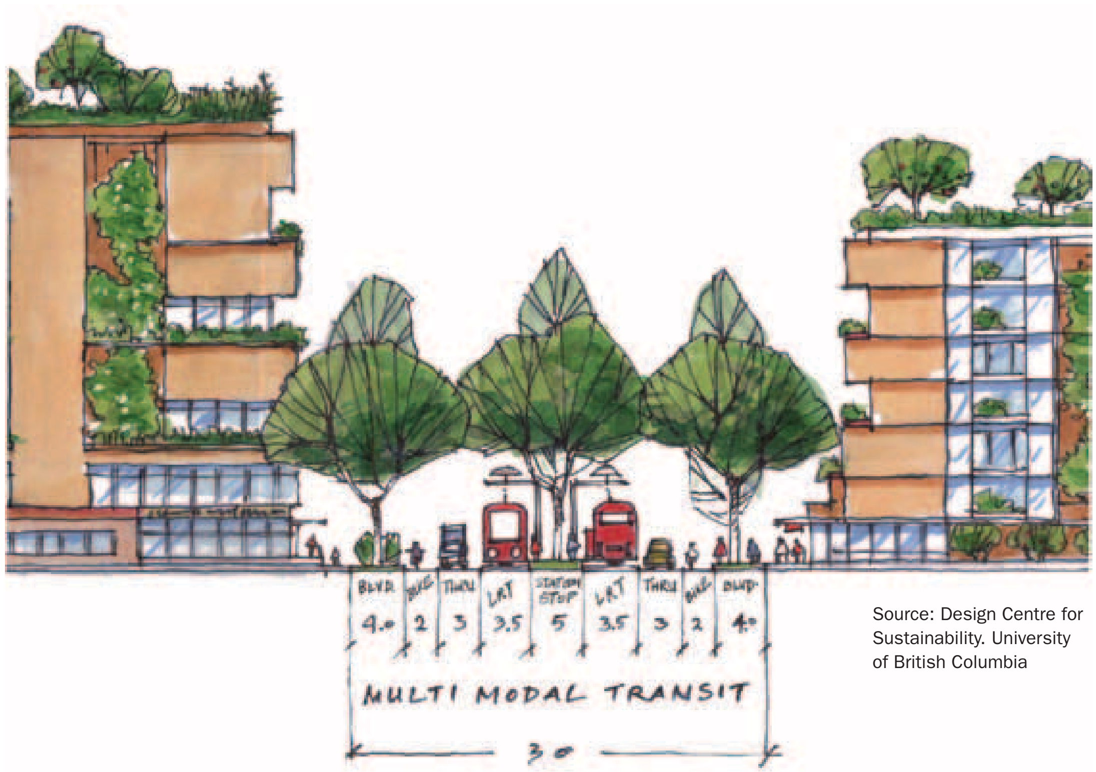
To aid in performing this vital task, a tool, or suite of tools, must be capable of providing a broad set of measurements and evaluative criteria. Available tools, including some not described in this report, are still incomplete, difficult to access, or challenging to use. Some require the guidance of skilled operators and large amounts of time and resources, while others are so oversimplified that they lose the ability to model the relationship between urban planning and GHG emissions.

While no one tool can yet address all of the desiderata identified by officials and experts in our research and conferences to date, the potential to build on the strengths of existing tools is promising. Continued tool development will serve to enhance connections among various tools, create new methods of evaluating urban form and GHG emissions, and establish test cases through which new tools can be applied and refined.

An ideal tool or integrated suite of tools should have the following characteristics.

Comprehensive

The tool should capture the GHG contributions of all relevant sectors, including build-



Source: Design Centre for Sustainability. University of British Columbia

ings and transport, and support the consideration of additional criteria related to the economy and livability. Sustainable urban design issues overlap, so the consequences of GHG-oriented decisions on associated concerns need to be revealed clearly. For example, a climate-focused planning strategy could have a serious impact on housing costs. Absent realistic assessment of these costs, decisions about future housing development might be rendered counterproductive or politically infeasible.

Three-dimensional

The tool should be grounded in the three-dimensional physical realities of the urban spaces it seeks to model. Moreover, tools should provide vivid and accurate descriptions of the consequences of future community design to avoid inhibiting the ability of planners to communicate the real-world implications of proposed actions.

Multi-scalar

The tool should be able to connect top-down (from regional and higher levels to the block scale) with bottom-up analysis, responding to the interactions between incremental site-scale decisions and regional and higher-level decisions on GHG emissions. This would require a facility to assess both a single-family subdivision and a new freeway, for example.

Policy-relevant

The tool should be supportive of the way policy is made and implemented, in terms that are direct and useful to decision makers. The tool must move fluidly between processes that generate GHG performance data and the policies that might influence this performance.

Iterative

The tool should have the capacity to test alternative scenarios in real time, including within multi-stakeholder decision processes and design and planning charrette environments, in order to produce results that can be evaluated rapidly and incorporated into plan modifications and improved outcomes.

Additive
The tool should build on and link to existing models and related applications.

Accessible
New tools need to be intelligible to a wide range of stakeholders, use a common language and interface, and have transparent outputs.

Affordable
The tool should be relatively inexpensive to acquire, and should require realistic staff and consultant time to obtain useful results. Current tools are often costly and labor-intensive.

To produce such a tool or suite of tools may appear daunting, but the need is great. We are poised to make planning and policy decisions at the international, national, state, provincial, regional, and local levels that will have potentially enormous consequences. Yet planners, developers, public officials, and citizens generally are not well equipped to set policies and evaluate the consequences of urban planning decisions aimed at reducing GHG emissions.

Within the North American context, most planning decisions are made at the local level, but the impacts of these decisions will be widespread. By the same token, as some jurisdictions begin to set targets for reducing emissions and allocating these reductions across sectors and geographies, they need to understand the potential, and limitations, of the role of urban planning in that process.

Perhaps the most critical gap we have identified is the inability of tools to move up and down the various scales to support effective planning and regulatory decisions, and to set and adjust policy. This report on the tools currently available to help reduce GHG emissions through urban planning illuminates their general approaches, scales, and utility in decision making. It can guide public officials and proponents of development projects in making better informed decisions with respect to climate change impacts, and help modelers and tool developers identify critical needs as they design the next generation of planning support tools and processes.

An urban garden path along a former railway corridor in Vancouver

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WEB RESOURCES

Tools

Athena Impact Estimator for Buildings
www.athenasmi.org/tools/impactEstimator/index.html

Community Energy and Emissions Inventory (CEEI)
www.env.gov.bc.ca/epd/climate/reduce-ghg/ceei-reports.htm

CommunityViz
www.communityviz.com

Development Pattern Approach (DPA)
www.env.gov.bc.ca/epd/climate/pdfs/ceei-nvan.pdf

Energy Demand Characterization (formerly the Canadian Urban Archetypes Project)
http://canmetenergy-canmetenergie.nrcan-rncan.gc.ca/eng/buildings_communities/communities/urban_archetypes_project.html

Envision Tomorrow
http://www.frego.com/projects/documents/envisiontomorrow_info.pdf

INDEX and Cool Spots
www.crit.com/documents/cool_spots.pdf

I-PLACE^{3}S
www.ruralgis.org/conference/2003proceedings/dayTwo/CommunityPlanning/morning_Session2A/place3s_McKeever.pdf

MetroQuest
www.metroquest.com

Neighborhood Explorations:
This View of Density
www.greenplaybook.org/resources/tools/tool_details95.htm

Tool for Evaluating Neighbourhood Sustainability
www.cmhc-schl.gc.ca/en/co/buho/sune/sune_007.cfm

UPlan
http://ice.ucdavis.edu/doc/uplan

Case Study Consultants

Criterion Planners
Portland, Oregon
www.crit.com

Design Centre for Sustainability
University of British Columbia, Vancouver
www.dcs.sala.ubc.ca

Fregonese Associates
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Andrew Contugno
Eric de Place
John Fregonese
Scott Fregonese
Cynthia Girling
Jay V. Hicks
Terry Hoff
Brian Hollingworth
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Ron Kellet
Gil Kelley
David Kooris
Andrew Laurenzi
Renee Lazarowich
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April 2008 Workshop
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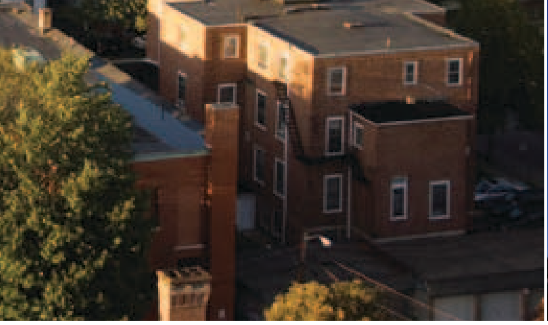

Urban Planning Tools for Climate Change Mitigation

This report focuses on the present state of tools to model and evaluate the relative climate change benefits of alternative development approaches in cities, ranging from the project to the neighborhood to the metropolitan scale. Continued tool development will enhance connections among various tools, create new methods of evaluating urban form and GHG emissions, and establish test cases though which new tools can be applied and refined.

An ideal tool or integrated suite of tools should have the following characteristics.

- ***Comprehensive:*** able to capture the GHG contributions of all relevant sectors, including buildings and transportation, and support the consideration of additional criteria related to the economy and livability.
- ***Three-dimensional:*** grounded in the physical realities of the urban spaces they seek to model, and able to provide vivid and accurate descriptions of the consequences of future community design.
- ***Multi-scalar:*** able to connect top-down (from regional to block scale) with bottom-up analysis and respond to the interactions between incremental site-scale decisions and regional and higher-level decisions on GHG emissions.
- ***Policy-relevant:*** supportive of the way policy is made and implemented, in terms that are direct and useful to decision makers.
- ***Iterative:*** capable of testing alternative scenarios in real time, including within multi-stakeholder decision processes and planning charrette environments, to produce results that can be evaluated rapidly and incorporated into plan modifications for improved outcomes.
- ***Additive:*** able to build on and link to existing models and related applications.
- ***Accessible:*** intelligible to a wide range of stakeholders, using a common language and interface with transparent outputs.
- ***Affordable:*** relatively inexpensive to acquire and easy to use by staff and consultants to obtain useful results.

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