Climate Change and Land Policies

Edited by

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LINCOLN INSTITUTE
OF LAND POLICY
CAMBRIDGE, MASSACHUSETTS

Library of Congress Cataloging-in-Publication Data

Climate change and land policies /
edited by Gregory K. Ingram and Yu-Hung Hong.
p. cm.
Conference proceedings.
ISBN 978-1-55844-217-7
1. Land use, Urban—Congresses. 2. Climatic changes—Government policy—Congresses. 3. Climatic changes—Environmental aspects—Congresses. I. Ingram, Gregory K. II. Hong, Yu-Hung.
HD1391.C64 2011
333.73'13—dc22 2011003415

Designed by Vern Associates

Composed in Sabon by Achorn International in Bolton, Massachusetts.
Printed and bound by Puritan Press Inc., in Hollis, New Hampshire.
♻ The paper is Rolland Enviro100, an acid-free, 100 percent PCW recycled sheet.

MANUFACTURED IN THE UNITED STATES OF AMERICA

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PREFACE

The impacts of climate change are recognized around the world: sea-level rise, powerful storms, flooding, and drought. Although scientists have not conclusively linked individual weather events to global warming, policy intervention is advisable to reduce the growing risks of significant economic and social damages linked to climate change. As an example of such damages, in February 2011 Cyclone Yasi hit Queensland, Australia, and destroyed half of its annual sugarcane and banana production, valued at AU$500 million (US$500.37 million). A recent study by Min, Zhang, Zwiers, and Hegerl (2011) also shows that human-induced increases in greenhouse gases have contributed to the intensification of heavy precipitation found over two-thirds of the Northern Hemisphere. To examine the role of land policy in designing and implementing climate change programs, the Lincoln Institute of Land Policy held a conference in Cambridge, Massachusetts, in May 2010. The chapters and commentaries in this book summarize the ideas discussed at that meeting.

Five themes emerged from the discussion. First, assessing the impacts of climate change on land use is complex and uncertain. Because climate impacts vary across regions and there is a lack of standardized models to predict climate outcomes, general statements about the effects of climate change on land use are difficult to make. Second, the major land use challenge for implementing renewable energy policy is the siting of facilities. Opposition from local communities and environmental groups may block the construction of wind farms, solar power plants, and transmission lines in their neighborhoods, which can in turn impede the adoption of alternative energy sources. Third, in designing urban form and transportation policy to reduce automobile use and fuel consumption, policy makers should pay more attention to employment density in cities because it is emerging as a key determinant of transit use. Congestion pricing also shows great promise as a tool to encourage public transit use. Fourth, while market approaches can facilitate environmental conservation by including the values of environmental services in market prices, this approach is challenged by the difficulty of valuing environmental services and by the complexity of negotiating and enforcing contractual agreements. Public and private property rights, local customs, attitudes toward technology and markets, and government capability all play important roles in the use of market mechanisms to preserve natural forests and environmentally sensitive sites. Fifth, strong leadership at the international and domestic levels is urgently needed to coordinate environmental initiatives to achieve a collective climate change policy. The chapters and commentaries in this volume present various perspectives on these issues.

The publication of this book has been a collaborative effort. We thank the authors and commentators for their willingness to share their insights and knowledge. We also thank Armando Carbonell and Peter Pollock for their assistance in the conference program's design. We appreciate the logistical support provided

by our conference planning team, which includes Melissa Abraham, Brooke Burgess, and Rie Sugihara. Last but not least, special thanks go to the volume's editors and designers, including Nancy Benjamin, Carol Keller, Barbara Jatkola, and Vern Associates, and especially to Emily McKeigue, who effectively managed this effort.

Gregory K. Ingram
Yu-Hung Hong

REFERENCE

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Introduction

1

Land Policies in the Face of Climate Change

Gregory K. Ingram and Yu-Hung Hong

In recent years, many nations and global environment interest groups have sought agreements on policies to keep climate change in check. Following the failure to reach an official agreement at a high-level conference in Copenhagen in December 2009, representatives of countries from around the world met again in November 2010 in Cancún. This time, pledges from rich countries to cut their greenhouse gas emissions by 2020 were formally put into UN documentation. Meanwhile, the ongoing increase in greenhouse gas emissions continued to exacerbate drought, high peak temperatures, and extreme weather patterns. If these emissions remain unabated, many scientists predict wetter weather for much of Southeast Asia (where seasonal flooding is a constant threat) and less rain in the dry areas of southern Africa and the southwestern United States. The earth's northern latitudes will become warmer and more arable, whereas the tropics and subtropics will become drier and less hospitable for human habitation. These changes in global temperatures and the subsequent relocation of human settlements and economic activities are likely to have huge economic and social impacts on the world's population.

Greenhouse gases include water vapor, carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), ozone (O_3), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulfur hexafluoride (SF_6). Table 1.1 illustrates the various sources of anthropogenic greenhouse gas emissions produced by all countries in 2000. CO_2 accounted for 77 percent of the total emissions, of which 24.6 percent was from electricity and heat generation (UNEP/GRID-Arendal 2008). Deforestation also caused a fair amount of CO_2 emissions and was responsible for 18.2 percent of the total greenhouse gas emissions in that year. Industry, transportation, and

Table 1.1
Global Anthropogenic Greenhouse Gas Emissions, by Sector and Source, 2000 (%)

CO_2	77.0
Electricity and heat	24.6
Deforestation	18.2
Industry	11.8
Transportation	9.5
Other fuel combustion	9.0
Fugitive emissions	3.9
CH_4	14.0
N_2O	8.0
HFCs, PFCs, and SF_6	1.0
Total	100.0

Source: UNEP/GRID-Arendal (2008).

other fossil fuel combustion contributed 11.8, 9.5, and 9 percent, respectively, to total CO_2 emissions.

In the United States, CO_2 accounted for 85 percent (5.9 billion metric tons CO_2 equivalent [Eq.]) of total anthropogenic greenhouse gas emissions in 2008 (EPA 2010). Table 1.2 shows the various sources of CO_2 emissions in the United States; 94.1 percent of emissions stemmed from fossil fuel combustion. Within this category, electricity generation accounted for 39.9 percent. Transportation was the second-largest contributor (30.2 percent), followed by industrial (13.8 percent) and residential (5.8 percent) fossil fuel combustion. These data clearly indicate that climate policy should be targeted at energy, transportation, and deforestation, strategies likely to have significant impacts on land use. Moreover, land policy, such as coastal zone planning and the design of urban form and transportation, could have significant implications for mitigating CO_2 emissions and adapting to new climate conditions.

To examine the relationships between climate change and land policy, the Lincoln Institute of Land Policy organized a conference in May 2010 for international scholars and policy makers to present papers and exchange ideas on this subject. Chapters and commentaries in this book summarize the presentations and discussions at the meeting. This chapter introduces those essays and is structured according to the five topics explored at the conference.

The first section assesses the likely impacts of climate change on land use; the second section examines how energy and climate change policies affect land resource allocation and land use planning; the third section analyzes the relationships among urban form, transportation, and CO_2 emissions; the fourth section

Table 1.2
Anthropogenic Carbon Emissions in the United States, 2008

	Million Metric Tons CO_2 Eq.	Percent
Fossil fuel combustion	5,572.8	94.1
Electricity generation	2,363.5	39.9
Transportation	1,785.3	30.2
Industrial	819.3	13.8
Residential	342.7	5.8
Commercial	219.5	3.7
U.S. territories[a]	42.5	0.7
Nonenergy use of fuel	143.2	2.4
Iron and steel production and metallurgical coke production	69.0	1.2
Cement production	41.1	0.7
Natural gas systems	30.0	0.5
Lime production	14.3	0.2
Incineration of waste	13.1	0.2
Ammonia production and urea consumption	11.8	0.2
Others	25.9	0.4
Total	5,921.2	100.0[b]

[a]U.S. territories include Midway Islands, Puerto Rico, American Samoa, Virgin Islands, Federated States of Micronesia, Marshall Islands Majuro, Northern Mariana Islands, Palau Koror, and Guam.
[b]The total does not add up to 100% because of rounding.

Source: EPA (2010).

explores selected market-based approaches to environmental conservation; and the fifth section evaluates the global environmental governance structure and U.S. federalism with respect to their ability to deal with climate change and public land management issues.

Climate Change and Risk Assessment

In 2007, the World Bank published a working paper predicting that 84 coastal developing countries could be threatened by rising sea levels if no mitigating measures were taken (Dasgupta et al. 2009). Among the countries studied, Vietnam was found to be the most vulnerable: a three-foot rise in sea level would

displace 11 percent of its population (roughly 17 million people) from the Mekong Delta. Of course, this prediction was drawn from a distribution of possible outcomes whose probability varies greatly and was based on an environmental risk assessment. In like manner, chapters in this section of the book assess the likely ranges of risk, identify the main sources of uncertainty, and evaluate different land management and human resettlement approaches to dealing with potential coastal flooding in the United States and around the world.

In chapter 2, Bruce Babbitt argues that the most extensive land use impacts in the United States caused by climate change will occur along coastlines. Rising sea levels are already encroaching on lowland regions, leading to coastal flooding and increased salinity of groundwater. Two approaches can be used to prevent flooding: (1) building levees and seawalls to hold back the seawater; and (2) relocating infrastructure and settlements to higher ground. Babbitt asserts that the first method can destroy coastal wetlands of significant ecological value and adversely affect the fishing industry. Although the second method may concede some land to the sea, it lets adjacent wetlands migrate inland, allowing habitat and fisheries to adjust naturally to the changing environment. Adaptation by relocating development and human settlements away from the shore will require regional land use planning that entails a high level of community participation and analyses incorporating hydrology, social sciences, ecosystem science, and resource economics.

Among the various challenges of relocation, the financing of coastal infrastructure reinvestment is paramount. Babbitt proposes setting up a coastal infrastructure fund with revenues coming from three sources: (1) fines and penalties resulting from the 2010 BP oil spill and future oil royalties from Gulf oil production; (2) borrowing based on an extension of the Build America Bond (BAB) program; and (3) a national infrastructure bank. A portion of the income from oil royalties is already given back to the coastal states. After the BP oil spill, some Gulf states requested that a larger share of these royalties be distributed to them for coastal restoration. This proposal provides an opportunity for the federal government to mandate these states to establish realistic plans for reconfiguring coastal infrastructure and managing retreat as a condition for transferring funds to local levels. The reauthorization of the BAB program also could help raise capital for rebuilding coastal infrastructure. Yet Babbitt expresses concern about the lack of national priorities and guidelines for directing these funds to support reinvestment in essential coastal infrastructure. The idea of forming a national infrastructure bank has been endorsed by President Barack Obama and has appeared in several legislative proposals. Such a bank would choose among the state and local governments' requests for funding to invest in roads, bridges, water and sewer systems, and public housing. With some clarification of national priorities, coordination among multistate projects, and detailed financing mechanisms, Babbitt predicts that the idea of an infrastructure bank will continue to gain visibility and political support.

Assessing the situations in other parts of the world, Robert J. Nicholls argues in chapter 3 that many world cities, such as London, New York, Tokyo, Shanghai, and Mumbai, are threatened by sea-level rise. After a 17 cm (6.6 in) rise in the twentieth century, Nicholls predicts that sea level will rise about 1 m (3.28 feet) in the twenty-first century. Without any policy responses, large land areas and millions of people will be displaced by increasing sea levels. Yet Nicholls admits that predicting the exact outcomes is difficult because of three factors.

First, cities built on deltas are likely to face more severe coastal flooding or erosion than other coastal areas because of collateral land subsidence. This subsidence may be caused by plate tectonics, glacial isostatic adjustment, or natural and anthropogenic-induced sinking. Because these nonclimate factors play out differently in various regions and are hard to predict correctly, Nicholls proposes that relative sea-level rise instead of global average trends should be used to assess potential effects on subsiding deltas. Second, sea-level rise also depends on the melting of land-based ice, the thermal expansion of ocean waters, and changing ocean dynamics. These natural changes are difficult to forecast. Third, proactive mitigation and adaptation policies could reduce impacts. Hence, the effectiveness of policy responses to climate change could alter the final outcomes. Owing to these uncertainties, anticipating the actual effects of sea-level rise caused by climate change is difficult.

Nicholls asserts that appropriate responses to sea-level rise require a combination of mitigation and adaptation. Some developed areas, such as London, The Netherlands, and Hamburg, Germany, have already formulated proactive adaptation plans. They represent optimistic situations in which investments in climate protection infrastructure have a high benefit-cost ratio. The main challenge remains in developing countries, especially in deltaic settings and small islands, where high adaptation costs can overwhelm government capacity and local economies. Nicholls labels them as the pessimistic situations.

In commenting on Nicholls's assessments, Douglas Meffert argues that a reasonable climate policy should incorporate elements of both optimistic and pessimistic views. The former perspectives can promote the economic value of proactive coastal infrastructure reinvestment to deal with sea-level rise. The latter can help policy makers mobilize stakeholders to facilitate public discourse on adaptation and mitigation strategies. Both can foster timely government and community actions to respond to climate change.

To assess other impacts of climate change, Robert Mendelsohn discusses in chapter 4 land use changes in agriculture, forestry, animal husbandry, and recreational activities. Although the precise magnitude of climate change is not known, Mendelsohn estimates that the range of global temperature rise will be between 2°C and 6°C (3.6–10.8°F) by 2100. Similar to Nicholls, Mendelsohn asserts that the change will vary across the planet. The estimated net annual damages from climate change will be between 0.1 and 1.0 percent of gross world product by 2100. In the United States, between one-third and two-thirds of total damages

will be caused by water shortages, sea-level rise, tropical cyclones, extinction of species, and productivity losses in agriculture, forestry, and outdoor recreation.

Agriculture is particularly sensitive to climate change. As the relative outputs of agriculture and forestry are altered by temperature increases, land productivity across the planet will be altered. Over the next several decades, warmer weather in low-latitude regions will increase the likelihood of drought. Midlatitude regions with cool weather will benefit from warming and more precipitation. High-latitude regions will be able to increase their agricultural outputs due to higher temperatures. Yet damages to low-latitude areas may spread to the midlatitudes by the end of the century if current greenhouse gas emissions are unabated.

Forestry will be affected by possible shifts of ecosystems to higher latitudes and elevations, causing the replacement or dieback of selected timber types. Although ecosystem shifts may lead to the extinction of some plants and animals, forestland will expand in most climate scenarios for the next century, according to Mendelsohn. Rising temperatures will also speed up the hydrological cycle, leading to more evaporation and rain. Because runoff will decrease and the location of increased precipitation is unclear, most studies predict that water supplies in most low-latitude regions will fall. Outdoor recreation and tourism are expected to benefit from warmer weather.

Mendelsohn believes that the best approach for dealing with climate change is to provide people with appropriate incentives, such as secure private property rights and proactive government policies to engage in local adaptation. Mismatches between standard government-mandated adaptation strategies and local conditions could make matters worse.

W. David Montgomery, the chapter 4 commentator, raises concerns about institutional deficiencies in both developed and developing countries in implementing adaptation and mitigation policies. First, he argues that damages from climate change in developing countries have been overestimated, thus leading to suboptimal levels of investment in mitigation. Second, climate change disproportionally harms developing countries that are not the major contributors of carbon emissions. Unless poor nations have enough money to make side payments to wealthy countries to stop their emissions, agreements on global mitigation initiatives will be hard to achieve. Third, effective private adaptation needs to be supported by government and cultural institutions. Most developing countries do not have these preconditions, and institutional reform takes a long time. He suggests paying more attention to the institutional constraints on climate policy and to technological advancements that can reduce adaptation and mitigation costs.

Climate Change Policies and Land Use

Because electricity generation is the primary source of CO_2 emissions, finding alternative energy sources is crucial for reducing carbon emissions. Yet the extraction of renewable energy by means of geothermal systems, photovoltaic arrays,

wind farms, and biomass plantations is more land intensive than the extraction of fossil fuels. Thus, the adoption of renewable energy and the construction of transmission lines will affect land use in rural and urban areas. In some cases, decisions on the siting of renewable energy facilities have been conflict-ridden. Moreover, mitigation and adaptation have different regional and local spatial implications, which may be in conflict: for example, mitigation often benefits from greater population density and adaptation from more open spaces and lower density. The chapters in this section examine the complex relationships between climate policy and land use planning.

In chapter 5, Clinton J. Andrews, Lisa Dewey-Mattia, Judd M. Schechtman, and Mathias Mayr project that by 2030, the global demand for energy will increase from the 2010 level of about 149,000 terrawatthours per year (TWh-yr) to about 199,000 TWh-yr. Generating the additional electricity to meet this demand by burning fossil fuels will increase CO_2 emissions. Hence, considerable attention has been paid to the development of renewable energy sources of electricity. The authors analyze how the adoption of renewable energy and the expansion of the associated infrastructures may affect land use. They compare conventional and alternative energy sources and divide them into three categories based on land intensity, which is defined as land area (km^2) required for delivering 1 TWh-yr.

Category I comprises nuclear power, geothermal, coal, solar thermal, and natural gas. These sources are not land intensive, but only two of them are renewable. Geothermal energy, which uses gas- and oil-drilling technology to harvest underground hot water, is not available in all locations. Similarly, high-temperature solar power plants must be located in areas where sunlight is abundant. Delivering electricity generated by these renewable sources in remote locations to consumers is unlikely to be cost-effective.

Category II includes solar photovoltaics, petroleum, hydropower, and wind. These sources require large tracts of land when implemented on a large scale. Rooftop solar panels may allow energy self-sufficiency only in sunny places and for single-story houses built with highly energy-efficient technology. Using photovoltaics in urban areas where buildings are often more than two stories high and do not have sufficient roof area is unlikely, the authors argue. Large-scale solar and wind farms may have to be located in remote areas where resources (land, sun, and wind) are available and where siting conflict is minimal.

Category III is the most land-intensive category and includes all biofuels. A primary concern about biofuels is their potential for displacing food production and forests from current arable lands. The authors assert that biofuels are unlikely to become an important energy source.

Because most renewable energy sources may have to locate away from cities, where energy demand is concentrated, transmission becomes an issue. Although transmission lines are not land intensive or expensive, their siting faces numerous institutional constraints, including misalignment of incentives to encourage the construction of new transmission lines, lack of review standards for permit applications, technical challenges associated with the intermittency of renewable

energy, and opposition from landscape protection groups. These constraints make siting of power facilities and transmission lines, not land intensity, a key barrier to the development of renewable energy sources.

Gordon Walker, the chapter 5 commentator, cautions against the use of a narrow definition of land intensity to measure land use impacts of energy sources. For instance, land use effects of nuclear power should include the land required for disposing of nuclear wastes or the potential impacts of a nuclear accident. He also identifies the technological and organizational heterogeneity within renewable energy types that can lead to diverse forms and levels of investment and in turn have very different land use impacts. The public does not always oppose renewable energy facilities, Gordon asserts. Microgeneration schemes and the early phases of new marine technologies seem to encounter little opposition. Gordon also suggests expanding spatial analysis to include temporal land use analysis that takes the longevity and flexibility of infrastructure into consideration.

Another land use planning issue related to climate policy is the potential tradeoffs in land use between adaptation and mitigation. Whereas typical mitigation measures, such as compact city structure and transit-oriented development, require a denser built environment, adaptive measures favor more open spaces to achieve cooling effects. More important, while mitigation policy has more long-term global benefits, adaptation produces more near-term local benefits. Local communities, therefore, often prioritize adaptation over mitigation, supporting policy that may not be in accord with global or national CO_2 emissions reduction efforts. In chapter 6, Elisabeth M. Hamin analyzes conflicts between mitigation and adaptation by reviewing the adaptation plans for London; Melbourne; Chicago; Toronto; Halifax, Nova Scotia; Keene, New Hampshire; and King County, Washington. She examines (1) whether the selected cities give higher priority to adaptation over mitigation in their policy statements; (2) the type of climate problems that these cities are trying to address; (3) conflicts between their adaptive actions and mitigation; and (4) preferences given by these municipalities to adaptive actions that complement global mitigation efforts.

Contrary to conventional wisdom, Hamin reports that these cities are placing more emphasis on mitigation than on adaptation or searching for ways to integrate the two approaches. In designing adaptation policies, cities are trying to select programs that are either space-neutral or land-efficient, thereby maintaining or increasing their current densities. Many adaptive actions aim to increase cities' future pleasantness and ecological conditions, which could enhance their desirability and thus attract new residents. Adaptation and mitigation are two essential components of any sustainable climate policy. They are not mutually exclusive, Hamin concludes.

In her commentary, Kristen H. Engel questions if Hamin's conclusions can be generalized to apply to newer and smaller cities, because the cities that Hamin examines are largely mature metropolitan areas. She also wonders whether a land-efficient climate policy implies an adaptive action, since such a policy, through the enhancement of local amenities, could limit urban sprawl, which is a mitigation

strategy, by deterring existing residents from moving to the suburbs. To further understand the dynamics between adaptation and mitigation at the local level, Engel suggests studying the relationship between density and the desirability of cities. If an optimal density level could be determined, a researcher would be able to ascertain whether a government action is designed to increase the livability of a city or simply prevent the area from potential harm due to climate change. The former would move the density of a city toward its optimal level, while the latter would move it beyond the optimum. Similar to Hamin, Engel asserts that an effective climate change strategy requires both mitigation and adaptation.

Urban Form, Transportation, and Emissions

As mentioned earlier, the transportation sector was responsible for more than 30 percent of CO_2 emissions in the United States in 2008. To lower transport-related emissions, automobile use and fuel consumption need to be curtailed. Many scholars have proposed high-density, mixed land use development as a solution. A recent report published by the National Research Council (NRC 2009) indicates that doubling the density of 25 percent of all new residential housing units in U.S. metropolitan areas may lower household vehicle miles of travel (VMT) by 5–12 percent. If the population drives 12 percent less, fuel use and CO_2 emissions could be reduced by about 1 percent by 2030. The model used to produce these estimates does not control for the impacts of travel preference and self-selection related to home location choice. More important, these forecasts are based on the average effects for metropolitan areas. Land use decisions for cities that are smaller or larger than the metropolitan areas require tailored assessments.

Another way to reduce automobile use is to increase public transit ridership. Public transportation requires a density level that is high enough to sustain its investment. As a rule of thumb, a population density of about 30 persons per hectare is required for public bus service. For a frequent and attractive bus service, a density of 45 persons per hectare is needed. There is a lack of systematic studies on the variations of and trends in urban density in the United States to determine where public transit is feasible.

The design and operation of residential and commercial buildings have major environmental impacts. Constructing "green buildings" has become a strategy for increasing the energy efficiency of current real estate development, leading to the development of a rating and certification system known as Leadership in Energy and Environmental Design (LEED). Recently, advocates have recommended extending the LEED rating system from certifying individual buildings to assessing construction impacts on entire neighborhoods (LEED for Neighborhood Development, or LEED-ND), but evaluation evidence has been lacking.

A reduction in automobile emissions also could be achieved through congestion pricing. Despite the ongoing analysis of traffic changes and revenue trends where congestion pricing has been applied, little is known either theoretically or practically about the land use impacts of congestion tolls.

The chapters in this section explore impacts of density, transit use, LEED-ND, and congestion tolls in detail.

In chapter 7, Marlon G. Boarnet, Douglas Houston, Gavin Ferguson, and Steven Spears analyze the nonlinear relationship between land use and VMT and related thresholds. Based on a travel diary survey in the greater Los Angeles area, the authors estimated the effects of regional employment accessibility on VMT in different locales. They divided their sample into quintiles. For households in the third and fourth quintiles of employment accessibility, they estimated that the elasticity of VMT with respect to employment accessibility is –0.83 (based on a spline regression) and –1.16 (based on a stratified sample). These results are as much as three to four times larger than those predicted in other studies. This suggests that policy makers should focus on employment accessibility at the metropolitan level, instead of neighborhood population density, when designing their public transportation and CO_2 emissions policies.

Although the authors found that easy access to rail does not have a significant impact on VMT, living near a bus station does reduce automobile use. Locating near a freeway also reduces VMT, but this effect is confined to households that are within 10 miles of a freeway. Based on these results, the authors argue for a transport–land use policy that focuses on employment subcenters. It should link residences to job centers through a combination of various transportation infrastructure. They caution, however, that such a policy in some places will yield a stronger reduction in VMT than in others, because the relationship between transport–land use planning and VMT is nonlinear.

Kenneth A. Small, the chapter 7 commentator, is less optimistic than these authors about the effectiveness of transport–land use planning in reducing CO_2 emissions. Although he agrees with the authors that employment access should be the focus of transportation analysis, he questions whether such a policy can actually reduce VMT in aggregate. He offers three reasons. First, changing land use and employment accessibility is not easy. Second, even if policy makers can utilize land use policy to reduce VMT at intermediate levels of accessibility, the advantage might be diluted by automobile use in other quintiles where VMT is unaffected by the policy. Third, other policies targeting the fuel efficiency of vehicles and decreases in coal-fired electricity generation are more cost-effective in lowering CO_2 emissions than VMT reduction through land use planning.

In chapter 8, Shlomo Angel, Alejandro Blei, Jason Parent, and Daniel A. Civco tracked the changes in transit-sustaining density in 20 U.S. cities from 1910 to 2000. They found a continuous decline in population density, which can pose a challenge to the investment in public bus service. Their observation is based on three measurements: (1) change in average population density within U.S. census tracts; (2) change in the share of metropolitan areas that can sustain public transit; and (3) change in the share of transit-sustaining urban population.

Starting in 1950, average tract density declined for 17 of the 20 cities. Only Los Angeles experienced a density increase between 1940 and 2000, with a tract density of 29.2 persons per hectare in 2000—the highest among all the cities in

the sample. Despite the declining trend, the authors found that the rate of density decrease has slowed down between 1980 and 2000.

The share of metropolitan areas that can sustain transit also has declined substantially over time. More than half of all urban land had a population density ranging from 0 to 10 persons per hectare in 2000. Less than 10 percent of urban land had a population density that could support public bus service.

The average share of transit-sustaining urban population increased between 1910 and 1920 and then declined, with the rate of decline increasing in 1930 and decreasing in 1980 on. Nearly a quarter of the U.S. urban population lived at a density of less than 10 persons per hectare in 2000.

In view of the declining trend of density historically, the authors recommend densifying urban areas by limiting fragmented urban development. Besides setting growth boundaries, city officials should (1) remove restrictions on higher-density development; (2) allow the subdivision of homes; (3) provide special incentives for building on small lots; and (4) encourage apartment house construction. They also propose extending the transit-sustaining measurement metric from population density to other indicators, such as open spaces and level of fragmentation, to fully account for dispersed urban spatial structures in assessing the feasibility of public transit development.

In her commentary, Susan L. Handy questions the definition of transit-sustaining density used in the study. She asserts that the criterion can vary over time due to changes in income and car ownership. She agrees with the authors that additional investigation of the spatial distribution of transit-sustaining density within urban areas is needed. In addition, employment density and the density of activity at trip destinations should be used as predictors of transit use. Other non-density-related factors, such as travel times, service reliability, station amenities, and public attitudes, also determine transit use and thus should be considered in any public transit feasibility analysis.

In chapter 9, Reid Ewing, Colin Quinn-Hurst, Lauren Brown, Meghan Bogaerts, Michael Greenwald, Ming Zhang, and Lawrence Frank examine how the LEED-ND program affects transit use. Based on a model that they developed in another study, the authors estimated the potential reduction in VMT and the energy and CO_2 savings of 12 LEED-ND certified projects. They calculated the shares of trips by walking and transit and the length of trips by automobile. Purposes of these trips were also taken into consideration.

The estimated VMT per trip for the selected LEED-ND pilot projects is 28–70 percent of the regional average. The estimated walking share is between 3 and 19.7 percent of trips, and the estimated transit share is between 2.8 and 12.3 percent of trips. All these predictions compare favorably with the regional averages. Weighted-average private vehicle trip lengths are between 3.6 and 5.7 miles; this range is shorter than the regional average. Based on these findings, the authors conclude that the projected environmental impacts of the LEED-ND pilots based on automobile use and CO_2 emissions will be smaller than those of non-LEED-ND developments.

Commentator Judith A. Layzer questions whether this conclusion can be generalized to other LEED-ND projects, because the cases were selected based on data availability and not from a random sample. Only 12 of the 56 eligible LEED-ND pilot projects furnished information. She also wonders whether the actual travel behavior of residents may differ from the projections. Transit use is not influenced solely by density; many other factors, such as the availability of parking for private vehicles, surcharges on fuel consumption, and congestion tolls, also play key roles in transport choice. More fundamentally, high-density developments may not always attract residents. If school quality determines residential location, housing units in the LEED-ND certified neighborhoods may not find too many suitors, thereby limiting the ability of this approach in shaping travel behavior.

In chapter 10, Kiran Bhatt reviews the experience of roadway congestion pricing strategies around the world, focusing on the systems in London, Stockholm, Singapore, and selected U.S. cities. He argues that most of the reviewed projects have successfully influenced travel behavior and prevented congestion from occurring on priced lanes. Congestion pricing in Singapore, London, and Stockholm has resulted in a 10–30 percent reduction in traffic in the charging zone. Speeds also have increased by 10–30 percent within and beyond the zone. More important, up to 50 percent of the discouraged car trips have been replaced by public transportation or car pools. Bhatt asserts that these traffic impacts have been stable over thirty years in Singapore and five years in London.

Financially, congestion tolls in London, Singapore, and Stockholm have covered both the operating expenses and costs of improvements to bus and rail services. In Singapore, revenues generated from congestion charges are 2.5 times the sum of operating and capital costs. In London, they are two times the total operating expenses. There is no evidence that retail stores in the charging zones have been adversely affected by congestion pricing and that businesses have opposed the policy. The perception that congestion pricing is unfair to low-income drivers has not been supported in the selected cases.

Although studies on the environmental impacts of congestion pricing remain tentative, the approach seems to decrease emissions in priced zones because of traffic reduction. In London, levels of nitrogen oxide, CO_2, and particulates fell by 13.4, 15, and 7 percent, respectively, between 2002 and 2003 within and beyond the charging zone.

Congestion pricing can influence land use by altering land values, rents, availability of labor, and business location. A 1996 study on this topic in London found that a £4 (more than US$6 based on the exchange rate in 2011) congestion toll would increase employment in central London by 1 percent, whereas inner and outer London employment would fall by 0.5 percent. The number of higher-income households in central London also would increase. These results imply shifts in residential and commercial activities and land use within London that were caused by the change in the relative price of commuting to the city center. In sum, as Bhatt argues, there is evidence to prove that congestion pricing can

reduce congestion and automobile emissions and provide new sources of funding for transportation investment.

In the chapter 10 commentary, Thomas Light pinpoints areas where additional evaluation of congestion pricing systems is needed. First, issues related to changes in traffic on nearby nontoll roadways remain understudied. Second, the level of public acceptance of congestion tolls is uncertain. The popularity of high-occupancy toll (HOT) lanes in the United States that Bhatt mentions may be due to the lack of good alternatives to automobile travel in urban areas. Third, long-run impacts of congestion pricing on land use must be evaluated with improved models that integrate transportation, economic, and location activities. With additional research on these issues, Light is optimistic about the future of congestion pricing, because improvements in its design and implementation, as well as advancement in tolling technology, will increase its benefits.

Market Approaches to Environmental Conservation

Global population expansion and rapid conversion of critical habitat to other uses pose a serious threat to natural resources. The lack of government policy to prevent deforestation in some developing countries intensifies the problem. Every year, millions of acres of forests are destroyed worldwide. Deforestation creates negative effects on climate change because burning trees and plants releases CO_2 into the atmosphere. It also reduces natural carbon sinks that absorb CO_2 generated by human activities. To conserve these natural resources, some market-based approaches have been devised to provide economic incentives to forest owners (or users) and farmers to preserve the natural state of their landholdings. One of these instruments is payment for environmental services (PES). The current main objectives of PES are for carbon mitigation and watershed and landscape protection. Payments involve voluntary cash or in-kind transfers from a buyer to a single seller or multiple sellers as incentives for natural forest preservation (or restoration) or for crop modification. The first two chapters in this section discuss the international experiences of PES. Chapter 11 deals primarily with natural forest and farmland preservation in developing countries, and chapter 12 concerns the conservation of biologically and culturally sensitive sites. Chapter 13 adds to the discussion of PES a comparison of a proposed U.S. cap and trade system with carbon taxes and environmental regulations.

In chapter 11, Sven Wunder and Jan Börner argue that PES systems have met with some success in both developing and developed countries. They report that the majority of PES systems are use-restricting instead of use-modifying. Using data from the ASB Partnership for the Tropical Forest Margins and the Secondary Forests and Fallow Vegetation in the Eastern Amazon Region–Function and Management Project of the SHIFT-Capoeira program in Brazilian Amazon, they come up with four explanations for why use-restricting policies are favored. First, conserving agricultural lands by applying the use-modifying approach produces fewer environmental services than preserving natural forests using the

use-restricting method. Carbon mitigation resulting from use-modifying PES is in the 0–3 tCO_2/ha/yr range, which is much lower than that resulting from use-restricting options in forestry and soil restoration (73.33 tCO_2/ha/yr). Second, the opportunity costs and technological complexity of use-modifying PES are higher than those of use-restricting PES. Farmers are often averse to adopting complex technologies because changes require substantial capital and labor investments. In the western and eastern Amazon studies, technological alternatives to traditional practices that could yield higher per-hectare net returns have largely been ignored by farmers. Prohibiting factors for technological adoption include culture and norms, labor market constraints, and limited information about technology performance. Third, negotiation and monitoring costs of use-modifying PES are higher than those of use-restricting PES. Population density is normally higher in prime agricultural areas than in forests. Hence, negotiations associated with agricultural modifications involve a large number of bargaining parties. Unlike the enforcement of use-restricting agreements for forests, which can rely on the use of remote sensing, monitoring agricultural land management requires direct field visits that are time-consuming and expensive. Fourth, successful use-modifying PES may induce farmers to expand their operations into environmentally sensitive areas. Crop changes can also generate the migration of farming activities across spaces due to unintended price effects on agricultural outputs and inputs. Based on these factors, the authors caution against any overstatement of benefits from use-modifying PES interventions.

James N. Levitt, the chapter 11 commentator, adds that use-restricting PES programs also have problems. One major challenge is to establish a set of generally agreed-on operational measurements to value environmental services provided by landowners. This is critical for determining whether conservation efforts undertaken by landowners should be rewarded and to what extent. Another challenge is that use-restricting PES landscapes are sometimes not complemented by adjacent conservation areas. For example, a preserved area may be surrounded by unprotected areas, making the PES areas vulnerable to poaching and encroachment. These areas can also become islands that fail to provide environmental services on a large scale. Levitt suggests a wider application of certification of forestry operations coordinated by the Forest Stewardship Council as a potential solution to these problems.

In chapter 12, John A. Dixon discusses another type of PES system that he calls direct rent capture (DRC). He argues that the reason for the lack of funding to conserve ecologically and culturally sensitive sites such as tropical rain forests, coral reefs, upland watersheds, landscapes, and cultural monuments is the disconnection between providers and users of environmental services. DRC, often in the form of admission or user fees, creates a direct link between the two parties by acknowledging environmental services as national assets and also recognizing the ability of consumers to pay for these services. Setting rules for making these services sustainable in the long run is a key component of these systems.

To illustrate how the DRC approach works, Dixon examines six cases, including Hanauma Bay in Hawaii, Bonaire Marine Park in the Caribbean, Galapagos National Park in Ecuador, Petra in Jordan, myriad sites in Egypt, and a landscape management system in Bhutan. In these cases, entrance fees and charges are used to raise revenues for maintaining the ecological and cultural services over time. DRC also helps users and providers to recognize the value and vulnerability of the services, thereby forging a partnership among government, civil society, and private groups to preserve these resources.

Dixon cautions that DRC may not work in situations where property rights to the natural resources are not well-defined. The implementation of such a system also requires some familiarity with market mechanisms and tourism. He reports that underpricing of services is common. The idea of raising prices to prevent excess demand often engenders political or social opposition, thereby rendering the approach to address overcrowding ineffective. Other rationing approaches, such as restrictions on the number of visitors, parking spaces, or licensed tourist companies, also are needed.

In her commentary, Tanya Hayes argues that financial resources alone are not sufficient to conserve sites of ecological or cultural value. Institutions such as government regulations and social norms for managing sensitive sites and distributing the costs and benefits of conservation to involved parties are essential. In cases where user fee systems are implemented in institutionally weak contexts, such as the Galapagos Islands, the success of tourism is largely at the expense of ecological preservation. In the Masai Mara National Reserve in Kenya, elite capture, corruption, and land-grabbing contribute to the failure to distribute the financial benefits to local communities. Hayes argues that designers of user fee systems should pay special attention to (1) the carrying capacity of the natural resource; (2) the potential impacts of tourism on the ecosystem; (3) the availability of enabling institutions; and (4) the legitimacy of the governing system for distributing the costs and benefits to interested parties.

Ian W. H. Parry and Roberton C. Williams III argue in chapter 13 that traditional benefit-cost assessments of different environmental policies often assume that the economy is in a Pareto optimum. Thus, additional welfare costs generated from interactions between the proposed environmental policies and preexisting distortions created by other taxes are ignored. These interactions can increase the costs of proposed programs such as cap and trade and carbon taxes unless the emissions allowances are auctioned or tax revenues are used to reduce other tax distortions.

Focusing on the energy sector, the authors argue that cap and trade in the United States would increase domestic gasoline prices, which would undermine the global competitiveness of U.S. industries and impose a heavy burden on low-income households. Depending on whether the revenues from auctioning allowances were used to mediate these adverse effects, the result of a cap-and-trade policy could be more costly than regulation or other comparable policies. The

estimated additional costs would be about $22–60 billion for a 5–15 percent reduction in CO_2 emissions. Carbon taxes would induce labor to substitute work for leisure, thereby increasing the welfare cost by 15–25 percent. One way to avoid the labor loss would be to establish a revenue-neutral principle that mandates the government to use the new collections to offset other tax distortions.

Regulations would have weaker impacts on energy prices and revenue-generating power than cap and trade and carbon taxes. Hence, they would have relatively few interactions with the preexisting distortions and create no distributive effect. Combining regulatory policies such as a CO_2 emissions standard with energy-efficiency standards for the energy sector may be preferable, because these approaches would avoid large increases in energy prices, which is a major political concern in formulating climate change policy. In this respect, regulatory approaches may be more cost-effective than market-based instruments. Parry and Williams, however, caution against any generalization of their analysis, because the specific design of the market-based and regulatory instruments could make a huge difference in their comparison.

Commentator Denny Ellerman questions whether the conventional regulatory approach represents a more cost-effective alternative to either carbon taxes or cap and trade. He provides two reasons for his skepticism. First, there is not enough research on how conventional regulatory measures are applied in practice. The lack of information makes accurate comparisons difficult. Second, environmental regulations generate distortions in the form of scarcity rents. Measuring such distortions is complicated by the opaqueness and obscurity of the details of implementation. More fundamentally, Ellerman is not optimistic that policy makers and scholars can agree on dealing with one distortion at a time and on which distortion. There is also uncertainty in devising an instrument that is neutral with regard to the preexisting distortions and distributive effects.

Governance and Environmental Policy

Judging from the vast numbers of public and private entities involved in formulating and negotiating global, national, and local climate policies, there is surely no lack of effort in dealing with climate change. At the international level, organizations such as the Global Environment Facility, United Nations Environment Programme, International Union for Conservation of Nature, and Intergovernmental Panel on Climate Change (to name just a few) represent alliances of governments and civil society with the primary mission of facilitating international agreements on biodiversity, climate change, and pollutants. Most developed countries have at least three tiers of government to oversee climate policy. For instance, state and regional initiatives have dominated U.S. environmental policies during the past decades. Although the U.S. Congress has continued to explore possible policy steps, states have moved into implementation in many areas and continue to be major forces. In a specific sector such as natural resource management, multiple public agencies operating at different government levels are carrying

out their conservation programs independently. For instance, federal and state governments own 37 percent (835 million acres) of all land in the United States, and 95 percent of these national resources are managed by four federal agencies. Yet it is unclear whether there is enough coordination among these international and national entities to ensure effective climate policy design and implementation. The chapters in this section evaluate the effectiveness of these different environmental governance structures. Chapters 14 and 15 review the structures at the global level and in the United States with respect to their ability to deal with climate policy issues. Chapter 16 examines, from an institutional perspective, U.S. public land management issues.

In chapter 14, Uma Lele, Aaron Zazueta, and Benjamin Singer address the nature and magnitude of global environmental challenges and the responses of international environmental and aid agencies. They evaluate the strengths and weaknesses of the global governance structure based on selected independent evaluations of the performance of international organizations. Although progress was made in the past in generating international consensus on policy issues, they argue that the current structure is inadequate and that an emergence of strong leadership to deal with the political economy issues of climate change is unlikely. They highlight four major challenges.

First, the traditional programs for reducing emissions from deforestation and forest degradation (REDD) focus primarily on forest carbon storage, but do not consider biodiversity, watershed protection, forest production, income generation, and other social and cultural values. Although there has been a gradual shift away from the traditional approach to new expanded programs (the so-called REDD+), these projects still need to incorporate some broader issues—such as commodity trades in the world markets, private capital flows, technology transfers, and adaptation to climate change—into their agenda. The authors assert that these factors are most important for poverty alleviation in forested areas where legal or illegal logging takes place. As observed by the authors, the increase in the number of actors involved in global environmental governance has complicated rather than facilitated the process of searching for a consensus on policy priorities.

Second, in addition to refining the REDD+ approach, mitigation in the housing, transport, and energy sectors is needed in all countries. Although investment and financing of mitigation in these sectors by both public and private organizations have been substantial, implementation issues abound, including cultural and institutional resistance to new technology, the lack of supply-side analyses and political economy approaches to reforming policy, and insufficient consultation with affected parties.

Third, with increasing attention to promoting mitigation in developing countries, parallel efforts in developed countries may receive less attention. The costs of mitigation are believed to be less in developing nations than in industrialized ones. Thus, it seems cost-effective to finance emissions reduction in emerging economies where emissions are increasing rapidly and where abatement costs are

lower than in developed countries. The authors estimate that private investors in the United States will have little incentive to invest in emissions reduction technology unless carbon prices reach $40 a ton.

Fourth, the capacity for conducting research and development on agricultural and natural resource management is limited and concentrated in developed countries. The biggest challenge will be increasing disbursements for the REDD+ programs. These projects, which target the poor and require patient capital, will be competing with traditional capital investments in the energy sector.

In view of these four impediments, Lele, Zazueta, and Singer argue that unless the REDD+ program can broaden its agenda and become more inclusive in decision making, it will have little impact on the global environment. They also suggest coordinating efforts across environmental and aid agencies with joint projects subject to careful monitoring and evaluation.

Commentator Peter M. Haas adds to the authors' discussion other political economy issues related to effective global climate change governance: (1) the different agendas in developing and developed countries regarding mitigation and adaptation; (2) low national concern; and (3) weak institutional mechanisms. To mediate these problems, he suggests increasing the inclusiveness and participation, as well as the voting rights, of less developed countries in decision-making processes. Treaties with enforceable provisions supported by proper monitoring, verification, and sanctions also could enhance governance prospects. It is also important to educate governments, elites, voters, and the private sector about the ramifications of climate change, so as to increase their willingness to pay for mitigation and adaptation. Finally, finding ways to motivate rapidly growing industries in emerging economies such as China and Russia to lower their emissions is essential.

In chapter 15, Barry G. Rabe and Christopher P. Borick analyze intergovernmental relations in handling environmental legislation in the United States by reviewing policy proposals introduced during the 111th Congress. Based on the results of the 2008 and 2009 National Survey of American Public Opinion on Climate Change, they also present some public views on intergovernmental responsibilities for climate policy. They argue that legislative debates on climate change in the United States seldom pay enough attention to the roles of different levels of government. Between 1975 and 2009, there were 479 congressional hearings on climate change, but few of them acknowledged the importance of state, regional, and local climate policy development. For example, the proposal of a federal cap-and-trade policy calls for a full preemption of existing emissions trading programs at the state and regional levels. Other federal initiatives also show the absence of any state, regional, and local partnership across government levels.

Although there seems to be a lack of policy coordination between federal and subfederal levels of government, regional cooperation among states exists. For example, the Western Climate Initiative (WCI) is a partnership of seven western states and four Canadian provinces. Other clusters of states have undertaken

environmental policy initiatives, including (1) mandates for renewable or low-carbon transportation fuels; (2) surcharges on electricity consumption; (3) review of carbon emissions as part of state siting reviews for electricity-generating and large manufacturing plants; and (4) state oversight of local land use planning decisions. This policy development underscores the importance of state, regional, and local regulations in future U.S. environmental policies.

To examine whether the existing governance structure matches the public preferences, the authors analyzed the results of a public opinion survey and found support for a multilevel governance approach to climate policy. In the 2009 survey, only 10 percent of respondents felt that federal and state governments have no responsibility in this area. The public also seemed more receptive to higher state emissions standards than to federal standards. In addition, survey respondents disapproved of the use of federal preemption powers to eliminate existing state policies, with the exception of increased gasoline taxes and setting fuel efficiency standards for automobiles. There was also more support for cap and trade than for a carbon tax.

Comparing the governance structures of countries in the European Union with the U.S. system, commentator Kristine Kern argues that the major fault of the U.S. system is the absence of vertical coordination. A vertically coordinated structure relies on a combination of bottom-up and top-down exchanges. It aims at working toward a convergence of policy ideas and preferences among states and seeks less regional and transnational cooperation. Kern asserts that federal action is urgently needed in the United States to set national priorities to coordinate state and local efforts. Federal involvement is also needed to collaborate with other countries and international agencies to manage global climate issues.

In chapter 16, Christopher McGrory Klyza discusses the relationship between the management of federal resource land and climate change. The federal agencies that oversee national land are the Bureau of Land Management (BLM), the Fish and Wildlife Service (FWS), the National Park Service (NPS), and the Forest Service. In 2009 the BLM oversaw 253 million acres of federal land, some of which is managed for multiple use. The land managed by the NPS and the FWS is, however, only for reservation and recreation. Klyza argues that climate change has affected federal land management in five areas: (1) biological diversity; (2) fire regimes; (3) hydrology; (4) carbon sequestration; and (5) energy management.

In terms of biodiversity, climate change can trigger the migration of species to new locations. Thus, the management of areas between reserves to increase the connectivity of the landscape to facilitate the movement of different species has become important. Climate change has also increased the danger of forest fires in some western states. Fighting these fires often costs more than $1 billion a year. Large wildfires also increase carbon emissions. Varying stream flows is another problem. The impacts of this problem on western public land include water shortages, lack of storage capability to adjust for seasonal rain, forest fires, and decreased forage quantity for wildlife and livestock.

Although carbon sequestration on public land increased substantially under a no-harvest management approach, the existing management patterns may increase harvesting back to the levels of the 1980s, which could turn public forests from carbon sinks into carbon sources. More than one-third of U.S. fossil fuel production takes place on federal public land. The federal government could help reduce fossil fuel use by limiting access to this energy source and by encouraging the use of public land to produce renewable energy such as biomass, geothermal, solar, and wind.

Public opinion on the environment and increased interest group mobilization have increased the awareness of federal agencies about the need to modify their land management practices to account for climate change. Yet actual implementation of new practices has been fraught with budgetary and bureaucratic issues. Slow responses from the agencies have been challenged by environmental groups in courts.

State land ownership and management varies across the country. Some states, such as New York, Florida, and Minnesota, have adopted land management or acquisition plans to combat climate change. The biggest challenge for state land management is the fiduciary responsibility of the states to administer school trust land to specifically benefit K–12 schools or universities. Revenues from these programs go to a permanent fund, with returns distributed to the beneficiaries. Arizona earned more than $16 million from its trust land in 2009 through agricultural, grazing, and mineral leasing and sales. Although laws permit the lease and sale of state trust land for conservation purposes, this use must not adversely affect the financial interest of the beneficiaries.

In his commentary, Roger A. Sedjo echoes Klyza's concern about the absence of legislative directives regarding climate change. This leaves the various agencies to determine their own policies, which are driven by agency leadership and court decisions. Adding to this problem are the uncertainties involved in predicting changes in climate across regions. The ability of different vegetative systems to adapt to changing climates also varies. Given the lack of central directives and the presence of these great uncertainties, Sedjo argues for reactive action as the best strategy for managing public land. Individual agencies should be given full discretion to address their unique climate problems based on local conditions.

Summary

Five insights on the relationships between land policies and climate change can be drawn from these chapters. First, predicting climate change impacts in general, and effects on land use in particular, is fraught with uncertainty and complications. This is partly because projections of impacts vary significantly depending on the assumptions used in the assessments. Addressing impacts across regions also requires careful calibration of models and data to account for local weather and physical conditions and mitigation and adaptive actions taken by interested

parties. Thus, general statements about land use impacts of climate change are difficult to make, rendering decisions on infrastructure investment for mitigating and adapting to new weather patterns or sea-level rise problematic.

Second, renewable energy policy will surely affect land use. Yet the major challenge is not the land intensiveness of renewable energy production, but instead its siting. Conflicts arising from the location of power facilities and transmission lines could impede the adoption of alternative energy sources. Land use planning is important, especially in devising policy to integrate adaptation and mitigation strategies. There seems to be a consensus among the chapter authors that these two types of strategies are not mutually exclusive.

Third, in designing urban form and transportation policy to reduce automobile use and fuel consumption, population density is not the only factor to consider. Focusing on employment density of metropolitan job centers may provide more effective transportation policy guidance. Although average population density in many U.S. metropolitan areas is too low to support public transit investment, other indicators, such as fragmentation level, should also be considered in transit feasibility studies. Congestion pricing could be employed to encourage public transit use as well. Similarly, compact development should focus not only on high density, but also on the need to provide complementary amenities, such as good schools and recreational facilities, to attract residents.

Fourth, PES approaches seem promising in environmental conservation. Their success, however, will depend on three types of transaction costs: (1) the cost of valuing environmental services; (2) the cost of negotiation; and (3) the cost of enforcement. More important, institutions such as public and private property rights, local customs and attitudes toward technological change and markets, and government capability will all play important roles in minimizing these costs. Variations in transaction costs explain the diverse performance to date of different PES systems in developed and developing countries.

Fifth, environmental initiatives of different countries, international aid agencies, and global environmental interest groups need to be coordinated to achieve the desired outcomes of collective climate change policy. Strong leadership is most critical. In similar fashion, coordination among different levels of government and public agencies in the United States to design and implement climate change and land management policies is required. At the moment, individual states and public agencies are pursuing their own policies, whose effectiveness could be magnified if they were systematized. Environmental governance structures at the international and national levels deserve much attention.

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