Climate Change and Sustainable Transportation: The Case of California

Elizabeth Deakin[1]

Abstract: California has adopted innovative legislation to tackle climate change. Energy-efficient buildings, lower-emissions industrial processes, and more fuel-efficient transportation vehicles operating on cleaner fuels are among the many strategies that are being implemented. However, to attain the needed reductions, California must find additional strategies to reduce greenhouse-gas emissions, especially from the transportation sector, which is a large fraction of the total emissions problem. This paper discusses the efforts that are underway to further increase transportation efficiency, shift transportation to less CO2-intensive modes, and slow or reverse growth in vehicle-kilometers of travel (VKT). The legislative mandate is leading to a new focus on methods for quantifying travel changes and emissions reductions, ranging from spreadsheet approaches to integrated transportation-land use models. It also is renewing interest in travel-demand management and land-use policies that could reduce overall travel. While a number of cities have embraced these strategies, their success in the face of the state's continuing growth will likely depend on both federal and state policies and funding incentives. **DOI: 10.1061/(ASCE)TE.1943-5436.0000250.** © *2011 American Society of Civil Engineers.*

CE Database subject headings: Climate change; Environmental issues; Government policies; Planning; Transportation models; Urban development; California.

Author keywords: Climatic change; Environmental issues; Government policies; Planning; Transportation models; Urban development.

Introduction and Overview

Concerns about climate change have led to worldwide efforts to reduce the emission of greenhouse gases (GHG). Although the United States has been slow to act on climate change issues, its state and local governments have taken the initiative on their own. This paper presents a review and analysis of recent climate change legislation enacted in California, a state that is playing a leadership role in U.S. efforts to reduce greenhouse-gas emissions by mandating energy conservation and emissions reduction for every sector of the state's economy. The paper focuses on California's transportation strategies to reduce emissions, where, in addition to low carbon fuels and energy-efficient vehicles, operational improvements and demand management strategies are being pursued. In particular, the paper discusses the efforts that are underway to shift transportation to less carbon-intensive modes and to slow or reverse growth in VKT through legislatively mandated land-use–transportation planning.

California's legislative mandates are renewing interest in transit and nonmotorized modes, travel-demand management, and land-use policies that could reduce overall travel. While a number of cities have embraced these strategies, others are dubious, and some are resistant. Whether these strategies will succeed will depend on a host of implementation issues.

The legislative mandate is leading to a new focus on methods for quantifying travel changes and emissions reductions, ranging from spreadsheet approaches to integrated transportation–land-use models. These methodological improvements aim in particular to improve the ability to assess the efficacy of pricing and land-use policies in reducing overall travel. However, the mixed reception for land-use strategies also reflects doubts about the acceptability of higher density development for both jobs and housing. In addition, some of California's local governments have concerns about the costs of higher density development, and in particular, infill. Thus, the success of this aspect of California's GHG-reduction strategy will likely depend on whether information on the risks of business-as-usual is believed and leads to changes in attitudes and/or whether incentives alter choices. This paper discusses these issues and their implications for transportation practice.

Global Warming and Transportation Strategies: Background

In its Fourth Assessment Report (Pachauri and Reisinger 2008), the Intergovernmental Panel on Climate Change states that by 2050, global greenhouse-gas emissions must be reduced by 50–80% from 2000 levels to avoid serious, widespread, and enduring harm resulting from climate change. Some countries have committed to reducing greenhouse-gas emissions through the Kyoto Protocol, and many others are engaged in discussions on ways to reduce emissions (including alternatives to reduction, such as carbon trapping and sequestration (see, e.g., U.S. DOE 2010), or climate engineering (Victor et al. 2009). However, as officials of the Organization for Economic Cooperation and Development note, progress has been difficult, and policy leaders now recognize that remarkable changes will be needed in economic activity and industrial structure if significant emissions reductions are to be attained (OECD 2008.)

The worldwide challenge is substantial because energy consumption is strongly linked to population expansion and economic growth, and the combustion of carbon fuels continues to be the major source of GHG emissions (especially CO2, the principal

[1]Professor, Dept. of City and Regional Planning, 228 Wurster Hall, Univ. of California, Berkeley, CA 94720-1850. E-mail: edeakin@berkeley.edu

Note. This manuscript was submitted on November 23, 2009; approved on November 6, 2010; published online on May 16, 2011. Discussion period open until November 1, 2011; separate discussions must be submitted for individual papers. This paper is part of the ***Journal of Transportation Engineering***, Vol. 137, No. 6, June 1, 2011. ©ASCE, ISSN 0733-947X/2011/6-372–382/$25.00.

GHG). The International Energy Agency (IEA 2008) forecasts that, in the absence of major new government policies or technological breakthroughs that are currently not foreseen, world primary energy demand is set to rise by 59% from 2004 to 2030. Furthermore, IEA estimates that 85% of that increase will be in the form of carbon-emitting fossil fuels: coal, oil, and natural gas. Two-thirds of the new demand will come from the developing world (IEA 2008.) Thus, under a business-as-usual scenario, in the absence of countervailing actions, greenhouse-gas emissions will increase.

A wide variety of strategies could be used to cut greenhouse-gas emissions. A new National Academy of Sciences report (NAS 2010) documents U.S. and international experience with energy efficiency in residential and commercial buildings, industry, and transportation and assesses the prospects for further savings in each sector. The NAS report concludes that technologies existing today or likely to be developed in the normal course of business could cut energy use in the United States by 30% and save money in doing so; higher energy prices or government policies and mandates could produce even greater savings. The report also notes, however, that formidable barriers to implementation exist and will take concerted effort to overcome.

From a global perspective, a widely noted study by McKinsey and Company (Enkvist et al. 2007) identifies a number of energy-efficiency and other strategies for reducing greenhouse-gas emissions that would likely cost less than 40 euros ($60) per ton. In the energy-efficiency, cost-saving category are insulation for new buildings, more efficient building heating, cooling, and lighting, fuel-efficient vehicles, and sugar cane biofuels. In the relatively low-cost category are carbon capture and sequestration for power generation and industrial processes, nuclear power, and some forms of wind power, reforestation and avoidance of deforestation, some biodiesels, and no-till agricultural practices. The McKinsey study concludes that, technically, measures costing no more than 40 euros a ton could produce 26.7 gigatons of abatement, a level that would bring GHG concentrations in the atmosphere to 400–450 ppm, close to a 50% reduction from business-as-usual levels.

However, the McKinsey study also notes that more than half of these potential low-cost abatements are located in developing economies, so that an effective global system of intervention would be needed. In addition, over half the low-cost abatement would come from interventions in transportation, buildings, forestry, and agriculture, with nearly one-quarter coming from efficiency-enhancing measures in buildings and transportation. Progress in reducing emissions in these sectors would require that the actions of literally billions of consumers be aligned with the emissions-reductions policies, most likely requiring a combination of regulatory requirements and financial incentives.

The complexities of achieving GHG reductions suggest that attainment of even 50% reduction from 2000 levels (the lower boundary of the IPCC estimate) will be a major challenge. At the same time, some experts believe that such a target is too low (e.g., Hansen et al. 2009.) Because of the uncertainties and risks, a number of analysts and policy makers have advocated a broader search for measures with GHG-reduction potential, including measures that are pursued for other reasons but produce GHG reductions as cobenefits (OECD 2008; Schipper et al. 2009).

Strategies for further reducing GHG from transportation are among those being widely discussed. Currently, transportation accounts for about 23% of the total greenhouse-gas emissions worldwide and 30% in OECD countries (OECD 2008). In addition, in many parts of the world, motorized travel is growing faster than either population or GDP, offsetting some of the gains in fuel efficiency and decarbonization. For example, China alone could have 300 million motor vehicles by 2030. While energy-efficient vehicles and fuels will moderate transport GHG emissions per vehicle-kilometers of travel compared to those experienced today, most analysts believe that we are unlikely to get more than 50–70% of the way to needed reductions with these strategies alone (Schipper 2009; Kammen et al. 2009.)

To minimize the total cost of greenhouse-gas reductions, measures to reduce emissions would be taken from the set of feasible actions in order of lowest marginal cost. Many transportation measures (e.g., new transit lines) would be extremely costly if viewed only as GHG-reduction measures, however. On the other hand, many such measures also produce other benefits in the form of reduced congestion, improved mobility and access, increased energy security, lower emissions of other air pollutants, less noise, and improved safety. These benefits offset costs, and the total benefits can be sufficient to justify these investments. The concept of decoupling economic growth from vehicle-kilometers of travel by promoting alternative modes thus has traction when considered from a total benefit-cost perspective, both in advanced economies and in the developing world (OECD 2008; Schipper et al. 2009.)

Reflecting this reasoning, transportation measures are being discussed that aim to improve the efficiency of transportation operations through better logistics and new technological enhancements, as are strategies to reduce vehicle-kilometers of travel through a combination of investments in transit and nonmotorized modes, transportation–land-use planning coordinated to shorten trips, and pricing to shape and moderate demand (OECD 2008; U.S. DOT FHWA 2009a; Shaheen et al. 2009; TRB 2008; U.S. DOE 2009; U.S. DOT FHWA 2009b; U.S. EPA 2008). GHG reductions would be one of the cobenefits of such measures.

Proposals to reduce VKT often raise concerns about the potential for negative social and economic impacts as well as the potential for public opposition. However, the evidence is strong that transportation carbon emissions at U.S. levels are not necessary for a healthy economy; the high variation in transport carbon emissions among the wealthiest nations suggests different approaches can be successful. Table 1 (Schipper et al. 2009) shows per capita GDP and CO2 emissions for the United States and other wealthy nations as well as for the world as a whole. The table shows that CO2 per dollar of GDP is declining, though not fast enough to reduce emissions to levels most scientists advocate. Note, however, that the U.S. CO2 emissions per capita are far higher than those of other developed countries and are disproportionately high compared to per capita GDP. Road transport emissions are a big part of the reason for the United States' poor performance.

Transport investment needs and their benefits and costs depend heavily on previous transportation investments, of course. In the developing countries where modern transportation systems are just now being established, investments to facilitate greater mobility and access at lower cost are often needed, and the issue is whether the chosen investments provide this mobility and access in the most efficient ways possible. In the more advanced economies, greater efficiencies may be gained from, e.g., better logistics and shift of freight from truck to rail, or congestion pricing of road use.

For the United States, transportation strategies that moderate VKT and reduce GHG are likely to provide several important cobenefits. One is air pollution reduction, a significant consideration in the many metropolitan areas that still have not achieved national ambient air quality standards. Improved mobility for transit users, cyclists, and pedestrians also is an important cobenefit. In addition, U.S. transportation is heavily oil-dependent and, therefore, intertwined with oil security considerations. At present, the United States consumes about a quarter of the world's total oil production, and its transportation systems are 95% dependent on oil (U.S. DOE 2009, 2010). World competition for oil is mounting sharply; by

J. Transp. Eng., 2011, 137(6): 372-382

Table 1. World and Regional Total Emissions per Capita, Total Emissions/GDP, Road Transport/GDP

Region	Per capita GDP, 2005	CO2, bn t	AARG[a], 1990–2005	CO2/capita, t	AARG, 1990–2005	CO2/$, kg	AARG, 1990–2005	CO2 in road transport/$	AARG, 1990–2005
World	$8.5	27.14	1.7%	4.2	0.3%	0.50	−1.6%	0.085	−1.1%
U.S.	$37.1	5.82	1.2%	19.6	0.1%	0.53	−1.7%	0.139	−1.0%
Japan	$27.2	1.21	0.9%	9.5	0.7%	0.35	−0.4%	0.065	−0.1%
OECD Europe	$22.7	4.08	0.2%	7.6	−0.3%	0.33	−2.0%	0.075	−0.6%

[a]AARG = annual average rate of growth for the period for each item in the preceding column; adapted from Schipper et al. 2008

2030, the IEA's "business-as-usual" projection is that global oil consumption will rise from 85 million barrels a day today to about 120 million barrels a day (IEA 2008) New fuels including biofuels are being developed, but it is unlikely that they will displace petroleum in a significant way in the near future. While the IEA is optimistic that sufficient oil is available, many experts are concerned about whether the investments will be made to increase production accordingly, and the reliability of supply is also at issue given the political geography of oil (because a substantial share of future supply will have to come from the Middle East and Africa). Moderating transport activity is a way of improving oil security (Gilbert and Perl 2010)

Transportation strategies that reduce VKT also may help address Americans' concerns about transportation costs and price volatility, even if energy supply keeps up with demand and is stable. Fuel prices are one of the reasons for a spate of bankruptcies in the airline industry in the last two years. In mid-2008, at-the-pump fuel costs topped $4 a gallon in some locations in the United States as oil prices surged to over $140 a barrel. Oil prices subsequently declined by half, bringing gas prices down as well, but long-term cost uncertainties remain. Because Americans currently travel more kilometers per capita than residents of any other nation, in vehicles only two-thirds as efficient as those of their European and Japanese counterparts, the transportation sector's uncertain fuel costs pose serious economic and social challenges. Reducing the distances traveled could be a way to reduce risk and cost.

While it has long been recognized that more fuel-efficient vehicles, low carbon fuels, and measures that reduce VKT can be effective, the U.S. federal government has been slow to embrace any of these strategies, and when it does, its actions are often limited. The United States did not sign the Kyoto Protocol. Until recently, the federal administration questioned the scientific basis for global warming, and federal agencies blocked state attempts to require cleaner fuels and more efficient automobiles to combat it. Largely out of concern for oil security, Congress enacted tighter corporate average fuel efficiency (CAFE) standards for light-duty vehicles in 2007, but the mandated increase, to 35 mpg by 2020, will bring the United States only to about the same efficiency level in 2030 (once the fleet turns over) as European cars had already achieved in 2006 (Schipper 2009.) The federal government has invested in biofuels research and has mandated biofuels use but not consistently and not always in the fuels that would maximize emissions reductions. Federal transportation legislation provides funds for transit, bike, and pedestrian infrastructure, but the total amounts available are dwarfed by funding for highways. Federal funds for transit operations are highly restricted, and, whereas highway operations improvements are eligible for funding, most road pricing strategies require special approval. Congress is now (2010) considering legislation to reduce greenhouse-gas emissions, as well as to renew surface transportation funding; but the proposals have already proven controversial, and what action will be taken and when is uncertain.

In this context, cities and states have provided much of the leadership for combating global warming in the United States, through energy regulations, transportation planning, and other means. For example, to mark World Environment Day in 2005, the mayors of 158 U.S. cities, including 10 of the 30 largest, signed an agreement pledging their cities to meet or beat the Kyoto Protocol targets for reducing emissions of greenhouse gases and to urge the federal and state governments to do the same. In addition, middle Atlantic and northeast states have already established a regional greenhouse-gas emissions-trading program (Sappenfield 2005) and the western states (including California) are doing so as well.

California Initiatives

The most comprehensive state and local actions to reduce greenhouse gases have been in California. Efforts build upon previous initiatives and add new ones. California has long been a leader in air pollution reduction and energy efficiency; among California's many programs have been low- and zero-emission vehicle mandates, motor vehicle emissions standards more stringent than federal requirements, rigorous building and appliance energy conservation standards, mandates that a portion of the state's electricity come from renewable resources, recycling requirements, water conservation requirements and incentives, and incentives for solar roofs. All of these programs reduce greenhouse gases as cobenefits of broader environmental and energy objectives.

In 2002, California enacted the first law in the United States to regulate greenhouse-gas emissions from motor vehicles—AB 1493, also called the Pavley bill after its sponsor (CA Assembly 1493 2002). The Pavley bill was met with stiff opposition; shortly after it was signed into law, motor vehicle manufacturers filed a lawsuit arguing that California lacked the authority to act because the law's effect was to regulate fuel economy, a field preempted by the federal government. In addition, EPA under the Bush Administration refused to regulate greenhouse gases as a pollutant and denied California the waiver it needed to act on its own. The Obama administration reversed the EPA decision, issuing the waiver and negotiating agreement with California and the automakers to adopt the Pavley auto emission standards nationwide, but then another lawsuit was filed in September 2009, with the U.S. Chamber of Commerce requesting review of the EPA decision to grant California the waiver [Chamber of Commerce of the U.S., et al. v. EPA, et al. (DC Cir. No. 09-1237)]. If the Pavley regulations are permitted to proceed, the California Air Resources Board (CARB) expects that they will reduce California passenger vehicle GHG emissions by about 22% in 2012 and about 30% in 2016 (CARB 2009b).

Two recent pieces of legislation further attack greenhouse-gas emissions: Assembly Bill (AB) 32, the California Global Warming Solutions Act (CA Assembly Bill 32 2006), and Senate Bill (SB) 375, Chapter 728 (CA Senate Bill 375 2008), signed into law in the fall of 2008 and designed to help implement AB 32

J. Transp. Eng., 2011, 137(6): 372-382

by incentivizing compact, transit-oriented development. Implementation plans are currently being developed for both laws, but sufficient work has been completed to identify the directions being taken and the issues raised.

AB 32 calls for a comprehensive program of regulatory and market mechanisms to achieve cost-effective reductions of greenhouse-gas emissions. The law aims to cut California carbon emissions in 2020 to 1990 levels of 427 million metric tons of CO2 equivalents (MMTCO2E). This would amount to GHG emissions almost 30% below the levels anticipated in a business-as-usual scenario. In addition, Gov. Arnold Schwarzenegger's Executive Order, issued in 2005 (EO S-3-05 2005), calls for ongoing reductions to 80% below 1990 levels by 2050, or 85 MMTCO2E (total emissions), as compared to the 1990 level of 427 MMTCO2E.

CARB is charged with developing the plans and programs needed to meet the AB 32 targets by the deadlines and is directed to consider a wide variety of measures in doing so (CARB 2009a). Reductions must be "real, permanent, quantifiable, verifiable, and enforceable by the state board" [CA Health and Safety Code § 38562(d)(1)]. Existing state agency authority is not reassigned, and so many other state agencies have implementation responsibilities. A Climate Action Team, established by EO S-3-05 and comprised of representatives of major state agencies, has been charged with identifying GHG-reduction measures and recommending them to CARB.

As required by AB 32, CARB issued a regulation requiring mandatory reporting of GHG emissions by the large industrial sources (previous reporting was voluntary). CARB also identified several "early action" measures whose implementation must begin by January 1, 2010. The early action measures include a low carbon fuels standard designed to cut life cycle emissions by about 10% (EO S-01-07 2007), as well as regulations to cut emissions from landfills, requirements for reduced use of gases with high global warming potential, and measures to reduce emissions from automotive refrigerants and ships in port.

CARB also developed a Scoping Plan, adopted in December 2008, setting forth the following strategies to reduce GHG emissions to 1990 levels by 2020:

- expanding and strengthening existing energy efficiency programs and building and appliance standards;
- achieving a statewide electric utility energy portfolio of 33% renewables;
- developing a California cap-and-trade program to create a regional market together with other Western Climate Initiative (WCI) partners (six other states and four Canadian provinces);
- establishing targets for transportation-related greenhouse-gas emissions for regions throughout California and pursuing policies and incentives to achieve those targets;
- adopting and implementing measures pursuant to existing state laws and policies, including California's clean car standards, goods movement measures, and the low carbon fuel standard; and
- creating targeted fees on water use and high potency greenhouse gases, as well as a fee to fund the administrative costs of AB 32 implementation.

Table 2 provides a more detailed list of the measures in the scoping plan and their current implementation status.

The estimated cost per ton of these GHG-reduction strategies ranges from −$408 (net savings) to $133, with all but one measure (the Renewables Portfolio Standard, recommended for energy security purposes and not considered in benefits calculations) costing less than $55 per ton (CARB 2008). CARB estimates that the combined package of measures that CARB and others must further develop into implementable programs and projects will save the state and its businesses money and create more jobs and personal income than business-as-usual. CARB also points out that without a change of course, rising global GHG emissions would result, by late in the century, in California heat waves, flooding from sea level rise, and loss of 90% of the Sierra snow pack, a major source of the state's water supply. These occurrences would harm public health,

Table 2. Status of California Air Resources Board Scoping Plan Measures for Greenhouse-Gas Reduction for 2020 Target Year (as of June 2010)

Category	Specific measures
Existing laws, regulations, policies, and programs	Light-duty vehicle greenhouse-gas standards (Pavley I)
	Renewables portfolio standard (to 20%)
	Solar hot water heaters
	Million solar roofs
	High speed rail
Measures strengthening and expanding existing policies and programs	Electricity efficiency
	Natural gas efficiency
	Renewables portfolio standard (from 20% to 33%)
	Sustainable forests
	Light-duty vehicle greenhouse-gas standards (Pavley II)
Discrete early actions	Low carbon fuel standard
	Cut high global warming potential (GWP) in consumer products
	Smartway technologies for heavy-duty tractor-trailer trucks
	Landfill methane capture
	Cut high GWP in semiconductor manufacturing
	Ship electrification in port (adopted)
	Cut SF6 in nonelectrical applications
	Mobile air conditioner repair cans
	Tire pressure program
New measures	California cap-and-trade program linked to WCI partner jurisdictions
	Increase combined heat and power
	Regional transportation-related GHG targets
	Goods movement systemwide efficiency
	Other vehicle efficiency measures
	Medium/heavy duty vehicle hybridization
	High GWP reductions from mobile sources
	High GWP reductions from stationary sources
	Mitigation fee on high GWP gases
	Reductions during oil and gas extraction
	Reductions during oil and gas transmission
	Reduced use of refinery flares
Changed regulations	Removal of methane exemption from existing refinery regulations

Adapted from CARB 2008.

J. Transp. Eng., 2011, 137(6): 372-382

create severe ecosystem damage, and require massive investments in mitigation.

Because transportation accounts for the largest share of California's greenhouse-gas emissions—38% over the period 2000–2004—a large share of the 146.7 MMT GHG reduction needed between 2012 and 2020 is expected to come from transportation. Indeed, current estimates give transportation a somewhat larger role, although some double counting may be involved. The Pavley vehicle fuel-efficiency standards are expected to be a major source of GHG reduction, accounting for 37.1 MMT, or 22% of the targeted reduction. Low carbon fuels were estimated in the CARB 2008 report to cut emissions by an additional 15 MMT, 10% of the target. Other reductions come from vehicle efficiency measures (4.5 MMT), improvements in goods movements at ports and elsewhere (3.7 MMT), more efficient heavy- and medium-duty vehicles (1.4 MMT), and high speed rail (1 MMT)—together accounting for 7% of the reduction target. Finally, "regional strategies"—transportation and land-use strategies to shift travel demand—are expected to reduce emissions by 5 MMT, or just under 3.5% of the targeted reductions by 2020.

For the regional strategies, the AB 32 Scoping Plan refers to SB 375 as the process for establishing more precise targets and implementation strategies. SB 375, widely referred to as an "anti-sprawl" bill (see, e.g., Fulton 2008), requires CARB to establish regional GHG-reduction targets for 2020 and 2035 and mandates that each of California's 18 metropolitan transportation organizations (MPOs) prepare a "sustainable communities strategy" (SCS) for meeting the targets in each metropolitan region. If an MPO's SCS cannot show attainment of the targets, the MPO must develop alternative planning strategies (APS) that do so.

SB 375 ties the regional transportation plan, a federal requirement, to regional housing-needs assessments required by state law. SB 375 also requires improvements in modeling to assess GHG impacts of transportation and land-use measures. It neither requires the new regional plans to be consistent with local government plans nor requires local governments to conform to the region's proposals, but it does require regional planning agencies' own funding decisions to be consistent with the SCS or APS. The major incentive the law provides for local compliance with the regional plan is regulatory streamlining [California Environmental Quality Act (CEQA) relief] for projects that are consistent with it. The CEQA relief is intended to serve as an inducement to local governments and private developers to implement such strategies.

The MPOs will have considerable flexibility in the development of SB375 sustainable communities strategies that reduce vehicle travel: CARB sets the targets, but the policy choices are left to each region. This does not mean that CARB has no views on what might go into a SCS, however. CARB's Scoping Plan anticipates that an SCS might include increasing public transit, carpooling, walking and biking choices, developing land-uses in patterns that reduce distances traveled, encouraging telecommuting, supporting employer-based programs such as four-day work-weeks, pricing transportation more efficiently—for example, with pay-as-you-drive insurance and congestion pricing—and using indirect source reviews to mandate trip-reduction strategies as a condition of development, among many other options.

A Regional Targets Advisory Committee (RTAC), appointed by CARB to advise on SB 375, issued its recommendations in the fall of 2009 (CARB 2009d). The RTAC called for the publication of best management practices guidance, recommended the development of simple spreadsheet models that could be used to evaluate regional strategies, proposed that social equity analysis be part of the regional strategies modeling, and supported the development of more rigorous econometric transportation–land-use models, as well as analysis methods that apply evidence from empirical studies. The committee also advised CARB to identify key underlying assumptions on vehicle efficiency, fuel costs, population, and employment to be consistently applied statewide and to develop more consistent and efficacious methods of forecasting interregional travel.

The RTAC further recommended that CARB develop performance monitoring metrics and procedures to allow transportation and land-use accomplishments to be tracked and evaluated. For example, they noted that measures of land-use change could include average residential and employment densities, housing product mix (attached, small lot detached, large lot detached), land-use location mix (infill, redevelopment, greenfield), percent of housing units accessible to transit, jobs/housing ratio, and housing affordability relative to local wages. For transportation, measures could include mode split, transit fares, cost of driving, percent of roads with sidewalks, percent of roads with bikeways, and parking price. (CARB 2009d).

Finally, the RTAC noted that funding for local government would be needed as implementation moves forward, and recommended both state action (especially state funding for SCS infrastructure) and pursuit of supportive changes in federal law as the next transportation bill is developed. In addition, the RTAC recommended strong incentives for exceeding the targets set by CARB, as well as public education and outreach to build understanding of the need for a new approach to growth.

CARB and the state's 18 metropolitan transportation organizations have taken action on several of the RTAC recommendations as of early summer 2010. CARB has funded research syntheses on both measures and models (CARB 2010c) and has begun to publish working papers on its web site (CARB 2010b). The MPOs have developed and run region-specific scenarios for 2020 and 2035, testing the impact of their current regional plans and several alternative scenarios. For the four large MPOs (Los Angeles, San Francisco, Sacramento, and San Diego), the analyses indicate that GHG emissions will decline by 3–13% on a per capita basis; this takes into account the state's fuel standards and the Pavley standards for vehicle emissions. The most ambitious scenarios tested by the four large MPOs, reflecting widely varying combinations of demand management, transit investments, pricing strategies, and land-use strategies, would reduce GHG emissions by 10–18% by 2035 (CARB 2010b). It is important to note that these percentage reductions are reported on a per capita basis; because growth in the four regions will be substantial, with population increases of 28–62% over the 2005–2035 period; in every case, even the most aggressive of the tested scenarios would be outstripped by growth.

The MPOs used their existing forecasting models, supplemented in some cases by postprocessors, to carry out the scenario tests. However, in nearly every case, the MPOs also acknowledge that improvements in the models are needed, especially with regard to demographic change (especially immigration and interregional migration), the detailed composition of the vehicle fleet (auto type choice), and land markets and economics. Most MPOs are investing in data and model improvements but acknowledge that the improvements will take time to develop, implement, and validate (CARB 2009c).

CARB must adopt final targets for the regions by September 30, 2010. CARB may also develop additional guidance on performance measures and modeling assumptions. The regions then have two years to develop their SCS or APS proposals before implementation is required. Targets will be reviewed and renewed as necessary on an eight year schedule, and plans will be similarly updated every eight years.

J. Transp. Eng., 2011, 137(6): 372-382

Can California's Sustainable Communities Strategies Succeed?

While SB 375's share of total greenhouse-gas reductions by 2030 is small, CARB is counting on the improved land-use and transportation policies and practices not only to contribute the total reductions needed by 2020 to achieve the goals of AB 32 but also to set the state on a pathway for further reductions after the 2020 deadlines. Unless new technologies emerge that allow substantially larger reductions in emissions from all sources, significant carbon sequestration is accomplished, or new methods such as climate engineering are developed (Victor et al. 2009), transportation and land-use strategies are likely to take on added importance after 2030.

However, sustainable communities face a myriad of challenges, ranging past the patterns of growth that have dominated in California, to questions about the efficacy of measures to actually reduce GHG, to policy conflicts at the state, local, and federal levels, to concerns about funding for local action.

Challenge of California Growth

California is the most populous state in the United States, with an estimated 38 million residents (2009). Its economy is among the largest 10 or 15 in the world and is expected to continue to grow faster than the U.S. average. Even accounting for the dampening effects of the economic recession that began in December 2007, sometime between 2025 and 2035, California's population is expected to reach 45–50 million. Thus, plans to reduce GHG emissions must do so in the face of rapid growth and change.

Growth is occurring in the context of globalization, where economic sectors are increasingly interconnected, but California's growth has also been driven by immigration and natural increase. The state's benign climate and its natural resources certainly have been important factors in California's growth, but so have excellent educational institutions and a legacy of public investments in growth-supporting infrastructure, including ports and airports, urban transportation systems, and water projects, at least in the past.

In keeping with worldwide trends, most of California's population growth and economic action has been concentrated in metropolitan regions. Today, California's four major metropolitan areas contain over three quarters of the state's population. However, the metropolitan regions themselves have been changing, with multinucleation—multiple centers within regions—becoming increasingly common. The regional growth pattern is both up and out, with infill and renewal of (healthy) centers, including those in previously edge suburbs, occurring at the same time that regions are expanding. Employment is increasingly locating outside of traditional centers in office parks and in stand-alone locations. One result of this pattern of growth is the emergence of "mega-regions," as edges and economies of previously distinct metro areas increasingly overlap.

Push-and-pull factors work in tandem to produce this growth pattern. The high costs of development in traditional centers have pushed growth out, whereas the lower costs of land and development at the edge have attracted it. Environmental amenities at the metro edge also attract many, but so do social and cultural amenities in the successful urban centers. On the other hand, crime or the perception of it pushes people and business away from some centers toward the more controlled environments of edge communities and business parks. School quality is a significant factor in location choice for many households. Image, lifestyle, and life cycle considerations have also shaped choices for both housing and business location, as have tax policies and incentives. Housing affordability is a significant issue both in the coastal cities and increasingly in the Central Valley.

Whether a growth pattern similar to that of recent decades will hold over the next 20 years is a matter of continued debate and research. Demographic trends suggest that California's population, like that of the rest of the United States, will become older on average, with more childless couples and more singles. These demographic changes, along with higher prices for building materials and transportation fuels, may signal shifts in demand for housing (the principal use of urban land), both in terms of its location and its size. Changes in employment opportunities and even in shopping habits could also reshape the pattern of development. But where and in what form growth occurs will also be shaped by public policy such as SB 375 (Deakin 2008).

What's at stake if development continues along current trajectories? A study conducted in the late 1990s projected where development would occur if it followed the patterns permitted under the city and county plans and zoning in place at that time (Landis et al. 1998). New development, occurring mostly at the edge of existing cities and towns but also scattered along highway corridors, would likely lead to continuous belts of urbanization down the Central Valley, currently a prime agricultural area producing a large share of the U.S.'s fresh fruits and vegetables. Additional belts of development would link the Bay Area with Sacramento and Los Angeles with San Diego. The costs of this pattern of growth would be measured in lost habitat and wetlands, lost prime farmland, and a loss of sense of place.

Other costs of business-as-usual would be seen in the transportation system. Because housing development would mostly occur at low densities (5–6 housing units per acre or less), transit and nonmotorized modes would be of little use to large numbers of California's residents. Many would, therefore, face traffic congestion without the option of travel alternatives. Other transportation externalities also would be high, including highway crashes and their attendant deaths, injuries, and property loss, as well as pollutant emissions and noise. And greenhouse-gas emissions would increase, not decrease, absent technological breakthroughs well beyond those currently anticipated.

Strategies to reduce global warming through sustainable community development could address many of these important environmental and social concerns that are tied directly or indirectly to transportation and land development. In addition, the linkage between transportation investment and affordable housing policy set forth in SB 375 could help to address one of the state's most pressing concerns—one that has by no means been alleviated by the current subprime mortgage debacle. The crisis revealed, among other things, the lack of sustainability of the de facto policy of providing "affordable" housing in new housing tracts located far from jobs and services and dependent on driving for every trip.

Efficacy of Land Use and Transportation Measures

SB 375 requires development of a sustainable communities strategy but leaves the details to the MPOs. CARB's Regional Targets Advisory Committee called for best management practices guidance to help the MPOs carry out this responsibility. However, California MPOs already have considerable experience with many of the measures likely to be included (Table 3), including decades of experience responding to federal Clean Air Act requirements for transportation control measures designed to reduce pollutant emissions over and above what could be attained through cleaner fuels and vehicles. In addition, regional transportation plans and corridor

J. Transp. Eng., 2011, 137(6): 372-382

Table 3. Land Use and Transportation Strategies for Sustainable Development

Category	Specific measures
Planning and urban design	Planning and zoning for higher densities
	Mixed use development
	Infill development
	Redevelopment at higher densities
	Renovation and reuse of existing buildings for more intensive activities (e.g., warehouse to condos)
	Compact growth
	Urban design plans to accommodate density and a mix of uses in a high quality urban environment
	Inclusionary zoning (for affordable housing)
	Density bonuses for affordable housing, public facilities, and amenities
Resource protection	Protection of high value resource lands (watersheds, forests, agriculture)
Service provision	Provision of parks and playing fields
	School siting to facilitate walk, bike, and transit access
	Infrastructure funding for infill development
Transit programs	Expanded public transit infrastructure and services
	Improved transit routing and scheduling
	Demand responsive transit services
	Transit priority treatments—bus rapid transit, traffic signal preemption, queue jump lanes
	Deep discount transit pass programs
	Shuttles for first and last mile connections to transit
Pedestrian and	Bicycle routes lanes, paths, and parking
bicycle programs	Pedestrian facilities (sidewalks, paths, crosswalks, and signs)
	Safe routes to school (and other major destinations)
Shared rides	Carpool and vanpool programs and facilities
	Carsharing programs designed to reduce auto ownership and parking needs
Parking management	Park-and-ride facilities for transit, carpool, and vanpool users
	Parking pricing (on- and off-street)
	Resident permit parking
	Parking cash-out
	Reduced parking requirements reflective of use and promotion of other travel modes
	Use of on-street parking to meet business and resident needs
	Parking maxima
	Parking location restrictions to avoid conflicts with pedestrian access
Street design	Traffic calming
	Complete streets
	Context-sensitive street design
Pricing	Congestion pricing
	HOT lanes
	Gas taxes
	Carbon taxes
Telecommunications substitutes for travel	Telecommuting and teleconferencing
	Compressed work schedules
Traffic operations and logistics	Fuel-efficient traffic signal timing
	Incident management systems
	Intelligent transport systems deployed to reduce energy and emissions
	Fuel-efficient freight shipping choices
	Improved logistics

studies in every metropolitan area have included analyses of transit investments, bike and pedestrian improvements, and a variety of other transportation management strategies, including pricing strategies.

The larger MPOs also have considerable experience making the transportation–land-use connections. At least five of the MPOs have previously conducted "blueprint planning", the California term for scenario planning designed to lead to a preferred growth scenario (Barbour and Teitz 2008). Following the approaches used in New Jersey, Minnesota, Oregon, Washington, and Utah, all of which had conducted such planning efforts in the 1980s and 1990s, California's scenario plans have compared auto-oriented, outward-expanding development to more compact growth oriented around transit, walking, and biking and have studied how alternative land-use locations, densities, and mixes affect mode choice, air quality, and public and private costs. Many of the MPOs also have been involved in transit-oriented development for particular communities, corridors, and station areas, as well as with corridor,

commercial district, and residential neighborhood programs involving infill development, traffic calming, and improved pedestrian and bike facilities.

In short, all California MPOs have past experience analyzing the efficacy of a wide variety of transportation and land-use measures and their consequences. They have less experience in evaluating the measures' actual performance, however, because implementation has been piecemeal and spotty.

At least some observers believe that slow and partial implementation of measures that could reduce VKT is, in part, because public preferences lie elsewhere—with the automobile and with suburban development patterns. Reluctance to change direction toward transit and nonmotorized modes also reflects strength of the institutions that have grown up to deliver auto-oriented transportation systems and development patterns, as well as the lack of competitive alternatives in most locations. Discussions of the MPOs' scenario tests indicated that most MPO directors are uncertain that the most ambitious of the scenarios could actually be implemented, noting that neither their own boards nor local jurisdictions seemed ready to act on the more ambitious pricing and land-use strategies.

As a result, VKT-reducing measures often raise concerns about cost-effectiveness, complexity, and public acceptability, and many of these concerns are realistic given current conditions. Transit, for example, only operates efficiently where demand is high enough to fill most seats, and that usually depends both on how autos are priced and on the population and employment density around the transit stations and stops. Walking and biking attract users in significant numbers only when there are destinations that can be reached in a reasonable amount of time by these modes and when development patterns and street designs make biking and walking safe and comfortable. Previous MPO studies of transportation-demand management strategies have, for the most part, found only modest impacts from proposed transit and bike and walking strategies, and in large part this has been because the underlying land-use patterns made these modes practical, attractive choices in only a few parts of the region.

Despite these concerns, there is also strong empirical evidence that demand management strategies can be effective when applied strategically in locations where land uses are supportive. Land-use planning (especially for housing) and urban design are, therefore, inextricably part of planning that aims to reduce VKT, and this recognition is an underlying premise of SB 375. But whether significant numbers of households will choose to live in transit-friendly locations and at higher densities remains a matter of debate in most regions. Household and business location choice are a complex function of many factors in addition to transportation (local services, amenities, crime rates, business climate, and school quality, among others.) Planning and zoning for higher density and mixed uses around transit is not enough to assure VKT reduction, if demand is limited for these locations and development types.

Some of the measures in Table 3 also raise concerns about unintended adverse consequences. For example, urban renewal programs can cause displacement of businesses and households, disrupting highly valued social networks. Transit-oriented development may lead to higher property values, but higher property values could displace or deter low- and middle-income households and small businesses from locating there. Increasing the cost of driving or parking could hurt those of modest means who have no alternative but to drive. Concerns about these effects have been part of the reason for reluctance to pursue such measures.

Role of Modeling

SB 375 calls for improvements in the ability to model transportation and land use strategies as part of the ongoing effort to identify and assess GHG-reduction opportunities. A number of the participants who commented on CARB's scoping plan and the RTAC's targets report identified model deficiencies as a problem, arguing that weak models make it difficult to estimate GHG reductions with confidence. All of the California MPOs use travel models to analyze their regional plans and proposed investments, but the quality of the models varies significantly; many MPOs reported to the RTAC that they could not model land-use considerations very well. (CARB 2009d). When travel models treat land use as largely exogenous, they tend to underestimate the efficacy of pricing, transit investments, and other interventions that influence location choice (Rodier 2008.)

Model improvements are underway at both the state level and at a number of the MPOs and show promise for improving MPO capacity for assessing transportation–land-use interactions and their GHG impacts. Nevertheless, even the best of the available and planned models have notable drawbacks, as do the databases typically used to estimate them. Further, land use is an area where many models tend to fall short, exhibiting:

- poor representation of density, mix of use, and urban design, largely because the models operate at a scale that is too aggregate to capture these factors;
- mediocre representation of housing location and housing type choice, an area where more research remains to be done;
- omission or only poor representation of walk and bike trips, partly because the networks for these modes are not represented accurately and partly because the aggregation level of the models is too high to deal with short trips; and
- poor or no representation of the effects of social factors such as status and sense of security in influencing travel and location choices.

Data also remain problematic, and basic research into some aspects of transportation–land-use modeling remains to be done.

As a result, many experts in the field recommend a mixed methods approach that relies not only on regional modeling and forecasting but also considers the findings from a variety of other studies, including empirical evaluations of implemented projects. In addition, sketch planning methods, such as simple spreadsheet models, can be used to augment regional models and, in some cases, may be an adequate substitute for them.

A useful recent study summarizing the findings of a variety of analyses of transportation and land-use interventions was produced by Ewing and Nelson. (2008.) Table 4 summarizes their findings on elasticity of demand, drawn from a number of sources using different methodologies, along with the writers' "best estimate" of long-term impact in California, given changing demographics and growth patterns.

The table confirms the strong effects of population and income on VKT (even in a high-income country where over 90% of households have access to an automobile), the VKT-inducing effect of highway lane miles, and the moderating effects of density, fuel price, and transit investments.

The RTAC has recommended that CARB provide both best management practices information and simplified, spreadsheet-based modeling tools to help MPOs and others develop sustainable development strategies. The RTAC further points out that these user-friendly tools would increase the ability of stakeholders not expert in modeling to assess the efficacy of various measures and, thus, would increase both the transparency of decisions and participation in them. Finally, the RTAC suggests that CARB itself

J. Transp. Eng., 2011, 137(6): 372-382

Table 4. Elasticities of VKT with Respect to Urban Variables

	National cross sectional	National longitudinal	California-modeled	CA "best estimate" (adjusted to reflect findings from the literature)
Population	0.97	0.87	0.77	0.95
Real per capita income	0.53	0.54	0.09	0.54
Population density	−0.21	−0.15	−0.15	−0.3
Highway lane miles	0.46	0.68	0.57	0.56
Transit revenue miles	−0.08	−0.02	−0.01	−0.06
Transit passenger miles	−0.07	−0.03	−0.01	−0.06
Real fuel price	NA	−0.17	−0.11	−0.17

Adapted from Ewing and Nelson 2008.

could use best management practices evidence and spreadsheet approaches as an accuracy check on each MPO's submittal. While efforts are underway to provide such advice and support, it appears that much more work will be needed to make model results both reliable and understandable to the public, as discussion of targets and performance at a May 2010 RTAC meeting illustrated (CARB 2010a).

Intergovernmental Cooperation and Funding Issues

The focus on modeling and analysis in SB 375 suggests that the evidentiary basis for GHG reduction is the major impediment to action. However, a far bigger issue may well be conflicting perspectives and imperatives among various levels of government, as well as serious funding issues. Whereas the law anticipates consultation and collaboration—and this is occurring between CARB and the MPOs—the law currently does little to overcome conditions that work against reaching agreement on a course of action and implementing it locally.

SB 375 relies on MPOs to develop sustainable development strategies or alternatives, but MPOs have little implementation authority, especially concerning land use. SB 375 makes it clear that local governments retain their land-use authority. The MPOs do not have to follow local land-use plans in developing their development strategies for SB 375, and the local governments do not have to comply with the regional plans. This arrangement does little to assure the success of the regional strategy.

MPOs themselves may have mixed objectives in developing GHG-reduction strategies. Since their boards are made up of local government officials, they seem unlikely to attempt to implement policies that would be opposed locally (Altmaier et al. 2009; Fulton 2008.) Furthermore, although SB 375 contemplates using MPO funds to support the adopted plan, MPOs usually have committed anticipated funds to specific projects far in advance of implementation. This long "pipeline" of projects and the commitments entailed in it most likely mean that, unless new funds become available, it will be years before new projects can actually be delivered.

In addition, MPOs' preliminary scenario tests suggest that some MPOs may find it expedient to put together their GHG-reduction plans primarily by drawing upon their current plans and programs of projects, adding politically popular measures such as expanded transit to the extent that financing allows but avoiding politically controversial GHG-reduction strategies such as parking pricing or restrictions on low-density housing development. Political commitments to projects in current plans are likely to be kept whether or not the projects reduce GHG emissions; as one MPO director put it at a meeting. In addition, there may be some risk that modeling to achieve targets will become a stronger objective than actually achieving said targets, as was sometimes the case with transportation-air quality plans under the Clean Air Act, where, rather notoriously, models were often run repeatedly with different assumptions until conformity to air quality requirements could be "demonstrated".

State support for MPO actions would be a boon, but current state policies are mixed in terms of their entire alignment with SB 375 objectives. For example, Proposition 1C, a 2006 state housing bond, supports infrastructure and transit-oriented housing in infill areas. However, Proposition 1B, a transportation bond passed in the same year, allocates the majority of funds to road expansion projects, and the legislature exempted these projects from SB 375 consistency requirements. In addition, whereas Assembly Bill (AB) 857 established an overarching set of planning priorities to guide state policy making, emphasizing infill, compact development, and protection of environmental and agricultural resources, little effort has been made by state agencies to translate these priorities into concrete actions, and efforts to include strong agricultural and open space protection into SB 375 were not successful. Requirements that state agencies produce a "report card" on their compliance with SB 375 may help realign policies, but how fast change will occur is not yet clear.

The CEQA streamlining for projects that implement the SCS or APS will remove one impediment for local governments; infill projects will be less likely to be caught up in CEQA challenges over localized traffic impacts. In addition, several California foundations have stepped forward to offer funding for affordable housing near transit. However, such projects often will face other serious challenges, including a lack of funding for infrastructure improvements and services needed to support the new development effectively. As several who testified at the CARB hearings noted, development on greenfields is largely self-financed through developer exactions, impact fees, and creation of service districts; infill and redevelopment/reuse projects often occur in a context of outmoded and deficient transportation and water and sewer facilities whose repair and upgrade cannot be levied against new development only.

Recent state budget cuts have worsened the situation by slashing transit funding and reducing funding for redevelopment, farmland protection, and local government activities.

Assessment: Prospects for California's Greenhouse-Gas Initiatives

California's new initiatives to reduce greenhouse gases are ambitious and innovative, but they also face a number of problems. While the state expects that most of the needed emissions reductions will come from technological advances, it also recognizes that changes in transportation and land-use patterns are needed in the next 20 years and even more so in the longer-term.

Recently, concerns have been raised about the direct and indirect land-use consequences of biofuels, another important strategy in California's efforts to reduce GHG emissions. While not all biofuels raise equal concerns, the least intrusive biofuels are currently those in need of considerable development to be cost-effective. As a result, biofuels' contributions to GHG reduction may be a longer-term prospect than once thought.

J. Transp. Eng., 2011, 137(6): 372-382

Sustainable community strategies can be effective only if they are actually implemented. Better modeling can help clarify the efficacy of various strategies, especially their land use impacts, but decision-makers also could draw upon empirical evidence from successful (and not-so-successful) cases to identify best practices and could develop simple spreadsheet-analysis approaches that use known demand elasticities and empirical findings to support quick response analysis. A bigger barrier to implementation of sustainable community strategies seems likely to be the limited incentives (and political disincentives) for MPOs to propose aggressive new directions or for local governments to implement such measures. Lack of funding for local action and mixed signals from the state further weaken the support for change. Finally, demand for higher density housing and for offices and other business locations served by transit and nonmotorized modes remains in question; surely there is a market for such locations and land uses, but its size is not clear.

Thus, California's GHG-reduction goals are likely to need further legislative support to be fully realized. It remains to be seen whether this will happen through state action or perhaps in upcoming federal initiatives in transportation, energy, and the environment. Further, public acceptance of new styles of living and working and higher real prices for transportation services may be the ultimate test of whether GHG reductions can be attained beyond those available from technology.

Finally, more work is needed on the costs and benefits of the measures that reduce greenhouse gases, including their cobenefits, such as improved public health, reduced energy costs, and avoided damage to infrastructure and the environment. Accounting for such cobenefits would not only allow for a more complete assessment of benefits and costs of various measures but also may be key to public acceptance.

References

Altmaier, M., Barbour, E., Eggleton, C., Gage, J., Hayter, J., and Zahner, A. (2009). "Make it work: Implementing Senate Bill 375." Institute of Urban and Regional Development, University of California, Berkeley, CA.

Barbour, E., and Teitz, M. (2008). "Blueprint planning in California: Forging consensus on metropolitan growth and development." Occasional Papers, Public Policy Institute of California, San Francisco. ⟨http://www.ppic.org/main/publication.asp?i=693⟩ (May 25, 2011).

California Air Resources Board (CARB). (2008). "Climate change scoping plan: A framework for change." ⟨http://www.arb.ca.gov/cc/scopingplan/document/adopted_scoping_plan.pdf⟩ (May 25, 2011).

California Air Resources Board (CARB). (2009a). "AB 32—Fact sheet California Global Warming Solutions Act of 2006." ⟨http://www.calepa.ca.gov/legislation/2006/FactSheetAB32.pdf⟩ (May 25, 2011).

California Air Resources Board (CARB). (2009b). "Clean car standards—Pavley, Assembly Bill 1493." ⟨http://www.arb.ca.gov/cc/ccms/ccms.htm⟩ (May 25, 2011).

California Air Resources Board (CARB). (2009c). "Meeting May 5, 2009—MPO self-assessment of current modeling capacity and data collection programs." Regional Targets Advisory Committee (RTAC). ⟨http://www.arb.ca.gov/cc/sb375/rtac/meetings/050509/mpoassessmentupdate.pdf⟩ (May 25, 2011).

California Air Resources Board (CARB). (2009d). " Recommendations of the Regional Targets Advisory Committee (RTAC) pursuant to Senate Bill 375—A report to the California Air Resources Board." ⟨http://www.arb.ca.gov/cc/sb375/rtac/report/092909/finalreport.pdf⟩ (May 25, 2011).

California Air Resources Board (CARB). (2010a). "Meeting May 25, 2010, of the Regional Targets Advisory Committee (RTAC)."⟨http://www.arb.ca.gov/cc/sb375/rtac/meetings/meetings.htm⟩ (May 25, 2011).

California Air Resources Board (CARB). (2010b). "Preliminary report on Metropolitan Planning Organization (MPO)/Air Resources Board (ARB) Senate Bill 375 (SB 375) target setting analyses." File No. 8000130. ⟨http://www.arb.ca.gov/cc/sb375/mpo/info.htm⟩ (May 25, 2011).

California Air Resources Board (CARB). (2010c). "Senate Bill 375—Research on impacts of transportation and land use-related policies." ⟨http://arb.ca.gov/cc/sb375/policies/policies.htm⟩ (May 25, 2011).

California (CA) Assembly Bill 1493. (2002). "An act to amend Section 42823 of, and to add Section 43018.5 to, the Health and Safety Code, relating to air quality (Pavley bill)."⟨http://www.arb.ca.gov/cc/ccms/documents/ab1493.pdf⟩ (May 25, 2011).

CA Assembly Bill 32. (2006). "The California Global Warming Solutions Act of 2006." Health and Safety Code Div. 25.5, 38500 et seq. ⟨http://www.leginfo.ca.gov/pub/05-06/bill/asm/ab_0001-0050/ab_32_bill_20060927_chaptered.pdf⟩ (May 25, 2011).

CA Senate Bill 375. (2008). Chapter 728, Statutes of 2008. ⟨http://www.leginfo.ca.gov/pub/07-08/bill/sen/sb_0351-0400/sb_375_bill_20080930_chaptered.pdf⟩ (May 25, 2011).

Deakin, E. (2008). "California futures: Accommodating growth in an era of climate change and rising fuel prices." *Access* (Univ. of California Transportation Center), 32, 4–7.

Enkvist, P.-A., Nauclér, T., and Rosander, J. (2007). "A cost curve for greenhouse gas reduction : A global study of the size and cost of measures to reduce greenhouse gas emissions yields important insights for businesses and policy makers." *McKinsey Quarterly* (McKinsey and Co.). ⟨http://www.fao.org/fileadmin/templates/agphome/scpi/cgwg/McKinsey.pdf⟩ (May 25, 2011).

Ewing, R., and Nelson, A. C. (2008). "CO2 reductions attributable to smart growth in California." University of Utah Metropolitan Research Center, Salt Lake City.

Executive Order (EO) S-3-05. (2005). "Greenhouse gas reduction targets for 2050." ⟨http://www.dot.ca.gov/hq/energy/ExecOrderS-3-05.htm⟩ (May 25, 2011).

EO S-01-07. (2007). "Low carbon fuels standard." ⟨http://www.arb.ca.gov/fuels/lcfs/eos0107.pdf⟩ (May 25, 2011).

Fulton, B. (2008). "SB 375 is now law—But what will it do?." *California Planning and Development Report*. ⟨http://www.cp-dr.com/node/2140⟩ (May 25, 2011).

Gilbert, R., and Perl, A. (2010). *Transport revolutions*, 2nd Ed., New Society Publishers, Gabriola Island, BC.

Hansen, J., et al. (2009). "Target atmospheric CO2: Where should humanity aim?" ⟨http://www.go350ppm.org/James%20Hansen.pdf⟩ (May 25, 2011).

International Energy Agency (IEA). (2008). *World energy outlook 2008*, IEA, Paris.

Kammen, D. M., Arons, S. M., LeMoine, D. M., and Hummel, H. (2009). "Saving fuel, reducing emissions—Making plug-in hybrid electric vehicles cost-effective." *Access* (Univ. of California Transportation Center), 34, 2–10.

Landis, J., Cogan, C., Monzon, P., and Reilly, M. (1998). "Development and pilot application of the California Urban and Bio-Diversity Analysis Model (CURBA)." *Rep. No. MG-1998-01*, Institute of Urban and Regional Development, Univ. of California, Berkeley, CA.

National Academy of Sciences (NAS). (2010). *Real prospects for energy efficiency in the United States*, National Academies Press, Washington, DC.

Organization for Economic Cooperation and Development. (2008). "Greenhouse gas reduction strategies in the transport sector: Preliminary report." Paris.

Pachauri, R. K., and Reisinger, A., eds. (2008). "Climate change 2007: Synthesis report, IPCC 4th assessment report (AR4)." Intergovernmental Panel on Climate Change (IPCC), Geneva. ⟨http://www.ipcc.ch/publications_and_data/publications_ipcc_fourth_assessment_report_synthesis_report.htm⟩ (May 25, 2011).

Rodier, C. (2008). "A review of the international modeling literature: Transit, land use, and auto pricing strategies to reduce vehicle miles traveled and greenhouse gas emissions." ⟨http://www.arb.ca.gov/planning/tsaq/docs/rodier_8-1-08_trb_paper.pdf⟩ (May 25, 2011).

Sappenfield, M. (2005). "Global-warming fight goes grass roots." The Christian Science Monitor (California edition), June 6.

J. Transp. Eng., 2011, 137(6): 372-382

Schipper, L. (2009) "Moving forward with fuel economy standards." *Access* (Univ. of California Transportation Center), 34, 11–15.
Schipper, L., Deakin, E., McAndrews, C., Scholl, L., and Frick, K. T. (2009). "Considering climate change in Latin American and Caribbean urban transportation: Concepts, applications, and cases." Center for Global Metropolitan Studies, Univ. of California, Berkeley, CA. ⟨http://metrostudies.berkeley.edu/pubs/reports/Shipper-ConsidClimateChange-LatinAmer.pdf⟩ (May 25, 2011).
Shaheen, S. A., Benjamin-Chung, J., Allen, D., and Howe-Steiger, L. (2009). "Achieving California's land use and transportation greenhouse gas emission targets under AB 32: An exploration of potential policy processes and mechanisms." Rep. to CARB and California Dept. of Transportation, Transportation Sustainability Research Center, Univ. of California, Berkeley, CA.
Transportation Research Board (TRB). (2008). *Driving and the built environment: Effects of compact development on motorized travel, energy use, and CO2 emissions—Spec. Rep. 298*, National Academies Press, Washington, DC.
U.S. Department of Energy (DOE). (2009). "Annual energy review 2008." *Rep. No. DOE/EIA-0384(2008)*, Energy Information Administration, Washington, DC.
U.S. Department of Energy (DOE). (2010). "Carbon sequestration: Key R & D programs and initiatives." ⟨http://fossil.energy.gov/programs/sequestration/⟩ (June 1, 2010).
U.S. Dept. of Transportation (DOT) Federal Highway Administration (FHWA). (2009a). "Highways and climate change." ⟨http://www.fhwa.dot.gov/hep/climate/index.htm⟩ (May 25, 2011).
U.S. DOT FHWA. (2009b). "Strategies to reduce greenhouse gas emissions from transportation sources." Chapter 5, *Transportation and global climate change: A review and analysis of the literature*., Washington, DC. ⟨http://www.fhwa.dot.gov/environment/glob_c5.pdf⟩ (May 25, 2011).
U.S. Environmental Protection Agency (EPA). (2008). "EPA staff technical report: Cost and effectiveness estimates of technologies used to reduce light-duty vehicle carbon dioxide emissions." *EPA420-R-08-008*, Washington, DC. ⟨http://www.epa.gov/otaq/climate/420r08008.pdf⟩ (May 25, 2011).
Victor, D. G., Morgan, M. G., Apt, J., Steinbruner, J., and Ricke, K. (2009). "The geoengineering option : A last resort against global warming?" *Foreign Affairs*, Mar/Apr.